

From wetlands to wellness: Makhana a functional superfood for nutritional and Health security of India

Makhana (fox nut), a traditional wetland crop of Bihar, is emerging as a nutrient-rich functional food supporting India's nutrition and health security. In recent years, increasing health awareness and market demand have transformed makhana from a local crop into a high-value agri-enterprise. Its rich protein, mineral and antioxidant content helps address hidden hunger and lifestyle diseases. A key innovation is the shift from traditional pond systems to scientifically managed pond-cum-field cultivation, which has improved productivity, processing efficiency and farmer income. Expansion of value-added products and stronger market linkages have further boosted its economic potential. Integrating makhana into public nutrition programmes such as Mid-Day Meal and ICDS offers a practical strategy to improve dietary quality. Future growth depends on enhancing productivity, decentralised processing and market integration to ensure sustainable nutrition and livelihood security.

Keywords: Functional food; Lifestyle disorders; Makhana; Nutritional security; Wetland agriculture

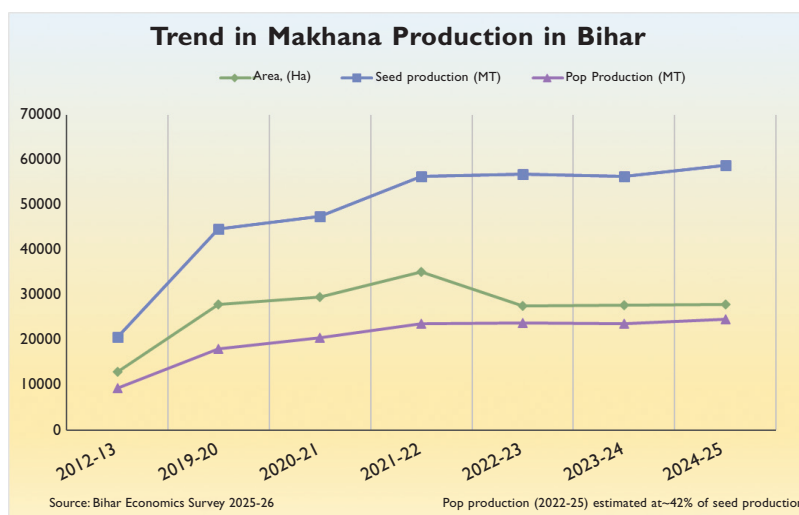
INDIA faces a dual nutritional challenge: Persistent hidden hunger marked by deficiencies of protein, iron and zinc, alongside a rising burden of non-communicable diseases (NCDs). While calorie availability has improved, diet quality remains inadequate. In this context, locally available functional foods that are nutrient-dense, affordable and culturally acceptable are essential.

Makhana (fox nut) represents one such indigenous solution. Traditionally cultivated in shallow wetlands, it has evolved from a fasting food to a modern health snack valued for diabetes management, cardiovascular health and weight control. With Bihar contributing nearly 80–90% of national production, makhana holds strategic importance for both nutrition and livelihood security.

Agro-ecological adaptation and production dynamics: India accounts for 70–80% of the global in Makhana production, out of which the Bihar is the leading producer, contributing over 80-90% of country's makhana production. The nine districts of

Bihar namely Madhubani, Darbhanga, Sitamarhi, Saharsa, Katihar, Purnia, Supaul, Kishanganj, and Araria are the major producers of makhana. These districts lie in the north Bihar floodplain region, resulting in low-lying wetlands, ponds, oxbow lakes and seasonal waterlogging conditions that are highly suitable for makhana cultivation. The total area under makhana cultivation in India is estimated to be 15,000 hectares. The average productivity of makhana in these districts is close to 1,800 kg/hectare. About 5 lakh families are directly involved in its cultivation, harvesting, popping, and marketing. Makhana is uniquely adapted to waterlogged and wetland ecosystems where most field

crops fail. The crop thrives under shallow standing water, warm humid conditions and organic-rich soils, making it particularly suitable for flood-prone regions of eastern India. Importantly, it utilises underexploited wetlands without competing for prime agricultural land or irrigation resources, thus contributing to climate-resilient farming systems.





Demonstration of scientific makhana cultivation at KVK



Makhana cultivation in wet land



Makhana field demonstration unit showcasing sustainable aquatic cultivation practices



Farmers harvesting makhana during KVK-led field demonstration in a wetland system

Traditionally confined to ponds and oxbow lakes, cultivation has gradually expanded to managed private ponds and modified low-lying fields. The shift toward pond-cum-field systems has enabled better water control, improved agronomic practices and enhanced productivity.

Over the last decade, Bihar has witnessed a substantial increase in makhana cultivation and output. The cultivated area expanded from approximately 13,000 ha in 2012–13 to nearly 28,000 ha in 2024–25. Seed production rose from about 20,800 MT to 58,800 MT during the same period, while popped makhana production increased from 9,360 MT to around 24,700 MT. The most significant growth occurred between 2019–20 and 2021–22, coinciding with improved pond management, varietal refinement and better processing skills. Though area stabilised after 2022, production efficiency improved, reinforcing Bihar's status as the national hub of makhana cultivation and value addition.

Processing and value chain addition of makhana

Processing and value chain development play a pivotal role in enhancing the economic, nutritional and market value of makhana, particularly in Bihar, which

dominates national production. Traditionally, makhana processing has been labour-intensive and skill-driven, but recent interventions have demonstrated significant scope for efficiency gains and income enhancement through improved practices.

Processing stages: The makhana value chain begins with harvesting of raw seeds from ponds and low-lying fields, followed by sun drying to reduce moisture content. Dried seeds are then graded and tempered before popping, a critical operation that determines expansion, texture and quality. Popping is traditionally carried out using heated sand in iron pans, requiring considerable skill. The popped makhana is subsequently roasted, polished and graded into different size categories, which directly influence market price. Proper drying and hygienic handling at this stage are essential to improve shelf life and food safety.

Value chain addition: Value addition in makhana has expanded beyond raw popped kernels to include roasted and flavoured snacks, makhana flour, laddoos, breakfast mixes and bakery ingredients. Such diversification significantly enhances consumer appeal and market reach. Field-level experiences in Bihar show that graded and packaged makhana fetches 30–50% higher prices compared to ungraded bulk sales.

Institutional and livelihood linkages: Women-led Self-Help Groups (SHGs) play a central role in post-harvest processing, grading and packaging of makhana. Establishment of decentralised processing units has reduced

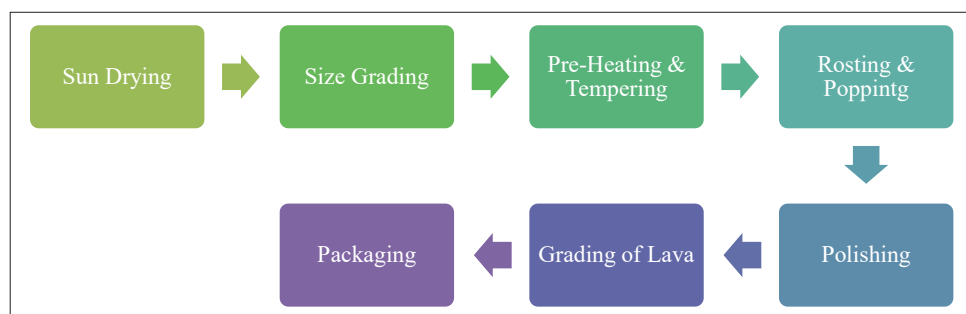


Table 1. Nutritional profile of makhana and its health benefits

Aspect	Key Observations	Nutritional/ Health Implications
Dietary category	Considered a dry fruit (panchmeva), comparable with almond, walnut, cashew nut and coconut	Enhances dietary diversity and acceptability
Protein and fat profile	Moderate protein (8.6–8.7%) with very low fat (0.2–0.5%) and low sodium	Suitable for diabetes, hypertension and cardiovascular disorders
Digestibility	Gluten-free and easily digestible	Ideal for children, elderly persons and convalescents
Carbohydrate quality	High complex carbohydrates with amylose content of 18–18.5%	Slow digestibility and low glycaemic response
Mineral richness	Rich in P, K, Ca, Mg, Fe and Zn	Supports bone health, haemoglobin synthesis, immunity and electrolyte balance
Micronutrient security	Addresses deficiencies of iron, zinc and magnesium	Helps combat hidden hunger
Protein quality	High essential amino acid index (EAAI: 89–93%); favourable arginine + lysine/proline ratio (4.74–7.6)	Protein quality comparable to fish and superior to rice and wheat
Functional role	Low fat, mineral-rich, high-quality protein food	Supports metabolic health, cardiovascular well-being and nutritional security

drudgery, improved quality consistency and enhanced women's income. Strengthening backward linkages (improved varieties and scientific pond management) and forward linkages (branding, certification and institutional procurement) is crucial for transforming makhana into a high-value, nutrition-sensitive agri-enterprise. The Krishi Vigyan Kendra of Bihar are playing a key role in scientific cultivation of makhana. A classic example of horizontal technology dissemination is the expansion of scientific makhana cultivation by KVK across ten villages—Sandalpur, Gaira, Mirzapur, Sukhi, Dak, Musahri, Bhansia, Denga, Padampur and Bistoria of Araria district. Initially, Sandalpur was developed as a model cluster, where 30 farm women were trained in improved production and processing practices, and the high-yielding variety *Sabour Makhana-1* was introduced. Subsequently, a Farmers Interest Group (FIG) comprising 30 growers was established, along with a commercial popping unit employing 20 workers. The FIG has evolved into a viable enterprise with an annual turnover of approximately ₹3.45 crore, and replication in neighbouring villages has led to the emergence of another FIG engaged in makhana pop exports, demonstrating the scalability of technology-driven livelihood interventions.

A similar institutional initiative is done by KVK Dharbanga in technical guidance to Shri Mithila Makhana Kisan Utpadak Sangathan Swavlambi Sahkari Samiti Limited. The FPO comprises over 560 member farmers and manages approximately 1,000 ha of pond-based makhana cultivation, with an average productivity of about

20 quintals per hectare. It has developed six value-added products—Makhana Atta, Pudina Snacks, Makhana Kheer Mix, Plain Makhana, Shishu Aahar and Makhana Vita enhancing market diversification and branding. The FPO has achieved an annual turnover of around ₹1 crore, demonstrating the viability of collective production, processing and marketing models in strengthening farmer incomes and nutrition-sensitive enterprises.

Nutritional profile and functional attributes of makhana

Makhana is recognised as a nutrient-dense food comparable to dry fruits. Both improved and local varieties contain: Protein: 8.6–8.7%, Fat: 0.2–0.5%, Carbohydrates: ~79–80%, Energy: 354–358 kcal/100 g and Amylose: 18–18.5%. Its low fat and low sodium

Traditional & Therapeutic Uses	•Traditionally used to relieve rheumatic pain & in bile-related disorders
Cardiovascular Protection	•Presence of bioactive compounds (Thioredoxin-1 and TRP-32) that Supports heart health and control of cardiac disorders
Reproductive & Immune Health	•Used in treatment of leucorrhoea •Exhibits immuno-stimulatory properties
Anti-inflammatory & Dermatological Uses	•Traditional use in scabies and gonorrhoea
Gastrointestinal Health	•Ripe seeds used for management of chronic diarrhoea
Antioxidant & Anti-ageing Properties	•Rich in flavonoids and antioxidants helps counter oxidative stress and free radical damage
Rejuvenative Effects	•Considered an anti-ageing food •Traditionally attributed mild aphrodisiac properties
Renal & Hepatic Functions	•Rhizome used as a natural diuretic in treatment of dropsy and jaundice; supports kidney and liver function

Source: (ICAR–NRCRM, 2020; Kumar et al., 2019)

Medicinal and therapeutic value of makhana



Makhana based food products



Branded marketing of makhana by KVK beneficiary



Makhana seeds

content make it suitable for heart-friendly diets. The moderate amylose content contributes to slow digestion and a lower glycaemic response. Makhana is also a source of phosphorus, potassium, calcium, magnesium, iron and zinc, helping address micronutrient deficiencies. Its high essential amino acid index (89–93%) indicates superior protein quality comparable to animal sources like fish and superior to staple cereals.

Role of makhana in addressing lifestyle disorders

Makhana plays an important role in dietary strategies aimed at preventing and managing lifestyle-related non-communicable diseases, owing to its favourable nutritional and functional attributes.

Diabetes and metabolic health: The predominance of complex carbohydrates and moderate amylose content in makhana results in a low glycaemic response, helping to prevent sudden spikes in blood glucose levels. Regular inclusion of makhana in the diet supports improved post-prandial glucose regulation, making it a suitable snack option for individuals with diabetes and metabolic disorders.

Cardiovascular health: Makhana is naturally low in fat and sodium, while providing essential minerals such as magnesium and potassium. This combination contributes to better blood pressure regulation, improved electrolyte balance and a reduced risk of cardiovascular complications, supporting heart-friendly dietary recommendations.

Weight management: The presence of dietary fibre and moderate-quality protein enhances satiety and prolongs the feeling of fullness. As a result, makhana helps curb overeating and reduces dependence on calorie-dense, unhealthy snacks, making it a useful component of weight management and obesity control programmes.

Integration of makhana into nutrition programmes

Field demonstrations in Bihar show that replacing fried snacks with 10–15 g of roasted makhana improves satiety and reduces sugar intake among school children. Makhana can be incorporated into:

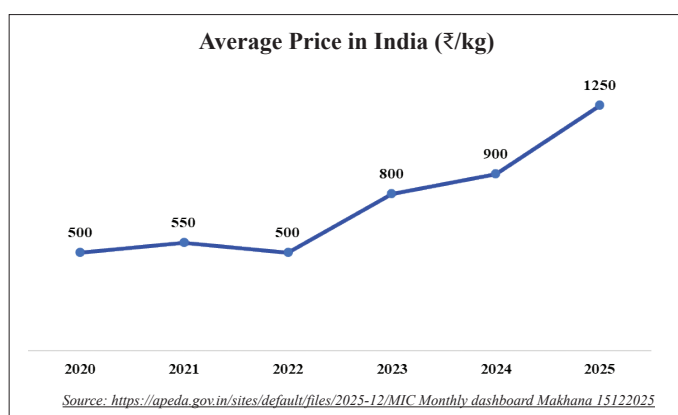
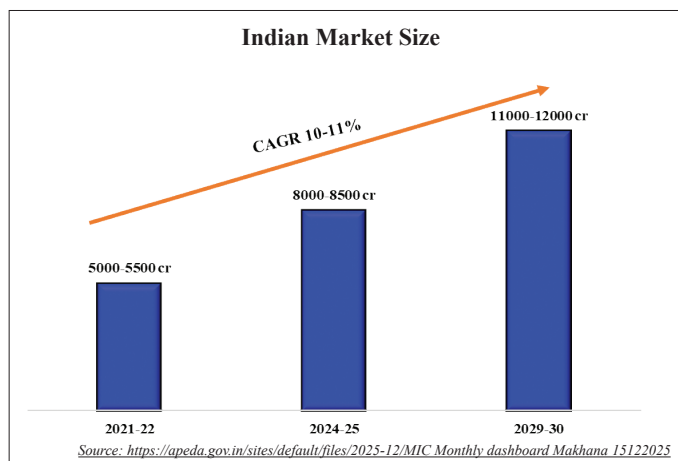
- Mid-Day Meal (MDM) as roasted snacks or cereal mixes
- ICDS supplementary nutrition for children and pregnant women
- Community nutrition campaigns promoting healthy snacking

Low moisture content (10–11%) and a shelf life of 6–8 months support decentralised distribution. Its inclusion can improve dietary diversity and support prevention of lifestyle disorders.

Health-driven market expansion

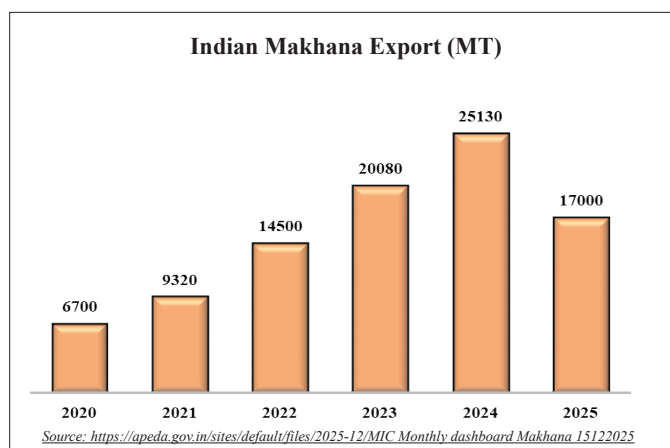
Domestic makhana prices in India have experienced a strong and sustained upward trend in recent years, largely driven by rising consumer awareness of health, nutrition and clean-label foods. Average prices have increased from approximately ₹500 per kg during 2020–2022 to nearly ₹1250 per kg in 2025, reflecting a clear shift toward health-focused snacking, premium branding and value-added makhana products. This escalation has been reinforced by supply-side limitations, as production growth has not fully matched the pace of expanding demand. As a result, the domestic market has become increasingly attractive for processors, often offering higher and more stable margins than exports. Seasonal dynamics also influence price movements; marginal increases are typically observed during early winter in northern Bihar—sometimes intensified by La-Niña-induced colder conditions—followed by stabilisation during summer. While lower

grades (4 and 5 Suta) have remained relatively steady, premium grades (6 and 7 Suta) have recorded a ₹20–30 per kg rise, reflecting stronger demand for superior-quality kernels among health-conscious consumers.



Simultaneously, India's makhana exports have expanded significantly in response to growing global demand for low-fat, gluten-free and plant-based snack options. Export volumes increased nearly four fold—from 6,700 MT in 2020 to 25,130 MT in 2024, registering a robust CAGR of around 39%. Growth has been supported by improved production practices, enhanced processing efficiency and wider adoption of organic and quality certifications. Premium kernels, particularly those exceeding 18 mm in size, dominate export markets due to their superior expansion and visual appeal. However, exports in 2025 are projected to remain slightly below the 2024 peak, with around 17,000 MT shipped during January–October, largely due to tariff pressures in the United States, which accounts for nearly 40 per cent of India's exports. Sustaining growth will depend on continued premiumisation, development of value-added health products and strategic branding in key markets such as the US, EU and Middle East.

Building on these domestic and export trends, India's makhana market has sustained a healthy annual growth of



17–18% between 2021–22 and 2024–25, largely propelled by heightened health consciousness, premiumisation and the rapid expansion of organised, branded players. Strong domestic consumption has insulated the sector from fluctuations in export demand, reinforcing market stability. The overall market size is projected to reach ₹11,000–12,000 crore by 2029–30. However, much of this expansion remains price-driven rather than volume-driven, as production has increased by only 4–5% during FY 2022–2025. The concentration of cultivation in Bihar's Mithilanchal and Kosi regions limits large-scale supply expansion, keeping prices firm. This scenario highlights the urgent need for productivity enhancement, improved water management, varietal improvement and farmer support to ensure sustainable, demand-responsive growth in the sector.

SUMMARY

Makhana is more than a niche wetland crop: It is a scalable source of nutrients, functional benefits and livelihood value that can be integrated into India's nutrition and health strategies. Evidence from Bihar, the nation's production engine for makhana demonstrates that modest, targeted interventions across pond management, processing hygiene, value addition and institutional procurement can deliver measurable gains for both dietary quality and rural incomes. To convert regional promise into national impact, coordinated research, targeted policy support and investment in decentralised processing are essential. By doing so India can legitimately move from wetlands to wellness, harnessing an indigenous superfood to strengthen nutritional and health security for millions.

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