Nutrition-Sensitive Agriculture: Challenges and Way Forward

Review Workshop Proceedings

Nutrition Unit

Bangladesh Agricultural Research Council

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From Research to technology and information

Review Workshop Proceedings

Editors

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The Editors

Abbreviation and Acronyms

ALART	-	Advanced Line Adaptive Research Trial
AWD	-	Alternate Wetting and Drying
BARC	-	Bangladesh Agricultural Research Council
BARI	-	Bangladesh Agricultural Research Institute
BRRI	-	Bangladesh Rice Research Institute
BINA	-	Bangladesh Institute of Nuclear Agriculture
BSRI	-	Bangladesh Sugarcrop Research Institute
BWMRI	-	Bangladesh Wheat and Maize Research Institute
BLRI	-	Bangladesh Livestock Research Institute
BFRI	-	Bangladesh Fisheries Research Institute
BJRI	-	Bangladesh Jute Research Institute
BADC	-	Bangladesh Agricultural Development Corporation
BUHS	-	Bangladesh University of Health Sciences
BIRTAN	-	Bangladesh Institute of Research and Training on Applied Nutrition
BFSA	-	Bangladesh Food Safety Authority
BARD	-	Bangladesh Academy for Rural Development
BCR	-	Benefit Cost Ratio
BAU	-	Bangladesh Agricultural University
BADC	-	Bangladesh Agricultural Development corporation
BNI	-	Biological Inhibition
BNNC	-	Bangladesh National Nutrition Council
CBC	-	Commercialization of Biofortified Crops
DAE	-	Department of Agricultural Extension
DoF	-	Department of Fisheries
DLS	-	Department of Livestock Services
DAM	-	Department of Agricultural Marketing
DU	-	Dhaka University
FAO	-	Food and Agriculture Organization
GAIN	-	Global Alliance for Improved Nutrition
GI	-	Geographical Indication
HRC	-	Horticulture Research Centre
INGO	-	International Non-Governmental Organization
ICARDA	-	International Centre for Agricultural Research in the Dry Areas
ICRISAT	-	International Crops Research Institute for the Semi-Arid Tropics
IRRI	-	International Rice Research Institute
KGF	-	Krishi Gobeshona Foundation
NARS	-	National Agricultural Research System
NSA	-	Nutrition Sensitive Agriculture
NGO	-	Non-Governmental Organization
NFP	-	National Food Program
RYT	-	Regional Yield Trial
RAINS	-	Resilient Agriculture for Improved Food and Nutrition Security
SRDI	-	Soil Resource Development Institute
SAU	-	Sher-e-Bangla Agricultural University
SAC	-	SAARC Agriculture Centre
USDA	-	United States Department of Agriculture
UNICEF	-	United Nations Children's Emergency Fund
WHO	-	World Health Organization

Contents

Foreword

Bangladesh has made remarkable progress in agricultural production over the past decades, emerging as a global example of success in rice production and food availability. Strong policy commitment, institutional and production support, the country has achieved near self-sufficiency in staple food production. However, despite these achievements, malnutrition in its multiple forms like undernutrition, micronutrient deficiencies, rising prevalence of overweight and diet-related non-communicable diseases continues to pose significant public health challenges. Aligned with the Sustainable Development Goals and the national development vision, the Government of Bangladesh has prioritized food and nutrition security as central to inclusive and sustainable development. While food availability has improved substantially, dietary diversity and access to nutrient-rich foods remain uneven across regions and socio-economic groups. In this context, the workshop on Nutrition-Sensitive Agriculture: Challenges and Way Forward was convened to explore how agricultural policies, research and practices in NARS in Bangladesh can effectively contribute to improved nutrition outcomes. The workshop brought together researchers, agricultural extension professionals, nutritionists, development partners and representatives of civil society to deliberate the integration of nutrition objectives into upcoming Nutrition-Sensitive Agriculture research, upscaling and awareness programme.

The discussions underscored that Bangladesh's agricultural system, traditionally focused on rice-centered production, must diversify toward nutrient-dense crops such as pulses, fruits, vegetables, livestock and fisheries. Given the country's vulnerability to climate change floods, salinity intrusion, droughts and cyclones, it is emphasized the importance of climate-resilient and nutrition-sensitive agriculture systems. Homestead gardening, small-scale aquaculture, poultry rearing and biofortified crop varieties were highlighted as promising approaches for improving household dietary diversity and micronutrient intake.

I infromed that the workshop also examined institutional and structural challenges to mainstreaming nutrition within agriculture. Limited cross-sectoral coordination among agriculture, health, and nutrition sectors, inadequate capacity of frontline extension services to deliver nutrition education, insufficient disaggregated nutrition data and market systems that prioritize staple crops over diversified foods were identified as key barriers. Gender inequality particularly women's limited access to land, credit and decision-making role were recognized as critical factor influencing household nutrition outcomes.

This proceedings after a threadbare discussion captures institute wise extended abstract and policy recommendations. The workshop serves as a platform for knowledge sharing and a reference for researchers, practitioners and decision-makers working to advance NSA in Bangladesh.

I express my sincere appreciation to all contributors, organizers and partner institutions whose commitment made this workshop successful. I really acknowledged Nutrition unit, BARC for conducting such workshop and published it's outcome.

Salam

Dr. Md. Abdus Salam
Executive Chairman

Preface

Agriculture has long been the backbone of the economy of Bangladesh, contributing significantly to employment, rural livelihoods and national food security. Over the past several decades, the country has achieved notable success in increasing food grain production, particularly rice, through technological innovation, policy support and farmer resilience. However, improved food production has not automatically translated into optimal nutritional outcomes, highlighting the need for an integrated and nutrition-focused approach to agricultural development.

Bangladesh continues to face a complex burden of malnutrition. While rates of stunting and underweight among children have declined over time, micronutrient deficiencies, especially iron, zinc, vitamin A and iodine remain prevalent. Nutrition-Sensitive Agriculture (NSA) offers a strategic framework to address these challenges by explicitly linking agricultural production systems with improved nutrition outcomes. It promotes diversified food production, enhanced access to nutrient-rich foods, gender empowerment, nutrition education and strengthened value chains that prioritize healthy diets. In the context of Bangladesh, where smallholder farmers dominate the agricultural landscape and climate vulnerability is high, adopting nutrition-sensitive approaches is both a necessity and an opportunity along with strategic document of NSA under Ministry of Agriculture. The workshop on Nutrition-Sensitive Agriculture: Challenges and Way Forward for NARS seeks to explore practical solutions, share research findings and foster dialogue among stakeholders committed to strengthening the agriculture-nutrition integration under NARS.

The proceedings that reflect collective insights into how agriculture in Bangladesh can evolve from a system, primarily focused on staple food production to one that ensures safe, diverse, affordable and nutritious diets for all. Within the National Agricultural Research System (NARS) of Bangladesh, integrating Nutrition-Sensitive Agriculture (NSA) is increasingly recognized as essential for aligning agricultural innovation with national nutrition goals. Institutions under NARS including crop, livestock, fisheries and horticulture research bodies play a pivotal role in developing technologies, varieties and production practices that shape the country's food systems. Through strengthened partnerships, targeted investments, community engagement, Nutrition-Sensitive Agriculture can serve as a transformative pathway toward improved health, enhanced resilience and sustainable national development. Through group work, stakeholders prioritized key programmes, timelines and strategic actions, helping to identify practical pathways for upcoming program development. This participatory process facilitated shared understanding, strengthened coordination and generated actionable recommendations to guide future planning and implementation of nutrition-sensitive initiatives for NARS.

Dr. Zakiah Rahman Moni
Director (Nutrition)

Workshop in Brief

Background

Nutrition-Sensitive Agriculture (NSA) has emerged as a critical approach to address malnutrition by integrating nutrition objectives into agricultural research, production and extension systems. Despite significant advances in agricultural productivity, challenges such as micronutrient deficiencies, dietary diversity gaps and limited nutrition awareness persist, particularly among vulnerable populations. NSA refers to agricultural approaches are integrated specific nutrition-related and food related outcomes and to reduce the underlying and basic causes of malnutrition. These causes may be related to access to food, caregiving resources, health resources, environmental sanitation and the food environment. Nutrition-sensitive agriculture promotes the production and consumption of diverse, safe and nutritious foods to address malnutrition in all its forms. Despite being food producers, many smallholder farmers remain nutrition insecure due to limited diversity, low income and poor market access. This approach focuses on diversified farming, improved markets, reduced food loss and nutrition education to ensure year-round access to healthy diets. The National Agricultural Research System (NARS) and allied stakeholders have been implementing various initiatives to promote nutrition-sensitive practices. However, there is a need to systematically review existing efforts, identify key challenges, share experiences and develop a coordinated way forward. This review workshop provides a common platform for researchers, extension professionals, This workshop consists of four session: the inauguration, technical presentations, group work and presenter's evaluation and other stakeholders to exchange knowledge, views, experiences and strengthen collaboration.

Session 1: Inaugural Session

Review Workshop on *"Nutrition-Sensitive Agriculture: Challenges and Way Forward"*

Date and Time : 15 January 2026
Venue : Auditorium, BARC
Chairperson : Dr. Md. Harunur Rashid, Director (Nutrition)

Objectives of the Workshop

The main objectives of the workshop are:

- To review and assess ongoing and completed NSA initiatives in NARS, including challenges and gaps in research and extension integration
- To facilitate experience sharing and coordination among scientists, extension officers and stakeholders to document best practices and lessons learned
- To document recommendations and way forward for scaling up NSA

Workshop Structure and Content

The workshopincludes:

- Technical presentations by NARS scientists on current research, plan and interventions related to NSA
- Experience-sharing sessions by the participants focusing on NSA implementation, challenges, at the community level.
- Way-Forward session to formulate recommendations and priority actions through groupwork.

Participant's list: (Annexure-1)

The workshop attended by:

- Scientists and researchers from NARS (BARC, BARI, BSRI, BINA, BFRI, BLRI, BWMRI, BJRI, SRDI)
- Extension personnel from agriculture and allied departments (DAE, DoF, DLS, BADC, DAM)
- Representatives from academia (SAU, DU, BUHS), development agencies, NGO, INGO, GAIN, FAO, KGF
- Policy planners and program implementers (BARC, SAC)

- Scientists from relevant stakeholder organizations (BIRTAN, BFSA)
- Private Organization (PRAN, ACI, Square Group, Amana)

Distinguished Guests:

The workshop was graced by **Dr. Md. Abdus Salam,** Executive Chairman, BARC, as the Chief Guest. **Mr. Ajit Kumar Chakraborty,** Member Director (Fisheries), BARC, attended the program as the Special Guest. The welcome address was delivered by **Dr. Zakiah Rahman Moni,** PSO (Nutrition), BARC and the session was chaired by **Dr. Md. Harunur Rashid,** Director (Nutrition), BARC. In their speeches, the guests emphasized the importance of ensuring food security along with improving food quality and nutritional adequacy. In his presentation, the Chair of the session, Dr. Md. Harunur Rashid, Director (Nutrition), highlighted a decline in rice consumption and an increase in vegetable and fruit intake in the daily diet of the people of Bangladesh. He also mentioned the objectives of this workshop are: To review and assess ongoing and completed NSA initiatives in NARS, including challenges and gaps in research and extension integration; facilitate experience sharing and coordination among scientists, extension officers and stakeholders to document best practices and lessons learned and document recommendations and way forward for scaling up NSA. He noted that this trend reflects increased purchasing power, improved availability of vegetables and fruits and a gradual change in dietary habits among the population.

Session 2: Technical session

The technical session of the workshop was attended by the following experts as resource persons:

Chairperson: Dr. Md. Abdur Razzak, Former Executive Chairman, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka.

Expert Members:

- **Dr. Md. Zulfikar Ali,** Former Director General, Bangladesh Fisheries Research Institute (BFRI), Mymensingh.
- **Professor Dr. Nazma Shaheen,** Former Director, Institute of Nutrition and Food Science, University of Dhaka.
- **Dr. Anil Kumar Das,** Senior National Consultant (Programme), FAO, Dhaka.
- **Professor Dr. Md. Mahbub Islam,** Department of Crop Botany, Sher-e-Bangla Agricultural University, Dhaka.
- **Dr. A. B. M. Khaleduzzaman,** Director (Production), Department of Livestock Services (DLS), Krishi Khamar Road, Farmgate, Dhaka.

During the technical session, representatives from the Bangladesh Agricultural Research Institute, Bangladesh Fisheries Research Institute, Bangladesh Institute of Nuclear Agriculture, Bangladesh Sugar crop Research Institute, Bangladesh Livestock Research Institute and Bangladesh Wheat and Maize Research Institute delivered Power Point presentations on their respective institutions' technologies, innovations, challenges and the way forward related to NSA.

Presenter 1: Dr. Shekh Hasna Habib, Senior Scientific Officer, Oilseed Research Center, BARI, Gazipur.

Topic: NSA of BARI: Technology, Innovation, Challenges and the Way Forward

Dr. Hasna Habib's presentation highlighted that Bangladesh Agricultural Research Institute is playing a vital role in improving food and nutrition security in Bangladesh through the development of high-yielding, nutrient-rich and climate-resilient crop varieties. She emphasized that despite progress in staple production, micronutrient deficiencies (iron, zinc, vitamin A) remain a major challenge, especially, for women and children. The paper showcased BARI's achievements across cereals, pulses, oilseeds, tubers, fruits, and vegetables, along with nutrition-sensitive management and post-harvest technologies. It also pointed out the importance of value addition and reducing post-harvest losses to enhance both nutrition and farmers' income. Finally, she stressed the need for scaling up these innovations, strengthening research-extension linkages and promoting nutrition-focused agriculture to ensure sustainable and diversified diets.

Recommendations:

- Priority should be given to the development of farmer-friendly technologies.
- There is a need for an efficacy study focusing on the level of absorption in the human body
- Nutritional differences between newly developed varieties and local varieties should be clearly documented and disseminated.
- Need to focusd on measurable nutrition outcomes
- Value-added products need to be developed
- Market research should be conducted to improve the marketing of produced nutrient-sensitive product.
- Varieties should be designed for specific products and end uses.

Speaker 2: Dr. Mritunjoy Paul, Senior Scientific Officer, BFRI, Mymensingh

Topic: NSA of BFRI: Technology, innovation, Challenges and the Way Forward

This paper presented in the workshop highlighted the significant role of fisheries and aquaculture technologies developed by Bangladesh Fisheries Research Institute (BFRI) in improving nutrition security through sustainable and diversified aquatic food systems. The study demonstrated that nutrient-rich fish, seaweed, dry fish, fermented fish products, bivalves and organic shrimp farming can effectively address protein deficiency and micronutrient malnutrition in Bangladesh. Findings showed that improved feed technologies, hygienic fish processing, low-cost fish dryers and eco-friendly aquaculture practices enhanced nutritional quality, food safety, production efficiency and economic returns. The paper also emphasized the importance of climate-smart and nutrition-sensitive aquaculture approaches that integrate public health, food technology and environmental sustainability. Overall, the technologies developed by BFRI provide scalable solutions for enhancing dietary diversity, reducing hidden hunger and supporting sustainable agricultural development in Bangladesh.

Recommendations:

- Research is urgently required on the use of antibiotics in fish, the use of pesticides in dried fish and the potential contamination of fish with heavy metals due to environmental pollution.
- Nutritional differences among fish produced from marine waters, open water bodies and aquaculture systems need to be systematically assessed.
- Safe fish production must be ensured through the use of nutritionally enriched feed and food inputs.
- All research activities of BFRI working on Nutrition-Sensitive Agriculture (NSA) should be documented.
- Promote farmer training, extension services and adoption of climate-smart and eco-friendly aquaculture practices, including balanced feed technologies, hygienic fish drying and organic shrimp farming to ensure sustainable production and safe aquatic foods.

Speaker 3: Mst. Rokeya Sultana, Scientific Officer, BINA, Mymensingh.

Topic: NSA of BINA: Technology, Innovation, Challenges and the Way Forward

The paper highlighted the importance of nutrition-sensitive and sustainable agricultural practices for improving food and nutrition security in Bangladesh. The authors presented research findings and field experiences on improved crop management, climate-smart technologies and farmer-focused interventions. She emphasized strengthening research-extension collaboration, capacity building and policy support for wider adoption of innovative practices. Overall, the paper provided practical recommendations for enhancing agricultural productivity, resilience and nutritional outcomes.

Recommendations:

- Collaboration with private organizations is needed to disseminate along with public-extension systems.
- Amino acid profile of produced soybean should be examined
- Enhance capacity building, policy support and multi-stakeholder collaboration among researchers, extension workers, farmers, and policymakers for scaling up climate-smart and NSA technologies across Bangladesh

Speaker 4: Md. Mostain Billah, Animal Production Research Division, BLRI, Savar, Dhaka

Topic: NSA of BLRI: Technology, Innovation, Challenges and the Way Forward

Mr. Billah's presentation highlighted that Bangladesh Livestock Research Institute is significantly contributing to NSA by improving livestock productivity and ensuring the supply of nutrient-dense animal-source foods like milk, meat and eggs. He highlighted those improved technologies such as "Shuborno" meat chicken and "Shuvra" layer enhance protein and micronutrient intake while being suitable for smallholder farmers. The paper also showed that indigenous and crossbred cattle along with improved fodder varieties, are boosting milk and meat production sustainably. In addition, value-added dairy and meat products (e.g., enriched dahi, whey beverages, sausages) improve nutritional quality and reduce waste. However, challenges like feed scarcity, weak extension and limited adoption remain and scaling up BLRI innovations is essential for better nutrition and livelihoods.

Recommendations:

- All research activities of BLRI related to Nutrition-Sensitive Agriculture (NSA) should be documented.
- The prescribed presentation format should be followed
- Promote large-scale dissemination and commercialization of BLRI-developed breeds, fodder varieties, and value-added livestock products to improve household nutrition, food security and rural livelihoods sustainably

Speaker 5: Mr. Sanjit Mondal, Scientific Officer, Farm Division, BSRI

Topic: NSA of BSRI: Technology, Innovation, Challenges and the Way Forward

The paper highlighted the potential of sugar-producing crops such as sugarcane, date palm, palmyra palm, nipapalm, stevia, and honey in improving nutrition and food security in Bangladesh. Several BSRI-developed varieties showed high levels of vitamins, minerals, antioxidants and low glycemic properties suitable for health-conscious consumers. The findings also emphasized the importance of value addition, proper storage and promotion of nutrient-rich sweetener products for improving public health and rural livelihoods. Overall, the paper demonstrated the role of sugar crops in supporting nutrition-sensitive and climate-resilient agriculture.

Recommendations:

- Amount of vitamin B1, B2 and B6 in Gur produced from sugarcane should be rechecked
- In honey production, qualitative data of honey derived from different floral sources should be clearly specified.
- Promote value addition, processing, storage and commercialization of healthy sweetener products from sugarcane, date palm, palmyra palm, nipa palm, stevia, and honey to improve public health, farmers' income and rural livelihoods.
- Develop awareness programs and supportive policies encouraging the consumption of nutrient-rich natural sweeteners and the integration of sugar-producing crops into national food and nutrition security strategies.

Speaker 6: Kazi Nazmus Salehin Rafi, Scientific Officer, BWMRI, Nashipur, Dinajpur

Topic: NSA of BWMRI: Technology, innovation, Challenges and the Way Forward

The paper presented in the workshop highlighted the serious micronutrient deficiencies prevailing in Bangladesh and emphasized the important role of wheat and maize in addressing hidden hunger through NSA. Bangladesh Wheat and Maize Research Institute has developed several biofortified, climate-resilient and high-yielding wheat and maize varieties enriched with zinc, iron, protein, folate and vitamin A to improve public nutrition and food security. The workshop also showcased innovative agronomic practices, nano fertilizer application and Biological Nitrification Inhibition (BNI) technologies for enhancing nutrient use efficiency, soil health and sustainable crop production. In addition, postharvest innovations such as corncob jelly, fortified maize-wheat cakes and crispy corn products demonstrated strong consumer acceptance and opportunities for value addition and rural entrepreneurship. Overall, the paper emphasized that continued investment in biofortification, climate-resilient crop development and nutrition-sensitive research is essential for achieving sustainable agriculture, reducing hidden hunger and supporting SDG 2 and SDG 3 in Bangladesh.

Recommendations

- The gluten content of the produced wheat needs to be analyzed and reported.
- Further research is needed on developing night-temperature-tolerant maize varieties
- Strengthen farmer training, nutrition-sensitive agronomic practices and sustainable soil management technologies such as nano fertilizer and Biological Nitrification Inhibition (BNI) to improve crop productivity, nutrient efficiency and climate resilience.
- Promote postharvest processing, value addition and commercialization of nutrient-rich wheat and maize products to reduce food loss, increase consumer access to healthy foods and enhance rural income generation.

General Recommendations for Presenting Organizations of NARS

- Food diversification is required to ensure Nutrition-Sensitive Agriculture (NSA)
- Women's participation should be ensured in all relevant NSA activities.
- Database should be generated and maintained for NSA research.
- Nutritional composition of released varieties should be assessed and documented.
- Research should focus on how nutritional requirements can be fulfilled through homestead gardening
- Research is needed to determine whether cold storage and long transporation affects the nutritional quality of potatoes
- Nutritional quality of off-season crops should be assessed and validated.
- Research should be conducted to examine whether process product remains nutritional quality.
- Nutrition loss of in agro products different study of post harvest losses need to be address.
- Research on the availability of low-cost, nutritious foods should be further strengthened and expanded

Extended Abstracts of NARS

Contribution of Bangladesh Agricultural Research Institute in Nutrition Sensitive Agriculture

Md. Moshiur Rahman[1], Jasmine Ara Chowdhury[2], Bahauddin Ahmed[3], Md. Golam Ferdous Chowdhury[4], Sheikh Hasna Habib[5], Mohammad Zahirul Alam Talukder[6], Mafruha Afroz[7], Md. Shahin Uz Zaman[8], Rojina Akter[9], Mst. Shamsun Naher[10], *Syeda Tasnim Jannat[11] and Md. Ripon Hasan[12]

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[12]SO, Agricultural Economics Division, BARI, Gazipur

1. Introduction

Ensuring food and nutrition security is a key priority for Bangladesh. While the country has made progress in staple food production, particularly rice, challenges remain in providing diverse diets rich in protein, vitamins and minerals. Many people, especially women and children, still suffer from deficiencies in iron, zinc, vitamin A and essential minerals. Climate change further threatens agriculture through heat, drought, floods and salinity. The Bangladesh Agricultural Research Institute (BARI), established in 1976 under the Ministry of Agriculture, is the nation's largest multi-crop research organization. BARI develops high-yielding and nutrient-dense varieties of cereals, pulses, oilseeds, tubers, spices, fruits, vegetables and flowers. Its work strengthens food systems through climate-resilient breeding, sustainable cropping systems, improved production and post-harvest technologies, value addition and nutrition-sensitive research. BARI's mission is to create high-yielding, nutrient-rich, and stress-tolerant crop varieties. This abstract summarizes BARI's contributions to enhance food and nutrition security in Bangladesh, highlighting crop-wise research achievements and their nutritional impact.

2. Materials and Methods

This study is based on the review of secondary information obtained from published books, reports, research articles, research summaries and documented crop development activities of the Bangladesh Agricultural Research Institute (BARI). Crop improvement programs applied introduction, hybridization, pedigree method and selection to develop nutrient enriched crop varieties. Germplasm was collected from different locations of Bangladesh, Plant Genetic Resources Centre of BARI, World Veg., ICARDA, ICRISAT, CIP and different countries. These varieties were evaluated for their contribution to essential nutritional components such as carbohydrates, proteins, fats and oils, vitamins, minerals and dietary fiber. Different postharvest researches were conducted using standard methods and protocols. Nutrition-focused varieties and associated technologies developed by BARI were evaluated through:

i) laboratory-based nutritional composition and shelf-life analysis, ii) multi-location agronomic performance trials, iii) yield and quality assessment, iv) profitability, v) climate adaptation and mitigation performance evaluation and vi) farmers' participatory trials and adoption studies.

3. Results

3.1. Minor Cereals

BARI has released many high-yielding, stress-tolerant minor cereal crop varieties such as barley, oat, millets, sorghum, quinoa, buckwheat, and chia. These minor cereals supply carbohydrates, fiber, and essential minerals, improving dietary diversity and food system resilience. Improved millets are rich in iron and zinc and are tolerant to drought and heat.

Table 1. Nutrient enriched minor cereal crop varieties developed by BARI and their main features and quality attributes

Crop	Variety	Yield (t/ha)	Key Nutrient / Trait	Adoption Area
Barley	BARI Barley-9	2.2–2.6	Protein 12%, drought tolerant	Barind Tract
	BARI Barley-7	2.2–2.5	Protein 11.5%, salt tolerant	Saline area
Foxtail millet	BARI Kaon-2	2.75–3.0	Protein 11.5%, Fe 45.6 ppm & Zn 36.2 ppm, better adapted to soils having low fertility	Char area
Proso millet	BARI Cheena-1	2.5–3.0	Protein 11.8%, heat & drought tolerant	Char & Barind Tract
Oat	BARI Oat-1	1.0–1.2	Protein 12.8%, fiber 3.7%, Fe 61.1 ppm, Zn 25.8 ppm, Mg 2449.6 ppm	Nationwide
Raghi	BARI Raghi-1	3.0–3.2	Protein 9.5%, Fe 45.8 ppm, Ca 3250 ppm	Barind & char area

3.2 Pulses and Oilseeds: BARI Masur-8 is a nutrient-rich, high-yielding BARI developed lentil variety high in iron, zinc, selenium, protein, and fiber to combat micronutrient malnutrition (Akhond *et al*., 2025). BARI also developed low-erucic-acid mustard varieties that provide healthy fats and vitamins while reducing reliance on imported edible oil.

Table 2. Nutrient enriched pulse and oilseed crop varieties developed by BARI

Crop	Variety	Yield (t/ha)	Key Nutrient / Trait	Adoption Area
Lentil	BARI Masur-8	2.0–2.5	Fe 74 ppm, Zn 61 ppm, Se 325 µg/kg	60–70% area coverage
Mustard	BARI Sarisha-18	2.0–2.5	Oil 42–44%, low erucic acid	25-36% in Barishal, Rangpur, Pabna, Rajshahi, Bogura district
	BARI Sarisha-19	1.7–2.5	Oil 40–42%, salt tolerant	-

3.3 Tuber Crops

BARI carries out research on potato, sweet potato, aroid, cassava and yam. Its potato and sweet potato varieties boost calorie intake, while orange-fleshed sweet potato variety helps to reduce vitamin A deficiency, especially, in children and women.

Table 3. Nutrient enriched tuber crop varieties

Variety	Trait	Yield (t/ha)	Key Nutrient / Trait	Adoption Area
BARI Alu-77	Late blight resistant	30–35	Carbs	Nationwide
BARI Alu-78	Salt & heat tolerant	40–45	Carbs	Coastal region
BARI Alu-101	Purple, high anthocyanin	40–45	Antioxidant	~10% farmers of the country
BARI Mistialu-7	Vit A 700 IU	40–45	Prevents night blindness	Dry flesh consumers
BARI Mistialu-8	Light yellow, Vit A 650 IU	40–45	Carbs, prevents night blindness	Char areas
BARI Mistialu-16	Deep orange, beta carotene	40–45	Prevents night blindness	Char areas
BARI Mistialu-17	Deep purple, Anthocyanin	25–30	Antioxidant	Char areas
BARI Mistialu-18	Deep orange, beta carotene	>45	Energy, prevents night blindness	Char areas
BARI Panikachu-1	Long stolon	25–30 (stolon), 15-20 (rhizome)	Iron, Vit K	Nationwide
BARI Panikachu-7	Resistant starch, Mn & Fe	8–11 (stolon), 60–75 (rhizome)	Gut health, reduces anemia	Nationwide, maximum in Bhola
BARI Shahebi Kachu-1	Long rhizome, β-carotene	60–90	Iron, Vit C & K, fiber	Barisal
BARI Cassava-4	Starch 33%	45	Carbs, Vit C & A, iron	Hilly area
BARI Mete Alu-3	Iron, Ca, Mn, beta carotene	30–35	Heart health, energy metabolism	Hilly area

3.4. Fruits and Vegetables

Fruits

Improved varieties of mango, banana, jackfruit, guava, pineapple and malta demonstrate considerable nutritional importance due to their high concentrations of vitamins, minerals, dietary fiber and antioxidants. These micronutrients are essential for growth, metabolic regulation, immune function, disease prevention and maternal and child nutrition. Selected BARI-developed fruit varieties showed enhanced nutritional attributes compared to local cultivars:

Table 4. Variety, key features related to nutrition and adoption of different nutrient-rich fruit varieties

Fruit	Variety	Yield (t/ha)	Key Nutrient / Trait	Adoption
Mango	BARI Aam-3	32–37	Vit A & C, fiber	Nationwide
	BARI Aam-4	35–40	Vit A & C, fiber	*NW Bangladesh
Banana	BARI Kola-1	45–60	Vit B & C, potassium	Nationwide

Fruit	Variety	Yield (t/ha)	Key Nutrient / Trait	Adoption
Jackfruit	BARI Kanthal-2	50–65	Vit A & C, potassium	Chittagong, Gazipur, Mymensingh, Sylhet
	BARI Kanthal-6	40–50	Vit A & C, potassium	Nationwide
Guava	BARI Peyara-2	30–35	Vit C, lycopene	Nationwide
Pineapple	Year-round production tech.	35–50	Vit C, bromelain	Chittagong, Tangail, Sylhet
Malta	BARI Malta-1	20–25	Vit C, antioxidants	Nationwide

*NW= North West

The yield advantage of the BARI-developed nutrient-rich fruit varieties over existing local varieties ranged from 15–35%. Improved quality parameters like enhanced fruit size and uniformity, improved shelf-life, better processing and cooking quality, and higher consumer acceptability were observed in those varieties. It is possible to earn 5 to 25 lakh taka or more per hectare from the fruit crops, and the net return increased by 20–40%. The adoption rates of the fruit varieties by the farmers are 60–75% in pilot intervention areas.

Vegetables

BARI has developed a wide range of year-round vegetables rich in vitamins, minerals, antioxidants, and dietary fiber which are presented in Table 5.

Table 5. Nutrient enriched vegetables varieties developed by BARI

Sl. No	Variety Name	Key Nutrient Related Traits	Type / Performance	Yield (t/ha)
1	BARI Hybrid Tomato-8	Vit. C 33 mg, β-Carotene 26 mg, TSS 7%	Hybrid, Heat tolerant	30–35
2	BARI Hybrid Tomato-11	Vit. C 34.4 mg, β-Carotene 20 mg, TSS 8.8%	Hybrid, Heat tolerant	35–40
3	BARI Mistikumra-1	Vit. C 22 mg, β-Carotene 90 mg, TSS 10.5%	*OP variety	40–45
4	BARI Hybrid Mistikumra-2	Vit. C 25 mg, β-Carotene 95 mg, TSS 11%	Hybrid	45–46
5	BARI Hybrid Sasha-1	Vit. C 3.68 mg, β-Carotene 42.5 mg, TSS 5.12%	Hybrid	30–35
6	BARI Sheem-1	Vit. C 12.54 mg, β-Carotene 22.32 mg, TSS 9.17%	OP variety	22–25
7	BARI Sheem-7	Vit. C 12.33 mg, β-Carotene 22.01 mg, TSS 9.57%	OP, Heat tolerant	14–15
8	BARI Lau-6	Vit. C 8–12 mg, β-Carotene 25–44 µg, Fiber 0.5–1.2%	OP, Year-round	35–60
9	BARI Mistimorich-1	Vit. C 120–130 mg, β-Carotene 1600 µg, Protein 0.8–1%	OP variety	20–25
10	BARI Mistimorich-2	Vit. C 180–185 mg, β-Carotene 120 µg, Protein 1%	OP variety	25–30
11	BARI Mistimorich-3	Vit. C 150–160 mg, β-Carotene 800–1200 µg	OP variety	30–35
12	BARI Begun-10	-	OP variety	40–50
13	BARI Begun-12	-	OP variety	55–60
14	BARI Hybrid Begun-4	-	Hybrid	55–60

Sl. No	Variety Name	Key Nutrient Related Traits	Type / Performance	Yield (t/ha)
15	BARI Tomato-21	-	OP variety	80–85
16	BARI Tormuj-1	-	OP variety	40–45
17	BARI Derose-2	-	OP variety	23–25
18	BARI Data-1	-	OP variety	35–40
19	BARI Lalshak-1	-	OP variety	20–22
20	BARI Gimakalmi-1	-	OP variety	40–45

*OP = Open pollinated

3.6. Management Practices

BARI's contributions extend beyond crop genetics to sustainable production systems. Agronomic management, soil health improvement technologies, bio-fertilizers and conservation agriculture practices enhance nutrient uptake and long-term productivity.

Table 6. Nutrition focused management practices developed by BARI

Technology	Agronomic Productivity (t/ha)	Profitability (BCR)	Adaptation/ Resilience	Adoption Area
Potato–Red amaranth–Maize–T. aman (4 crops)	REY 38, LUE 98.7%	3.46	Crop diversification, high cropping intensity	Irrigated rice zone
Zero-tillage garlic (mulched)	Yield 5–6	3.31	Adopted in saline area, saves time & energy	Coastal saline areas
Pea + Hybrid maize intercropping	MEY 18.19	3.24	Efficient resource use, provides both carbohydrate and protein	Maize growing areas
Onion–Jute pattern (beel)	REY 18.08	3.08	Efficient land use, diversified income	Faridpur beel area
Watermelon relay with garlic	GEY 17.36	3.98	Enhances cropping intensity	Chalanbeel region
Relay maize with potato	PEY 28.59	2.67	Better resource use	Potato growing areas
Cheena + Groundnut intercropping	GEY 3.20; LER 1.76	4.65	Climate-resilient legume–cereal system, provides both carbohydrate and oil	Charlands
Mustard + Boro mixed cropping	REY 9.27	2.88	Enhances oil consumption	Cumilla
Mustard–Sesame–T. aman (3 crops)	REY 11.82	2.00	Cropping intensity 300%	Barind area
Mustard–Spinach–T. Aus–T. aman	REY 24.30	3.41	Higher productivity & employment	-
Pea + Sunflower intercropping	SEY 6.64	3.80	Diversified cropping	-
Fenugreek INM (poultry manure + fertilizer)	Yield 2.10; protein 21.4%	2.0–2.5	Improves protein & nutrient efficiency	Small farmers

Technology	Agronomic Productivity (t/ha)	Profitability (BCR)	Adaptation / Resilience	Adoption Area
Potato + vegetables intercropping	PEY 45.01	2.98	Nutritional diversification	Potato growing areas (Munshiganj etc.)

REY = Rice Equivalent Yield, LUE = Land Use Efficiency, MEY = Maize Equivalent Yield, GEY = Garlic Equivalent Yield, PEY = Potato equivalent yield, LER = Land Equivalent Ratio, SEY = Sunflower Equivalent Yield, BCR = Benefit Cost Ratio

3.7. Post-Harvest Technology and Value Addition

Post-harvest losses significantly affect food and nutritional security of the nation. BARI has developed improved storage, handling, processing, packaging and transportation technologies that reduce losses and preserve nutrients. Value-added products such as dried fruits, vegetables, and spices, pickle, chutney, jelly, jam, candy, chips, formulated powder, and processed fruits, vegetables and spices products diversify diets and create additional income (Islam *et al*., 2023).

Table 7. Nutrition focused post-harvest management technologies and value-added products developed by BARI

Value-added products/ Post-harvest Technology	Key Performance	BCR / Profitability	Adaptation & Resilience	Adoption Area
Vacuum fried jackfruit chips	Low-oil crispy chips, better color & nutrients, shelf life ~6 months	BCR 2.95	Supports year-round processing & market linkage	Jackfruit growing areas (Gazipur, Tangail, Jashore, Narsingdi, Hill tracts)
Osmotically dehydrated jackfruit slices	Reduced moisture, better flavor, longer storage	BCR 2.50	Improves shelf life & value addition	Dhaka, Gazipur, Tangail, Jashore
Edible coating for fresh-cut guava	Maintains moisture, color & Vit-C; extends shelf life 3–4 days	—	Low-cost natural preservation	Guava growing areas; export interest
Guava–pineapple jelly	High nutritional value (high antioxidants, Vit C), improved flavor; shelf life ~8 months	BCR 2.20	Natural preservatives, value addition	Guava & pineapple growing areas
Jackfruit seed flour	High carbs & protein; suitable for food fortification	—	Utilizes by-products & reduces waste	Some entrepreneurs using dryers
Dehydrated onion	High nutritional density (8-11 times) and protein content; Increased shelf life	Profitable due to off-season sale	Converts perishable crop to shelf-stable product	Limited adoption by entrepreneurs
Dehydrated garlic	Increased Vitamin-C (~4.5 times); Increased shelf life	Higher off-season price	Long-term storage & nutrient concentration	Limited adoption by entrepreneurs

Value-added products/ Post-harvest Technology	Key Performance	BCR/ Profitability	Adaptation & Resilience	Adoption Area
Plum pickle & candy	Shelf life >12 months; higher energy & micronutrients	Higher market price	Reduces waste & transport cost	Limited adoption by entrepreneurs
Natural potato storage (field)	Storage 3–4 months without quality loss	Low-cost storage	Useful for smallholding farmers	Potato growing areas

4. Challenges and Way Forward

Challenges:

- Difficulty in combining high yield and nutrition in fruits.
- Limited development of nutrient-rich varieties.
- Lack of nutritional profiling of cultivated fruit varieties.
- Ensuring year-round safe and nutritious fruits.
- High post-harvest losses and processing gaps.
- Climate change impacts.
- Biotic and abiotic stresses.
- Limited export infrastructure.
- Limited access to finance and investment.
- Market volatility and price fluctuations.
- Weak extension, lack of technical knowledge and marketing support.
- Consumer awareness gaps.
- Limited availability of quality jackfruit and guava for processing.
- High cost or unavailability of packaging, coating materials and processing equipment and machinery (freeze dryers, integrated waxing machines).
- Lack of skilled manpower, labs and facilities.
- Limited seed production (sweet potato, aroids) and problem in mechanization (potato).
- Labor shortages and lack of trained personnel.
- Limited national and international collaboration.

Future research Priorities:

- Nutrition related data bank for released varieties.
- Expand climate-resilient and nutrition-enhanced breeding programs.
- Develop hybrid and stress-resistant fruit varieties with high nutritional value.
- Ensure year-round, off-season and lean-season fruit production.
- Develop technologies for safe production, post-harvest loss reduction and urban/suburban cultivation.
- Strengthen research–extension–nutrition linkages.
- Integrate nutrition education into agricultural advisory services.
- Promote nutrient-dense crop varieties and value-added products.
- Improve post-harvest infrastructure and market linkages.

- Invest in human resource development.
- Strengthen financial and policy support and research-to-market linkages.
- Utilize advanced technologies.
- Promote nutrition-focused crop cultivation and value chain development.
- Household nutritional survey, adoption, impact and perception studies of the BARI released nutrition-rich crop varieties.
- Establish Model for Nutrition Focused Gardens
- Piloting and commercialization activity of BARI mandated nutrition sensitive crop varieties and technologies.

5. Conclusion

BARI is the largest research organization in Bangladesh that contributes to food and nutrition security, advancing crop improvement, nutrition-sensitive agriculture, sustainable farming, and technology adoption and dissemination of multiple crops. Its work enhances food availability, dietary diversity, nutritional quality, and farmers' livelihoods, supporting SDG-2. Scaling BARI's innovations is vital for a resilient, nutritious and sustainable food system.

BARI may more focus on nutritional analysis of the released varieties, expansion of climate resilience and nutrition focused breeding programs and technology development for post-harvest loss reduction to strengthen nutrition-sensitive agriculture. Household nutritional survey, adoption, impact and perception studies of the BARI released nutrition-rich crop varieties may be undertaken with proper funding for determining the best nutrient-rich varieties and organizing campaigns for popularizing the same. Model of Nutrition Focused Gardens may be established in and around BARI Headquarter and Regional Agricultural Research Stations (RARS) to demonstrate nutrient-rich BARI varieties and technologies of the area involving scientists, extension personnel, farmers, food processors, agricultural traders, entrepreneurs, and relevant stakeholders for inspiring domestic consumption and foreign exports. Piloting and commercialization activity of BARI mandated nutrition sensitive crop varieties and technologies for food and nutrition security as well as employment generation may also be implemented.

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Development and Evaluation of Nutrition-Sensitive Rice Varieties for Improved Food and Nutritional Security in Bangladesh

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Introduction

Rice is the staple food in Bangladesh, providing more than 70% of daily caloric intake. Vitamins and essential micronutrients including B vitamins, β-carotene, iron, zinc and high-quality protein are critical for maintaining human health, particularly in populations heavily dependent on cereal-based diets. In such systems, iron- and zinc-biofortified rice, protein-enriched rice and pigmented varieties such as black or red rice can play an important role in improving micronutrient supply and antioxidant intake. B vitamins-including thiamine, riboflavin, niacin, folate and vitamin B_{12} are vital for energy metabolism, red blood cell formation and neurological function and their deficiencies are associated with anemia, impaired cognitive development and reduced productivity (WHO, 2026). Iron is essential for hemoglobin synthesis and oxygen transport and iron deficiency anemia affects nearly one-third of women of reproductive age worldwide, leading to decreased productivity and increased maternal health risks (UNICEF, 2023).

Rice remains the dominant staple in Bangladesh though per capita consumption is gradually declining. With an annual reduction of 0.028%, energy intake is projected to fall to 2201 kcal by 2030 and 2188 kcal by 2050, sustained by approximately 363–365g rice/day (Shozib *et al.* 2020). Despite increased rice production from high-yielding varieties, deficiencies in essential nutrients such as zinc and iron persist among the population. Women and children are particularly vulnerable, as their diets consist largely of polished rice with low micronutrient content, a condition known as 'hidden hunger.' Addressing this requires improving not only food quantity but also its nutritional quality. Zinc is critical for immune function, growth, cognitive development, and wound healing, especially in predominantly rice-based diets with limited animal-source foods. Globally, hidden hunger affects approximately 38% of pregnant women and 43% of preschool-aged children (Trijatmiko *et al.*, 2016). In Bangladesh, the National Micronutrient Survey 2019–20 reported zinc deficiency in 31% of children under five and 43.4% of women (icddr,b, 2021). Zinc deficiency increases susceptibility to infections such as diarrhea and pneumonia and impairs growth, cognitive performance and long-term productivity (Afsar, 2022; The Daily Star). Strengthening zinc intake through dietary diversification, supplementation, fortification and especially rice biofortification is therefore a key public health priority. Zinc-enriched and pigmented rice varieties provide promising solutions. Pigmented rice-such as black, red and purple pericarp rice—contains higher levels of antioxidants, fiber and essential micronutrients than polished white rice. Black rice is particularly rich in anthocyanins (approximately 100–400 mg/100 g), while pigmented varieties also provide higher total phenolics (200–500 mg GAE/100 g), dietary fiber (2–4%), iron (2–5 mg/100 g) and zinc (1.5–3.0 mg/100 g) compared to white rice (Finocchiaro *et al.*, 2007; Zhang *et al.*, 2010; Shao *et al.*, 2014; FAO, 2019). These bioactive compounds are associated with reduced oxidative stress, improved metabolic health, enhanced immune function and better glycemic response. Promoting such varieties can improve diet quality while creating value-added market opportunities for farmers. β-carotene, a provitamin A carotenoid abundant in pigmented crops, is converted to vitamin A in the body and supports vision, immunity, and antioxidant defense; vitamin A deficiency remains a public health concern in South Asia (FAO, 2022).

The Bangladesh Rice Research Institute (BRRI) is actively developing β-carotene-enriched rice varieties. While rice contributes significantly to energy intake and provides small amounts of B vitamins in its whole-grain form, milling and polishing reduce micronutrient content. Thus, populations relying heavily on polished rice are at increased risk of micronutrient deficiencies. Improving the nutritional profile of rice through biofortification and promoting nutrient-dense varieties is critical to addressing hidden hunger in rice-dependent regions. Crop management practices also influence rice nutritional quality. Optimized fertilization, soil health management, irrigation, integrated pest management, and micronutrient supplementation can enhance both yield and grain nutrient content. These agronomic interventions complement genetic improvements and support nutrition outcomes at scale. Nutrition-Sensitive Agriculture (NSA) integrates these strategies by aligning agricultural production with nutrition and public health objectives. In Bangladesh, NSA emphasizes improving diet quality in rice-based systems through biofortification, promotion of nutrient-dense crops (including pulses, vegetables, and pigmented rice), and diversification of farming systems by integrating fish and livestock. Advanced research tools, such as genomics, marker-assisted breeding and phenomics, accelerate the development of rice varieties that combine high yield, climate resilience, and enhanced micronutrient density. By improving crop productivity, nutritional quality, and integration with health initiatives, NSA strengthens rice-based food systems in Bangladesh. This comprehensive approach helps reduce micronutrient deficiencies, improve immune function and child development and enhance long-term food and nutrition security.

This study aims to develop and evaluate high-yielding, nutition-enriched rice varieties under NSA approaches to improve both productivity and nutritional quality. It examines growth performance, yield, morpho-physiological traits and grain quality of promising biofortified genotypes, alongside optimized crop management, to enhance food and nutritional security and reduce micronutrient deficiencies in Bangladesh.

Materials and Methods

Field experiments were carried out at BRRI, Gazipur during the T. Aman and Boro seasons using promising zinc-enriched along with nutrient enriched rice lines along with standard check varieties. The trials followed recommended agronomic practices with proper replications. In T. Aman, fertilizers @108 (234 kg Urea): 17.4 (87 kg TSP): 58.5 (117 kg MoP): 14 (78 kg Gypsum): 4.3 (12 kg $ZnSO4$) kg NPKSZn/ha were applied in the trial whereas in Boro, fertilizers @138 (300 kg Urea): 20 (100 kg TSP): 83 (165 kg MoP): 20 (112 kg Gypsum): 4 (11 kg $ZnSO4$) kg/ha NPKSZn were applied in the trial. All phosphorus, two-thirds of potassium, sulfur, and zinc were applied during land preparation; nitrogen was applied in three equal splits at 10, 30, and 40–50 days after transplanting (DAT) and the remaining potassium was applied during the second urea top-dressing. Standard irrigation, weeding and pest management practices were maintained to ensure optimal crop growth. Grain samples were analyzed for zinc, iron, protein,and amylose content, and data were collected on yield, yield components, milling recovery, cooking quality, economic performance, and adaptability. In addition, molecular breeding approaches were used to genotype zinc-enriched lines with molecular markers to confirm the presence of high-zinc genes. Lines carrying the target genes were selected as donor parents for hybridization to develop high-zinc varieties and laboratory analyses were conducted to measure grain zinc content and validate phenotypic expression. Laboratory protocols for pigmented rice were followed as standard protocols of Rice Analytical Laboratory and grain quality and nutrition division laboratory of BRRI.

Results and Discussion

Nutrition-sensitive rice genotypes demonstrated superior performance compared with conventional varieties in both productivity and nutritional composition. Zinc-enriched rice is particularly important because zinc deficiency is widespread in Bangladesh, especially among women and children. Zinc is essential for growth, immune function, cognitive development, and overall health. BRRI has developed a range of nutrient-enriched rice varieties to combat micronutrient deficiencies and enhance dietary quality in Bangladesh. To address zinc deficiency, BRRI released varieties such as BRRI dhan62, BRRI dhan64, BRRI dhan72, BRRI dhan74, BRRI dhan84, and BRRI dhan100, BRRI dhan102 which contain 19.8–27.6 mg of zinc per kg of polished rice, compared with 12-16 mg/kg in conventional varieties. These varieties not only help meet daily zinc requirements for women and children but also maintain high yields (4.5–8.1 t/ha) across diverse Aman and Boro rice-growing ecosystems. BRRI dhan84 is a high yielding rice variety containing both zinc and iron (10 mg/kg), providing essential micronutrients to help meet human dietary iron requirements. Molecular breeding approaches, including introduction of the *OsVIT2* mutant gene in BRRI dhan48 with marker-assisted selection was completed in Japan with the collaboration of JICA, increased zinc and iron accumulation by ~1.2 and ~1.5 times, respectively without yield penalties.

These lines are being evaluated for yield assessment along with check varieties at BRRI. At the same time the line with *OsVIT2* mutant gene is used for hybridization with high yielding varieties to incorporate high yield and high zinc and iron. Functional nutrition studies showed antioxidant-rich rice improved oxidative defense and could provide 20-40% of the estimated average requirement (EAR) of zinc for women and children. Integration of genomics, agronomy and nutrition science accelerates breeding and links crop improvement to public health outcomes. Globally, biofortification programs have reached over 50 million people, demonstrating measurable improvements in dietary intake (Harvest Plus, 2022).

Transgenic rice is being developed to increase high zinc and iron in polished grains, using genes like *Zmpsy1* and *ApFer* gene into popular rice varieties through backcross breeding. These lines can provide more zinc, supplying 20–40% of daily requirements in rice-based diets (Bouis & Saltzman, 2017). Integrated with nutrition-sensitive agriculture, such rice enhances micronutrient intake, reduces hidden hunger, and strengthens food and nutrition security in Bangladesh. At BRRI research on high iron and zinc rice using transgenic rice as parent is undergoing. In T. Aman 2024-25, eleven hemizygous (H-type) plants were identified in BC_2F_1 under the BRRI dhan87 background. Four BC_1F_1 crosses (BR11712-4R-93, BRRI dhan98, BRRI dhan103, BRRI dhan107) were developed to enhance iron and zinc and one BC_3F_1 produced 137 seeds. In Boro 2024–25, ten fixed (B-type) lines and 34 hemizygous plants were identified from BC_1F_1 (BR11712-4R-93, BRRI dhan98, BRRI dhan103) and BC_3F_1 (BRRI dhan87), along with one confirmed F_1 utilizing BRRI dhan103. Three BC_2F_1 crosses produced 688 seeds. Research on β-carotene enriched or golden rice using transgenic rice as parent is undergoing. GR2E lines were introgressed via MAS into six BRRI varieties; 54 lines (BRRI dhan71 and BRRI dhan87 backgrounds) were multiplied for confined trials. Seeds of 22 high-GR2E CFT lines will be preserved for future evaluation. In addition to zinc, BRRI has developed iron-enriched and pigmented rice lines, including black and red rice, which are rich in anthocyanins, phenolic compounds, dietary fibre and essential minerals. These varieties support antioxidant intake, improve metabolic health and provide greater nutritional value than conventional polished rice. BRRI has developed vitamin E and antioxidant enriched BRRI dhan115, the first high-yielding black rice variety in Bangladesh. The variety is developed from a cross between Padi Kool (black rice) and BRRI dhan28 using anther culture technique to produce doubled haploid plants in the F_1 generation. The average yield of BRRI dhan115 is 7.4 t/ha having growth duration of 140-142 days in Boro season. The black color grains contain 14.98 mg/kg vitamin E, 29.12 mg/kg cyanidin-3-glucoside (C3G), and 536.61 μM AAE antioxidants per 100 g rice. The BRRI dhan115 represents a significant advancement in biofortified rice development for Bangladesh due to its high nutritional value and good yield performance. At the same time, the development of pigmented rice lines including black and red rice is ongoing. Several lines were developed and they were evaluated in different trials at BRRI Gazipur. Some advanced materials were evaluated in on-stations in Regional Yield Trial (RYT) and some were evaluated in Advance Rice Adaptive Research Trial (ALART) under on-farm conditions for their specific and general combining ability. In T. Aman 2024-25 season, the highest yielding genotype was BR12839-4R-106, producing 3.33 t/ha grain yield with 130 days growth duration and a total antioxidant capacity (TAC) was 615.61 μM. This was followed by the genotype BR12839-4R-137, which produced 3.25 t/ha yield with 123 days growth duration and a TAC was 609.05 μM. In PVT, the proposed line BR12836-4R-63 produced 9.29% higher yield having higher C3G contents which was 492.27 mg/kg, ensuring its suitability as a variety to be released. In Boro 2024-25 season the genotypes BR12839-4R-138-4 and BR12839-4R-106 produced 5.5 t/ha yield where the antioxidant capacity of these two genotypes were 654.22 and 609.05 μM AAE/100g (BRRI, 2026)

Reports suggested that black rice and BRRI dhan84 together exemplify the dual frontier of nutraceutical rice research in Bangladesh. Black rice, enriched with Cyanidin-3-Glucoside (C3G), demonstrates potent antioxidant, anti-inflammatory, and anti-cancer properties, with fortification strategies (Shozib *et al.*, 2021) and water-extraction methods (Shozib *et al.*, 2026) proving effective in retaining bioactivity and enhancing gut health. In parallel, BRRI dhan84 emerges as the most nutraceutically superior high-yielding variety, combining high zinc, antioxidants and water-soluble vitamins with optimal nutrient retention at a 10% milling degree (Shozib *et al.*, 2025). Collectively, these findings position black rice as a therapeutic nutraceutical chassis and BRRI dhan84 as a functional food ingredient, offering synergistic potential to combat malnutrition, improve mineral bioavailability and manage chronic diseases such as cancer and inflammation in rice-dependent populations.

BRRI has developed low glycemic index (GI) rice to help manage diabetes, a condition that is increasingly common in Bangladesh. Low GI rice varieties such as BR16, BRRI dhan46, BRRI dhan69, and BRRI dhan105 form an important part of BRRI's collection of health-focused rice. Through advanced molecular breeding, trait-marker analysis and precise nutrient profiling, BRRI continues to deliver high-yielding, climate-resilient and nutrient-rich rice varieties, promoting nutrition-sensitive agriculture and supporting national food and nutrition security.

BRRI has also developed protein-rich rice varieties that provide higher protein than conventional rice, helping improve nutrition in Bangladesh where rice is the main food. Rice gives some protein that supports growth and tissue repair, and its value increases when eaten with foods like lentils, beans, fish, eggs, milk, and meat. In a country where rice supplies most daily calories, these varieties help improve dietary protein intake, especially for low-income people. Regular consumption supports child growth, muscle development and overall health, while helping reduce malnutrition and related problems. The list of different nutrition enriched rice varieties along with protein rich varieties are mentioned in the Table 1.

Table 1. The list of different nutrition enriched rice varieties of BRRI, Bangladesh

SN	Nutritional Trait	Varieties	Amount/ Percentage	Gain yield
1	Antioxidant	BR5	700 μ M AAE/100 g (Total Antioxidant Capacity)	3.0 (t/ha)
2		BRRI dhan34	415.6 μ M AAE/100 g (Total Antioxidant Capacity)	3.5 (t/ha)
3		BRRI dhan84	479.22 μ M AAE/100 g (Total Antioxidant Capacity)	6.5 (t/ha)
4	Low GI	BR16	52.41 (GI Value)	6.0 (t/ha)
5		BRRI dhan46	53.1 (GI Value)	4.7 (t/ha)
6		BRRI dhan69	54.9 (GI Value)	7.3 (t/ha)
7		BRRI dhan105	55 (GI Value)	7.6 (t/ha)
1	GABA (Gamma Amino Butyric Acid)	BRRI dhan31	12.5 mg / 100 g pre-germinated seed	5.0 (t/ha)
1	High Zinc	BRRI dhan62	19.8 mg/kg	4.5 (t/ha)
2		BRRI dhan64	24.0 mg/kg	6.5 (t/ha)
3		BRRI dhan72	22.8 mg/kg	6.0 (t/ha)
4		BRRI dhan74	24.2 mg/kg	7.1 (t/ha)
5		BRRI dhan84	27.6 mg/kg	6.5 (t/ha)
6		BRRI dhan100	25.7 mg/kg	8.0-9.6 (t/ha)
7		BRRI dhan102	25.5 mg/kg	8.0-9.6 (t/ha)
1	High Protein	BRRI dhan34	10.20%	3.5 (t/ha)
2		BRRI dhan36	10.00%	5.0 (t/ha)
3		BRRI dhan37	10.30%	3.5 (t/ha)
4		BRRI dhan66	10.80%	4.5 (t/ha)
5		BRRI dhan81	10.30%	6.5 (t/ha)
6		BRRI dhan86	10.10%	6.5 (t/ha)
7		BRRI dhan90	10.30%	5.0 (t/ha)
8		BRRI dhan91	10.40%	3.5 (t/ha)
9		BRRI dhan96	10.80%	7.0 (t/ha)
10		BRRI dhan107	10.07%	8.2 (t/ha)
11		BRRI dhan109	10.60%	6.0 (t/ha)
12		BRRI Hybrid dhan4	10.60%	6.5 (t/ha)
13		BRRI Hybrid dhan7	10.30%	7.0 (t/ha)
1	Iron	BRRI dhan84	10 mg/kg	

Puffed, popped and flattened rice are commonly eaten in Bangladesh and India because they are convenient and have a long shelf life. Although puffed and popped rice are easier to digest, flattened rice generally provides better protein utilization. This indicates that processing methods and variety selection greatly affect nutritional value (BRRI, 2005). Various processed rice products such as biscuits, cakes, noodles, puffed rice and extruded snacks help increase dietary diversity and improve nutrient intake. BRRI's energy-rich rice biscuit (~5.15 kcal/g) has potential for reducing malnutrition and supporting school feeding and relief programs as an alternative to wheat (Shozib *et al.*, 2020). Fermented rice bran further enhances nutrition by increasing protein (29.52%), fat (5.38%), fiber (38.96%), and antioxidant properties, while rice bran oil contains higher levels of γ-oryzanol, vitamin E, and unsaturated fatty acids (Alauddin *et al.*, 2024). Similarly, rice noodles made from BR26, BRRI dhan28, and BRRI dhan29 offer good energy (~346 kcal/100g), protein (~9 g) and important minerals with good acceptability (Dipti *et al.*, 2023). Recent advances in rice improvement integrate biofortification, functional grain development, grain quality enhancement and improved agronomic practices to simultaneously boost productivity, nutrition, and sustainability. Nutritional enhancements included notable increases in grain zinc and protein content while maintaining competitive yields and pigmented rice varieties provided high antioxidants, fiber, and micronutrients. Improved grain quality-with higher milling recovery, desirable shape and acceptable cooking characteristics-enhanced market acceptability. Crop management optimization improved nutrient-use efficiency, stress adaptation and profitability. A conceptual framework to integrate nutrient sensitive agriculture is given herewith (Figure 1).

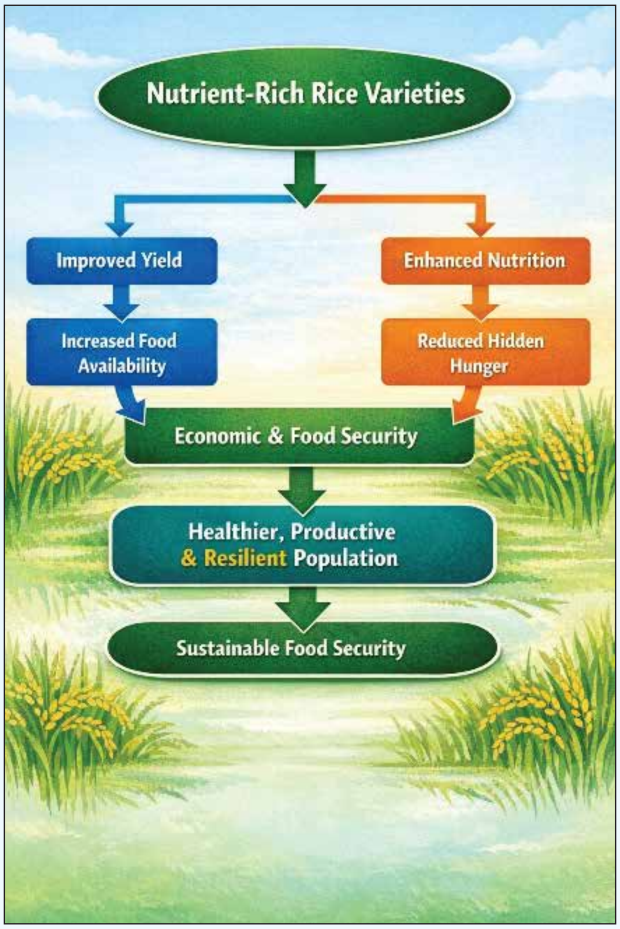

Figure 1. Conceptual framework showing how nutrient-rich rice varieties contribute to sustainable food security (Author-generated).

Conclusion and Way Forward

Rice research in Bangladesh, led by BRRI, is shifting toward nutrition-sensitive and functional foods, developing biofortified rice enriched with zinc, iron, protein, β-carotene and antioxidants using advanced breeding tools. These varieties help reduce micronutrient deficiencies, improve immunity and prevent non-communicable diseases, while supporting value-added products like biscuits and noodles for better dietary diversity. Scaling adoption through extension, nutrition programs, farmer training and supportive policies can strengthen food security, reduce healthcare costs, boost productivity and contribute to SDG-2 by addressing hidden hunger.

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Nutrition-Sensitive Agricultural Programs at BINA for Sustainable Food and Nutrition Security

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1. Introduction

Achieving sustainable food and nutrition security remains one of the foremost challenges for Bangladesh. As a nation where agriculture constitutes the backbone of the economy and provides livelihoods for millions, the sector plays a decisive role in shaping food availability, dietary diversity and overall nutritional outcomes (FAO, 2014). Ensuring food and nutrition security in Bangladesh requires an integrated approach addressing productivity, nutritional quality, soil sustainability and postharvest loss reduction. Despite significant gains in crop production, Bangladesh faces three major interconnected challenges: (a) Micronutrient malnutrition (hidden hunger) affecting women and children (Sperotto *et al.*, 2010; Bouis & Saltzman, 2017). (b) Soil fertility decline and nutrient imbalance due to intensive cropping and imbalanced fertilizer use (FRG, 2018). (c) High postharvest losses (20 - 40%) in horticultural crops due to perishability, microbial spoilage and inadequate storage systems (FAO, 2011). Biofortification of rice (*Oryza Sativa* L.) with micronutrients is widely recognized as a sustainable strategy to alleviate human Fe and Zn deficiencies in Bangladesh where rice is the staple food. Despite progress in rice production, dietary diversity remains limited, leaving women and children vulnerable to iron, zinc, vitamin A and other micronutrient deficiencies. Bangladeshi children become stunted growth and underweight due to micronutrient deficiencies; particularly iron (Fe) and zinc (Zn) deficiency. Anemia is also highly prevalent among children and women in Bangladesh due to iron deficiency (Khanom, *et.al.*, 2021). Biofortification, achieved through plant breeding, offers a sustainable solution to combat micronutrient deficiencies by enriching staple and other crops with essential vitamins and minerals, ensuring better nutrition for communities that rely heavily on these foods (Bouis & Saltzman, 2017). Bangladesh Institute of Nuclear Agriculture (BINA) has implemented mutation breeding, hybridization, and marker-assisted selection to develop nutrient-enriched crop varieties that integrate nutrition, productivity and climate resilience. Gamma irradiation has been recognized as a safe and effective non-chemical technology for sprout inhibition, microbial control, and shelf-life extension (Diehl, 1995; WHO, 1999). In Bangladesh, gamma irradiation has shown promising results in improving shelf life and preserving the quality of fresh fruits, vegetables, and processed products (Akhther *et al.* 2022; in Akhther *et al.*, 2023). Soil health and appropriate nutrient management are critical components of sustainable agriculture, influencing crop yield, environmental sustainability and overall food security (Pando *et. al.*, 2024). The Soil Science Division of BINA has developed location specific technologies to address these challenges. Crop profitability is a critical factor in sustainable agricultural development. The Benefit-Cost Ratio (BCR) provides a measure of profitability, helping identify varieties that maximzes returns relative to production costs (Sarker *et. al.*, 2021).

Nutrition-sensitive agriculture (NSA) in Bangladesh focuses on transforming agricultural systems from staple production toward improved nutrition, emphasizing dietary diversification, biofortification, and gender integration. This approaches make agriculture into a dynamic food-based activity, leading to nutritional security. BINA has developed integrated NSA approaches through its Plant Breeding, Soil Science, Agricultural Economics and Horticulture divisions to reduce production losses, enhance nutritional quality, and improve farmers' income. Collectively, these innovations contributing strengthen food security, farmer's profitability, and climate resilience in Bangladesh.

2. Materials and Methods

2.1 Development of Nutrient-Enriched Varieties

Nutrient-enriched rice, pulses, oilseeds, vegetables and fruits were developed through mutation breeding (gamma irradiation, 150–400 Gy), hybridization, pedigree selection and marker-assisted selection in the Plant Breeding Division of BINA. Germplasm sources included local cultivars and elite lines from IRRI, ICARDA and ICRISAT. Multi-location trials were conducted across diverse agro-ecological zones of Bangladesh following national varietal testing and release protocols. Nutritional profiling (Fe, Zn, protein, vitamin A, vitamin C, oil content, amylose percentage, and total soluble solids) was performed at laboratories of BINA, BAU and IRRI Bangladesh Grain Quality Testing Services. Agro-economic performance was assessed using yield, production cost and net profit, while grain and product quality were evaluated through physical, biochemical and consumer-preferred traits. The integrated breeding approaches demonstrated significant potential for enhancing nutritional quality and economic viability of cereals, oilseeds, pulses and horticultural crops in Bangladesh.

2.2 Economic study of different popular crop varieties of BINA

This study was conducted to analyze the profitability of rice, pulse and oilseed varieties producing farmers in different districts of Bangladesh developed by the BINA. Data for the present study were collected from sample crop varieties farmers through face to face interview method using a pre-tested interview schedule. In the study, costs and return analysis were done on both cash cost and full cost basis for estimating profitability.

2.3 Soil Fertility and Nutrient Management

Field experiments were conducted across diverse agro-ecological zones (Mymensingh, Rangpur, Rajshahi, Dinajpur, Bogura, Jamalpur, Ishwardi, Satkhira, Kurigram, Noakhali and Gazipur) under both the farmer's field and research station. Evaluated technologies included:

- Rhizobial and Bradyrhizobial biofertilizers for pulses and oilseeds
- Fertilizer management of Binadhan-11 after submergence for maximize yield
- Biofortification of zinc and iron in wheat and increasing yield
- Fertilizer management technology for zero-tillage mustard production
- Increasing crop production and preserving soil fertility through organic fertilizer use in drought-prone areas
- Sustainable soil health and yield increasing in char areas through Biochar application with minimum tillage
- Saving chemical fertilizers through the use of Phospho-Vermicompost
- Reducing potassium fertilizer by rice straw management

Metrics included yield, nutrient replacement rates, soil pH and organic carbon, microbial biomass and economic returns. Soil chemical parameters (pH, OC, N, P, K, S, Zn, Mg), yield and economic return were assessed using standard analytical methods (Page *et al.*, 1982; AOAC, 2016).

2.4 Postharvest Gamma Irradiation

A series of postharvest research have been conducted in the Horticulture Division of BINA by applying different doses of gamma radiation and other advanced technologies to various horticultural crops (onion, garlic, potato, mango, banana, tomato, Pineapple jam, drying etc) since 2020 to 2025 to evaluate shelf life and quality at ambient condition. Parameters investigated were size, colour, texture, TSS, weight loss, sprouting, disease incidence (DI), disease severity (DS), pH and vitamin C content during the period of storage.

3. Results

3.1 Nutrient-Enriched Varieties

The following tables present the nutritional profiles of crop varieties developed by BINA through mutation breeding and other advanced techniques.

Table 1. Nutrient enriched and stress tolerant Rice Varieties Developed by BINA

Variety	Season	Yield (t/ha)	Nutrient content/Special Trait	Profitability (BCR)	Adoptation Area
Binadhan-7	Aman	4.8**	Amylose 24.5%, Early matured	1.81	All rice growing areas
Binadhan-10	Boro	5.5 (saline) 7.5-8.5 (non-saline)	Amylose 26%, Salt tolerant	1.36	Coastal area
Binadhan-11	Aman	4 - 4.5 (submerged) 4.5 (non-submerged	Amylose 23.74%, Submergence tolerant	1.58	submerged-prone area
Binadhan-12	Aman	4-4.5 (submerged) 4.5 (non-submerged)	Amylose 24.36%, Submergence tolerant and minicate type grain	1.47	submerged-prone area
Binadhan-17	Aman	6.8	Amylose 24.36%, early matured and high yielding, 40% less water and 30% urea required	1.66	All rice growing areas
Binadhan-19	Aus	4.5	Amylose 23.8%, drought tolerant	1.41	Drought-prone Barind area
Binadhan-20	Aman	4.5	Amylose 26.3%, iron 6.0, Zinc 29.0, long & slender grain with red pericarp	1.93	All rice growing areas
Binadhan-21	Aus	4.5	Amylose 24.9%, drought tolerant	1.63	Drought-prone Barind area
BINA dhan25	Boro	7.6	Amylose 25.1%, Protein 6.6, Premium quality	1.60	All rice growing areas
BINA dhan26	Aman	6- 6.5	Amylose 26.4%, Protein 9.4%, BLB resistance	–	All rice growing areas
BINA dhan27	Aman	6.3	Amylose 25.7%, Protein 10%, Blast resistance	–	All rice growing areas
BINA dhan28	Aman	6- 6.5	Amylose 27.42%, Aromatic rice	-	All rice growing areas
BINA dhan29*	Aman	6.3	Amylose 26.9%, iron 6 ppm, Zinc 30ppm, Protein 7.8 %, long & slender grain with red pericarp	-	All rice growing areas

*Proposed variety

** Yield: Avrage

Table 2. Nutrient enriched and stress tolerant Pulse and Oilseed Crops Developed by BINA

Crop	Variety	Yield (t/ha)	Nutrient content/Special Trait(%)	Profitability (BCR)	Adoption Areas
Lentil	Binamasur-8	2.5	Protein 30%, Disease resistant	1.66	Barind area
	Binamasur-10	1.9(Normal) 1.5(drought)	Protein 32–33%, Drought tolerant	1.70	Barind area
Mungbean	Binamoog-8	1.8	Protein 22.4%, Synchronous maturity	1.87	Barind area
Chickpea	Binasola-7	1.7	Protein 23.5% , Low disease incidence	1.6	Barind area
	Binasola-8	1.8	Protein 23.8%, High seed weight	1.6	Barind area
Mustard	Binasarisha-9	1.6	Oil 43%, Water logging tolerant	1.76	All mustard-growing areas
	Binasarisha-11	1.6	Oil 44%, Alternaria Blight Resistant	1.94	All mustard-growing areas
Sesame	Binatil-2	1.4	Oil 40%, Vit- A, D, E and Vit-K	-	All sesame-growing area
	BINA til6	1.3	Oil 48%, 2-3 days Water logging tolerant	-	All sesame-growing area
Groundnut	Binachinabadam-4	2.6 (Rabi) 2.4 (Kharif-2)	Protein 27%, oil 48.6, high yielding	2.04	Char areas
	Binachinabadam-8	2.56(Normal) 1.8 (Salinity)	Protein 28.1%, oil 46.9, Salinity tolerant	1.75	Coastal areas
	Binachinabadam-9	2.9 (Normal) 1.9 (Salinity)	Protein 23.8%, oil 48 %, Salinity tolerant	1.90	Coastal areas
	Binachinabadam-10	2.8(Rabi) 2.2 (Kharif-2)	Protein 28.1%, oil 50.6%, High yielding & Salinity tolerant	1.95	Char areas
Soybean	Binasoybean-2	2.6(Rabi) 2.9 (Kharif-2)	Protein 43 %, oil 19%, Short duration & high yielding	1.99	Char areas
	Binasoybean-5	2.4-3.0(Rabi) 2.5-3.3 (Kharif-2)	Protein 43 %, oil 20%, Short duration	1.65	Char areas
	Binasoybean-6	2.5-3.0 (Rabi) 2.6-3.2 (Kharif-2)	Protein 44%, oil 20%, Climate resilient	1.65	Char areas

Table 3. Nutritional Composition of Vegetables, Fruits, and Leafy Crops

Crop	Variety	Key Nutrient	**Content** (mg/100g)
Tomato	Binatomato-10	Vitamin C	23.09
Tomato	Binatomato-11	Vitamin C, Lycopene	24.39
Tomato	Binatomato-12	Vitamin C	25.64
Lemon	Binalebu-1	Vitamin C	55–62
Patshak	Binapatshak-1	Vitamin A	10.70
Sofeda	BINA Sofeda-1	Vitamin C	15.58

3.2 Economic study of different popular crop varieties of BINA

The table shows (Table 1 & 2) the Benefit-Cost Ratio (BCR) of various crop varieties developed by the BINA. BCR is a key economic indicator that helps evaluate the profitability of crop production — a higher BCR means greater economic return compared to the cost of cultivation. The table includes major crop groups such as rice, pulses and oilseeds, highlighting their comparative economic performance under similar conditions.

The data suggests that rice varieties showed moderate profitability, ranging from 1.36 (Binadhan-10) to 1.93 (Binadhan-21). Pulse crops performed better, with Binamoog-8 (1.87). Oilseed crops exhibited the highest BCR values, particularly Binachinabadam-4 (2.04) and Binasoybean-2 (1.99), indicating superior profitability compared to rice. (BINA Annual Report, 2020-2026)

3.3 Soil Fertility and Nutrient Management

- Biofertilizers: Increased nodulation and biological nitrogen fixation (50–300 kg Nha^{-1}), boosting pulse and oilseed yields by 15–150%.
- Fertilizer management of Binadhan-11 after submergence: Farmers could get 5 tha^{-1} which is quite similar to regular yield (5.5 tha^{-1}) by managing fertilizer dose after flood.
- Biofortification of zinc and iron in wheat and increase yield: Zinc fertilization increased wheat yield by 18% and grain Zn concentration to 30 ppm.
- Fertilizer management technology for zero-tillage mustard production: Zero tillage mustard cultivation yields a profit of 60,133/- to 77,619/- per hectare, resulting in an income-expenditure ratio of 2.17 and 2.80 respectively
- Increasing crop production and preserving soil fertility through organic fertilizer use in drought-prone areas: Combined use of 70% chemical fertilizers with poultry manure or 75% chemical fertilizers with vermicompost increased the yield of Aman by 1% and Mustard by 14% respectively.
- Sustainable soil health and yield increasing in char areas through Biochar application with minimum tillage: Implementing IPNS (Integrated Plant Nutrition System) by using biochar 2 t ha^{-1} under a minimum tillage system increases soil organic carbon levels and improves the physical properties of the soil.
- Saving chemical fertilizers through the use of Phospho-Vermicompost: Grain yield and straw yield increases by 14% and 12.7% respectively by application of phospho-vermicompost.
- Reducing potassium fertilizer by rice straw management: By applying rice straw 2.5 tha^{-1} & 3 tha^{-1}, a high yield of Aman rice (5.10 t ha^{-1}) & Boro rice (6.0 tha^{-1}) respectively can be achieved even by reducing potassium fertilizer application by 25%.

3.4 Postharvest Technologies

Minimizing postharvest losses of horticultural perishables through irradiation and other advanced storage technology significantly improves nutrition outcomes in Bangladesh. Extended storage life and reduced spoilage increase year-round availability of fruits and vegetables. Nutritional quality such as vitamin C, sugars and TSS is maintained without significant deterioration. Reduced losses also stabilize market supply and make nutrient-rich foods more affordable.

Table 5. Effect of Gamma Irradiation on Shelf Life of Selected Horticultural Crops

Sl.	Crop Name	Result	Adaptation
01	Onion (cv. Taherpuri and Lal Teer King)	❖ The maximum storage duration of onions was around 7-9 months ❖ Weight loss was significantly reduced in the 100 Gy irradiated bulbs (2.25-47.72%) as compared to control (2.17-84.84%) after 1 to 9 months storage at ambient room condition. ❖ Complete inhibition of sprouting after irradiation ❖ TSS and pH slightly increased with time and ranged from 11-16% Brix and 5.52-6.14.	Onion growing area like Faridpur, Madaripur, Rajbari Pabna, Natore
02	Garlic (cv. Italy and Patnai)	❖ The maximum storage duration of garlic was around 7-8 months. ❖ 30 Gy was found to be the best considering minimization of weight loss, disease incidence, disease severity. ❖ Complete inhibition of sprouting after irradiation	Garlic growing area like Pabna, Natore, Meherpur, Sirajganj
03	Potato (CV. Diamant and Cardinal)	❖ Weight loss and rotting were significantly reduced ❖ Complete inhibition of sprouting ❖ Shelflife extension up to 3-4 months at ambient room condition ❖ TSS slightly increased and Vitamin C decreased with time.	Potato growing area like Bugura, Rangpur Munshiganj, Dinajpur,
04	Mango (Himsagar and Amrapalli	❖ 400-500 Gy extended the shelf life 10-14 days in Himsagor mango as compared to control (6-7 days). ❖ The minimum weight loss, DI and DS (3.9%, 11.0% and 8.6%) were found irradiated wrapped mangoes as compared to control (unwrapped, non irradiated 18.2%, 80.0% 74.7%). ❖ TSS and Vitamin C, there were no significantly difference among the treatments and ranged from 17-18% Brix 17-23 mg/100gm	Mango growing area like Satkhira, Rajshahi, Chapainawabganj, Noagaon
05	Banana (cv. Amritosagar)	❖ 400 Gy and wrapped in LDPE bags (25 µ) improved shelf life (15-16 days) as compare with control (8-10 days) at ambient condition without deteriorating quality and taste like TSS, Vitamin C, Reducing and non-reducing sugar.	Banana growing area like Narshigdi, Tangail, Bugura, Hill tract
06	Litchi (cv. Bedana)	❖ 1000 Gy increased the shelf life (upto 5 days) with retaining good external color and taste.	Litchi growing area like Dinajpur, Pabna, Rajshahi
07	Tomato	❖ 3.0 kGy extended the shelf life 25-28 days without deteriorating quality and taste like TSS, Vitamin C, reducing and non-reducing sugar.	Tomato growing area like Rajshahi, Moulvibazar, Cumilla, Jashore

Sl.	Crop Name	Result	Adaptation
08.	Pineapple jam	❖ The chemical composition of Pineapple jam renges from 73.0-77.7% dry matter, 22.3-26.7% moisture, 0.65-0.75% ash, 0.48-0.68% protien, 0.52-0.85% fibre, 70.8-74.6% carbohydrate, 63.5-66.7% TSS, Brix 3.0-3.5 mg/100 gm Vitamin C ❖ No fungal infection found on irradiated jam after one year storage.	Pineapple growing area like Tangail, Sylhet.
09.	Dehydrated pineapple	❖ The chemical composition of dehydrated pineapple ranges from 81.1- 86.1% dry matter content, 13.9-18.3% moisture content, 1.07-2.07% ash, 0.65-1.05% fat, 1.87-2.78% protien, 5.04-7.25% fibre, 72.67-74.42% carbohydrate, 36.5-40.7% Brix TSS and 2.5-5.0 mg/100 gm Vitamin C ❖ No fungal infection found on irradiated dehydrated pineapple after one year storage	Pineapple growing area like Tangail, Sylhet.

Overall, postharvest loss reduction enhances dietary diversity, food security, and micronutrient intake and enhanced marketability, especially during lean seasons.

4. Challenges and way forward

Challenges:

- Lower yield of nutrient enriched crop varieties
- Lack of profitability study of released varieties
- Low extension among farmers for adaptation
- Lack of awareness
- Lack of accredited nutritional quality testing laboratories and skilled manpower
- Lack of nutritional profiling of cultivated crop varieties
- Significant post-harvest losses and inadequate processing infrastructure
- Adverse impacts of climate variability and change
- Prevalence of biotic and abiotic stresses
- Market instability driven by price volatility
- Shortage of skilled labor and trained professionals.
- Insufficient national and international research collaboration

Way forward:

- Development of high yielding bio-fortified varieties of different crops with export potential
- Integration of stress tolerant with nutritional traits
- Improve post-harvest managements: milling, grading, storage and packaging
- Linkage among stakeholders (BADC, DAE, NARES organization, NGOs, dealer and contact growers)
- Nutrition related data bank for released varieties.
- Expand climate-resilient and nutrition-enhanced breeding programs.

- Advance technologies for safe crop production, reduction of post-harvest losses
- Strengthen linkages among research, extension, and nutrition
- Promote nutrient-rich crop varieties and develop value-added products
- Upgrade post-harvest infrastructure and establish stronger market connections
- Invest in human resources development
- Enhance financial and policy support

5. Conclusion

Nutrition-sensitive crop varieties enriched with zinc, iron, protein and minerals are a powerful tool to fight hidden hunger in Bangladesh. By combining high yields with superior nutritional quality, the bio-fortified grains can improve public health, strengthen immunity and build a more resilient food system. To maximize impact, BINA should prioritize nutritional profiling of released varieties, expand climate-resilient and nutrition-focused breeding programs and develop technologies to reduce post-harvest losses. BINA's integrated research approach successfully addresses major agricultural constraints from soil to storage. Postharvest gamma irradiation significantly reduces losses and improves shelf life of horticultural perishables, while nutrient-enriched varieties, BCR and sustainable soil management enhance productivity and nutritional outcomes. Adoption of these technologies at national scale can reduce postharvest loss by 20-40%, increase crop yield by 15-150% depending on crop, improve micronutrient intake, reduce fertilizer dependency, enhance climate resilience. This integrated strategy supports national food security, nutrition policy, and sustainable agricultural development.

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BLRI Technologies and Innovations for Nutrition Sensitive Agriculture in Bangladesh: A Comprehensive Review

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1. Introduction

Nutrition Sensitive Agriculture (NSA) integrates agricultural production with nutritional issues to address malnutrition and food insecurity. In Bangladesh, the livestock sector plays a pivotal role in supplying nutrient dense animal source foods, including milk, meat and eggs, which are rich in high quality protein, essential amino acids and micronutrients. However, the sector continues to face constraints such as low genetic potential, seasonal feed scarcity, suboptimal management practices and limited access to value-added technologies. Bangladesh Livestock Research Institute serves as the national body addressing these challenges through a multidisciplinary research mandate. Its core functions encompass genetic improvement and conservation of livestock and poultry particularly cattle and buffalo breed development, advancement of feed and nutrition research, and optimization of housing and management systems of livestock and poultry. In addition, BLRI focuses on the development of technologies for fodder production, processing, and conservation, as well as the value addition and utilization of livestock products and by-products (milk, meat, manure, and hides). Through applied and adaptive research, BLRI identifies field level constraints and develops context specific technological packages to enhance productivity and sustainability. The integration of these research within NSA frameworks has significant potential to improve livestock performance, increase the availability of safe and nutritious foods, and strengthen food and nutrition security while supporting the livelihoods of smallholder farmers.

2. Materials and Methods

This study integrated data from the Bangladesh Livestock Research Institute to evaluate the contribution of improved livestock, fodder and value-added products to NSA. Performance and nutritional data of BLRI Meat Chicken-1 "Shuborno" and BLRI Layer-1 "Shuvra" were assessed alongside improved fodder varieties such as Pakchong, BMP Napier and BLRI-developed grasses based on biomass yield, crude protein and animal performance. Dairy innovations including gelatin enriched dahi and whey-based beverages, as well as processed meat products like chicken sausages, were evaluated for physicochemical composition, nutritional quality and sensory attributes using standard analytical methods. Additionally, indigenous cattle breeds such as Red Chittagong Cattle, Pabna cattle and Munshiganj cattle, along with crossbred lines, were analyzed based on productivity, growth performance and feed efficiency. All data were compiled from BLRI publications, field trials and laboratory analyses to assess their role in enhancing livestock productivity, food security and human nutrition.

3. Results

3.1 BLRI Meat Chicken-1 "Shuborno" in Nutrition Sensitive Agriculture

Bangladesh Livestock Research Institute (BLRI) developed BLRI Meat Chicken-1, commercially known as "Shuborno," as a climate-adapted meat chicken breed replicating the taste and quality of indigenous deshi chicken. From a nutrition-sensitive agriculture perspective, Shuborno directly addresses the critical challenge of animal protein deficiency in Bangladesh. Its meat is rich in high-quality protein, essential amino acids, B vitamins and key minerals, including iron and zinc (Table 1), offering a nutritionally superior yet affordable alternative to conventional broiler meat. Reaching a market weight of approximately

950 g to 1 kg within just 58 days, with a mortality rate below 2% and no need for temperature-controlled enclosures, Shuborno is accessible to smallholder and backyard farmers, ensuring that nutritious and animal-source food reaches low-income households. Its lower dependence on antibiotics results in safer and healthier meat.

Table 1. Proximate nutritional composition of Shuborno meat per 100 g edible portion

Nutrient	Shuborno	Broiler	Native Chicken
Crude Protein (g)	21–23	18–20	20–22
Crude Fat (g)	2.5–3.5	5.0–7.0	2.0–3.0
Energy (kcal)	110–125	130–150	105–120
Iron (mg)	1.2–1.5	0.9–1.2	1.3–1.6
Zinc (mg)	1.8–2.2	1.5–1.8	1.9–2.3
Cholesterol (mg)	60–70	75–90	55–65

[Data Source: BLRI (2022a)]

3.2 BLRI Layer-1 "Shuvra" in Nutrition Sensitive Agriculture:

Bangladesh Livestock Research Institute developed BLRI Layer-1 Shuvra as a climate-resilient, high-performing chicken suitable for rural and semi-intensive systems. Developed through selective breeding with exotic germplasm, it combines high productivity with adaptability to local conditions. Shuvra contributes significantly to nutrition-sensitive agriculture by supplying eggs rich in high-quality protein, essential amino acids, vitamins, and minerals, thereby supporting household nutrition security. It reaches sexual maturity at around 19 weeks and produces approximately 280-295 eggs per year, with an average egg weight of about 62 g, ensuring both nutritional value and market acceptability. [Data source: BLRI (2023a)]

3.3 BLRI Cattle Research and Nutrition Sensitive Agriculture

BLRI continues research on the improvement and conservation of indigenous cattle breeds such as Red Chittagong Cattle (RCC), Pabna cattle, and Munshiganj Cattle (MC), while also developing crossbred beef lines, integrating these efforts with nutrition-sensitive agriculture to enhance livestock productivity, food security, and human nutrition. These cattle play a vital role in nutrition-sensitive agriculture by providing a consistent supply of nutrient-dense milk and meat rich in high-quality protein, essential fatty acids, vitamins, and minerals. The important features of these cattle breeds are presented in Table 2.

Table 2. Comparison of Indegenous and crossed cattle in terms of Nutrition Sensitive Agriculture

<table>
<tr><th rowspan="2">Cattle Breed</th><th colspan="7">Parameters addressed under Nutrition Sensitive Agriculture</th><th rowspan="2">Data Sources</th></tr>
<tr><th>Milk Yield (Liter/day)</th><th>Body Weight (kg)</th><th>ADG (gm)</th><th>Carcass Weight (kg)</th><th>FCR</th><th>Milk Fat (%)</th><th>Milk Protein (%)</th></tr>
<tr><td colspan="9">Indigenous/Local</td></tr>
<tr><td>RCC</td><td>3-4</td><td>350-450</td><td>-</td><td>-</td><td>-</td><td>4.5-5.0</td><td>4.5</td><td>BLRI publication No. 305</td></tr>
<tr><td>MC</td><td>4.5-5 (Max. 8)</td><td>300-400</td><td>-</td><td>-</td><td>-</td><td>5.9</td><td>3.2</td><td>BLRI (2017); BLRI (2023b)</td></tr>
<tr><td>Pabna</td><td>-</td><td>354</td><td>460</td><td>206</td><td>7.8</td><td>-</td><td>-</td><td>BLRI (2026);</td></tr>
</table>

Cattle Breed	Parameters addressed under Nutrition Sensitive Agriculture							Data Sources
	Milk Yield (Liter/day)	Body Weight (kg)	ADG (gm)	Carcass Weight (kg)	FCR	Milk Fat (%)	Milk Protein (%)	
Crossbred								BLRI (2026); BLRI (2023c)
Limousine cross	-	488	650	285	11.90	-	-	
Simmental cross	-	542	740	313	11.22	-	-	
Charolais cross	-	487	670	287	11.33	-	-	
Brahman cross	-	417	570	246	12.16	-	-	

(N.B.: ADG=Average daily gain; FCR=Feed conversion efficiency)

3.4 Fodder Crops Boost Milk and Meat Production

Bangladesh Livestock Research Institute (BLRI) has successfully developed and improved several high-yielding, nutrient-enriched, and stress-tolerant fodder varieties through advanced management practices and genetic improvement techniques. These include BLRI Napier-1 (Bajra), BLRI Napier-2 (Arosha), BLRI Napier-3 (hybrid), BLRI Napier-4, Pakchong, Wruk-Wona, Zara, BMP Napier, BLRI Grass-5 (salt-tolerant), and drought-tolerant Napier (Pakchong Gy-60), along with winter fodders such as Oat. These improved fodder crops have been evaluated based on both qualitative and quantitative parameters and are well-adapted to diverse agro-ecological conditions. Their adoption significantly enhances forage availability and nutritive value, thereby improving livestock productivity, particularly in terms of milk and meat production, and contributing to the growing demand for animal-source nutrition.

Table 3. Fodder crop research at BLRI and their nutritional quality

Fodder/Variety/Cultivar	FBY (t/h/y)	Key Nutrient (*CP)	Animal Performances/ Adoption Area/Conservation	Data Sources
BLRI Napier-1 (Bajra)	220	11.3%	This improved fodder germplasm is conserved at BLRI germplasm bank and is continuously propagated and distributed to beef and dairy farmers	Roy *et al.*, 2025
BLRI Napier-2 (Arosha)	201	12.3%		
BLRI Napier-3 (hybrid)	198	12.2%		
BLRI Napier-4	236	12.4%		
Pakchong	274	12.4%		
Wruk-Wona	243	11.9%		
Zara	239	12.4%		
BMP Napier	280	15-16%	Local bulls gained 600 g/day fed on sole BMP Napier, while Holstein Friesian crossbred bulls gained 810 g/day.	BLRI (2022b)
BLRI Grass-5 (salt-tolerant)	264	11-12%	This fodder tolerates coastal salinity in Bangladesh (Soil: 1.75-5.00 and Water: 7.50-11.50 dSm^{-1} saline area	BLRI (2022c)
Drought-tolerant Napier	254	12-14%	Barind region	BLRI (2024a)
Oat (at 90 days)	65	10.2%	Conserved at BLRI	BLRI (2024b)

* CP=Crude Protein

3.5 Gelatin Enriched Dahi

The Gelatin-enriched dahi developed by the BLRI offers improved nutritional quality and contributes to enhanced food and nutrition security by providing a value-added dairy product with better functional and dietary benefits. Firstly, gelatin was extracted from cattle hides and then incorporated into Dahi. In Table 2, the gelatin-enriched dahi showed higher protein (5.79%), total solids (31.78%), fat (3.24%), and ash (1.05%) than market dahi, indicating improved nutritional quality, while pH and acidity remained within the normal fermentation range.

Table 4: Nutritional comparison of BLRI developed gelatin enriched dahi and dahi available in market.

Parameters	pH	Nutritional Composition (%)				
		Acidity	Fat	Protein	Total solids	Ash
Gelatin enriched dahi	4.5	1.05	3.24	5.79	31.78	1.05
Dahi available in market	4.3-4.4	1.0-1.2	2.5-3.0	3.0-4.5	18.0-25.0	0.6-0.9

[BLRI 2025; Rakib MRH et al., (2016); Harun et al., (2005)]

3.6 Nutritional Quality and Sensory Evaluation of Whey-Based Beverages

Bangladesh Livestock Research Institute has developed whey-based beverages as value-added dairy products, utilizing milk whey and fruit pulp (mango) to produce nutritious drinks rich in proteins, minerals, and bioactive compounds, thereby reducing waste and enhancing food and nutrition security. The mango-based whey beverage when formulated with the blending of 80% whey and 20% mango pulp, had desirable sensory quality and physicochemical stability for up to 14 days at 4°C. Probiotic inoculation (Lactobacillus acidophilus) is being explored for functional enhancement. [Data sources: BLRI (2025a)].

3.7 Quality Evaluation of Chicken Sausages

BLRI developed and improved sausages contained 76.17% moisture, 37.33% crude protein, 10.93% fat, and 3.00% ash, with minimal fiber (0.27%), indicating a high-protein product that contributes to meeting human protein requirements and enhancing nutrition security. Microbial counts remained within acceptable limits during storage, although slight yeast and mold growth (40 cfu/g) was detected after 30 days of frozen storage. However, sensory evaluation for appearance, flavor, tenderness, juiciness, texture, taste, and overall acceptability is presented in Table 5 where BLRI developed sausages showed higher overall acceptability scores (3.87/5) compared to other brands. [Data sources: BLRI (2025b)]

Table 5: BLRI developed sausages and other brand sausages

Parameter	Sausages Brands		
	Golden harvest	Kazi	BLRI
Appearance	3.50	3.50	3.62
Flavor	3.50	3.62	3.25
Tenderness	3.12	3.75	3.62
Juicyness	3.25	3.50	3.50
Textute	3.25	3.37	3.62
Taste	3.25	3.25	3.50
Overall acceptability	3.25	3.62	3.87

4. Challenges

- Inadequate funding for research, scaling, and farmer support programs
- Limited dissemination and adoption of BLRI-developed technologies
- Seasonal fodder scarcity and inadequate quality feed resources
- Weak extension services and farmer training gaps
- Climate stresses (salinity, drought, flooding) affecting productivity
- Limited access to value addition and processing technologies

- Poor market linkage
- Low awareness of nutrient-rich animal-source foods
- Limited laboratory facilities and technical support

5. Way Forward

- Increase investment and funding for research, innovation, and field-level implementation
- Strengthen technology transfer and farmer-level dissemination by Bangladesh Livestock Research Institute
- Upgrade laboratory facilities and ensure technical capacity for quality testing and research
- Scale up climate resilient fodder and livestock systems
- Improve feed and forage production and supply chains
- Enhance extension services and capacity-building programs
- Promote public private partnerships for wider adoption
- Integrate livestock production with nutrition education and policy support

6. Conclusions

Bangladesh Livestock Research Institute-developed technologies across poultry, cattle, fodder and dairy systems substantially enhance NSA by improving animal productivity, increasing the availability of nutrient-dense animal-source foods and strengthening food and nutrition security in Bangladesh

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Evaluation of Sugar-Producing Crops for Nutritional Quality and Food Security in Bangladesh

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Introduction

Sweetness in Bangladesh is more than taste; it is closely linked with daily diets, culture, rural markets, seasonal livelihoods and small-scale food processing. Sweeteners such as sugarcane juice, date pain jaggery, palm sugar, molasses, stevia, golpata (nipa palm sap and honey contribute to both nutrition and income. However, they are often considered only in terms of sugar content, overlooking their minerals, antioxidants, bioactive compounds and economic value. Food security includes not only availability of food but also access, utilization and stability of safe and nutritious diets. The Bangladesh Sugarcrop Research Institute (BSRI) works on sugarcane and other sugar crops like stevia, date palm, palmyra palm and golpata, which grow in marginal and coastal areas. Nipa palm (Nypa fruticans) from coastal Bangladesh has also shown nutritional and antioxidant potential, highlighting its importance as an underutilized sweetener resource. Bangladesh has achieved food sufficiency through high-yielding cereals but still faces "hidden hunger," with about 31% of under-five children and over 43% of women suffering from zinc deficiency (icddr,b, 2021). As more than 70% of calories come from rice, dietary diversification is urgently needed through nutrient-sensitive crops. While sugarcane has been the main focus of the sugar industry, broader sugar crops offer additional nutritional value. BSRI works on Palmyra palm, date palm and nipa palm, which grow in marginal and coastal areas and produce jaggery rich in minerals and vitamins. Chewing sugarcane and stevia provide fiber-rich and low-calorie alternatives suitable for health-conscious and diabetic populations. Honey also contributes important enzymes and antioxidants, though its quality varies with source and storage conditions. Therefore, this study evaluates major sugar-producing crops and natural sweeteners in Bangladesh for their nutritional quality and contribution to food and nutrition security.

Materials and Methods

Experimental Site and Sampling: BSRI has conducted all the research programs in Bangladesh Sugarcrop Research Institute, HQ, Ishwardi, Pabna.

Sugar crops: Date palm sap was collected from 20 (Twenty) genotypes during the winter season from February 09 to February 16, 2025. The samples were first cut juice at the interval of three days of earlier eat from BSRI Date palm garden. Palmyra palm data was recorded during the peak summer tapping period (April 23-29, 2025). 10 (ten) genotypes were selected for collecting juice from BSRI palmyra palm garden. Nipa palm performance was measured per peduncle in coastal regions (Barishal) 09 (nine) genotypes were selected for collecting juice. Palm sap was collected using traditional tapping methods with earthen pots in minimize fermentation. The juice was analyzed for Volume (litre), Brix% and Gur recovery %.

Sugarcane: Five gur-producing sugarcane varieties (Isd 37, Isd 39, BSRI Akh 45, BSRI Akh 46 and BSRI Akh 48), two chewing sugarcane variety (BSRI Akh 42 and BSRI Akh 49) were harvested at physiological maturity. Cane juice was extracted using a BSRI developed power crusher with an extraction efficiency of approximately 55-70%.

Physicochemical Analysis: Sugarcane juice were chemically analyzed for the following quality parameters such as Brix (%), Purity (%), Pol % cane, Reducing Sugars (%), Fibre% in the laboratory of BSRI Total Soluble Solids (Brix%) were measured using hydrometer method. Juice pH was determined using a glass electrode pH meter. The Lane and Eynon (original) method was used to determine reducing sugars as described by Varma, 1988.

Gur (Jaggery) Production: Gur (Jaggery) samples were prepared in the laboratory at harvest as per the method standardized at Bangladesh Sugarcrop Research Institute (BSRI), Ishurdi, Pabna. Gur (Jaggery) were prepared by open pan boiling (116°C-118°C) method then subjected for analysis. The procedure laid out by Bangladesh Sugarcrop Research Institute (BSRI), Ishurdi, Pabna for preparation of gur (Jaggery) was adopted. The gur (Jaggery) samples ware processed without adding any hazardous chemicals. The gur (Jaggery) samples were stored for further observations. Prepared gur (Jaggery) was chemically analyzed for the following quality parameters such as sucrose%, reducing sugar%, moisture%, pH, color transmittance and gur (Jaggery) recovery%. For nutritional and biochemical profiling Crude protein, Fat, Dry matter, Ash, Moisture, Total energy (Kcal) and all minerals & Vitamin were analyzed. Chewing sugarcanes were evaluated for Glycemic Index (GI) and mineral ppm and Stevia leaf samples were analyzed for Nitrogen, Calcium and Zinc concentrations.

Honey: Two samples of Mustard honey were used. One is fresh mustard honey and another is two years old mustard honey. There was a comparison between these two samples on the basis of nutrient analysis.

Results and Discussion

Sugarcane: Recent nutritional profiling of Bangladeshi sugarcane juice varieties has shown that sugarcane juice can be studied not only for sweetness but also for minerals and water-soluble vitamins. Nutrition-sensitive chewing sugarcane genotype BSRI Akh 49 demonstrated superior performance compared with BSRI Akh 42. Because the chart 1 (a) & 1 (b) shows that, BSRI Akh 49 has low Glycemic Index (GI 40) and higher protein (0.35%) content. BSRI Akh 49 (GI 40) and BSRI Akh 42 (GI 44) fall well within the "Low Glycemic" category.

Table 1 (a): Nutritional properties of Chewing cane juice (BSRI Akh 42)

Name of Variety	Protein%	Fibre(%)	Sugar content (%)	Energy (Kcal/100ml Serving)	Glycemic Index (GI)
BSRI Akh 42 (100% Juice)	0.24	12.54	10.13	41.58	44

Name of Variety	Ca ppm	K ppm	Mg ppm	Na ppm	P ppm	Zn ppm	Fe ppm
BSRI Akh 42 (100% Juice)	199	381	157	179	85	1.83	3.09

Table 1 (b): Nutritional properties of Chewing cane juice (BSRI Akh 49)

Name of Variety	Protein%	Fibre(%)	Sugar content (%)	Energy (Kcal/100ml Serving)	Glycemic Index (GI)
Black Ruby (100% Juice)	0.35	11.88	10.64	40.96	40

Name of Variety	Ca ppm	K ppm	Mg ppm	Na ppm	P ppm	Zn ppm	Fe ppm
Black Ruby (100% Juice)	241	430	87	165	89	0.98	3.06

This suggests they are far safer for pre-diabetic individuals than refined sugar. BSRI Akh 49 is a powerhouse of Calcium (241 ppm) and Iron (3.06 ppm). According to the Bouis & Saltzman (2017) framework on biofortification, providing minerals through a natural juice snack is more effective for absorption than synthetic supplements. The high fiber content (11.88-12.54%) also aids in slowing sugar absorption, which explains the low Glycemic Index. BSRI Akh 42 was rich in Potassium (381 ppm) and Sodium (179 ppm). As Afsar (2022) notes, shifting from refined soda to these natural, fiber-rich chewing canes could be a primary defense against childhood obesity in Bangladesh.

Table 2 (a): Quality parameters of juice in five gur producing canes

Varieties	Brix%	Sugar content%	Reducing sugar%	Purity%	Fibre%
Isd 37	19.5	12.13	0.48	87.39	15.05
Isd 39	19.7	13.40	0.36	87.80	15.59
BSRI Akh 45	21.1	13.41	0.24	89.35	15.91
BSRI Akh 46	20.0	12.91	0.58	89.00	15.72
BSRI Akh 48	21.8	13.89	0.42	92.23	13.06

From table 2 (a), among the five varieties tested, the variety BSRI Akh 48 performed better compared to others. It recorded the highest Brix (21.8%) and Sugar content (13.89%). This means BSRI Akh 48 juice is more concentrated, requiring less boiling time and fuel-a major cost-saving factor for local farmers. Furthermore, its Purity (92.23%) was the highest, which is essential because pure juice crystallizes more easily into solid gur. On the other hand, BSRI Akh 45 had the lowest Reducing Sugar (0.24%). This is a significant finding because high levels of reducing sugar can prevent gur from hardening, making it sticky and difficult to store during the humid months in Bangladesh (Madan et al., 2004). Meanwhile, Isd 37 and Isd 39 showed moderate performance, making them reliable "all-rounder" choices for traditional juice consumption

Table 2 (b): Nutritional properties of Sugarcane gur (in five gur producing canes)

Varieties	Sucrose%	Reducing sugar%	Moisture%	pH	Color Transmittance	Gur Recovery%
Isd 37	76.60	6.20	6.70	5.51	66.0	9.60
Isd 39	76.68	4.92	7.34	5.28	62.3	9.50
BSRI Akh 45	79.73	4.65	8.76	5.14	45.87	9.50
BSRI Akh 46	74.38	6.53	9.09	5.30	42.35	8.33
BSRI Akh 48	80.37	5.88	7.74	5.65	58.82	10.33

Table 2 (c): Nutritional properties of Sugarcane gur (in five gur producing canes)

Test Parameter	Varieties				
	BSRI Akh 45	BSRI Akh 46	BSRI Akh 48	Isd 37	Isd 39
Crude Protein (DM basis)	5.51%	7.05%	4.25%	2.72%	1.80%
Crud Fat (DM basis)	0.28%	0.37%	0.40%	0.09%	0.13%
Crude Ash	2.78%	3.39%	2.01%	1.78%	1.53%
Dry Matter	86.77%	89.21%	90.85%	86.64%	90.16%
Moisture	13.23%	10.79%	9.15%	13.36%	9.84%
Iron (Fe)	48.17 ppm	57.75 ppm	44.70 ppm	63.30 ppm	52.19 ppm
Calcium (Ca)	0.13%	0.19%	0.13%	0.20%	0.09%
Phosphorus (P)	0.05%	0.03%	0.01%	0.08%	0.18%
Vit B6	1.06 mg/kg	1.36 mg/kg	7.38 mg/kg	2.66 mg/kg	
Vit B1	0.78 mg/kg	0.67 mg/kg	1.34 mg/kg	1.24 mg/kg	0.46 mg/kg
Vit B2	1.60 mg/kg	0.52 mg/kg	7.46 mg/kg	9.25 mg/kg	0.62 mg/kg
Total Gross Energy	3888 kcl/kg	3878 kcal/kg	3885 kcal/kg	3834 kcl/kg	3848 kcl/kg

Table no. 2 (b) describes that, BSRI Akh 48 gave the highest yield for gur production with a gur recovery of 10.33%. This means for every 100kg of cane, we get over 10kg of gur. In contrast, BSRI Akh 46 performed poorly here, yielding only 8.33kg, likely due to its higher moisture content (9.09%). In the Bangladeshi market, consumers prefer gur that is golden or light-colored. Isd 37 produced the most attractive gur with a color transmittance of 66.0, followed closely by Isd 39. While BSRI Akh 48 is excellent for quantity, Isd 37 might be the best choice for farmers aiming for the "premium" bright-colored gur market (BSRI, 2018). Isd 37 also had the lowest Moisture (6.70%). Lower moisture is a key indicator of better shelf life, as it prevents the growth of mold and keeps the gur firm for a longer period.

From table 2 (c), the nutritional analysis of gur (Jaggery) of BSRI released five gur-producing sugarcanes (Isd 37, Isd 39. BSRI Akh 45, BSRI Akh 46 and BSRI Akh 48) reveals that sugarcane gur (Jaggery) can be a major source of protein and vitamins. BSRI Akh 46 contains 7.05% crude protein, which is a 300% increase over the standard variety Isd 39 (1.80%). This makes BSRI Akh 46 a "nutrition-sensitive" crop that can help mitigate protein-energy malnutrition in rural regions. Evaluation of sugarcane varieties identified Isd 39 and BSRI Akh 48 as vitamin power houses. Isd 39 contained the highest recorded Vitamin B6 at 10.39 mg/kg, while BSRI Akh 48 exhibited a total gross energy per kilogram exceeding 3885 Kcal. Such high energy and vitamin density are critical for labor-intensive agricultural populations in Bangladesh. BSRI Akh 48 recorded remarkably high levels of Vitamin B6 (7.38 mg/kg) and B2 (7.46 mg/kg). These vitamins are essential for the neurological health of children. This variety also showed the highest gur (Jaggery) recovery (10.33%), making it the ideal variety for gur production. These varieties function like biological factories, turning soil nutrients into a high-value, protein-enriched sweetener that follows the biofortification principles laid out by Bouis & Saltzman (2017).

Palmyra Palm

Palmyra palm products note the importance of palm gur (Jaggery), neera and candy as alternative sweetener products, showing their relevance for food processing and value addition.

Table 3 (a): Quality parameters of juice in ten palmyra palm genotypes:

No. of palmyra palm genotypes	Amount of juice (litre)	Brix (%)	Gur recovery (%)
01	4.0	12.40	12
02	4.5	12.0	11.50
03	3.5	12.5	12
04	2.5	12.6	12
05	2.0	14.0	**13.5**
06	5.0	11.5	11.50
07	6.0	13.0	13.0
08	5.0	12.70	12.5
09	1.7	14.0	**13.0**
10	5.5	11.04	11.00

*Data collection date: 23rd April/2025 to 29th April/2025
(Data were recorded for morning time)

From table 3 (a), Ten Palmyra palm genotypes showed juice yield of 1.7 to 5.5 liters per tree per day. Despite the high temperatures, Genotypes 05 and 09 produced a remarkably stable juice with 14% brix. Genotypes no. 05 and 09 stood out with the highest gur recovery of 13.5% and 13.0%, respectively. Interestingly, these high-recovery gur genotypes maintained a low pH (-5.6), indicating a higher concentration of organic acids which act as natural preservatives and a barrier, preventing the sugar from breaking down into sticky "reducing sugars."

Table 3 (b): Physical and Nutritional properties of palmyra palm gur

(Tested for highest gur recovery %)

No. of genotypes	Texture	Color	Sucrose%	Reducing Sugar%	pH
05	Hard	Golden	65	15	5.67
09	Hard	Golden	63	16	5.65

Table 3 (b) revealed that, the gur from these palms was hard, crystalline and a vibrant golden color with a sucrose content of 63-65%. As noted by Panda *et. al.*, (2023), the lower reducing sugar content (15-16%) in these specific genotypes makes the gur (Jaggery) less hygroscopic, meaning it says dry and fresh for longer periods in Bangladesh's humid climate.

Date Palm

Table 4 (a): Quality parameters of juice in twenty date palm genotypes

No. of genotypes	Amount of juice (litre)	Brix%	Gur recovery %
01	5.1	16.20	13.5
02	5.5	15.0	13
03	2	18.0	**14**
04	3	16.0	13
05	2.2	17.6	13.5
06	5.6	13.0	12
07	1.9	16.0	11
08	4	14.0	12
09	2.4	15	13
10	1.6	17.4	13.5
11	6.2	14.0	12
12	5.2	16.8	**14**
13	3.9	15.0	13.5
14	2.6	17.0	13.5
15	3.1	14.2	12
16	3.2	16.2	13
17	1.7	17.2	13.5
18	3	15	13.2
19	6.2	14.6	13
20	2	17.2	**13.8**

*Data collection date: 09th February/2025 to 16th February/2025
(Data were recorded only for 1st cut)

The sap and gur (Jaggery) are commonly used in winter foods, sweets and traditional recipes. Table 4 (a) showed that the Date palm genotypes (01-20) showed superior brix levels compared to Palmyra with Genotype 03 reaching 18.0%. The gur recovery % was consistently high, peaking at 14% (Genotypes 01, 12 and 20).

Table 4 (b): Physical and Nutritional properties of date palm gur

(Tested with highest recovery %)

No. of genotypes	Texture	Color	Sucrose%	Reducing Sugar%	pH
03.	Hard	Golden Brown	85	6.8	6.72
12.	Hard	Golden Brown	83	6.6	6.74
20.	Hard	Golden Brown	84	7.2	6.75

Here Table 4 (b) describes, the sucrose purity in Date palm gur (83-85%) was significantly higher than Palmyra, leading to a more refined sweetness and a distinctive golden-brown color. Islam *et al.*, (2015) highlighted that date palm sweeteners improve antioxidant status in consumers and the cold-weather harvest preserves phenolic antioxidants that are often lost in summer crops. Our data confirms that the high mineral concentration in the juice directly correlates with the hard texture and high recovery rate of the gur (Jaggery).

Nipa Palm

Banglapedia notes that nipa sap can be boiled to produce brown sugar, and recent Bangladeshi research has evaluated nipa juice and molasses for nutritional composition and antioxidant activity.

Table 5: Quality parameters of juice in nine nipa palm genotypes

Plant no.	Peduncle no.	Juice per Peduncle (ml)	Brix %	Total juice (Lt.)	Gur (gm)	Recovery%
1	20	470	15.5	9.4	1342.9	14.3
2	35	550	14.8	19.25	2583.9	13.4
3	12	627	16	7.524	953.6	12.7
4	22	744	13.3	16.368	2046	12.5
5	25	576	13.5	14.4	1872.6	13
6	60	434	13.4	26.04	3038.5	11.7
7	28	721	15.3	20.188	2571.7	12.7
8	9	453	16	4.077	494.2	12.1
9	50	478	13	23.9	2731.4	11.4

From table no. 5, Nipa palm showed exceptional peduncle productivity for Plant no. 6 produced over 26 liters of total juice, with a Brix of 13.4%. Despite the high volume, the gur recovery remained efficient at 11.7% to 14.3%. Nipa palm is traditionally grown in brackish waters; The high sodium (Na) and potassium (K) content typically found in Nipa sap (Tamunaidu & Saka, 2011) likely contributes to the unique salty-sweet profile that is highly valued in specialty confectionery. This makes nipa palm a promising but still underutilized resource for future food security and coastal economic development.

Stevia

Stevia is different from the other samples because it is not mainly an energy source. Instead, it is valued for sweetness with low caloric contribution. Stevia is traditionally used as a zero-calorie sweetener; however, our analysis shows it is also a rich source of micronutrients, particularly zinc (62.87 ppm).

Table 6: Nutritional properties of Stevia

Stevia leaf	N%	P%	K%	S%	Ca%	Mg%	Zn%
	1.71	0.128	0.14	0.25	1.24	0.104	62.87

Stevia leaves showed significant micronutrient density, particularly zinc at 62.87% and calcium at 1.24% in table 6. These findings suggest that these crops can satisfy sweet cravings while providing essential minerals that are often missing in refined sugar diets. This makes it relevant for people who need to reduce sugar intake, including diet-sensitive and diabetic consumers. However, its acceptance depends on taste, processing quality, consumer awareness and availability. Zinc deficiency is a public health priority in Bangladesh (icddr, b, 2021), Stevia extracts could be used not just for sweetness, but as a dietary supplement to support immune function and growth in children.

Honey

Honey has a special position because it is both a sweetener and a natural food product. Its quality depends strongly on floral source, season, geography and handling. Different types of honey like mustard honey, lichi honey, balck cumin honey, Sundarban honey etc. are commercially available in Bangladesh market. The chart 7 showed that, the comparative analysis of mustard honey revealed significant biochemical shifts during 2-year storage. Fresh honey showed moisture content of 16.73%, which increased to 18.49% due to its hygroscopic nature, potentially raising fermentation risks. Most critically, hydroxy methyl furfural (HMF) levels rose drastically from 10.54 mg/kg to 53.63 mg/kg, serving as a clear indicator of thermal degradation and aging. Freshness biomarkers, specifically Diastase activity and Proline content, showed sharp declines in old honey (falling to 5.53 DN and 210.53 mg/kg, respectively). Furthermore, the color deepened from 43.64 mm to 51.43 mm, indicating Maillard reactions and sugar breakdown during the storage period these findings emphasize that while mustard honey is a nutrient-dense resource, proper storage and shelf-life management are vital for maintaining its enzymatic and nutritional integrity. Better honey quality assessment can help protect consumers, support beekeepers and improve market value.

Table 7: Physico- biochemical properties of fresh and old mustard honey

Parameter Examined	Acceptable Range	Fresh Mustard Honey	2-Year-Old Mustard Honey	Instrument/Method Used
Moisture Content (%)	16-20%	16.73%	18.49%	Digital Refractometer
pH	3.4-6.1	4.23	3.87	pH Meter
Free Acidity (meq/kg)	≤ 50	18-28	35-50	Titration Method (NaOH)
Electrical Conductivity (uS/cm)	< 800 for blossom honey	328	386	Conductivity Meter
HMF (mg/kg)	<40 (fresh); <80 (storage allowed)	10.54	53.63	UV-Vis Spectrophotometer
Reducing Sugars (%)	≥ 60	69.43	62.95	HPLC
Sucrose Content (%)	≤ 5	2.13	1.53	HPLC
Diastase Activity (DN)	≥ 8	14.42	5.53	Spectrophotometer
Color (Pfund Scale)	Light amber to amber (15-85 mm)	43.64 mm	51.43 mm	Spectrophotometer
Ash Content (%)	≤ 0.6	0.23	0.36	Muffle Furnace
Proline Content (mg/kg)	≥ 180	395.25	210.53	UV-Vis Spectrophotometer
Viscosity (Pa.s)	2-10 (temp dependent)	5.53 at 20℃	4.13 at 20℃	Rotational Viscometer
Total Soluble Solids (°Brix)	≥ 80%	82.34	80.25	Digital Refractometer
Water Activity (a_v)	≤ 0.6	0.54	0.58	Water Activity Meter

Conclusion

The evaluation of sugar-producing crops is important for Bangladesh because these resources are linked with nutrition, culture, rural income and food security. Sugarcane, stevia, date palm, palmyra palm, nipa palm and boney each have distinct nutritional and economic value. A comparative assessment of their proximate composition, sugar profile, mineral content, antioxidant activity and quality parameters can help identify promising sweetener sources for future development. BSRI has developed the vast diversity and nutritional potential of sugar crops and natural sweeteners. Palm genotypes (05 and 09) offer superior gur (Jaggery) recovery, while chewing canes (Black Ruby) and stevia provide low-Gl and mineral-rich alternatives. The date palm genotype (03, 12 and 20) showed higher sucrose% and lower reducing sugar with having an attractive gur (Jaggery) of golden brown color. Sugarcane gur (BSRI Akh 48) can significantly contribute to the national intake of Zinc, Iron, and B-vitamins. However, the study of Mustard Honey underscores the vulnerability of natural sweeteners to storage conditions, where increased HMF and enzymatic loss can degrade quality Future policies should incentivize the cultivation of these multi-functional crops. Bangladesh Sugarcrop Research Institute (BSRI) needs establishing standardized storage protocols, and increasing productivity of sugar crops and natural sweeteners to ensure comprehensive nutritional security in Bangladesh.

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Technologies Developed by Bangladesh Fisheries Research Institute (BFRI) are Intended to Promote Nutrition-Sensitive Agriculture through Sustainable and Improved Fish Production Practices

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1. Introduction

Malnutrition, particularly protein-energy malnutrition and micronutrient deficiencies (iron, zinc, iodine, vitamin A and essential fatty acids) remain a major public health challenge in many developing countries. Aquatic foods from fisheries and aquaculture are rich sources of high-quality protein, essential fatty acids, vitamins and bioavailable micronutrients, making them vital for addressing malnutrition and hidden hunger (Ahern *et al.*, 2021). Aquaculture contributes more than 60% of total animal protein intake and provides livelihoods for millions of people across the value chain in Bangladesh (Ghose, 2014). Beyond the conventional aquaculture practices, marine fish products, seaweed, dry fish and non-conventional aquatic resources offer substantial potential to also address hidden hunger and diversify diets. Fish are unique "superfoods" providing highly bioavailable nutrients like essential amino acid along with EPA and DHA, which are crucial for brain development and cardiovascular health. Additionally, fish provide iodine, selenium, zinc and vitamins viz. A, D and B_{12} that are often limited in cereal-based diets. Moreover, consuming whole part includes the head, bones and viscera of small indigenous species (SIS) and smallmarine fish (like anchovies or sardines) which are the primary reservoirs for calcium, iron, and vitamin A compared to filleted fish. Dry fish is the low-cost nutrient concentrate which contribute three times higher nutrient density per gram compared to fresh fish. Properly processed dried fish products retain concentrated levels of calcium, iron and zinc (Rahman *et al.*, 2012). Furthermore, fermented dried fish products derived from small indigenous species enhance mineral bioavailability and provide additional functional benefits, particularly in low-income communities. Fermented dried fish products from several small indigenous species (SIS) are rich in protein and other essential minerals (Moniruzzaman *et al.*, 2024). Seaweed called the nutrient powerhouse of the ocean is an underutilized component of the fisheries sector that offers a distinct nutritional profile like polysaccharides, minerals and iodine (Miah *et al.*, 2026). Edible seaweeds contain bioactive polysaccharides, dietary fiber, antioxidants, essential minerals and particularly high levels of iodine necessary for thyroid function (Sobuj *et al.*, 2024). In addition to these conventional aquatic foods, several non-conventional resources including mussels, oysters and clam offer high nutritional yields with minimal production inputs. Bivalves and snail are particularly rich in iron, zinc and vitamin B12 and they also function as a natural biofilters that enhance ecosystem sustainability as well as provide highly nutrient-dense food for human consumption (Wright *et al.*, 2018). Nutrition-sensitive interventions emphasize efficient culture management, alternative protein sources from different aquatic components, nutrient-balanced aquatic product and long-term preservation to improve growth performance and nutritional quality of aquatic product which directly reflect on human health. Among these interventions, probiotics and amino acid balanced plant-based diets for culturable species, marine fish product, seaweed, dry fish and non-conventional aquatic resources have shown considerable potential. The present report synthesizes findings from different experiments conducted at Bangladesh Fisheries Research Institute (BFRI) to evaluate the biological performance, nutritional enhancement and economic profitability of nutrition-based aquaculture interventions.

2. Methodology

2.1. Experimental Species

The reports incorporate five primary categories of aquatic biomass

- ❖ Freshwater Fish: Emphasis on commercially important sp. like climbing perch koi (*Anabas testudineus*) under semi-intensive pond culture systems
- ❖ Marine Fish Product: Focus on little tuna (*Euthynnus affinis*) collected from local landings center.
- ❖ Seaweed: *Ulva sp., Hypnea musciformis* and *Gracilaria tenuistipitata* species from coastal intertidal zones in Cox's Bazar.
- ❖ Dry Fish: Sourcing of traditionally sun-dried fish vs. experimental samples (fresh fish) to measure nutrient analysis and comparison between two sources.
- ❖ Fermented Dry Fish: Freshwater small indigenous species (SIS) like Puti, Taki, Kholisha, Mola, Chanda, Chela, Batashi and Dhela were selected to identify nutrient and microbiological comparison between traditional and experimental methods.
- ❖ Non-Conventional Sources: Two bivalves and one snail were collected from wild sources for outdoor floating raft culture in intertidal zone.
- ❖ Shrimp: Emphasis on commercially important sp. like Penaeus monodon using eco-friendly management protocol

2.2. Amino Acid–Supplemented Diets for Nutritive Cultured Fish

Plant-based diets were formulated by partially and fully replacing fishmeal with soybean meal, mustard oil cake and other plant protein sources. Limiting amino acids, lysine and methionine, were supplemented at graded levels (0.45% & 0.9% lysine and 0.90% & 1.80% methionine) to achieve balanced amino acid profiles. Control treatments included a conventional fishmeal-based diet without amino acids.

2.3. Processing of Marine Fish Product

Little tuna (*Euthynnus affinis*) collected from BFDC Cox's Bazar was used to prepare fish mince and fish balls, stored frozen at -18 °C before processing. The fish were thawed, cleaned, filleted and mechanically minced under low temperatures (5-8 °C) to maintain quality. Spices were dried at 50 °C for 24 hours, ground into fine powder, sieved and refrigerated for later use. The mince was mixed with salt, sugar, spices, starch, MSG and vegetable oil, then stirred, blanched and shaped into balls. Finally, the vacuum-packed fish balls were preserved using deep freezing (-18 °C) and refrigeration (4 °C) to evaluate quality.

2.4. Seaweed Culture and Nutrition

The floating raft method was applied for the culture which was made of bamboo poles and recycled plastic drums. Micronutrient-enriched seaweed species *Ulva sp., Hypnea musciformis* and *Gracilaria tenuistipitata* were selected for culture experiments. Production and nutrient assessment were done after completion of 90 days culture period.

2.5. Dry Fish production by Using Mechanical Fish Dryer

Low cost, easy-to-fabricate and easy-to-operate fish dryer was developed that can be suitably employed at small to large scale fish drying yards of the Bangladesh coast. The fish dryer, sized 5 x 1.7 x 2 m3 was constructed by using square size metallic bar, black painted metallic plate, transparent 1.2 mm celluloid polythene sheet for better insulation and efficient utilization of heat energy. A motorized fan was used to force air circulation on the whole system between the entry and the exit of the drying chamber and also used an exhaust fan to reduce moisture contained excess air flow.

2.6. Processing of Fermented Dry Fish

Fresh fish was washed, eviscerated and uniformly salted prior to fermentation under controlled temperature and time regimes to ensure consistent product quality. Smoking was conducted at 50–55 °C followed by controlled drying to achieve target moisture levels and final products was vacuum packaged to preserve physicochemical stability and sensory attributes. Vacuum-packed products stored at both room and controlled temperatures for systematic shelf-life evaluation. Periodic assessments were monitored microbial load, lipid oxidation and biochemical changes to determine storage stability.

2.7. Non-Conventional Aquatic Sources (Bivalves and Snail) Culture and Nutrition

According to our sea wave condition this experiment was implemented by off-bottom culture methods. Experimental structure where setup with three cultures subtract: Plastic fruit basket, stainless still basket and net bag. Three different stocking densities of oyster, green mussel and clam were laid on trays and allowed to grow until marketable size. End of the culture period production and nutrient values of oyster, green mussel and clam were measured.

2.8. Organic shrimp (*Penaeus monodon*) farming using eco-friendly management protocol

The experimental design comprised three treatments: T1 (No Feed), T2 (Traditional Farming) and T3 (Improved Organic Farming). Traditional feeds, such as rice bran, wheat bran and mustard oil cake (20%), were regularly used in the experimental period. In accordance with the guidelines, rules and specifications established by the European Union (2009) and the International Federation of Organic Agriculture (IFOAM, 2009), a feed that is made with locally accessible organic ingredients and has at least 35% protein.

3. Results and Discussions

3.1. Nutritive Fresh Fish

Diets partially replacing animal protein with plant protein supplemented with 0.45% lysine and 0.90% methionine achieved growth performance and feed efficiency comparable to fishmeal- based diets, while reducing feed costs. Fully plant-based diets with higher amino acid inclusion showed significantly ($p<0.05$) lower performance and less production, underscoring the importance of balanced amino acid profiles (Table-1).

Table-1: Growth, nutrient utilization and production of koi (*Anabas testudineus*) under semi-intensive pond culture systems

Parameters	Dietary Treatments		
	Diet-1 (Fish Meal Based Diet)	Diet-2 (partially replaced animal protein with plant protein-based diet with 0.45% lysine + 0.90% Methionine)	Diet-2 (Fully plant protein-based diet with 0.90% lysine + 1.80% Methionine)
Initial weight (g)	11.56± 1.02	11.36± 1.05	11.64± 1.11
Final weight (g)	82.32±10.01^a	73.41± 6.03^b	51.37± 7.46^c
Weight gain (g)	70.76±10.40^a	62.05± 12.00^b	39.73± 8.92^c
Feed conversion ratio	2.03± 0.12^a	2.20± 0.14^{ab}	3.23± 0.86^c
Protein efficiency ratio	1.87 ± 3.65^a	1.65± 2.07^b	1.26± 3.04^c
Production (Kg/ha)	5,532.03	4,998.09	3,351.36
Benefit cost ratio	1.01	1.29	1.00
Proximate composition of koi (%w/w basis)			
Protein	16.93^a ±0.33	16.78^a ± 0.62	15.29^b ± 0.56
Lipid	3.87 ± 0.51	3.98 ± 0.38	4.03 ± 0.45

Amino acid balanced diets improved daily weight gain, nutrient retention and improved BCR of koi production while reducing reliance on costly animal protein sources.

3.2. Nutritive and Safe Marine Fish Product

Fresh tuna fillet showed moderate moisture (65.44%) and protein (21.28%) with the highest lipid content (9.63%). Deep-frozen fish balls (-18 °C) had the highest protein (25.53%) and ash (2.21%) but lower lipid content (8.36%). Refrigerated fish balls (4°C) exhibited the highest moisture (71.27%), with moderate protein and lipid levels; differences were statistically significant ($p< 0.05$).

Table-2: Proximate composition of raw tuna and fish balls in two different preservation methods

Samples	Proximate composition (%)			
	Moisture	Crude protein	Crude lipid	Crude Ash
Fresh fillet of tuna	65.44 ± 0.23[b]	21.28 ± 0.64[c]	9.63 ± 0.87[a]	1.12 ± 0.69[b]
Fish ball in deep freezing (-18̊C)	65.97 ± 0.69[b]	25.53 ± 0.56[a]	8.36 ± 0.69[b]	2.21 ± 0.95[a]
Fish ball in freezing (4˚C)	71.27 ± 0.96[a]	23.65 ± 0.70[b]	9.02 ± 0.47[ab]	1.56 ± 0.76[b]

Under **refrigeration (4°C),** *Salmonella spp*. remained absent throughout storage, while *Staphylococcus spp.* appeared after Day 30 and *Escherichia coli* was detected on Day 60.

Under **deep freezing (-18 °C),** both *Salmonella spp.* and *Staphylococcus spp.* were absent during the entire 60-day period. However, *Escherichia coli* was detected only on day 60 in deep-frozen samples, indicating better microbial stability at-18 °C compared to refrigeration.

Table-3. Color map representation of the presence and absence of the selected bacteria

Storage types	Refrigeration (4 °C)					Deep Freezing (-18 °C)				
Days / Bacteria	Day 0	Day 15	Day 30	Day 45	Day 60	Day 0	Day 15	Day 30	Day 45	Day 60
Salmonella spp.	-	-	-	-	-	-	-	-	-	-
Staphylococcus spp.	-	-	-	+	+	-	-	-	-	-
Escherichia coli	-	-	-	-	+	-	-	-	-	+

"+" = Presence of bacteria and "-" = Absence of bacteria

Deep freezing (-8 °C) preserved higher protein content and ensured better microbial stability compared to refrigeration (4 °C), where Staphylococcus spp. and Escherichia coli appeared during later storage. Overall, -18 °C storage maintained superior nutritional quality and safety over 60 days.

3.3. Production and Nutritive Values of Cultured Seaweed

Seaweed production varied among the four species evaluated over a 90-day culture period. Among the studied species, *Hypnea musciformis* demonstrated superior biomass production, whereas *Ulva lactuca* and *Gracilaria tenuistipitata* exhibited higher mineral density, highlighting their potential in nutrition-sensitive aquaculture systems (Table-4)

Table-4: Production, proximate composition, iodine and minerals contents of four commercially important seaweeds of Bangladesh.

Production of seaweed					
SL. No.	Parameters	*Ulva lactuca*	*Ulva intestinalis*	*Hypnea musciformis*	*Gracilaria tenuistipitata*
1	Total production (kg/m^2/90days)	27-28	25-26	30-31	14-15
Proximate, iodine and mineral contents of seaweed					
1.	Protein (%)	29.27	14.61	20.71	13.67
2.	Iodine (mg/100g)	41.20	29.93	12.71	47.21
3.	Potassium (mg/100g)	629.56	4012	3815	BDL
4.	Calcium (mg/100g)	812.58	1853	281	755
5.	Iron (mg/100g)	425.39	5.23	1.83	85.32
6.	Magnesium(mg/100g)	645.80	1813	2875	32.61
7.	Copper (mg/100g)	3.77	0.21	0.3	0.4
8.	Zinc (mg/100g)	4.77	1.09	2.41	1.83

The vitamin and heavy metal accumulation content of the studied seaweed species varied considerably *Ulva lactuca* demonstrated comparatively higher vitamin concentrations but also showed relatively elevated heavy metal levels, whereas *Hypnea musciformis* presented a balanced profile with high Vitamin E and lower (Table-5).

Table-5: Vitamin contents (mg/g) and Heavy metal (mg/kg) of four commercially important seaweeds

Vitamin content of seaweed					
SL. No.	Test Parameters	*Ulva lactuca*	*Ulva intestinalis*	*Hypnea musciformis*	*Gracilaria tenuistipitata*
1.	Vitamin B_{12} (mg/g)	1.53	0.72	0.91	0.40
2.	Vitamin E (mg/g)	1.74	1.36	2.31	-
Heavy metal content of seaweed					
1.	Mercury (Hg) (mg/kg)	0.359	0.151	0.119	0.591
2.	Lead (Pb) (mg/kg)	0.594	0.014	0.104	-

Hypnea musciformis produced the highest biomass, while *Ulva lactuca* showed the highest protein and vitamin levels but relatively higher heavy metals. *Hypnea musciformis* presented a more balanced nutritional and safety profile for nutrition-sensitive aquaculture.

3.4. Hygienic and Nutritive Dry Fish by Using BFRI Fish Dryer

The seven organoleptic (sensory) characteristics of the dried fish products produced in the BFRI fish dryer were found very attractive compared to the traditional products (table-6)

Table-6: Comparative organoleptic characteristics of the dried fish products produced by traditional method and BFRI Fish Dryer

Sl. No.	Characteristics	Dried fish products	
		Traditional method	BFRI Fish Dryer
1	General appearance	Less shiny	Comparatively shinier
2	Flavour	Very strong flavoured and in some cases strong odour of decomposed fish remained	Different grade of the product (A, B & C) mild to strong flavoured but never like decomposed fish
3	Filthiness	Filthy materials generally present	Filthy materials generally not present
4	Scales & gut	Not descaled or gutted	Descaled or gutted
5	Texture	Mostly soft but skin ruptured	Particularly soft and good and skin not ruptured
6	Wetness	High	Low in all cases
7	Saltiness	Usually, highly salty	Not salty in every case

The nutritional contents were found better (Table-7) for the products produced by the BFRI fish dryer compared to the traditional one, mainly due to the removal of moisture in higher percentage. The percentage of actual protein content based on nitrogen was also found to be higher due to the lower degree of spoilage in the product produced by the BFRI fish dryer.

Table-7: Comparative proximate composition of the dried fish products produced by traditional method and BFRI Fish Dryer

Sl. No.	Constituent (%)	Dried fish products	
		Traditional method	BFRI Fish Dryer
1	Moisture	Generally, moisture content high (25-30%)	Generally, moisture content very low (10-12%)
2	Protein	Generally, protein content low (50-55%)	Generally, protein content high (60-70%)
3	Lipid	Generally, lipid content low (08-10%)	Generally, moisture content high (10-12%)
4	Ash	Generally, ash content low (10-12%)	Generally, moisture content high 12-14%)

Dried fish produced using the BFRI fish dryer showed superior sensory quality better appearance, cleaner texture, lower moisture, less saltiness and absence of decomposed odor compared to traditional products. Nutritionally, BFRI dried fish had lower moisture and higher protein, indicating improved preservation efficiency and reduced spoilage.

3.5. BFRI Made Safe and Nutritive Fermented Dry Product (*Shidol*)

The improved BFRI method produced fermented dry fish (shidol) with significantly higher protein and fat content and lower moisture compared to traditional shidol (Table-8). Traditional shidol exhibited poor quality with high TVB-N and peroxide values, exceeding acceptable limits for consumption, while BFRI shidol exhibited lower TVB-N and peroxide values. Microbiologically, improved method shidol showed lower microbial loads, lower yeast mold count and no presence of coliform bacteria (Fig-1).

Table-8: Proximate composition of BFRI made *shidol* and traditional *shidol*

Parameter	BFRI made *Shidol*			Traditional *Shidol*		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Moisture (%)	18.73	17.56	19.73	25.52	24.42	26.72
Crude lipid (%)	18.92	18.15	20.19	14.05	13.25	14.78
Crude Protein (%)	33.48	30.21	37.15	31.80	29.55	34.58

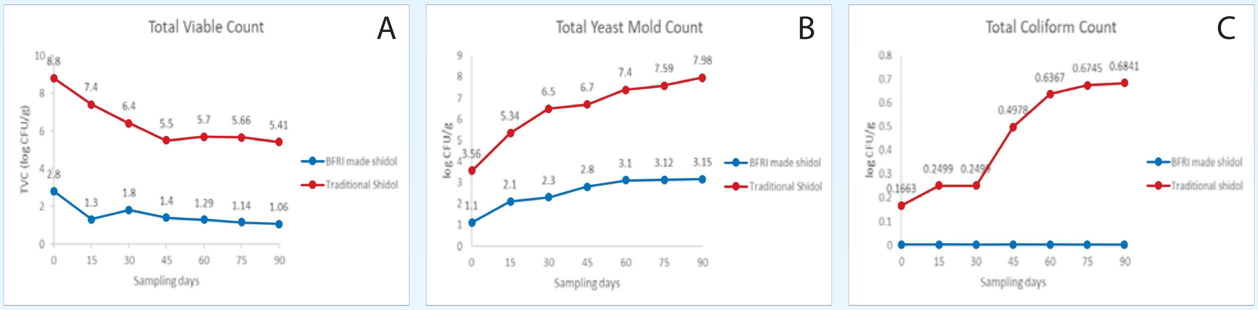

Fig. 1. (A) Total viable count; (B) Total yeast mold count, and (C) Total coliform count of BFRI made *shidol* and traditional *shidol*

The improved BFRI method produced *shidol* with high nutrient content and better biochemical quality compared to traditional *shidol*. It also ensured superior microbial safety, with lower total viable and yeast mold counts and no coliform contamination.

3.6. Production and Nutritive Values of Non-Conventional Aquatic Sources (Bivalves and Snail)

Among the three species green muscle and clam demonstrated superior production yield per unit area than oyster. In nutrition concern oyster and green mussel provided higher concentrations of protein and essential minerals than clam which highlighting their importance in nutrition-sensitive aquaculture systems (Table-9)

Table-9: Production, edible part protein and mineral contents of oyster, green mussel and clam

Production				
SL.No.	Parameters	oyster	green mussel	clam
1	Total production (kg/m^2/120days)	3.34-3.50	7.39-7.80	6.10-7.20
Edible whole-body protein and minerals contents				
1.	Protein (%)	15.53-18.76	13.53-13.89	12.18-14.20
2.	Potassium (mg/100g)	276.43-568.82	286.43-562.324	0.32-0.78
3.	Calcium (mg/100g)	86.61-214.78	84.61-224.77	0.61-0.80
4.	Iron (mg/100g)	9.09-13.08	5.07-13.08	0.07-0.08

Green mussel achieved the highest yield followed by clam, while oyster showed lower yield. However, oyster and green mussel provided higher protein and essential mineral contents than clam, underscoring their higher nutritional value in nutrition-sensitive aquaculture.

3.7. Growth and Nutrient Outcome of Organic *P. monodon*

Higher growth was observed in T1 in comparison to others after 105 days culture period, in T1, T2 and T3 were 24.53±0.93g, 21.85±0.85g and 15.67±1.02g respectively, compare to control. The nutrient analysis showed significant differences ($p < 0.05$) among the treatments for both protein and lipid contents. Fish from the Formulated Organic Feed group (T3) exhibited the highest protein (24.27 ± 0.82%) and lipid (4.86 ± 0.94%) contents, followed by the Traditional Feed group (T2) with protein and lipid values of 22.41 ± 1.47% and 3.54 ± 1.62%, respectively. The lowest protein (18.99 ± 1.26%) and lipid (2.04 ± 1.33%) contents were observed in the No Feed group (T1). The results indicate that the formulated organic feed improved the nutritional composition of fish compared to traditional feeding and no feeding conditions

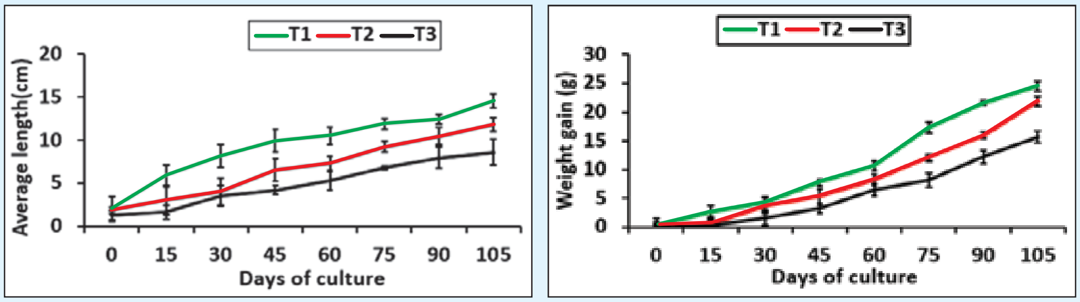

Fig. 2. Growth Performance of shrimp (A) Average length (cm) (B) Weight gain (g)

Table-10: Nutrient composition of P monodon

Parameters	No Feed (T_1)	Traditional Feed (T_2)	Formulated Organic Feed (T_3)
Protein (%)	18.99± 1.26^{a}	22.41± 1.47^{b}	24.27± 0.82^{c}
Lipid (%)	2.04± 1.33^{a}	3.54± 1.62^{b}	4.86± 0.94^{c}

4. Challenges

Despite significant advancements in fish nutrition research, several major challenges still hinder the sustainable development of aquaculture. One of the primary challenges is the continuous fluctuation in the prices of feed ingredients, especially protein-rich raw materials. In addition, feeding trials, nutritional evaluations and laboratory analyses require sophisticated equipment, skilled manpower and substantial financial investment, making research activities expensive and time-consuming. Another important challenge is the limited awareness and adoption of improved feeding technologies among farmers, particularly in rural areas where traditional practices are still commonly used.

5. Way Forward

Greater emphasis should be given to nutrition sensitive, climate-smart and functional aquafeeds that can enhance fish health, stress tolerance and disease resistance under changing environmental conditions. Research on alternative protein and energy sources is essential to reduce dependence on expensive fishmeal and conventional feed ingredients. In addition, advanced studies on amino acids, fatty acids and enzyme-based feed technologies are needed to improve nutrient utilization and feed efficiency for all culturable species. These approaches will enhance aquaculture productivity while ensuring long-term environmental sustainability.

6. Conclusion

Nutrition-sensitive aquaculture shifts the paradigm from production-centric aquaculture to nutrient-centric aquaculture. Scientist of BFRI link aquaculture to nutrition outcomes by measuring nutrient production and quality, evaluating processing effects, analyzing consumption and affordability and converting these into dietary intake and health impacts such as improved nutrition and reduced deficiencies. Nutrient content of fresh fish, marine fish products, seaweed, dry fish, fermented dry fish and non-conventional fisheries resources collectively enhance dietary diversity, micronutrient intake and sustainable food systems.

Integrating these components into aquaculture planning can substantially contribute to national nutrition security, public health improvement and sustainable development goals. Moreover, these approaches provide scalable, climate-smart and nutrition-sensitive solutions for sustainable aquaculture development in Bangladesh.

7. Recommendation

Future research should shift from a production-centric approach toward the comparative evaluation of nutrient yield per unit area, including protein, iron, iodine, vitamin A, EPA, DHA, and other essential micronutrients, rather than focusing solely on total aquatic biomass production. To achieve this objective, urgent capacity building and the establishment of advanced laboratory facilities are required to accurately assess micronutrient composition, bioavailability and potential contaminants in diverse aquatic resources. While nutrient composition data are available, further research is needed to assess bioavailability and human absorption efficiency, particularly for minerals from dried, fermented and whole-fish products. Clinical or community level feeding trials would strengthen evidence linking aquatic food consumption to measurable health outcomes. Adoption of multidisciplinary framework integrating aquaculture nutrition, public health, food technology, environmental sustainability and economic viability will be given preferences for scaling nutrition-sensitive aquaculture to combat malnutrition in Bangladesh.

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Nutrition-Sensitive Wheat and Maize Research at Bangladesh Wheat and Maize Research Institute to Mitigate the Hidden Hunger

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Introduction

Bangladesh faces a critical challenge with significant micronutrient deficiencies among vulnerable populations. According to the National Micronutrient Survey (2019-2020), substantial proportions of children and non-pregnant non-lactating (NPNL) women suffer from zinc (31% in children and 43.40% in women), iron (15.10% in children and 14.10% in women), and vitamin A deficiencies (50.90% in children and 7.50% in women) (IPHN, 2021). The Bangladesh Wheat and Maize Research Institute (BWMRI) addresses this nutritional crisis through wheat and maize development, biofortification, agronomic innovation, crop and soil management advances and postharvest research aligned with the global nutrition-sensitive agricultural framework (FAO, 2013).

Biofortification through conventional breeding and molecular technology has proven effective in addressing micronutrient malnutrition in developing countries (Bouis & Saltzman, 2017). BWMRI involves the implementation of biofortification to develop varieties rich in vitamins A, C, B3, and B9 (Folate), calcium, iron, magnesium, phosphorus, potassium, zinc, protein, fat, energy, and carbohydrates to reduce micronutrient deficiency among Bangladeshi people (Shaheen *et al.*, 2013).

In Bangladesh, maize serves as the primary ingredient in animal feed production, with feed mills consuming 35–36 lakh tons of maize annually (Ali, 2022). Approximately 40% of this demand are sourced domestically and 60% are imported (Emerging Rating, 2022). Wheat usage as animal feed is estimated at 280,000 metric tons annually, primarily as wheat bran (USDA FAS, 2024). Local wheat production accounts for only 15% of national demand, with an FSI consumption of 6.8 million metric tons (USDA FAS, 2023). Poultry farms produce 570 million tons of meat and 7.34 billion eggs annually, heavily relying on maize feed (BBS, 2019). Compared with rice and wheat, maize has the highest yield (10.91 t/ha) and return (BCR = 1.63) in Bangladesh (Rahman, 2010). Current trends for wheat and maize production and demand are shown in Table 1.

Table 1: Production and demand trends of Wheat and maize in Bangladesh

Item/Subject	Wheat (MMT)	Maize (MMT)
Current demand	7.80	8.00
Production	1.11	7.39
Demand by 2050	12.00	10.00
Yield (t/ha)	3.86	10.91

(MMT = million metric tons); Source: BBS (2019)

Materials and Methods

BWMRI employs a multifaceted approach to nutrition-sensitive agriculture, encompassing nutrient rich and biofortified germplasm evaluation, participatory varietal selection, biofortification and breeding programs, agronomic innovation, advancement in crop and soil management and postharvest innovation etc. The institute conducts systematic breeding for zinc and iron enriched wheat varieties using Zn-efficient germplasm from CIMMYT and high-quality protein maize (QPM) with increased folate and vitamin A contents (BWMRI, 2025). Nutrition-sensitive agronomic practices include specific cropping patterns where short-duration Aman rice (BRRI Dhan 71/90 or BINA Dhan 7/15) is planted in the first week of August; quick-maturing potato (BARI Alu 13/31) from 15–20 October for 60 days; short-duration wheat (BARI Gom 32, BWMRI Gom 1 or BWMRI Gom 4) from 15–20 December and heat-tolerant BARI Hybrid Maize 17 (or BARI Mung 6 as an alternative) from the first week of April (Sarker, 2014). In addition to that, leaf cutting or defoliation and detopping technologies for maize plant ensures nutrition into both human and animal food system (Jahan et al., 2023; Rajkumara *et al.*, 2020). BWMRI is also establishing a synergistic soil plant nutrient continuum that simultaneously addresses macronutrient efficiency and micronutrient bioavailability through the transformative application of nano fertilizer and biological nitrification inhibition (BNI) as part of nutritional-sensitive soil science innovation.

Research methods include (i) multilocation trials (MLTs); (ii) assessments of climate resilience traits, including heat tolerance (>30°C during grain filling), salinity tolerance (8–12 dS/m) at seedling stage and disease resistance, using standard CIMMYT, 2005 protocols and (iii) comprehensive nutritional analysis using atomic absorption spectroscopy (AAS) and the establishment of AOAC protocols for proximate composition and mineral content. Postharvest research focuses on gluten and starch profiling, corncob jelly development from agricultural residues and composite maize–wheat flour fortification at varying ratios (70:30, 60:40, 50:50, and controls) and consumer preference study was done using nine-point hedonic scales with 30–45 semitrained panelists and one-way ANOVA ($p<0.05$) (BWMRI, 2025).

Results and Discussion

Nutritional Composition of BWMRI-Released Wheat and Maize Varieties

Wheat and maize are rich in protein, vitamin and other nutrients. Shaheen *et al.*, 2013 conducted the nutritional profiling of different human food derived from wheat and maize at Institute of Nutrition and Food Science, Dhaka University. Table 2 presents key proximate, mineral, and vitamin data for major wheat and maize products.

Table 2: Nutritional composition of wheat and maize products (key parameters)

Food items	Energy (Kcal)	Protein (g)	Fat (g)	Carb (g)	Dietary fibre (g)	Ash (g)	Zn (mg)	Fe (mg)	Vit. A (mcg)	Vit. B9 (Folate) (mcg)	Vit. C (mg)
Wheat kernel (whole, raw)	1450	11.20	2.90	62.00	12.20	1.60	2.79	4.90	5	38	0
Wheat flour (Brown)	1410	11.30	2.10	62.20	10.70	1.50	3.02	4.90	5	29	0
Wheat flour (White, refined)	1470	9.80	1.00	73.10	2.70	0.60	1.55	2.70	0	20	0
Semolina (raw durum wheat flour)	1470	10.90	1.40	70.60	3.90	0.50	2.18	1.10	0	57	0
Maize kernel (dried, raw)	1450	9.90	3.40	64.70	7.30	1.60	3.27	2.90	140	20	0

Food items	Energy (Kcal)	Protein (g)	Fat (g)	Carb (g)	Dietary fibre (g)	Ash (g)	Zn (mg)	Fe (mg)	Vit. A (mcg)	Vit. B9 (Folate) (mcg)	Vit. C (mg)
Sweet corn (raw)	621	3.50	1.40	28.70	2.80	0.80	0.80	0.70	56	29	5.90
Maize flour	1500	6.90	3.90	69.60	7.30	1.50	1.73	2.40	0	25	0
Popcorn (Salted)	1380	10	3.10	58.60	12.90	1.60	3.70	2.80	87	28	0

Here, Kcal= Kilo calorie; g=gram; mg=milligram; mcg=microgram

BWMRI has released 38 wheat varieties till date. Salient features of some of the nutrient rich, biofortified, climate resilient and disease tolerant wheat varieties are presented in Table 3. Moreover, BARI Gom 33 with 50–55 ppm zinc is significantly above the 25–30 ppm Zn of conventional varieties combined with heat and salt tolerance and BWMRI Gom 3 with 40–45 ppm zinc. Both meet the HarvestPlus target of 40 ppm for zinc-biofortified wheat (Hossain *et al.*, 2019).

Table 3: Representative BWMRI-released wheat varieties with prominent characteristics

S.N.	Variety	Release Year	Special Characteristics
1	BARI Gom 25	2010	Salt tolerant (8-10 dS/m), heat tolerant, leaf spot & wheat rust resistant
2	BARI Gom 26	2010	Heat tolerant, Wheat stem rust (UG 99) resistant and leaf spot disease tolerant.
3	BARI Gom 27	2012	Heat tolerant, Leaf spot disease tolerant, Wheat rust and wheat stem rust (UG 99) resistant and high yielding (4.2 - 5.5 t/ha).
4	BARI Gom 28	2012	Heat tolerant, leaf spot & wheat rust resistant, high yielding (4.5 - 5.5 t/ha)
5	BARI Gom 29	2014	Heat tolerant, Wheat stem rust (UG 99) and wheat rust resistant and leaf spot disease tolerant.
6	BARI Gom 30	2014	Heat tolerant, wheat blast & rust resistant, high yielding (4.5 - 5.5 t/ha)
7	BARI Gom 30	2017	Slightly Heat tolerant, Leaf spot disease tolerant, Wheat stem rust (UG 99) and wheat rust resistant and high yielding (4.6 - 5.0t/ha)
8	BARI Gom 32	2017	High gluten content (12.28%), heat tolerant, wheat blast & rust resistant, high yielding (4.3 - 5.2 t/ha)
9	BARI Gom 33	2017	Salt tolerant (8-10 dS/m), heat tolerant, wheat blast & rust resistant, Zinc biofortified (50-55 ppm), high yielding (4.8 - 5.5 t/ha)
10	BWMRI Gom 1	2019	Heat tolerant, leaf spot & wheat rust resistant, high yielding (4.5 -5.5 t/ha)
11	BWMRI Gom 2	2020	Leaf spot and wheat rust (UG 99) resistant, high yielding (4.0 - 5.0 t/ha)

S.N.	Variety	Release Year	Special Characteristics
12	BWMRI Gom 3	2020	Heat tolerant, wheat blast & rust resistant, Zinc biofortified (40-45 ppm), high yielding (4500-5500 kg/ha)
13	BWMRI Gom 4	2022	Salt tolerant (8-10 dS/m), heat tolerant, leaf spot & wheat rust resistant, high yielding (4500-5500 kg/ha)
14	BWMRI Gom 5	2024	Heat tolerant, wheat blast & rust resistant, high yielding (4600-5500 kg/ha)

On the contrary, BWMRI has released 21 hybrid and 9 open pollinated (OP) maize varieties till date. BARI Hybrid Maize 5 is a quality protein maize (QPM) with 0.48% lysine (nearly double that of conventional maize at 0.25%), 0.11% tryptophan, and 11% total protein (BWMRI, 2025). BARI Sweetcorn 1 provides high carotene (vitamin A precursor) and 18% fructose. BWMRI Hybrid Baby Corn 1 contains exceptional amounts of folate (180–220 μg/100 g). Special characteristics of some important maize varieties are presented in Table 4.

Table 4: Representative BWMRI-released maize varieties with prominent characteristics

Sl.	Variety	Release Year	Special Characteristics
1	Khoi Bhutta	1986	Yield rate 3.5-4 t/ha Rabi, 2.5-3.5 t/ha Kharif, good carb source with 90-95% popping capacity
2	BARI Sweetcorn 1	2002	High carotene (vitamin A precursor), 18% fructose, yield 10-10.5 t/ha; matured leaves are good animal feed
3	BARI Hybrid Maize 5	2004	Quality Protein Maize (QPM): 0.11% tryptophan, 0.48% lysine (~double conventional), 11% total protein; yield 9-10 t/ha (Rabi)
4	BARI Hybrid Maize 9	2007	Yellow and dent grain. Yield is 11.5–12.5 tons/hectare in Rabi and 8.5–9 tons/hectare in Kharif season.
5	BARI Hybrid Maize 13	2016	Drought tolerant, white grain; yield 8.2-8.9 t/ha (1 irrigation), 10.1-11.2 t/ha (normal irrigation)
6	BARI Hybrid Maize 16	2018	Saline tolerant, high yield (11.57 t/ha Rabi), purple silk with anthocyanin
7	BARI Hybrid Maize 17	2019	Heat tolerant, high yield (11-12 t/ha Rabi, 8.5-9.5 t/ha Kharif)
8	BWMRI Hybrid Baby Corn 1	2020	Rich in folate (180-220 μ g/100 g), TSS 12.2 Brix, yield 2.30-2.65 t/ha (Rabi)
9	BWMRI Hybrid Maize 1	2020	Short variety, high yield (11-13 t/ha), Pink silk with high anthocyanin and does not spoil in rain due to leaf coverings
10	BWMRI Hybrid Maize 2	2022	Highest yield (12-14 t/ha Rabi), slight green silk, rain-resistant leaf covering

Nutrition-Sensitive Agronomic Practices

A specialized cropping pattern for light-textured soils in northern Bangladesh integrates early potato–wheat–maize/mungbean–aman rice in sequence, ensuring year-round productivity, soil fertility maintenance, and diverse nutritional outputs (Sarker, 2014).

Detopping technique is characterized by cutting the upper portion of the maize plant leaving one leaf above the cob after 30 days of silk appearance. This increases the yield of the resulting biomass without negatively affecting the grain yield (Rajkumara *et al.*, 2020).

Leaf cutting or defoliation technology includes the removal of leaves after 140 days of planting maize plant. This technique removes all leaves except the two top and bottom leaves aroud the cob. This practice also improve the forage quality without negatively affecting the grain yield (Jahan *et al.*, 2023). Moreover, the cultivation of BARI Triticale 1 and 2 and high-biomass maize varieties (BARI Hybrid Maize 9, 13 and BWMRI Hybrid Baby Corn 1) ensures higher biomass and diversified nutrition directly into animal and indirectly into human food systems.

Nano Fertilizer and Biological Nitrification Inhibition (BNI)

BWMRI is continuing its research to advance nutrition-sensitive soil management through the application of nano fertilizer and biological nitrification inhibition (BNI). Nanourea consists of nitrogen nanoparticles (~20–50 nm) whose absorption efficiency is reportedly up to 80%, far exceeding that of conventional urea (~30–40%) (Mahajan *et al.*, 2023; Shukla *et al.*, 2021). Enhanced nitrogen use efficiency (NUE) minimizes leaching and denitrification losses and increases grain protein content and amino acid composition in pipeline varieties to address protein deficiency (FAO, 2022).

BNI, identified in Brachiaria humidicola and certain wheat varieties, suppresses the abundance of nitrifying bacteria (Nitrosomonas europaea) and slows ammonium-to-nitrate conversion in the rhizosphere (Subbarao *et al.*, 2021). The incorporation of BNI-capable germplasm conserves soil nitrogen reduces N_2O emissions, and increases the solubility and plant uptake of zinc and iron micronutrients-which are both deficient in Bangladeshi women and children (Hossain *et al.*, 2019). Together, precision nitrogen delivery and BNI-mediated rhizosphere optimization can be used to establish a synergistic soil-plant nutrient continuum that addresses macronutrient efficiency and micronutrient bioavailability simultaneously (Black *et al.*, 2013).

Postharvest innovation: Gluten profiling of BWMRI-released wheat varieties

Fourteen BWMRI wheat varieties were analysed for dry gluten content (Table 5). The samples were subsequently milled, the dough was soaked for 2 hours, the starch was removed (confirmed by the iodine test), and the samples were oven-dried at 140°C for 2 hours.

Table 5: Dry gluten content of BWMRI-released wheat varieties

Sl.	Variety	Dry Gluten (%)
1	BARI Gom 32	12.28
2	BARI Gom 22 (Sufi)	11.86
3	BARI Gom 25	11.57
4	BWMRI Gom 5	11.18
5	BARI Gom 33	10.56
6	BWMRI Gom 4	10.32
7	BWMRI Gom 3	9.50
8	DURUM Wheat	9.32
9	BWMRI Gom 1	9.07
10	BARI Gom 24 (Prodip)	8.48
11	BARI Gom 30	8.24
12	BWMRI Gom 2	7.16
13	BARI Gom 21 (Shatabdi)	3.92
14	Triticale	2.01

High-gluten varieties (>10%) such as BARI Gom 32, BARI Gom 22 (Sufi), BARI Gom 25, BWMRI Gom 5, BARI Gom 33 and BWMRI Gom 4 are best suited for bread, pasta, noodles and pizza with excellent dough strength and gas retention. The medium-gluten varieties (7–10%), BWMRI Gom 3, DURUM, BWMRI Gom 1, BARI Gom 24 (Prodip), BARI Gom 30, and BWMRI Gom 2, are ideal for cakes, flatbreads (roti, chapati, paratha, and naan) and general household flour. Low-gluten varieties (<7%): BARI Gom 21 (Shatabdi) and Triticale are suited for biscuits, cookies, muffins, and baby food. Persons with celiac disease or wheat allergy must avoid all gluten-containing varieties (BWMRI, 2025).

Postharvest Innovation: Corncob Jelly Development

Five corncob jelly formulations (S1–S5) were evaluated sensorially. Sample S3 (13 cobs + 800 g of sugar + 20 g of pectin + 8 g of citric acid per 1100 ml of extract + 2 g of KMS) achieved the highest scores across all the attributes (Table 6) and was rated "liked very much" on the 9-point hedonic scale. Corncob of BARI Sweetcorn 1 comprises 12% cob husk, 50% kernel, and 38% rachis/cob by weight, meaning that 38% of each corn ear is utilizable for jelly production and transformation of agricultural waste into a nutritious, marketable product consistent with circular economy principles (BWMRI, 2025). Characterization of BARI Sweetcorn 1 corncob is shown in Figure 1.

Table 6: Sensory evaluation scores for corncob jelly (*=highest for attribute; ** =overall best)

Sample	Color	Texture	Flavour	Smell	Overall
S1	7.78	6.89	8.00*	5.89	6.11
S2	6.33	6.00	6.56	7.00	7.11
S3**	8.44*	7.89*	8.00*	7.89*	8.11*
S4	6.67	6.11	6.22	7.11	7.22
S5	7.67	6.56	6.22	6.44	6.00

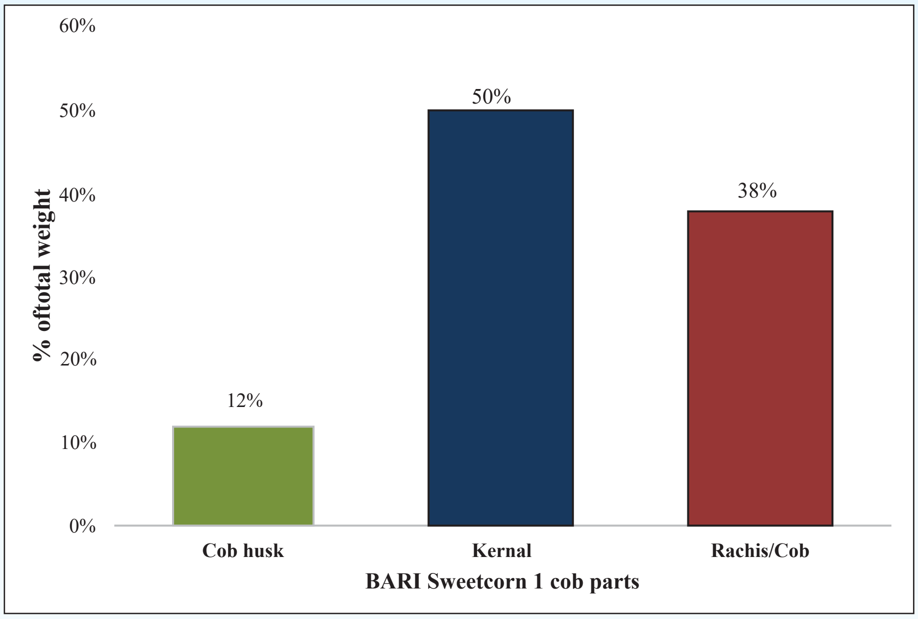

Figure 1: Corncob characterization of BARI Sweetcorn 1

Postharvest Innovation: Maize Flour Fortification in Pusti Cakes

Five wheat-to-maize ratio formulations were tested: S1 (70:30), S2 (60:40), S3 (50:50), S4 (100% maize), and S5 (100% wheat control). Sample S2 (60:40) demonstrated superior performance across all the sensory attributes (Table 7) and was rated "Liked Very Much". This formulation balances nutritional enhancement (increased protein, fibre and micronutrients from maize) with cost-effectiveness (maize flour costs 30–40%

less than wheat flour) and consumer acceptability, which is consistent with the results of composite flour research (BWMRI, 2025).

Table 7: Sensory evaluation scores for Pusti Cakes at different wheat:maize ratios (* = highest; ** = overall best)

Sample	Color	Texture	Flavour	Smell	Overall
S1 (70:30)	7.78	7.11	7.89	6.11	6.67
S2** (60:40)	8.44*	8.56*	8.22*	8.11*	8.67*
S3 (50:50)	6.22	6.33	6.56	7.33	7.56
S4 (100% Maize)	7.44	6.22	6.78	6.67	6.56
S5 (100% Wheat)	7.22	6.67	7.11	7.56	7.11

Novel Processing: Deep-Fried-Crispy Corn from Raw Kernels

Four hybrid maize varieties and baby corn were processed into crispy corn snacks. The BWMRI hybrid maize 2 (S4) emerged as the most preferred, with the highest scores for color, texture, and overall acceptability (Table 8), and was rated "liked moderately". Its superior performance is attributed to its optimal moisture content (12–14%), kernel hardness and starch composition suitable for deep-frying (BWMRI, 2025).

Table 8: Sensory evaluation scores for crispy corn from different maize varieties (* = highest; ** = overall best)

Sample	Variety	Color	Texture	Flavour	Smell	Overall
S1	BARI Hybrid Maize 16	7.67	6.11	7.67	6.78	6.78
S2	BARI Hybrid Maize 17	6.89	6.56	8.00*	5.78	6.44
S3	BWMRI Hybrid Maize 1	6.44	6.89	7.00	6.44	7.33
S4**	BWMRI Hybrid Maize 2	8.11*	8.33*	6.56	8.11*	7.89*
S5	Baby Corn	5.89	6.00	6.33	5.89	6.33

Conclusion

BWMRI has established a comprehensive nutrition-sensitive agricultural research program addressing hidden hunger through biofortification, innovative postharvest technologies, agronomic practices, innovative crop and soil management. The development of zinc and iron enriched wheat varieties (40–55 ppm Zn), high-quality protein maize (0.48% lysine and 11% total protein), and specialty corn (sweetcorn and baby corn) directly targets micronutrient deficiencies prevalent in Bangladesh.

Special nutrition-sensitive agronomic cropping patterns (early potato–wheat–maize/mungbean–Aman rice) increase farm profitability, maintain soil fertility, and ensure nutrition for Bangladeshi people. Detopping, leaf cutting or defoliation and cultivation of BARI Triticale 1 & 2, BARI Hybrid Maize 9 & 13, and BWMRI Hybrid Baby Corn 1 further increase biomass yield and integrate nutrition into both animal and human food systems. The synergistic application of Nano fertilizer and BNI represent the strategic commitment of the BWMRI to reducing hidden hunger through sustainable, field-scalable crop production. Gluten profiling of released wheat varieties will support decision-making in terms of variety selection, breeding, industrial processing, and public health. Postharvest innovations demonstrate strong consumer acceptance (hedonic scores >8.00 for optimal formulations) and the potential for agricultural waste valorization.

Key challenges remain, such as competition among winter crops, which reduces the area of wheat; yield gaps of 1.5–2.0 t/ha between research stations and farmers' fields; climate change impacts (0.5–2.0°C temperature increases affecting wheat production); emerging diseases (wheat blast causing 10–30% yield losses; fall armyworm in maize) and a dependence on foreign hybrid seeds (85–90% of maize seeds imported); and inadequate postharvest infrastructure, which causes 10–15% losses. Continued investment in biofortification research (targeting 60+ ppm Zn in wheat and 0.6% lysine in maize), nutrition-sensitive agronomy, soil science and postharvest technology will contribute to achieving projected demands of 12 MMT wheat and 10 MMT maize by 2050 while mitigating the hidden hunger crisis, which is consistent with SDG 2 (Zero Hunger) and SDG 3 (Good Health and Well-being).

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Extended Abstract from Other Organization

Climate-Resilient and Nutrition-Sensitive Agricultural Interventions for the Food Systems Transformation in Bangladesh

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1. Introduction

Bangladesh has made considerable progress in reducing undernutrition over the past two decades, yet micronutrient deficiencies and increased climate shocks continue to constrain food security, household diets, and smallholder livelihoods. The Global Alliance for Improved Nutrition (GAIN) addresses these interlocked challenges through a nutrition-sensitive agriculture (NSA) portfolio in Bangladesh that promotes biofortified and climate-resilient crops, strengthens local seed production and market systems, supports multi-stakeholder governance platforms, and connects rural food producers with markets and consumers. Drawing on programme data from four complementary GAIN projects-the Nourishing Food Pathways (NFP) programme, the Diversified Resilient Agriculture for Improved Food and Nutrition Security (RAINS) project, the Commercialisation of Biofortified Crops (CBC) programme and the Climate Action at Local Level (CALL) project-this paper documents GAIN's work across four crop-level interventions: zinc and iron-enriched lentil (BARI Masur-8), biofortified zinc rice, zinc and iron-enriched wheat (BARI Wheat-33), and beta-carotene-enriched orange-fleshed sweet potato. It further documents cross-cutting climate-smart agriculture practices, governance mechanisms, market linkage models, and youth and gender integration. The evidence shows that crop choice, seed systems, post-harvest management, market linkage, and behaviour change must function together as a system-not as isolated project activities-if agriculture is to deliver better diets while helping climate-vulnerable communities adapt and build resilience. Outcomes include demonstration plots reaching over 17,000 farmers across 89 unions, seed access for 1,600 lentil farmers through BADC, 52 zinc rice demonstration plots across 12 Upazilas, 400 salinity-tolerant rice plots in coastal areas, 5,000 MT of zinc rice procured by the Directorate General of Food and Multi-Stakeholder Platforms functioning across 189 unions. These results point toward food systems transformation when nutrition, climate and institutional levers are treated as a unified pathway rather than separate programme components.

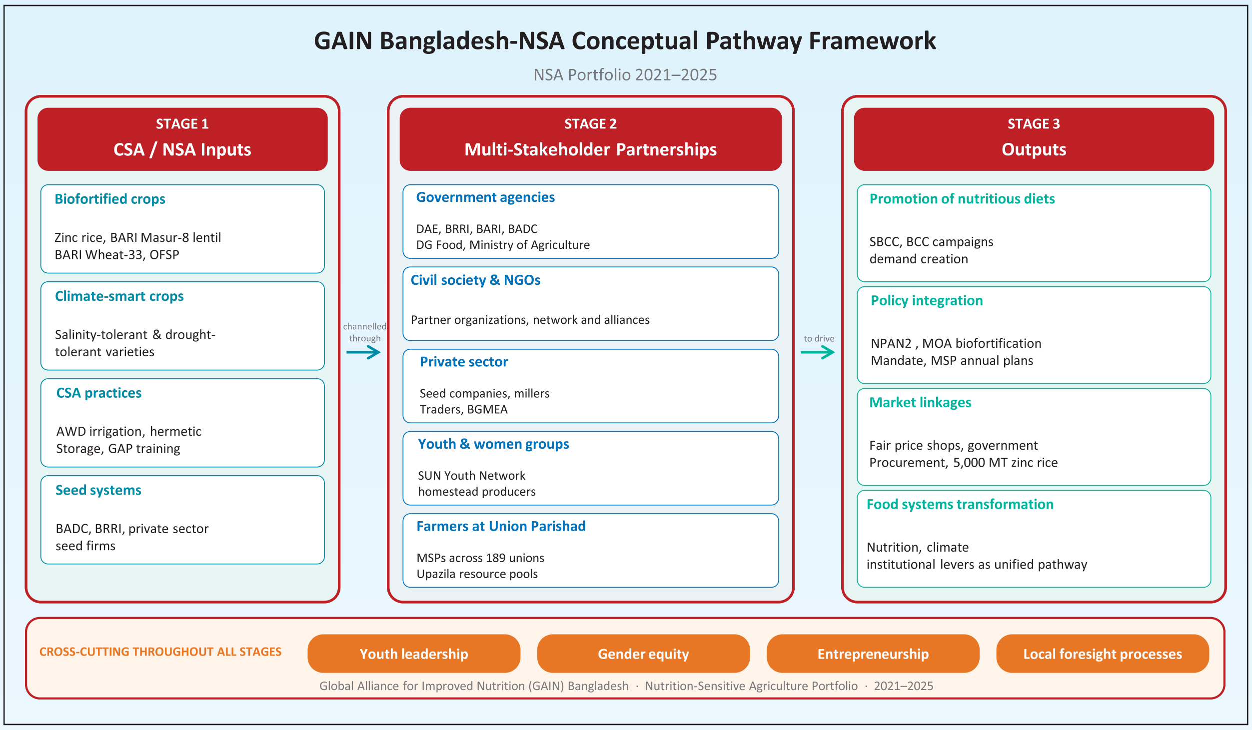
Bangladesh's food system is at a critical juncture. The country has achieved substantial gains in agricultural productivity and has reduced stunting from 41% of children under five in 2011 to 24% by 2022 (NIPORT & ICF, 2023). Yet the dietary pattern remains overwhelmingly cereal-centred: average rice consumption sits at 328.9 g/person/day (BBS, 2023), while intake of pulses, vegetables, fruits, and animal-source foods is between one-quarter and one-half of healthy diet recommendations (Foresight4Food, 2024). Zinc deficiency affects approximately 55% of the population, with prevalence of 44.6% among pre-school-age children and 57.3% among non-pregnant non-lactating women (Rahman *et al.*, 2016). At the same time, climate hazards-drought, salinity intrusion, riverine flooding, flash floods, and heat stress-are compressing agricultural calendars, damaging seed stocks, and eroding the livelihoods of smallholder farming families across the country (Ghosh *et al.*, 2023; Moon, 2023). Globally, agrifood systems account for roughly one-third of anthropogenic greenhouse gas emissions, making climate-smart agricultural practices essential not just for adaptation but for mitigation (FAO, 2025).

Addressing these interlinked challenges requires more than isolated crop or nutrition interventions. The Bangladesh National Food and Nutrition Security Policy 2020 and its Plan of Action (2021–2030) explicitly position food system transformation as a national priority, calling for biofortification, large-scale food fortification, dietary diversification and climate change adaptation to function as complementary strategies. The EAT–Lancet Commission (Willett *et al.*, 2019) similarly argued that a "Great Food Transformation"-simultaneous changes in production diversity, supply chains, market access, and dietary behaviour-is necessary to achieve health and planetary goals. Nutrition-sensitive agriculture, defined as agricultural development that explicitly incorporates nutrition objectives, targets vulnerable groups, and leverages multiple pathways from production to diet (Ruel & Alderman, 2013), has been positioned as a central mechanism for driving this transformation in countries like Bangladesh.

1.1 GAIN's Role and Programme Architecture in Bangladesh

GAIN is a Swiss-based foundation established at the United Nations in 2002 to address malnutrition by making nutritious and safe foods more accessible and affordable for vulnerable people. In Bangladesh, GAIN has operated since 2013 through four interlocking programme streams directly relevant to NSA:

Commercialisation of Biofortified Crops (CBC) programme, Nourishing Food Pathways (NFP) programme, Diversified Resilient Agriculture for Improved Food and Nutrition Security (RAINS) project and Climate Action at Local Level (CALL) project.



Together, these programmes form GAIN's NSA architecture in Bangladesh. Unlike many single-crop or single-sector interventions, GAIN's approach treats crop promotion, climate adaptation, seed system strengthening, market linkage, multi-sectoral governance, and behaviour change as elements of a single integrated system rather than parallel activities. The conceptual pathway works in three stages: CSA/NSA input (biofortified and climate-smart crops, climate-smart practices) channelled through multi-stakeholder partnerships (government, civil society, private sector, youth, women and farmers' groups at local level) to drive promotion of nutritious diets and policy integration as outputs-with cross-cutting work on youth leadership, gender, entrepreneurship, and local foresight processes running throughout.

1.2 Value Addition

This paper makes three specific contributions. First, it documents GAIN's NSA interventions from the perspective of programme data and field experience outreach numbers, crop performance, institutional reach and market linkage outcomes rather than relying primarily on external analyses. Second, it integrates the four crop interventions (rice, lentil, wheat, sweet potato) within a shared climate-nutrition framework, demonstrating how their combined deployment addresses overlapping nutritional and climate vulnerabilities across different climate hotspots. Third, it identifies where policy, governance and supply chain barriers constrain scale and proposes a practical way forward for Bangladesh's food systems transformation agenda.

2. Methodology

2.1 Study Design and Data Sources

This paper applies a mixed-methods approach, drawing on both quantitative programme data and qualitative field documentation collected across GAIN Bangladesh's NSA portfolio between 2021 and 2025. Primary data sources include:

- Programme monitoring data from CALL, CBC, RAINS, and NFP projects: including demonstration plot records, seed distribution logs, farmer training attendance, outreach figures and marketing transaction records.
- GAIN internal project reports and progress reviews covering NSA intervention outcomes, challenges and adaptive management decisions across the four-year implementation period.
- Focus group discussions and key informant interviews conducted with farmers, extension workers, millers, traders and Union Parishad representatives in Naogaon, Jamalpur, Khulna, Satkhira, Dhaka and Gazipur.
- Nutrition content data for promoted crop varieties-zinc, iron, selenium, and beta-carotene content-drawn from published variety characterisation studies and BARI/BRRI release dossiers (Zaman *et al.*, 2022; Mottaleb *et al.*, 2025; SAARC Agriculture Centre, 2025).
- Government and partner data on seed systems, food procurement, and social safety net coverage from BADC, BRRI, the Directorate General of Food and the Department of Agricultural Extension (DAE).

Secondary data sources include the Bangladesh Demographic and Health Survey 2022 (NIPORT & ICF, 2023), the Household Income and Expenditure Survey 2022 (BBS, 2023) and the Foresight4Food Bangladesh food system analysis (2024), used to contextualise programme results within the national nutrition and food system landscape.

2.2 Analytical Framework

Analysis of programme outcomes follows three dimensions aligned with GAIN's NSA impact pathway:

- **Nutrition and climate value:** micronutrient content of promoted varieties, climate adaptability, water and emissions implications.
- **Reach and adoption:** demonstration plots established, farmers trained, seed distributed, and institutional coverage.
- **Market and governance outcomes:** market linkages developed, government procurement triggered, policy changes influenced and institutional platforms established.

The paper documents the core NSA intervention data in Table 1 before developing thematic analysis in the Results and Discussion section. Challenges are examined using a four-domain framework-social, economic, environmental, and governance-aligned with the indicators relevant to Bangladesh's NPAN2 monitoring framework.

2.3 Core NSA Interventions Summary

Table 1 summarises GAIN's four core NSA interventions, their nutrition and climate value, programme contributions between 2021–2025, and priorities for scale-up.

Intervention	Nutrition & Climate Value	GAIN Contribution (2021-2025)	Scale-Up Priorities
BARI Masur-8 Lentil	Fe 74 mg/kg; Zn 61 mg/kg; Se 325 µg/kg. Drought-tolerant, nitrogen -fixing. Yields 1,973 kg/ha (+20-30% vs conventional). Reduces chemical fertiliser use (Zaman et al., 2022).	85 demonstration plots across 10 Upazilas. Seed (2 kg) to 1,600 farmers via BADC. Training on GAP, intercropping, post-harvest handling and hermetic storage (with BAU).	Expand to char, drought-prone, coastal areas. Strengthen public procurement. Hermetic silo scale-up with DAE. Policy advocacy for pulse inclusion in safety nets.
Biofortified Zinc Rice	25 mg Zn/kg (up to 50% of daily Zn requirement). Salinity- and drought-tolerant varieties (BRRI dhan74, dhan84, dhan100, dhan102). Reduces CH_4 via AWD pairing (IRRI, n.d.).	52 zinc rice demonstration plots across 10 Upazilas. 400 salinity-tolerant rice plots in Khulna and Satkhira. 5,000 MT procured by DG Food for social safety nets (2022). 300+ private seed firms engaged.	Prioritise BRRI dhan84/dhan102. Maintain varietal identity post-farmgate. Develop standards, labels, consumer demand. Integrate into school feeding and VGF programmes.
BARI Wheat-33	Zn 50-55 mg/kg; Fe 60 mg/kg. Requires 1-2 supplementary irrigations vs 20-25 for Boro rice. Blast-resistant. Higher market price per unit weight than rice (Mottaleb et al., 2019; SAARC, 2025).	Demonstration plots in Jamalpur and Naogaon. Promoted as Boro-rice substitute in drought-prone areas. Farmer training on crop rotation and vegetable intercropping with T-Aman.	Scale in drought-prone Barind areas. Link growers with flour processors and fortified food channels. Document water-saving and income outcomes.
Orange-Fleshed Sweet Potato (OFSP)	Beta-carotene 13,000+ IU/100g. No irrigation required. Yield up to 40 MT/ha vs 10 MT/ha conventional. Leaves edible and nutritious. Adapts to saline, drought-prone and char conditions (CIP, 2020).	Demonstration plots and farmer training in saline-prone, drought-prone and char areas. Promotion of production, harvesting, post-harvest handling and household dietary use.	Strengthen vine availability and cold chain. Women-led community processing. School and community promotion. Strengthen local market linkages.

GAIN Bangladesh core NSA interventions, 2021-2025: nutrition and climate value, programme contribution and scale-up priorities.

3. Result and Discussion

3.1 Biofortified Zinc Rice: Adoption, Supply Chain, and Government Integration

Rice accounts for approximately 66% of daily caloric intake in Bangladesh, with per capita consumption of 390–450 g/day-nearly three times the global average (WFP, 2018). This concentration makes rice the country's most powerful dietary vehicle for micronutrient delivery at scale. Since the release of BRRI dhan62 in 2013, BRRI has progressively improved zinc rice varieties, with BRRI dhan84 and dhan102 now demonstrating commercially competitive yield and price characteristics alongside a zinc content of 25 mg/kg, which can meet up to 50% of daily adult requirements (Mottaleb et al., 2025; Lividini et al., 2024).

Under the CBC and CALL programmes, GAIN established 52 zinc rice demonstration plots across 10 Upazilas during the Boro season and 400 salinity-tolerant rice demonstration plots in the coastal Upazilas of Khulna and Satkhira. The coastal plots directly addressed the challenge of land lying fallow for six or more months due to saline intrusion, converting unproductive land into cultivation areas and contributing to household food security. In 2022, this work contributed to a landmark procurement milestone: the Directorate General of Food procured approximately 5,000 metric tons of zinc rice for distribution through social safety net programmes-demonstrating that government procurement can function as both a nutrition delivery channel and a demand-creation mechanism for biofortified crops. The Ministry of Agriculture also issued a policy mandate requiring all newly released crop varieties to be enriched with at least one micronutrient, embedding biofortification into the national agricultural development system (GAIN internal, 2023). Over 300 private sector seed companies have now engaged in zinc rice variety promotion.

Despite this progress, three structural barriers persist. First, approximately 90% of first-time zinc rice growers did not replant in a subsequent season, citing coarse grain texture, weak market price relative to conventional varieties and uncertain demand (Bashar et al., 2019). BRRI dhan84 and dhan102-with finer grain type and higher expected revenue-represent the most credible pathway to reversing this pattern. Second, rice is sold by grade after the farmgate, meaning zinc rice is mixed with conventional rice of similar grade. This post-farm identity loss prevents millers from sourcing differentiated zinc rice, weakens consumer traceability and eliminates the price premium needed to motivate supply chain actors. Third, consumer awareness of zinc rice as a nutritionally distinct product remains low across income segments, limiting demand pull from the consumption end of the value chain.

3.2 BARI Masur-8 Lentil: Nutrition, Climate-Smart Farming, and Seed Systems

Bangladesh's domestic lentil production meets only about 25% of national demand, while per capita pulse consumption at 17 g/day is well below the healthy diet threshold of 45 g/day (BBS, 2023). BARI Masur-8, developed by ICARDA in collaboration with BARI and released in 2015, addresses this gap with a variety that is simultaneously high-yielding, nutritionally superior, and climate-adaptive (Zaman et al., 2022).

Between 2021 and 2025, GAIN established 85 demonstration plots of BARI Masur-8 across 10 Upazilas in Jamalpur and Naogaon. In partnership with BADC, GAIN distributed 2 kg of BM8 seed to 1,600 smallholder farmers in climate-vulnerable char and floodplain areas-where conventional lentil cultivation has been limited by drought and post-harvest loss risks. GAIN also co-developed hermetic storage silos with Bangladesh Agricultural University to reduce post-harvest losses from moisture and store-pest damage, a recurring constraint in flood-affected char areas. Farmers receiving training on Good Agricultural Practices, intercropping with vegetables, and climate-resilient storage reported improved crop establishment and reduced seed loss in the first season of adoption.

Iron deficiency anaemia affects 42–50% of women of reproductive age and pregnant women in Bangladesh (FAO et al., 2024). BM8's 74 mg/kg iron content, 61 mg/kg zinc, and 325 µg/kg selenium profile means regular household consumption at typical serving sizes can make a meaningful contribution to addressing deficiencies in all three micronutrients. Its nitrogen-fixing root nodules improve soil fertility without chemical fertiliser addition-a feature that reduces input costs for smallholders and supports the soil health of rotation systems. The relatively short crop duration and compatibility with vegetable intercropping during the T-Aman fallow period also increases cropping intensity and household income for participating farmers.

3.3 BARI Wheat-33: A Climate-Smart Boro Substitute

In drought-prone areas of the Barind plateau (Rajshahi, Chapainawabganj, Pabna, Natore, Naogaon) and riverine estuaries of Jamalpur, Boro rice cultivation is increasingly unsustainable due to groundwater depletion and unpredictable dry-season rainfall. BARI Wheat-33 - enriched with 50–55 mg/kg zinc and 60 mg/kg iron, blast-resistant, and requiring only 1-2 supplementary irrigations against the 20–25 required for Boro rice-represents a practical and nutritionally superior substitution option (Mottaleb et al., 2019; SAARC Agriculture Centre, 2025).

GAIN's CALL project established BARI Wheat-33 demonstration plots in Jamalpur and Naogaon and trained farmers on crop rotation, vegetable intercropping in the fallow period between wheat harvest and T-Aman planting, and post-harvest handling. Productivity under water-limited conditions is 30–50% higher than conventional wheat varieties, and the crop commands a higher market price per kilogram than rice, improving per-hectare income for farmers who switch a portion of their Boro season cultivation. Modelling based on micronutrient content and typical dietary patterns in target areas suggests that regular wheat consumption from BARI Wheat-33 can meet 40–50% of daily zinc requirements (Mottaleb et al., 2019; Taleon et al., 2022), while the dramatic reduction in irrigation requirements reduces both groundwater extraction costs and the energy use associated with irrigation pumping.

3.4 Orange-Fleshed Sweet Potato: Vitamin A and Marginal Land Utilisation

Vitamin A deficiency remains a concern in coastal and char areas of Bangladesh where dietary diversity is constrained by climate shocks, market distance and income poverty (IPHN, 2016). Orange-fleshed sweet potato, with over 13,000 IU of beta-carotene per 100 grams, offers a food-based solution that is uniquely suited to Bangladesh's most climatically marginal zones: it requires no irrigation, tolerates saline and drought-prone soils, and yields up to 40 MT/ha on marginal land-four times the yield of conventional varieties (CIP, 2020). Leaves are edible and nutrient-dense, extending dietary diversity beyond the root crop alone.

Under CALL, GAIN promoted climate-resilient OFSP varieties across Khulna, Satkhira and char areas, delivering demonstration plots, vine distribution and farmer training on cultivation, harvesting, and post-harvest handling. Community-level promotion targeted women and young children as the populations most at risk of vitamin A deficiency, integrating OFSP into existing homestead gardening initiatives. The crop's high yield on otherwise unproductive land, combined with its low input requirements, gives it strong economic appeal for resource-constrained farming households and an important entry point for women-led food production at the household level.

3.5 Climate-Smart Agriculture Practices Across the Portfolio

GAIN's NSA interventions are underpinned by a set of climate-smart agriculture practices that address water use, emissions, soil health and post-harvest loss simultaneously across all four crop systems.

Alternate Wetting and Drying (AWD) in Rice Systems

In all rice demonstration areas, GAIN promotes AWD irrigation, which reduces irrigation water use by 25–30% and methane emissions by up to 48% without reducing yield when properly managed (IRRI, n.d.; CCAFS, 2011). AWD was adopted in demonstration sites in Naogaon, Jamalpur, Khulna and Satkhira, with farmers trained on field management through Upazila Resource Pool training-of-trainers sessions. AWD's combination of water saving, methane reduction and cost saving-by reducing fuel use for irrigation makes it both a climate mitigation practice and a livelihood benefit.

Seeds, Storage, and Packaging

Seed quality and availability are foundational constraints for NSA adoption. GAIN's seed systems work across CALL and CBC included: partnership with BADC and private seed companies for breeder and certified seed multiplication of zinc rice and BM8 lentil; distribution of quality seed to first-time adopters in climate-vulnerable areas and development of hermetic silo prototypes with Bangladesh Agricultural University for post-harvest storage of lentil seed and grain in flood-affected char areas. Packaging innovations tested within CBC focused on maintaining varietal identity of zinc rice after the farmgate, addressing the supply chain segregation challenge that currently prevents millers from sourcing differentiated biofortified products.

Capacity Building Through Resource Pools

Ten Upazila-level Resource Pools, led by DAE and including DLS, DoF and private sector participants, were formed under CALL to serve as institutionalised cascade training mechanisms. Between 2021 and 2025, these pools reached approximately 17,000 farmers across 89 unions in Naogaon, Jamalpur, Khulna, and Satkhira through three-day training-of-trainers sessions covering Climate-Smart Agricultural technologies, Bangladesh GAP (Good Agricultural Practices) and Applied Nutrition. The resource pool model creates a locally owned extension infrastructure that can continue beyond the project cycle, unlike direct GAIN staff-to-farmer training models that depend on continued programme funding.

Market Linkage Through Fair Price Shops

GAIN's Workforce Nutrition programme creates a direct market linkage between CALL-trained rural smallholder farmers and urban factory workers through Fair Price Shops (FPS) operating at RMG factory premises in Dhaka, Gazipur, and Chattogram. FPS source fresh vegetables and nutritious produce from CALL farmers, providing workers with safe, affordable food while giving farmers access to a stable, relationship-based market. The MoU signed with the Ministry of Labour and Employment (MoLE) as well as with BGMEA in 2023 provides a policy and institutional anchor for wider scaling through Bangladesh's approximately 4,500 RMG facilities.

3.6 Cross-Cutting Interventions: Youth, Gender, Policy and Governance

Women's and Youth Empowerment

GAIN's NFP, CALL and RAINS projects explicitly integrate women and youth as agricultural actors and nutrition change agents, not merely as beneficiaries. Youth led collective actions promoted nutrition sensitive agriculture practices at the community level and Women lead homestead gardens producing OFSP and vegetables; youth entrepreneurs are trained in vermi-compost production and local market facilitation; and peer group networks (Pushti Bondhu) carry SBCC messages on nutrition and dietary diversity within communities. Evidence from analogous homestead food production programmes in Bangladesh confirms that women's dietary diversity scores and children's dietary diversity improve significantly when women control production decisions and have explicit support for empowerment pathways (Waid et al., 2024; Sinharoy et al., 2022).

Multi-Stakeholder Platforms and Local Governance

GAIN supports Union Parishad-level Multi-Stakeholder Platforms (MSPs) across 189 unions, aligned with NPAN2's multi-sectoral governance architecture. Each MSP brings together Union Parishad leadership, DAE, DLS, health facilities, civil society, youth groups, women's networks, market committees and entrepreneurs to develop annual nutrition, food and climate action plans; advocate for local budget allocation and report practical evidence upward to Upazila and District-level nutrition coordination committees. MSPs represent the governance layer that embeds NSA within locally owned institutional systems rather than external project delivery a precondition for sustaining localisation process gains after programme closure.

Large-Scale Food Fortification as Complementary Strategy

GAIN's Large-Scale Food Fortification (LSFF) work runs alongside NSA as a complementary micronutrient delivery strategy. Bangladesh's Edible Oil Fortification Act (2013) and Salt Iodisation Act (2021) established mandatory fortification frameworks for two of the country's most widely consumed food vehicles. GAIN has supported private sector compliance capacity, quality monitoring and regulatory strengthening.

4. KEY CHALLENGES

GAIN's five-year NSA implementation experience reveals a consistent set of challenges across the four crop systems and four programme hotspots. These are examined below through the four domains most relevant to food systems transformation in Bangladesh.

Social: Consumer awareness of biofortified crops remains low and willingness to pay for nutritional attributes is limited without sustained behaviour change communication. Women's access to seeds, training, and markets is constrained by time poverty and social norms, while youth remain underrepresented as agricultural and market actors-both representing underutilised levers for sustained household-level change.

Economic: The absence of a price premium for biofortified crops offers millers, traders and farmers a bit economic incentive to segregate supply chains or adopt new varieties. Formal seed multiplication takes several growing seasons and farmer adoption of new varieties typically lags variety release by five to ten years-a mismatch with programme timelines. Post-harvest losses from moisture and pests, particularly for lentils in flood-prone char areas, further erode the gains from higher-yielding varieties.

Environmental: Floods, cyclones, saline intrusion and drought events regularly damage demonstration plots and seed reserves. At the same time, biofortified rice loses its identity at the farmgate when mixed with conventional rice of similar grade, removing the traceability foundation needed for product standards and consumer trust.

Governance: National policies including NPAN2 and the NFNSP 2020 include NSA provisions, but mandatory biofortified product standards remain lacking, cross-sectoral coordination between agriculture, health and local government is limited and NSA activities are rarely embedded in local government annual budgets-leaving sustainability dependent on donor project cycles rather than institutionalised systems.

5. Conclusion and Way Forward

5.1 Conclusion

GAIN's experience across five years of NSA programes in Bangladesh confirms a central finding: nutrition-sensitive agriculture delivers its greatest impact when agronomy, horticulture, climate adaptation, seed systems, markets, behaviour change and governance are treated as components of a single integrated system rather than as separate project activities. The combination of 52 zinc rice demonstration plots, 85 lentil plots, BARI Wheat-33 promotion in drought-prone areas, OFSP in coastal and char zones, 400 salinity-tolerant rice plots, 5,000 MT of zinc rice in government procurement, 16,000 farmers reached through Upazila Resource Pools, and MSPs functioning across 189 unions reflects a portfolio that is beginning to reshape local food systems. The policy mandate from the Ministry of Agriculture requiring micronutrient enrichment in all new crop varieties signals an important institutional shift. Yet structural barriers-post-farm supply chain fragmentation, weak product standards, low consumer awareness and thin market incentives for biofortified crops-remain the primary constraints on reaching the scale needed for population-level nutrition impact.

5.2 Way Forward

Over the next three to five years, GAIN Bangladesh's NSA programes will concentrate on the following integrated scale pathways:

- **Prioritise commercially competitive zinc rice varieties:** BRRI dhan84 and dhan102 offer the grain type, yield and market price needed to achieve mainstream farmer adoption. Seed distribution, DAE extension partnerships and food procurement linkages should be concentrated on these varieties to build critical mass.
- **Establish biofortified product standards:** Working with BSTI and relevant ministries, GAIN will advocate for voluntary and eventually mandatory zinc content standards for labelled biofortified rice products, creating the regulatory foundation for a differentiated market.
- **Scale BARI Masur-8 lentil in climate-vulnerable area**s: Expansion to additional char, drought-prone, and

  coastal zones should be accompanied by hermetic storage scale-up through DAE, BAU and private sector partners, and advocacy for lentil inclusion in national social safety net procurement.
- **Use social safety nets and school feeding as scale channels:** Government procurement through VGF, school feeding, and food-for-work programmes provides a demand anchor for biofortified crops and reaches the children and low-income women who carry the highest micronutrient deficiency burden.

- **Embed NSA in Union Parishad annual budgets:** Supporting MSPs across at least 200 unions to formally incorporate NSA activities into Union Parishad annual development plans and budgets converts project-funded pilots into locally financed, institutionally owned programmes.
- **Strengthen SBCC through youth and SUN networks:** SUN Youth Network Bangladesh and SUN Business Network Bangladesh provide trusted, locally credible platforms for demand-side SBCC. Training young entrepreneurs and community nutrition champions as biofortified crop advocates and market facilitators builds local ownership of the NSA agenda.
- **Document climate-nutrition co-benefits:** GAIN will partner with BARC, BRRI, BARI, and BAU to generate evidence on water savings, emissions reductions, income impacts and dietary changes from NSA interventions-building the knowledge base to inform Bangladesh's next generation of food systems programming and BARC's nutrition research mandate.

Acknowledgements

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Session 3: Group Works

Following the question-and-answer session of the technical session, the participants were divided into three groups for identifying major problems and prioritize for solving with the engagement of key stakeholders. The thematic areas for groupwork were-

- Research areas related to NSA
- Challenges in scaling out of NSA intervention
- Awareness, capacity and knowledge management

Each group was requested to select five priority issues related to Nutrition-Sensitive Agriculture from ten identifying areas and present them in an open discussion. Based on the discussion, the following recommendations were made for NARS organizations. Participants were divided into three groups. Each group identified ten key areas for implementation and then prioritized the top five areas based on their organizational mandates.

- **Research Organizations** identified and prioritized key research areas.
- **Extension Organizations** (including DAM, BADC, BNNC and private organizations) focused on research–extension linkages and prioritized challenges related to scaling out NSA interventions.
- **NGOs and other relevant organizations** (including BIRTAN, SAC, KGF, and others) identified priority areas related to **awareness, capacity building, and knowledge management.**

Each group leader presented their group's findings. Director (Nutrition), Director (TTMU) and PSO (Nutrition) coordinated group 1, group 2 and group 3 respectively. This was followed by open discussions among all stakeholders. Based on these discussions, the findings from all groups were reviewed, refined and finally aggregated into a consolidated set of priorities.

Group-1: Prioritize Research area in NSA

This group selected 10 Major research problem related to NSA

1. Lack of Breeding program and modern biotechnological tools for nutrient enriched variety
2. Lack of Nutrient dense germplasm
3. Pesticide residue and toxicity intrusion
4. Climate change and nutrient dense variety
5. Lack of quality assurance
6. post-harvest loss Food/crop processing
7. Lack of quality lab facility
8. Management practices for nutrient enrich crop production
9. Food habit and dietary consumption behavior
10. Lack of research collaboration among national and international organization


Group 1: Group discussion and Presentation

Table:1 Prioritized five major area

Sl. No	Prioritized Problem	Major activities	Time frame (Year)	Lead Organization	Co-lead Organizations	Supportive Organizations
1.	Lack of Breeding program and modern biotechnological tools for nutrient enriched variety	Parent/material selection Usage of cutting-edge technology	5-10	BARI BLRI BFRI	BARC and Other NARS	Universities. DAE and NGOs
2.	Post-harvest loss Food/crop processing	Research on post-harvest managements Determination of maturity index	2-3	BARI	BARC and Other NARS	Universities. DAE, DAM, BCSIR, Food Safety Authority and NGOs
3.	Pesticide residue and toxicity intrusion	Follow GAP Determination of pre harvest interval	2-3	BARC	NARS	Universities. DAE, DAM, BCSIR and NGOs
4.	Climate change and nutrient dense variety	Climate smart variety and technology	3-5	BARC	NARS	Universities. DAE, DAM, BCSIR and NGOs
5.	Lack of research collaboration among national and international organization	Collaboration among different stakeholders Women empowerment	3-5	BARC	NARS	MoA, Universities. DAE, DAM, BCSIR and NGOs

Group-2: Prioritize challenges in scaling out of NSA intervention

The group identified the major challenges in scaling out of NSA intervention

1. Lack of zone-wise climate resilient nutrient-enriched crop varieties extension
2. Lack of Awareness in Farmers and Consumer
3. Weak Market Linkage and Value chain system
4. Huge Post Harvest Loss
5. Weak supply chain, value chain, addition and processing
6. Gender inequality, Women limited decision-making power
7. Lack of entrepreneurship development
8. Lack of advertising
9. Lack of coordination among different organizations
10. Food safety & Quality concerns

Group 2: Group Discussion & Presentation

Table 2: Prioritized 5 major area

Sl. No	Prioritized Problem	Major activities	Time frame (Year)	Lead Organization	Co-lead Organizations	Supportive Organizations
1.	Lack of zone-wise climate resilient nutrient-enriched crop varieties extension	✓ Selection of location, technology ✓ Training of extension person farmers ✓ Project formulations	2-5	DAE, DLS, DoF	NARS	NGO & private organizations
2.	Lack of awareness among farmers and consumer	✓ Conduct training and extension works ✓ Awareness campaigning	1-3	DAE, DLS, DoF	DAM, FAO, World Fish	NGO, Private organizations
3.	Weak market linkage and value chain system	✓ Interdepartmental coordination ✓ Strengthening logistic support of DAM	2-5	DAE, DoF, DLS	DAM, BFSA, BSTI	NGO, Private organizations
4.	High post harvest loss	✓ Conducting training and awareness for reduction of postharvest loss ✓ Mechanization ✓ Processing and storage facilities development	2-5	DAE, DoF, DLS	DAM, BFSA,	NGO, Private organizations
5.	Weak value value- chain and processing	✓ Processing and storage facilities development ✓ Training, Awareness	3-5	DAE, DoF, DLS	DAM, BFSA,	NGO, Private organizations

Group-3: Awareness, capacity & knowledge management

This group selected 10 Major research problem related to NSA

1. Inclusion of NSA in the agricultural policies
2. Inadequate awareness to conduct the NSA research
3. Lack of nutritional knowledge in the education institution
4. Inadequate sectoral coordination
5. Food Behavior
6. Insufficient inter-organizational linkage
7. Lack of monitoring and evaluation in the food processing
8. Improved food value chain
9. Inadequate awareness on NSA in the MASS media program
10. Improved management of food storage

Group 3: Group Discussion & Presentation

Table 3. Prioritized five major area on Awareness, capacity & knowledge management for NSA implementation

Sl. No	Prioritized Problem	Major Activities	Duration (Year)	Lead Organization	Co-lead Organizations	Supportive Organizations
1.	Lack of inclusion of NSA in agricultural policies	✓ Policy review and gap analysis ✓ Advocacy meeting with policy makers ✓ Development of policy briefs on NSA benefits ✓ Integration of NSA into national agricultural strategies	3-5	Ministry of Agriculture	DAE, DLS, DoF, BNNC, BIRTAN, Hortex Foundation, BFSA, BCSIR, MoFood, MoFL. MoE	NGOs, INGO, Private Organization FAO, Farmer Associations
2.	Lack of inclusion of NSA in research	✓ Identify research gaps on NSA ✓ Funding and promote NSA-focused research projects ✓ Strengthen collaboration between universities and research centers ✓ Publish and disseminate research findings	3-5	BARC	Universities, NARS	NGOs, INGO, Organization FAO, Farmer Associations
3.	Lack of nutritional knowledge in educational institutions	✓ Integrate nutrition and NSA topics into school curricula ✓ Train teachers and lecturers on nutrition education ✓ Conduct awareness programs and campaigns in schools ✓ Develop nutrition education materials	1–2	BIRTAN	DAE, DLS, DoF, BNNC, BIRTAN, Hortex Foundation, BFSA, BCSIR, MoFood, MoFL MoE	NGOs, INGO, Private Organization FAO, Farmer Associations

Sl. No	Prioritized Problem	Major Activities	Duration (Year)	Lead Organization	Co-lead Organizations	Supportive Organizations
4.	Improper manageme nt of food storage	✓ Training farmers and households on proper storage techniques ✓ Promote low-cost improved storage technologies ✓ Develop food storage guidelines and manuals ✓ Strengthen postharvest management systems	Year 1–3	Ministry of Food and BADC	Local Government Authorities DAE, DLS, DoF, BNNC, BIRTAN, Hortex Foundation, BFSA, BCSIR, MoFood, MoFL. MoE	NGOs, INGO, Private Organiozation FAO, Farmer Associations
5.	Inadequate awareness in the MASS media on NSA	✓ Develop media advocacy strategy on NSA ✓ Highlighting NSA benefits through multiple media ✓ Train journalists and media professionals on NSA and nutrition-sensitive agriculture ✓ Use social media campaigns to promote NSA messages ✓ Celebrate national nutrition and agriculture days through media	Year 1–2	Ministry of Information / Media Authority	Ministry of Agriculture, Ministry of Health, BARTAN	Media Houses, NGOs, FAO, UNICEF, Civil Society Organizations

Session 4: Presenter Evaluation and Best Presenter Award

A total of six papers were presented in the workshop, showcasing diverse research findings and innovations. All presenters were evaluated based on criteria such as presentations according to format, content quality, clarity of presentation, relevance, methodology and response to questions. The evaluation was conducted by an expert panel to ensure fairness and transparency. Among the presenters, the most outstanding presentation was recognized with the Best Presenter Award for its excellence in capturing research quality, delivery and overall Performance. This session encouraged healthy competition and motivated researchers to enhance the quality of their scientific communication. Among them, Mr. Kazi N. Salehin Rafi, Scientific Officer, Bangladesh Wheat and Maize Research Institute (BWMRI), received the Best Presenter Award with high appreciation for his excellent delivery, strong research content and effective communication.

Conclusion:

The one-day review workshop on Nutrition-Sensitive Agriculture (NSA), being organized by Nutrition unit, Bangladesh Agricultural Research Council aims to share research findings, technologies and experiences with a broader agriculture, nutrition and development community.

The workshop discussed:

- information needs for improving NSA and food systems
- role of innovative approaches and extension media in promoting nutrient-rich crops and animal-source foods
- policy priorities for strengthening nutrition-sensitive interventions at the grassroots level

The deliberations among diverse participants will help strengthen existing networks for knowledge sharing, promote best practices and develop strategies to address gaps in nutrition, food security and sustainable agricultural development in Bangladesh.

Expected Outcomes

- Consolidated review of NSA initiatives, experiences and documented .
- Identified key technical, institutional and field-level challenges.
- Enhanced understanding and collaboration among researchers and extension personnel.
- Documented recommendations and way forward for strengthening NSA

The Review Workshop on “Nutrition Sensitive Agriculture: Challenges and Way Forward” and the proceedings will serve as an important starting to align research, extension and stakeholder efforts.

Review Workshop
on
"Nutrition Sensitive Agriculture, Challenges and way forward"

Organized by : Nutrition Unit, Bangladesh Agricultural Research Council
Venue : Auditorium BARC, Farmgate, Dhaka
Date : 15 January 2026

Time	Topics
09:00-09:10	Registration: Muhammad Habibur Rahman, Computer Operator, Nutrition Unit, BARC.
09:10-09:15	Recitation from the Holy Quran
09:15-09:20	Welcome Address by Dr. Zakiah Rahman Moni, PSO, (Nutrition) BARC
09:20-09:30	Speech by the Special Guest Mr. **Ajit Kumar Chakraborty**, Member Director (Fisheries), BARC
09:30-09:40	Speech by the Chief Guest **Dr. Md. Abdus Salam,** Executive Chairman, BARC
09:40-09:50	Speech by the Chair Person & brief overview of this workshop **Dr. Md. Harunur Rashid**, Director (Nutrition) BARC
09:50-10:30	**Tea & Health Break**

Technical Session I

Session Chair	:	**Dr. Md. Abdur Razzak**, Former Executive chairman, BARC Farmgate, Dhaka
Rapporteur	:	**Dr. Md. Shahzad Kuli Khan**, PSO, Fisheries Division, BARC
Expert Members		• Dr. Mouin us Salam, Consultant (HDR), PARTNER, APCU-BARC • Dr. Md. Zulfikar Ali, Former Director General, Bangladesh Fisheries Research Institute, Mymensingh • Professor Dr. Nazma Shaheen, Former Director, Institute of Nutrition and Food Science, University of Dhaka. • Dr. Anil Kumar Das, Senior National Consultant (Program), FAO, Dhaka. • Professor Dr. Md. Mahbub Islam, Crop Botany Department, Sher-e-Bangla Agricultural University, Dhaka • Dr. A.B.M. Khaleduzzaman, PhD, Director, (Production), Department Livestock Service, Krishi Khamar Road, Farmgae, Dhaka.

Time	Topic	Presenter/Speaker
10:30-11.10	NSA of BARI: Technology, Innovation, Challenges and the Way Forward	Representative from BARI
11:10-11:40	NSA of BFRI: Technology, Innovation, Challenges and the Way Forward	Representative from BFRI
11:40-12:10	NSA of BINA: Technology, Innovation, Challenges and the Way Forward	Representative from BINA
12:10-12:45	**Open discussion**	
12:45-1:45	**Lunch & Prayer**	

Technical Session II

Session Chair	:	**Dr. Md. Abdur Razzak**, Former Executive chairman, BARC Farmgate, Dhaka
Rapporteur	:	Dr. Md. Shahzad Kuli Khan, PSO, Fisheries Division, BARC
Expert Members		• Dr. Mouin us Salam, Consultant (HDR), PARTNER, APCU-BARC • Dr. Md. Zulfikar Ali, Former Director General, Bangladesh Fisheries Research Institute, Mymensingh • Professor Dr. Nazma Shaheen, Former Director, Institute of Nutrition and Food Science, University of Dhaka. • Dr. Anil Kumar Das, Senior National Consultant (Program), FAO, Dhaka • Professor Dr. Md. Mahbub Islam, Crop Botany Department, Sher-e-Bangla Agricultural University, Dhaka • Dr. A.B.M. Khaleduzzaman, Director, (Production), Department Livestock Service, Krishi Khamar Road, Farmgae, Dhaka.

Time	Topic	Presenter/Speaker
01:50-02.30	NSA of BRRI: Technology, Innovation, Challenges and the Way Forward	Representative from BRRI
02:30-03.00	NSA of BLRI: Technology, Innovation, Challenges and the Way Forward	Representative from BLRI
03:00-03:30	NSA of BWMRI: Technology, Innovation, Challenges and the Way Forward	Representative from BWM RI
03:30-4:00	NSA of BSRI: Technology, Innovation, Challenges and the Way Forward	Representative from BSRI
04:00-4:45	**Group Work & Presentation**	
04:45-5:00	**Award Giving Ceremony and Closing Remarks**	

Annexure

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Photographs of the different event:

Inaugural Session

Expert Panel of Technical Session

Technical Presentation

Interactive Session

All paper presenter along with expert members

Receiving best presenter's certificate

Women participation in this workshop

বাংলাদেশ কৃষি গবেষণা কাউন্সিল
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