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REVIEW ARTICLE

A Review on Gorgon Nut

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ABSTRACT

Euryale ferox is the only species of the genus. It is commonly called Fox nut, Gorgon nut, Prickly water lily. The distribution of this species is now limited to the tropical and subtropical regions of south-east and East Asia. It has adapted to the tropical climate of India and is found in natural, wild forms in various parts of north-east India (Assam, Meghalya, and Orissa) and scattered pockets of central and northern India (eg. Gorakhpur and Alwar). However, Mithila (North Bihar) is the principal area of its present existence. Makhana is best grown in age- old perennial water bodies with a rich mucky bottom providing nutrients to the plants. Harvesting and processing of seed is still carried out by traditional methods. Makhana (*Euryale ferox* Salisb.) is one of the most common dry fruits utilized by the people due to low fat content, high contents of carbohydrates, protein and minerals. Both raw and fried Makhana are fairly rich in essential amino acids. Edible perisperm constitutes 80 per cent starch. *Euryale ferox* is a store house of macro- and micro-nutrients. The seeds are eaten raw or roasted. The seeds are sold in market and used as a farinaceous food.A lot of medicinal uses are recommended in the Indian and Chinese system of medicine. The different dietary components of the seeds were investigated to assess its nutritional significance.

Key Words: Gorgon nut (*Euryale ferox*), Makhana, Medicinal value, Proximate composition.

INTRODUCTION

Euryale ferox is the only species of the genus. It is commonly called Fox nut, Gorgon nut, Prickly water lily. In Hindi and Bengali- Makhana, Telegu- Mellunipadmamu, Uriya- Kuntapadamu, Punjab - Jewar. It is a stemless, prickly, acquatic herb, rootstock short and thick[1]. The leaves are submerged, oblong, orbicular corrugated about 6-100 cm in diameter; reddish green above, purple below, densely spinous [2].

The flowers are solitary, submerged, and epigynous with four persistent, thorny sepals inserted on the torus above the level of the ovary, together with many seriate petals. Most flowers are cleistogamous, but chasmogamous flowers may also be produced. The inferior, multicarpellary ovary develops into a spongy berry like fruit which is densely prickly, the size of an orange, and contains 30-40 pea size seeds with hard black seed coat and a mucilaginous aril. The pulpy aril keeps the seeds floating for a few days after they dehisce, before they finally settle down to the bottom of the water [3].

Habit and Habitat

The distribution of this species is now limited to the tropical and subtropical regions of south-east and East Asia. It is found growing wild in India in the south to as far north as Manchuria[4-5]. In China it has been cultivated in the Hainan and Taiwan islands for 3 - 4 millenia[3]. Its distribution includes the islands of Taiwan (Formosa) and Kyusyu, Shikoku and Honsyu in Japan[6]. The northern limit in Japan corresponds to about 38° 30'N on the Pacific coast and 37° 55' N on the Japan sea coast. In India also Makhana has been growing in the temperate lakes of Kashmir as an ancient natural crop [2]. The deteriorating conditions of the lakes in Kashmir had diminished the number of plants to few in Dal and Manasbal lakes and a single plant in Nagin Lake [7]. It has adapted to the tropical climate of India and is found in natural, wild forms in various parts of north-east India (Assam,

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Meghalya and Orissa)[8] and scattered pockets of central and northern India (eg. Gorakhpur and Alwar). However, Mithila (North Bihar)is the principal area of its present existence where it is extensively cultivated in Darbhanga, Madhubani,Samastipur and Saharsa districts and partly in the Muzaffarpur, Champaran and Purnea districts. It also grows in some areas of Nepal, Bangladesh, Korea and North America, Further it has been reported to grow as a native plant in the lakes of Manchuria [9]. It has completely vanished from Tegelem clay in Holland and at Lachvin in Russia [10].

CULTIVATION

Makhana is best grown in age- old perennial water bodies with a rich mucky bottom providing nutrients to the plants. Growth of plants is not proper in freshly excavated ponds or water area because they lack the highly nutritive mucky bottom [11]. Makhana cultivation requires minimum expenditure as new plants germinate from the seeds left over from the last harvest. The only investment required is in thinning out the overgrowths, transplanting into sparse areas, adding insecticides and the collection of dispersed seeds from the pond bed during harvest [12].

The cultivation of this aquatic crop involves clearing of pond, broadcasting of seeds, thinning and gap-filling, plant protection, harvesting and collection of seed. Cleaning of pond is normally done during September-October each year before the sowing of Makhana Seeds. Algal plants are removed and there should be 90-120 cm of standing water in the pond even in summer.

Freshly excavated pond requires even broadcasting of pre-germinated seeds in October or November @ 125kg/ha over the entire water surface covering the pond. Ponds under running cultivation do not require broadcasting as saplings are produced from the left over seeds. Yet triennial replacement, @ 50 kg/ha of pre-germinated seeds, is advised. Sprouting occurs in February-March, which is followed by thinning so that all the saplings get the essential requirement. Closely grown plants are transplanted into sparser patches maintaining a gap of one meter between two plants. During April- May, the entire water surface gets covered with huge leaves. Flowering starts by the end of May. Fruits appear in June. Mature Fruit burst around August-September and the seeds get scattered all over the bottom [11-12].

Traditional methods of pest control are used to protect the plants from the possible pests like, the grasshopper (*Hieroglyphus banian*), giant water bug (*Belostoma indicum*) and aquatic beetles (*Cybister confusus*). In case of severe attack 5% BHC dust is broadcasted to protect the plants [12].

HARVESTING

Collection of scattered seeds of Makhana is done manually during August-November. The entire floor of the pond is swept by experienced fishermen to form heaps of the sunken seeds that are scooped out with the help of a horn shaped split bamboo contrivance. Smaller and lighter seeds which float on the water are collected with the help of small nets. Collected seeds are thoroughly thrashed by feet to remove the membranous cover. Harvesting of seeds is a tedious job. The yield of seeds varies from 2.5-3.0 tones per hectare of pond [11-13].

PROCESSING

Processing of seed is still carried out by traditional methods. Seeds are sun-dried in the morning between 8-11 am so that the moisture content reaches around 31 per cent. Water is sprinkled to keep the seeds fresh and moisture content optimum. The other steps involved are drying, size grading, pre-heating and tempering, roasting and popping. Seeds are now further dried to facilitate removal of kernel from the seed coat.

Seeds are passed through different size of sieves to differentiate them into 5-7 grades. Uniform heat transfer occurs when seeds of same size are heated during preheating and roasting. Graded seeds are heated in an earthen pitcher or cast iron pan with continuous stirring over fire at 230°-335° C for approximately 6 minutes. Tempering of seeds is followed by storing them in open baskets for 40-50 hr. This loosens the kernel within the seed coat and increases the yield of popped seeds. Tempered seeds are roasted in 300 gm lots in an open pan over fire at approximately 230°-335° C. When a crackling sound is heard 5-7 seeds are taken out kept on a hard surface and hit with a wooden hammer. Seed coat breaks and due to sudden release of pressure, the kernel pops out in expanded from. Seed coats are then removed manually. The perisperm of the seed forms the edible part.

The popped kernels known as Makhana are now polished by rubbing it against baskets made of bamboo splits without any delay to avoid

absorption of moisture. Grading is done on the basis of size and whiteness. Polished and graded product is finally packed in polythylene - lined gunny bags [11-13]. **Fig.1**

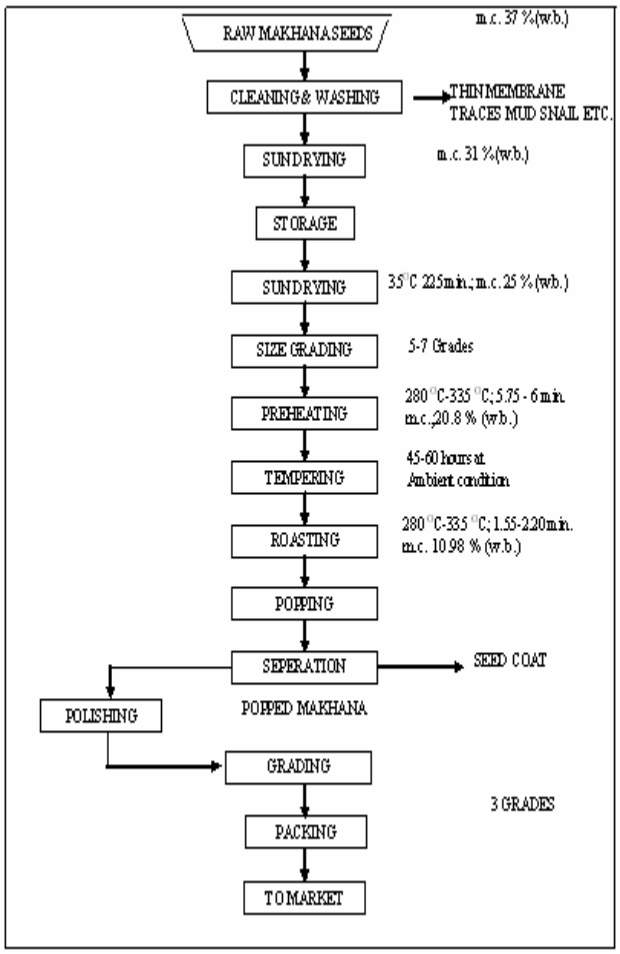

Fig 1 Processing of Makhana

NUTRIONAL VALUE

Makhana (*Euryale ferox* Salisb.) is one of the most common dry fruits utilized by the people due to low fat content, high contents of carbohydrates, protein and minerals. The calorific value of raw seeds (362 k cal/100g) and puffed seeds (328 k cal/100g) lie close to staple foods like wheat, rice, other cereals and some aquatic plants like *Nelumbo* and *Trapa*[14-15]. Roasting and popping cause a loss in the calorific value.

Makhana is a good source of carbohydrate, protein and minerals. The chemical constituents of the popped kernels (g/100g) are 12.8 moisture, 76.9 carbohydrate, 9.7 proteins, 0.1 fat, 0.5 total minerals, 0.02 calcium, 0.9 phosphorus, 0.0014 iron[13-14]. Bilgrami et al.[16] found makhana superior to dry fruits such as almond, walnut, cashew nut and coconut in contents of sugar, proteins, ascorbic acid and phenol. According to Nath & Chakraborty[17] nitrogen content of defatted seed powder is 1.36 per cent by Kjeldhal's method which means 8.5 percent protein. Sixteen types of amino acid are present in the kernel. Both raw and fried Makhana are fairly rich in essential amino acids. The values relating to essential amino acid index (EAAI) and chemical score (CS) of makhana are close to that to fish[18]. The of EAAI in raw Makhana and popped Makhana are 93 per cent and 89 per cent which are higher than the values for rice (83 per cent) , wheat (65 per cent), bengal gram (81.5 per cent) , cow's milk (88.8 per cent), fish (89.2 per cent), and mutton (87.24 per cent). Makhana protein (10-12%) is a bit lower when compared to cereals. Still it is nutritionally superior to many plant and animal based diets due to high EAAI and CS [19-21]. The biological value (BV) of puffed seeds was found to be 55 which is lower than in other plant and animal based diets. It may be due to the high ratio of leucine to isoleucine present in it. The lower BV recommends its use as a complementary food item.The ratio of arginine+lysine to proline shows better utilization of protein in rat growth.It is 6.3 in raw and 4.74 in puffed makhana seed. A+L/P was found to be higher (7.6) in a wild population from Tripura[17]. Protein and amino acid composition (g/16gN) of makhana when compared with egg and FAO / WHO pattern showed higher content of arginine, alanine and tyrosine. A remarkable loss was seen in the values of tyrosine while, the values were higher for lysine, arginine, threonine, serine, glutamic acid, glycine, alanine, valine, cystine, isoleucine, leucine and phenylalanine on popping[18] . Jha[21] reported net protein utilization (NPU 49.3), true digestibility (TD 89.6) apparent digestibility (AD 69.1) of makhana were comparable to the values of most cereals.The above values were lower when compared to soyabean, egg and human and cow milk[18] .**Table 1,2** & **3**

Table 1: Protien and amino acid composition (g/16gN). of makhana when compared with egg and FAO/WHO pattern

Amino acid	Makhana		Egg	FAO/WHO (1973)
	Raw	Fried		
Lysine	3.79	4.69	6.7	5.4
Histidine	3.15	3.12	3.5	2.5
Arginine	15.19	16.07	6.7	5.2
Asparatic acid	5.76	5.05	10.4	7.7
Threonine	3.34	3.51	5.1	4
Serine	5.05	5.64	6	7.7
Glutamic acid	16.64	17.06	25.02	14.7
Proline	4	3.24	-	10.7
Glycine	3.01	3.28	3.6	2.2
Alanine	5.5	5.84	3.5	6.1

Valine	5.18	5.49	7.5	5
Cystine	0.75	1.21	3.0	-
Methionine	3.06	2.95	2.3	3.5
Isoleucine	4.18	4.8	5.8	4
Leucine	8.34	8.85	8.9	7
Tryosine	6.38	2.91	3.6	3.05
Phenylalanine	5.78	6.12	6.7	3.05
Tryptophan	n.d	n.d	1.5	1
Ammonia	0.9	1.16	-	-
Protien(%)	11.1	11.5	-	-

Source : Jha et al.[18] n.d. = not determined.

Table 2: Comparative value of Essential Amino Acid Index (EAAI) and bilogical value (BV) of foods:

Feeds	EAAI	BV	CS(% EGG)
Edible items			
Rice	82.88	68	54.93
Wheat	65.18	62.6	39.7
Bengal gram	81.55	68	53.33
Soyabean	85.59	50.7	52.6
Amaranth	57.72	-	40.93
Human milk	81.55	-	59.7
Cow's milk	88.8	84.5	52.54
Fish	89.2	59.7	65.7
Mutton	87.24	74	71.46
Makhana			
Fried	89.97	55	56.57
Raw	93.63		70

Source : Jha et al. [18].

Table 3: Comparative value of leucine to isoleucine and arginine + lysine proline ratios in foods.

Feeds	leucine/ isoleucine	(arginine+lysine) / proline
FAO/WHO pattern	1.75	0.99
Rice	1.66	4.00
Wheat	1.66	0.71
Soyabean	1.45	2.86
Amaranth	1.27	3.41
Human milk	-	1.58
Cow's milk	1.76	-
Fish	1.71	5.18
Mutton makhana	1.56	-
Raw(Tripura ample)	1.9	7.6
Raw (Bihar sample)	1.84	6.3
Fried (Bihar sample)	1.99	4.74

Source : Jha et al. [18].

Makhana is a good source of carbohydrate. Edible perisperm constitutes 80 per cent starch. Nath and Chakraborty[22] reported 77 per cent starch in the perisperm. Protein-free starch was fractionated into 25.3 per cent amylose and 74.7 per cent amylopectin. The iodine-binding capacity of amylopectin indicated that 0.47 per cent amylose was present in this fraction. The chemical composition and properties of starch are given in the **Table 4**. Trace metals like Cu, Na, Ca, Fe, and Mg reported a declining trend on purifying starch. The loss was more pronounced for Ca and Mg illustrated in **Table 6**

Table 4: Chemical composition and properties of starch of *Euryale ferox.*

Determination	Whole starch	Protein free starch
Yield (%) from seed meal	52.5	n.d
Moisture (%)	14.4	13.5
Ash (%)	15	0.15
N (%) by kjedahl method	1.36	Nil
Protien (%) by amino acid analysis	7.32	Trace
Total carbohydrate (%)	77.33	86.85
Amylose (%),potentiometrically	n.d	25.3
Amylopectin (%) with respect to amylose	n.d.	74.7

Source :Nath & Chakraborty[22] , n.d.,not determined.

Table 5: Properties of starch, amylose, and amylopectin from the seeds of *Euryale ferox.*

Determination	Starch	Amylose	Amylopectin
Iodine binding capacity	5.36	21.2	0.1
Blue value	0.31	1.28	0.05
Specific rotation	142.5	135	132.5
Average chain length by periodate oxidation	29	380	23(22)
Average chain length by methylation		395	20
intrinsic viscosity [h](dl/g)	1.15	0.78	1.2

Source :Nath & Chakraborty[22] n.d.,not determined.

Table 6: Detection of trace metals present in the starch of *Euryale ferox*

Sample	Cu ppm	Na ppm	Ca ppm	Fe ppm	Mg ppm
Seed meal	<1	1000	>1000	100	>2000
Whole starch	1	1000	>1000	100	>2000
Purified starch	<1	800	<200	80	100

Source :Nath & Chakraborty[22] , n.d.,not determined.

Euryale ferox is a store house of macro- and micro-nutrients [23].Vegetative parts also contain good amount of N (0.167 per cent and 0.197 per cent) along with the edible seed (1.56 per cent N equivalent to nearly 10 per cent crude

protein). The values are considerably higher than that present in some of the most common fruits (0.6 to 4.4 per cent). P content in makhana (2397 mg /kg) was higher than common fruits like guava, litchi and mango (300 to 800 mg /kg). K is accumulated more in rhizome (2170 mg /kg) than in the seeds (159 to 240 mg /kg). *E. ferox* is a sodium loving crop. It accumulates sodium even in low sodium soils. Na content in the seeds ranged between 180 to 200 mg /kg. Various common fruits like mango, litchi, and banana had Fe content in the range of 105 to 678 mg /kg while Fe in various parts of makhana plant was found to be 1994 to 2236 mg /kg [24]. Zn content in makhana fruit (42.9 to 66 mg/Kg)was also reported to be higher than common fruits and vegetables like cucumber, mango, banana and colocasia (23.3, 7.3, 5.3 and 15.5 mg /kg respectively)[25]. Both the plant and the seed contain Cu in the uniform range of 8.3 mg /kg but it ranged from 12.5 to 16.7 mg /kg in fruit sheath and petiole. Mn content also showed the same trend. The value was higher for makhana fruits (25 to 35 mg /kg) than present in mango, cucumber and banana (7.3 mg/kg, 14.4 mg/kg and 29.6 mg/kg respectively[23] .The above data revealed that fruit sheath was a good source of minerals.

The seeds are eaten raw or roasted. Sometimes seeds are boiled in salt water. On roasting in hot sand the seed coat swells and bursts and can be easily peeled off. The seeds are sold in market and used as a farinaceous food. The seed flour is used as a substitute for arrow root. It is nutritious and easily digested [26].In Kashmir fruits are edible. The seeds are consumed in raw or roasted forms as well as dried seeds are crushed to produce nutritious bread [2]. *E. ferox* is used as delicious vegetable by the people of Manipur during autumn and summer. The leaf petiole and seeds are taken raw in salad and chutney forms. Vegetable dishes and curry is also prepared with it. However, in some other areas people also use tender leaves, seed aril and fruit skin in the preparation of chutney after removing the prickles by means of fire or some other means[27]. In North India and Bihar makhana serves as a dessert delicacy. After frying the seeds are used as snacks as well as in the preparation of vegetable dishes.

MEDICINAL VALUE

A lot of medicinal uses are recommended in the Indian and Chinese system of medicine. Makhana is recommended for treatment of diseases regarding respiratory, circulatory, digestive, excretory and reproductive systems. Dragendroff[28] found the whole plant to bear tonic, astringent and non-obstructing properties. Diseases of spleen, polyuria, spermatorrhoea, gonorrhoea, articular pains, micturition, and seminal loss are also treated with it. Stuart, Crevost and Petelot, Liu, Roi, Kariyone and Kimura[29-33] reported the seeds to be effective in increasing the secretion of hormones. It acts as an expectorant and emetic [34]. Sharma [35] noted its medicinal impacts in treating circulatory disorders and also as a cardiac stimulant. The farinaceous seeds have binding action in dysentery. Though in overdoses its causes constipation and flatulence. The edible seeds are known for its tonic, astringent, deobstruent, anti-rheumatic, anti-diuretic and roborant properties. It is also utilized to overcome postnatal weaknesses in women. In case of men its aphrodisiac and spermatogenic potential is utilized [18].

Ayurveda, the Indian system of medicine recommends makhana to be beneficial in Tridosas (the seminal Ayurvedic theory of diagnosing diseases on the basis of three principal defects of the body), especially in Vata (rheumatic disorders) and Pitta (bile disorders). In the Unani system of medicine seeds are used against dysmenorrhoea. According to the principles of Chinese medicine, its main functions are to tonify the spleen and stop diaorrhea, to strengthen the kidneys and control the essence, or jing; and to dispel dampness. To treat diaorrhea, euryale seed is typically incorporated into a larger formula containing white atractylodes and dioscorea.It is included as "Chien-Shih" in the chinese medicinal formula "Su-Shin" (a tonic especially required for the growth of the children)[36]. The seeds contain suffcient amount of vitamins so, used to treat beriberi, a disease caused by deficiency of Vitamin B1 [37]. Quadrat-I-Khuda et al. [38] found its starch granules to be very small (1- 3 um as compared with 2.2 - 7.5 um of *Nymphea stellata* Wild. and 15.91 -39.0 um *Trapa bipinosa* Roxb.) making it effective against digestive disorders. *E. ferox* is used as a tonic and for the treatment of leucorrhoea.

Puri et al. [39] reported E. ferox to be a good immunostimulant. Feeding of *E. ferox* stimulated humoral immunity and suggested its applications in mothers after delivery and invalids. Gordon euryale seed is analgesic (insensitizes pain) and aphrodisiac. It is taken internally in the treatment of chronic diarrhoea, vaginal discharge, kidney

weakness associated with frequent urination, impotence, premature and involuntary ejaculation and nocturnal emissions. It also regulates blood pressure; relieves numbness and aching near waist and knees. It is suitable for arthritis; impotence; and premature aging[40].The American Herbal Products Association has given *Euryale* seed a class 1 rating, meaning that it can be safely consumed when used appropriately.

Three samples of makhana were procured from the local market to study their proximate composition. Small variations were observed in the different parameters analyzed. These may be due to environmental differences like soil, water, and air.

Table 7: Proximate Analysis of makhana

Constituents	Sample A	Sample B	Sample C
Moisture (%)	10.82	12.13	9.19
Protein (%)	10.72	11.72	10.64
Fat (%)	0.417	0.418	0.399
Total ash (%)	0.428	0.428	0.398
Iron (%)	0.0042	0.0042	0.0043
Calcium (%)	0.0386	0.0344	0.0392
Phosphorus (%)	0.0775	0.0899	0.0769
Vitamin A (IU/g)	62.94	63.84	62.23
Vitamin C (%)	0.203	0.187	0.183

Moisture content was found lowest in sample C which may be due to the variation in environmental conditions and cultivation practices. Protein content in makhana ranged between 10.64 to 11.72 per cent. The estimated content was found to be lower than reported earlier. The fat content of all the three samples were comparable to each other. In the present study, a fat content of 0.4 per cent was observed; while the reported values were quite lower (0.1 per cent). Approximately, 0.4 per cent total ash content was observed in the three makhana samples. Makhana contained a good amount of calcium (0.0344 to 0.0392 per cent) and phosphorus (0.0775to 0.0899 per cent), but the iron content (0.0042 to 0.0043 per cent) was quite lower. The vitamin A content ranged from 62.23 to 63.84 IU/gm and that of vitamin C ranged from 0.183 to 0.203 per cent.

In Indian market makhana is a costly item. It is not a food for the crowd. It has a great nutritional value but complete nutritional significance of makhana could be revealed by further investigations only.

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