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Overcoming challenges, Makhana stands out as a powerful medicinal superfood: A review

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Abstract

Makhana (*Euryale ferox* Salisb.), or gorgon nut, has evolved from a traditional Asian aquatic food into a globally recognized medicinal superfood due to its high nutritional profile (Protein, Mg, K) and antioxidant properties. Rich in ayurvedic, kidney-strengthening, and anti-aging compounds, this low-fat snack has transitioned from local consumption into a \$43 million industry focused on healthy eating. Ancient Usage as a key medicinal ingredient in India and China for over 3, 000 years to strengthen the spleen and kidneys, treat chronic diarrhea, and manage diabetes and cardiovascular complications. Recognized as a potent antioxidant, high-protein (9.0-11.5%), and high-mineral (Ca, Micronutrients like Zn Cu and Fe) food that combats aging, obesity, and cardiovascular diseases. Traditionally hand-processed by the Mallah community, makhana production has modernized to include automated roasting and popping, creating varied "black to white" seed preparations. The "black diamond" is now popular globally as a healthy, gluten-free, low-calorie alternative to junk food, driven by varied flavoring trends. Low Glycemic Index of makhana is ideal for managing diabetes. Ongoing research into Makhana flour and processed items like Barfi, Kalakand, and flour mixtures offer healthier snack alternatives. Agricultural advancement like, use of gamma rays for creating genetic variation in makhana gene pool and better techniques to improve yields and overcome the limitations of its low productivity.

Keywords: Chhani, consumption, fuel-wood, households, Lanchaan

Introduction

Origin of Makhana (*Euryale ferox*)

Primary Centre of Origin

Archaeological evidence indicates that modern humans (*Homo sapiens*) occupied Northern Eurasia during the Upper Paleolithic, starting as early as 45, 000 to 42, 000 years ago in regions such as the Don River in Russia, with Initial Upper Paleolithic (IUP) sites spreading across Siberia and East Asia, characterized by blade technology. Simultaneously, evidence of human interaction with *Euryale ferox* (Gorgon nut or makhana) dates back to the Lower/Middle Pleistocene, with the oldest known use at the Acheulian site of Gesher Benot Ya'aqov, Israel, over 750, 000 years ago.

A. Origin and Archaeological Evidence of *Euryale ferox*

1. Deep Pleistocene Origin: While *Euryale ferox* (prickly water lily) is now cultivated mostly in East Asia, its earliest recorded use is 750, 000-790, 000 years ago in the Acheulian culture at Gesher Benot Ya'aqov, Israel.
2. Contemporary humans migrated into northern Eurasia over 45, 000 years ago, initiating the development of various high-latitude foraging techniques. Meanwhile, *Euryale ferox* was already being utilized much earlier during the Acheulian period in the Levant.

[*****Eurasia represents the largest continental expanse on the planet, encompassing all of Europe and Asia (Nield, 2013 and McDaniel *et al.*, 2011)^[34, 30].

(McDaniel *et al.*, 2011)^[30]. The idea of Europe and Asia as separate continents originates from ancient times and is primarily cultural, although their boundaries have historically fluctuated. For instance, the ancient Greeks initially included Africa within Asia while designating Europe (Wiesner-Hanks and Merry 2006)^[41]. as a distinct landmass. Eurasia is linked to Africa via the Suez Canal, and the two regions are occasionally grouped together to refer to the largest continuous landmass on Earth, known as Afro-Eurasia (McColl, 2005)]^[29].

1. Neolithic Collection: Archaeobotanical evidence indicates *E. ferox* was a frequent wild food source during the Neolithic period in the Yangtze region of China, with significant finds at sites such as Kuahuqiao, Hemudu, and Tianluoshan.
2. Traditional Harvesting and Processing: Evidence suggests that prehistoric humans developed specialized techniques for collecting *Euryale* nuts, which require underwater harvesting and careful processing (drying, roasting, popping) due to the plant's thorns.

B. Intersection of Evidence

While modern humans spread into northern Eurasia (45,000+ years ago) and began developing diverse, high-latitude foraging strategies, *Euryale ferox* was being exploited much earlier (Acheulian period) in the Levant. Its later, extensive use in the Neolithic Yangtze region marks a transition from wild foraging to systematic collection of aquatic resources. [*****Ancient Eurasia comprised diverse, influential civilizations and early states spanning from the Atlantic to the Pacific, including Mesopotamia, Egypt, the Indus Valley, and China]

Secondary Centre of origin of Makhana

The *Euryale ferox* species was first described by Richard Anthony Salisbury in 1805. It belongs to the water lily family Nymphaeaceae (RBG, 2023)^[38]. This species serves as the type species for its genus *Euryale* (MBG, 2024)^[28]. In 1811, Henry Cranke Andrews introduced *Anneslea spinosa*, which is now considered a synonym of *E. ferox* (Andrews, 1811). Later, in 1853, Jules Émile Planchon described *Euryale indica*, which is also regarded as a synonym (Planchon, 1853). The suggestion to place it in a separate family, *Euryalaceae* J. Agardh, proposed by Jacob Georg Agardh in 1858, (MBG, 2024)^[28], Reveal and Chase, 2011)^[40] has been dismissed. Unlike other water lilies, *Euryale*'s pollen grains contain three nuclei (Cronquist, 1981)^[2]. The fruit is a spiny capsule measuring 5-10 cm in diameter, filled with numerous spongy-textured seeds (Flora of China, 2025)^[4]. It flourishes in nutrient-rich soil submerged in water. It is intolerant of shade or cold during the growing season; however, when it enters dormancy in winter, it remains unharmed by extreme winter cold. Research in archaeobotanical shows that *Euryale ferox* was a commonly gathered wild food during the Neolithic era in the Yangtze area, with numerous discoveries from the locations of Kuahuqiao, Hemudu, and Tianluoshan (Fuller *et al.*, 2009)^[5]. The first documented use of *E. ferox* dates back to Gesher Benot Ya'akov, Israel, found among Acheulean culture artifacts from 750,000-790,000 years ago (Goren-Inbar and *et al.*, 2014)^[9]. The *Euryale* genus derives its name from a legendary Greek creature, the Gorgon Euryale (Lariushin, 2012)^[25]. The specific epithet *ferox* translates to fierce or ferocious in Latin (NZPCN, 2024)^[35].

Euryale ferox is a perennial species that is indigenous to an area extending from northern India to Taiwan, and across China, Korea, and Japan, reaching as far as eastern Russia (RBG, 2024)^[39]. In 2022, *E. ferox* was noted as having naturalized in Serbia, likely spread by migrating birds from plants cultivated in botanical gardens (Živković *et al.*, 2023)^[44]. Makhana is extensively cultivated in India by the fisherman community as here wetlands are more, labor is very chief and makhana provides Eco-System Services (ESS) to live up rural and poor section of people in Bihar. In addition, it has become part and parcel of Mithila-Religious culture and its use in Ayurvedic preparation. While in China, it is cultivated as a medicinal superfood only and there makhana is consumed by every section of the people. The cultivation in Japan and South Korea is limited. On the other hand, Pakistan, Bangladesh and Russia it is mainly cultivated and reared for educational and academic purposes. The species is classified on the Red List of endangered plants in Japan and given the designation "vulnerable", as it is threatened both by water pollution and by land reclamation there (Imanishi, and Imanishi, 2014; Kumar *et al.*, 2018)^[14, 23]. It is similarly rated as vulnerable (VU) in South Korea (Kim, 2014)^[22]. It is classified as a species of Least Concern (LC) in the IUCN Red List of Threatened Species due to its extensive use and cultivation in China (Zhuang, 2011)^[43]. However, a global population decline has been reported (Imanishi and Imanishi, 2014)^[14] due to the high cost of cultivation and processing in foreign countries.

Present Categories of Makhana or Gorgon Nut Plant in Global Scenario

- IUCN Red List least concern species
- Flora of Korea, Chiana, Bangladesh, India, Mongolia, Japan, Myanmar, Taiwan, Russia, etc.
- Medicinal plants of Asia, *Euryale* Plants described in 1805, Plants used in traditional Chinese and Indian medicine (Ayurveda). Taxa named by Richard Anthony Salisbury

Annexure I (A) &(B)



(A) Map of Eurasia showing the location of the Xiaohu cemetery in the Tarim Basin, the ancient Silk Road routes, and the various areas that were occupied by cultures closely associated with the settlement of the Tarim Basin. The map emphasizes the connections between these cultures and trade routes that flourished along the Silk Road to Japan and South Korea.

Table (B): A brief discussion on Natural Distribution of Makhana

1.	Natural Distribution and Ancient Presence	Historical Usage and Cultural Presence in the Region
	I. Broad Asian Range: <i>Euryale ferox</i> is natively found in stagnant freshwater bodies such as wetlands, ponds, and lakes across eastern and southern Asia. II. Northern Distribution: The plant grows naturally in parts of eastern Russia (including the Amur region), Korea, and Japan (Shikoku, Honsyu). III. Neolithic Evidence: Archaeobotanical evidence shows that <i>Euryale ferox</i> was a wild food source in the Yangtze Valley of China during the Neolithic period, around 2000 BC, suggesting widespread ancient usage. IV. Earliest Records: The earliest known record of <i>Euryale ferox</i> use dates back 750, 000-790, 000 years ago in Gesher Benot Ya'aqov, Israel, indicating a very ancient and widespread presence, although modern exploitation is concentrated in Asia.	i. Russia: While not a staple food in modern Russia, <i>Euryale ferox</i> occurs in natural habitats in the Far East (Lachvin in Russia), where it is part of the wetland ecosystem. ii. Japan (Hasu no Mi): Known as "lotus seeds" or Hasu no Mi, the seeds have historically been used in Japanese traditional medicines, teas, and wagashi (traditional sweets). iii. Korea (Yeonssi): Referred to as Yeonssi, fox nuts are traditionally used in Korea for their medicinal properties, particularly in soups and teas for health benefits. iv. China (Qian Shi): China has documented the use of <i>Euryale ferox</i> in traditional medicine for over 2, 000 years, with records in ancient texts dating back to the Tang Dynasty.
2.	Reason for cultivation in North Bihar as well as India	Reason for Cultivation of Makhana in other countries beside India
	I. Ideal Climate and Geography: The region has a unique wetland ecosystem, with hundreds of ponds, lakes, and marshes that provide the perfect conditions for aquatic fox nut cultivation, especially in districts like Darbhanga, Madhubani, Purnea, and Katihar. II. Unique Wetland Ecosystem: North Bihar, specifically in the Mithila region, is the natural birthplace of makhana due to its water-rich landscape, which allows for traditional, and now increasingly scientific, farming methods. III. High Economic Return & Demand: Known as an "economic crop," makhana provides significant income opportunities for local farmers, with increasing global demand bolstering the economy. IV. GI Tagging: The "Mithila Makhana" has received a Geographical Indication (GI) tag, boosting its premium status and securing the market for the region, say IMPRI Impact and Policy Research Institute. V. Government Support: With the establishment of the National Makhana Board, the government is investing to upgrade technology, improve processing, and boost exports using traditional knowledge.	I. Cultural Significance & Local Consumption: In China and Japan, the plant is historically cultivated, with seeds used in traditional medicine, lotus seed paste, desserts, and local delicacies. II. Growing Global Demand & Superfood Status: As a highly nutritious, gluten-free, low-calorie snack (high in protein, magnesium, and antioxidants), it is becoming popular in Western markets (USA, UK, Canada, Australia, Arabian States) as a healthier alternative to potato chips and popcorn, creating an incentive for local production.

Present Status of Makhana (*Euryale ferox* Salisb.)

Euryale ferox, commonly known as prickly waterlily, (Lee *et al.*, 2015) ^[26] makhānā, or Gorgon plant, is a species of water lily found in southern and eastern Asia, and the only extant member of the genus *Euryale*. The edible seeds, called fox nuts or gorgon nuts, are dried and eaten predominantly in Asia. The plant is cultivated for its seeds in lowland ponds in India, China, and Japan. The Indian state of Bihar produces 85-90% of the world's gorgon nuts. The Chinese have cultivated the plant for centuries. In India, more than 96, 000 hectares of Bihar were set aside for cultivation of *Euryale* in 1990-1991. In the northern and western parts of India, the seeds are often roasted or fried like popcorn, which is known as *Lava*. In recent years, Mithila Makhana has gained recognition as a superfood in the global market. Indian Prime Minister, Mr. Narendra Modi referred to makhana as a superfood during a rally in Bhagalpur on 24 February 2025 (Khapudang *et al.*, 2024) ^[21]. Its demand is swiftly rising in the markets of the western world. The United States has emerged as the largest consumer and importer of makhana. Following the USA, Canada and Australia rank as the next two significant importers of Makhana. Media reports have also labeled it as "The Black Diamond." India stands as the largest exporter of Makhana across the Globe. Furthermore, the Mithila region is the foremost producer of Makhana in India, accounting for 80-90 percent of the total cultivation of

Makhana in the country (Lariushin, 2012) ^[25]. On 24 February 2025, Prime Minister, Mr. Narendra Modi declared that Makhana should be made available in markets worldwide (Khapudang *et al.*, 2024) ^[21]. Bihar Agricultural University, Sabour played a crucial role in obtaining a geographical indication (GI) tag for Mithila Makhana, a well-deserved recognition achieved in April 2022 (Hindusthan, 2021 and JOI, 2022) ^[13, 20]. This achievement was made possible through the persistent political efforts and the cause of securing the GI tag for Mithila Makhana within the halls of the Indian Parliament on multiple occasions. With the GI now officially registered under the name of Mithilanchal Makhana Utpadak Sangh based in Purnia, the significance and authenticity of this traditional product are further emphasized (HT, 2021) ^[12]. Furthermore, the recognition has not only elevated the status of Mithila Makhana but has also created a sense of pride and ownership among the local producers and the community. Highlighting the ease of access to this exceptional product, the Postal Department of India took an innovative step by initiating a dedicated courier service specifically tailored for the delivery of Mithila Makhana in Bihar as well as India, effective from the 28th of January 2021 (Kumar, 2021 and News-18, 2021) ^[24, 33]. This strategic move not only promotes the widespread availability of Mithila Makhana within the region but also reinforces its uniqueness and cultural importance among consumers and enthusiasts alike.

In February 2025, during the budget speech, Union Finance Minister Nirmala Sitharaman announced the establishment of the Makhana Board in Bihar. The primary objectives of the Makhana Board will be to improve the production, processing, value addition, and marketing of makhana grown in the Mithila region of Bihar, India (India Today, 2025a) ^[15]. On February 23, 2025, Union Agriculture Minister Shivraj Singh Chauhan visited the ICAR-National Makhana Research Centre in Darbhanga to engage farmers involved in the cultivation of Mithila Makhana and discuss the formation of the proposed National Makhana Board (Jagran, 2025) ^[17]. The following day, February 24, 2025, Prime Minister, Mr. Narendra Modi reiterated the announcement regarding the establishment of the National Makhana Board during a rally in Bhagalpur (India Today, 2025 b) ^[16]. The land area dedicated to the production of Gorgon nuts has expanded to 35, 000 hectares (86, 000 acres) as of 2022. The center (ICAR-NRC for Makhana) has created a more productive variety (Swarna Vaidehi), which has led to an increase in farm income, and is currently in the process of designing a harvesting machine (Gupta, 2024) ^[11]. The history of makhana (Gorgon nuts) is a story of transformation, moving from a humble, traditionally harvested wetland crop in Bihar to a globally recognized superfood, with Bihar producing and supply over more than 80% of the world's requirements. This journey involved overcoming significant labor, environmental, and infrastructural challenges, transforming the industry from an "ancient snack" to a "modern superfood" valued at over 3, 000 crores in India. Makhana (*Euryale ferox*), a native of Eu-Russia, South-East Asia and China, has spread throughout Asia, specifically to Korea, Japan, Russia, Thailand, Bangladesh and Pakistan, thriving stagnant sweet water present in tropical/sub-tropical wetlands. While considered a native and major producer, cultivation is concentrated in Bihar, with smaller areas in Assam, Manipur, Odisha, Tripura, Uttar Pradesh and West Bengal. The Both countries China and Japan, have historically cultivated the plant, utilizing it differently than India. In addition to seeds, they consume the roots (rhizomes) as a vegetable, and use Makhana paste to create pastries and cakes. In South Korea, it is known to exist with the seeds, which are used in local culinary practices as part of snacks. In case of Thailand and other's countries, it is cultivated for consumption as a snack known as *Med-bua-op*.

Regarding expansion and modern trade, while endemic to Asian wetlands, India has become the commercial powerhouse for supplying global markets, with significant exports going to Japan. The plant's natural spread is likely

linked to migratory birds passing through the temperate, humid zones of east Asia and north India. Some pilgrims carried makhana seeds from Europe and introduced them to India in an effort to gain knowledge about this remarkable crop known for its health benefits and versatility. The journey of these seeds marked an important exchange of agricultural knowledge and practices between cultures. Makhana, often referred to as gorgon nuts, has gained popularity over the years due to its nutritional properties and is now widely used in various culinary applications. This introduction not only enriched the Indian agricultural landscape but also fostered a deeper understanding and appreciation for diverse farming techniques and the significance of biodiversity in crop production under fresh water wetlands of India.

Makhana Nutritional Fact

Makhana provides significant nutritional and medicinal benefits, being abundant in protein (9-11.5%), fiber (0.5-1.5%), and healthy carbohydrates (72-76%) while remaining low in calories, combating lifestyle diseases, thus earning its designation as a superfood (Jana *et al.*, 2024) ^[19]. It is rich in kaempferol and quercetin, compounds recognized for their anti-aging, anti-inflammatory, and antioxidant effects. Its distinctive amino acid profile includes various anti-aging elements (Jana and Idris, 2018) ^[18]. This remarkable combination not only helps mitigate the effects of aging but also plays a crucial role in promoting cardiovascular health. Furthermore, it enhances kidney function, supporting the kidneys in their essential tasks, and aids in the detoxification process, assisting the body in eliminating harmful substances. Makhana is often utilized in Ayurveda and Unani medicine for the treatment of hypertension, insomnia, arthritis, and other lifestyle-related ailments. Das *et al.*, (2006) ^[3] noted that Makhana pop could alleviate myocardial reperfusion injury. The hearts of rats treated with Makhana exhibited significantly increased levels of thioredoxin-1 (Trx-1) and thioredoxin-related protein-32 (TRP-32) compared to the control hearts. These results illustrate the cardioprotective properties of Makhana and suggest that these beneficial effects may be closely associated with the extract's ability to enhance the expression of TRP-32 and Trx-1 proteins while effectively neutralizing harmful reactive oxygen species (ROS). The presence of tyrosine in Makhana supports the production of epinephrine, which is vital for a child's brain development (Garabal *et al.*, 2018) ^[6].

Glimpses of Makhana from pond to plate





Key Hurdles Overcome by the Makhana Food Industry:
Hazardous & Labor-Intensive Harvesting: Traditionally, farmers (often from the Mallah community) had to dive into deep, murky, and cold water to collect seeds, exposing themselves to risks like infections, cuts from thorns, and extreme physical strain.

Solution: Scientific farming methods have been introduced, allowing for cultivation in shallower water (30 cm to 1 meter), reducing the need for deep diving and easing the labor process.

Recurrent Floods in Mithilanchal Region: As makhana grows in waterlogged, low-lying areas, flooding often destroyed the crop, leading to financial loss.

Solution: Researchers introduced net fencing around ponds (locally known as *chatti jaal*), supported by bamboo poles. This innovative barrier protects the floating seeds from being washed away during monsoon floods.

Lack of Mechanization in Processing: Popping the seeds was a manual, slow, and specialized skill that led to high costs and low efficiency.

Solution: The development of specialized machines by institutes like CIPHET (Ludhiana) has facilitated the mechanization of makhana popping, and it is now known as the "Vardan" technology.

Middleman Domination and Low Farmer Income: Previously, a fragmented supply chain allowed intermediaries to dictate prices, leaving farmers with low profits (often 100-250 INR/kg) while the market value was much higher.

Solution: The formation of Farmer Producer Organizations (FPOs), the "One District One Product" (ODOP) scheme, and direct marketing by startups are increasing farmer bargaining power.

Low Productivity & Poor-Quality Seeds: Traditional, non-scientific methods resulted in lower yields, often between 1.7-1.9 tonnes per hectare.

Solution: The introduction of improved seed varieties like 'Swarna Vaidehi' has drastically increased yields (up to 25 q/ha in some cases).

Negative Public Perception/Lack of Awareness: For a long time, makhana was considered merely a "fasting food" or something for elders.

Solution: Strategic rebranding as a premium, low-calorie, high-protein "superfood" with diverse, flavored options (e.g., peri-peri, caramel) has opened it up to a global, health-conscious audience.

Lack of Recognition and Regional Support: The industry was unorganized and lacked national attention.

Solution: The awarding of the Geographical Indication (GI) tag as "Mithila Makhana" in April 2022 elevated its status, highlighting its uniqueness to Bihar and facilitating better marketing.

Seasonal Dependence and Water Scarcity: Farmers struggled to maintain the necessary 4-6 feet of water during the dry pre-monsoon season.

Solution: The adoption of polythene lining (100-micron sheets) to seal the bunds has minimized water seepage, allowing farmers to maintain necessary water levels even during dry spells.

Why does Makhana Cultivation Flourish in Mithilanchal of North Bihar?

Makhana, commonly known as fox nut, has found an ideal environment for cultivation in the Mithilanchal region of North Bihar, thriving due to its unique geographical, ecological, and cultural conditions. This area produces over 80% of India's total output, thanks to abundant wetlands, stagnant shallow ponds, known as *chaurs*, and fertile waterlogged fields, particularly in Darbhanga and Madhubani. The flourishing industry owes its success to several key factors. The region's waterlogged areas combined with high humidity and warm climate create optimal conditions for the growth of *Euryale ferox*, or makhana. Generations of local farmers and fishermen, having honed specialized techniques for both cultivation and processing, pass down their knowledge to preserve these practices. Additionally, the crop exhibits remarkable flood tolerance, thriving in stagnant water, thus providing a reliable income source even when other crops might fail. Makhana is not only gaining recognition as a health food, known for being low in fat and high in protein, but it also possesses cultural and medicinal significance, often used in marriage ceremonies and offerings to deities in Bihar. The

recent grant of a Geographical Indication tag in 2022 ensures the authenticity and quality of the product, marking a significant milestone. Further support from government initiatives, including the establishment of a specialized Makhana Board in Bihar, aims to enhance infrastructure and facilitate better market access. This evolution from traditional seasonal pond harvesting to more efficient high-yield field cultivation has established the Makhana industry as a vital contributor to the local economy, ensuring its continued growth and sustainability.

Conclusion

Despite encountering above mentioned challenges, fluctuating market prices, insufficient infrastructure, and the makhana industry primarily known for its production of makhana seeds continues to evolve and adapt. This resilience is, in part, due to the proactive measures taken by the government, which recently established the National Makhana Board. This board is dedicated to promoting the growth and sustainability of the industry by implementing strategic initiatives designed to bolster production and enhance the livelihoods of farmers. In addition to creating this supportive regulatory framework, the government is also committed to facilitating further mechanization within the sector. This involves introducing advanced harvesting and processing technologies that can increase efficiency and reduce labor costs, ultimately leading to higher yields and improved quality of the product. Furthermore, efforts are being made to expand market access for makhana producers, ensuring that they can reach broader consumers and secure fairer prices for their products. Makhana is a photo-sensitive crop that flourishes in various types of soil, showcasing its remarkable adaptability. The most crucial factor for successful makhana cultivation is water, as this plant requires a consistent supply to grow effectively. Thanks to its broad adaptability, makhana can thrive in regions affected by both harsh winter conditions and the sweltering heat of summer, adjusting well to local climatic conditions while maintaining a resilient identity. Human civilization holds this crop in high regard, recognizing its numerous benefits. In return, makhana provides a bountiful yield, serving as a valuable source of quality food that meets the rising demand in today's world.

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