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Euryale ferox Salisb. is an Immense Potential Aquatic Cash Fruit Crop: A Review

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ABSTRACT

This review article scrutinizes immense potentiality of Makhana and some of the vibrant technologies developed/ refined/ adopted to improve wetlands ecosystem productivity in the Eastern Indo Gangetic plains. *Euryale ferox* Salisb. (Makhana/Fox nut/Gorgon nut/ Prickly water lily) is the only monotypic species of the genus *Euryale*, belonging to the family Nymphaeaceae. The plant is native to South-East Asia with the prevalence of tropics to sub-tropics accomplished with humid to sub-humid environment. In general, its distribution is extremely limited to tropical and subtropical regions of South-East and East Asia and is known to exist in Korea, Japan, China, Oudh, Dal Lake Kashmir, East Bengal. In India, it is distributed in Bihar, West Bengal, parts of Assam, Manipur, Tripura, Eastern Odisha, Madhya Pradesh, Rajasthan (Alwar) and Eastern Uttar Pradesh. However, Mithila region (*holy land of Ma Vaidehi / Sita*) of North Bihar is the principal area of its present existence where it is extensively cultivated considered as a potential aquatic cash crop. Bihar accounts for more than 80 percent of total makhana production in the country and that makhana production takes place in 20 out of its 38 districts, mostly situated in the North of the state. 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. Makhana seeds are popularly called as *'Black Diamond'* as raw and famously known as *'white ball'* when it popped. The yield of seeds varies from 2.5-3.0 tonnes per hectare of pond.Makhana cultivation provides livelihood to thousands of resource poor farmers, particularly in Bihar.Importance and scope, agrotechnology of Makhana developed and refined for Eastern Region conditions are briefly discussed in this article.

Keywords: Fox nut (Euryale ferox), Makhana, Nutritional and Medicinal value, chemical composition.

INTRODUCTION

The genus Euryale was first described by Salisbury in 1806 as a monotypic genus of the family Nymphaeaceae, but sometimes treated under separate family Eurylaceae (Qaiser, 1993).According to Stewart (1972) Euryale *ferox* Salisb., in Kon. & Sims., Ann. Bot. 2: 74. 1806; FBI 1-113. Dal Lake Kashmir, 5200´, common (Euryalaceae in Fl. Europaeae); SAH. Herb. GCU, LHR.*Euryale ferox* is the only species of the genus. Makhana (Euryale *ferox* Salisb.) is emergent macrophyte also known as Gorgon nut/Fox nut, Prickly water lily is an important aquatic fruit crop. It is a stemless, prickly, aquatic herb, rootstock short and thick rhizome(Kak, 1985 and Md. Ajaib *et. al.,* 2010). The leaves are orbicular, floating, globular, green and corrugated above and deep purple beneath, supported by stout, porous and prickly ribs about 6-120 cm in diameter; densely spinous (CSIR,1952).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 serrate 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 (Jha *et al.,* 1991). The popped expanded kernel of the gorgon nut (*Euryale ferox*) is characterized by its hard seed coat (shell), black colour and round shape seed. Makhana seeds are popularly called as '*Black Diamond*' as raw and famously known as '*white ball*' when it popped (Jha and Prasad, 2003).

Habit and Habitat:

The plant is native to South-East Asia with the prevalence of tropics to sub-tropics accomplished with humid to sub-humid environment. The plant does best in hot, dry summers and cold winters. For its proper growth and development, the conducive range of air temperature is 20^{o} C-35^{o} C, relative humidity 50-90 per cent and annual rainfall 100cm-250cm (Mandal *et al.*,2010). The maximum daily temperature in summer is 41-46^{o} C (Jalali & Jamzad, 1999and Nasir& Rafiq, 1995). It is found growing wild in India in the south to as far north as Manchuria (Regel, 1862), further it has been reported to grow as a native plant in the lakes of Manchuria (Sukatscheff *et al.*, 1906 and Komarov, 1927). It has completely vanished from Tegelem clay in Holland and at Lachvin in Russia (Sculthrope, 1967).The main distribution of *Eurayle* is Pakistan (Kashmir) eastward to India (Qaiser, 1993), In general, its distribution is extremely limited to tropical and subtropical regions of South-East and East Asia and is known to exist in Korea, Japan, China, Oudh, Dal Lake Kashmir, East Bengal (Blatter, 1927; Stewart, 1972 & Han, 1998). In China it has been cultivated in the Hainan and Taiwan islands for 3-4 millenia (Jha et al., 1991). Its distribution includes the islands of Taiwan (Formosa) and Kyusyu, Shikoku and Honsyu in Japan (Okada, 1935). The northern limit in Japan corresponds to about 38° 30'N on the Pacific coast and 37° 55' N on the Japan sea coast. It is also grown wild in Malaysia, Thailand, Philippines, Russia, North

America, Nepal, Haor basins of Kishoreganj, Maulvi Bazar and Sylhet districts and in some parts of Naogaon district of Bangladesh (Jha and Prasad 1993a and Md. Almujaddade *et. aL.*, 2008), Marala Headworks wetlands, North West side of Punjab, commonly growing along the water inlets on the left bank of River Chenab, facing Village Gondal, District Gujrat, Pakistan (Md. Ajaib *et. al*, 2010) and some parts of India. In India also Makhana has been growing wild in the temperate lakes of Kashmir as an ancient natural crop (CSIR, 1952). The deteriorating conditions of the lakes in Kashmir had diminished the number of plants too few in Dal and Manasbal lakes and a single plant in Nagin Lake (Kak, 1985). In India, it is distributed in Bihar, West Bengal, parts of Assam, Manipur, Tripura, Eastern Odisha, Madhya Pradesh, Rajasthan (Alwar) and Eastern Uttar Pradesh (Vermaand Jha,1999.Singh, 2003).

However, Mithila region (*holy land of Ma Vaidehi / Sita*) of North Bihar is the principal area of its present existence where it is extensively cultivated considered as a potential aquatic cash crop. Bihar accounts for more than 80 percent of total makhana production in the country and that makhana production takes place in 20 out of its 38 districts, mostly situated in the North of the state (Misra,1998). Makhana is also known as a crop of ponds, land depressions, ox-bow lakes, shallow swamps, ditches and fields rich in nutrients (Singh, 1992). Area under makhana cultivation is about 20,000 ha. in the state of Bihar, major Makhana producing districts include Darbhanga, Sitamarhi, Madhubani, Muzaffarpur and Champaran, Saharsa, Supaul, Madhepura, Araria, Kishanganj, Purnea and Katihar of Mithila and Koshi region [Choudhary and Patnaik (1985); Mishra *et al.*, 2003; Shanker *et al*. 2010 and Kumar *et al.*, 2011] .

AGRONOMICAL PRACTICES:

Makhana as a crop can be cultivated in any pond that is shallow and stagnant. However, localized expertise of makhana cultivation has cast doubts on its propagation beyond its traditional territory. According to Thakur (1978), Fox nut 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. The dead and abandoned courses form the stagnant channels, which are also utilised for cultivation of fish, deep water rice, Makhana and other aquatic eatables (Ahmad and Singh 1991, 1997; Datta Munshi et al. 1991, Dehadrai 1994; Jha 2000 etc.). The majority of these ponds are owned by the government and leases for short-term use are auctioned by the fishermen's cooperative society. However, a number of ponds are in private hands. Most of the cultivation is done by the Fisherman community (Mishra et al., 2003). Kumar *et al.* (2011) showed that the cultivation of makhana could be done in general agricultural fields having clayey soils which are being used for rice cultivation. Jha and Prasad (1996) was opined that 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 harvesting. The cultivation of this aquatic crop involves clearing of pond, broadcasting of seeds, thinning and gap-filling, plant protection, harvesting and collection of seed. Ponds under running cultivation do not require broadcasting as saplings are produced from the left-over seeds. 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 pregerminated 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 (Thakur, 1978& Jha, S.N. and Prasad,1996).Ex-situ culture studies of Euryale ferox Salisb. using fresh mature seeds were carried out in an arboretum. Production of fresh fruit has been estimated to be 3.05 t/ha (Md. Almujaddade *et. aL.*, 2008). Pramanik *et. al.*, (2013) reveal that seed yield of makhana increased significantly by different integrated nutrient management (INM) packages applied on the crop and fishes. The result exhibited highest yield with N4 (3 t FYM + 1 t neem oilcake + N : P2O5 : K2O @ 20 : 30 : 20 kg ha-1 + spraying of Zn (Chelamin) at 20, 40 and 60 DAT on makhana + fish-feed (plants and fishes both received a well-balanced organic and inorganic sources of plant nutrients along with fish-feed including zinc spray). 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 (S.N. and Prasad, 1996).

HARVESTING:

Time of harvesting is very important for maximum yield of any crop. Collect the Makhana seeds in late summer and early autumn. Collection of scattered Makhana seeds from bottom of pond 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 (locally known as *Ganj*). Collected seeds are thoroughly thrashed by feet to remove the membranous cover. Harvesting of seeds is strenuous and tedious job. The yield of seeds varies from 2.5-3.0 tones per hectare of pond (Thakur, 1978; Jha and Prasad, 1990; Md. Almujaddade *et. aL.*, 2008; Pramanik *et. al.*, 2013)

METHODS OF PROCESSING:

Processing of Makhana seeds is very tedious and still carried out by traditional methods due to lack of efficient processing technology. Presently, the efficiency of new machines is very low and cost of machines are too high. The benefit cost ratio of new machines is too low. The machines are not running hassle free. It is not complete automated processing plant. Too much electricity is consumed and also required more man powers for operating these machines. 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 57 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 edible part of makhana seed is *perisperm*. 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 polyethylene - lined gunny bags (Thakur, 1978 & Jha, S.N. and Prasad, 1990).

Raw Makhana Seeds m.c.37% (w.b.)
⇩
Cleaning & Washing-----Thin membrane, Traces mud snail
⇩
Sun drying m.c.31% (w.b.)
⇩
Storage
⇩
Sundrying 35 ^{o}C 225 min, m.c.25% (w.b.)
⇩
Grading of seed on Size 15-16 grades
⇩
Pre Heating 280 ^{o}C - 335 ^{o}C, 5.75 to 6 min m.c.20.8% (w.b.)
⇩
Tempering 45-60 hrs at ambient condition
⇩
Roasting 280 ^{o}C - 335 ^{o}C, 1.5 to 2.20 min m.c.10.98% (w.b.)
⇩
Poping
⇩

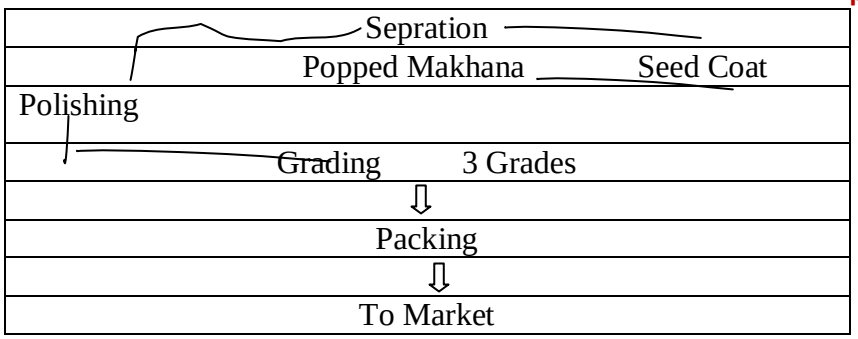

Fig.1. Flow sheet of Makhana seeds Processing:

NUTRIONAL VALUE:

Edible parts of seeds contain 12.8 % moisture, 9.7 % protein, 0.1 % fats, 0.5 % minerals, 76.9 % carbohydrate s, 1.4 mg/100g of iron and traces of carotene (CSIR, 1952). Fox nut (*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.Boyd (1968) and Jha (1968) were reported that 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. According to Boyd (1968) and Jha and Prasad(1990), 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. Makhana is superior to dry fruits such as almond, walnut, cashew nut and coconut in contents of sugar, proteins, ascorbic acid and phenol (Bilgrami *et al.*, 1983).Nath & Chakraborty (1985) was observed that 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. Jha *et al.*, (1991) was revealed that values relating to essential amino acid index (EAAI) and chemical score (CS) of makhana are close to that to fish. 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 plants and animal-based diets due to high EAAI and CS [Sikka *et al.*, (1979); Eggum and Duggal (1977) and Jha, V. (1987)]. According to Nath and Chakraborty (1985), 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.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 were investigated by Jha, *et al.*,(1991). According to Jha (1987), 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. Jha, *et al.*,(1991) The above values were lower when compared to soyabean, egg and human and cow milk (Jha, *et al.*,1991).Table 1,2 & 3

Table 1: Protein 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	5.84	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.*,(1991) 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.*,(1991).

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	1.56	-
Makhana		
Raw(Tripura sample)	1.9	7.6
Raw (Bihar sample)	1.84	6.3
Fried (Bihar sample)	1.99	4.74

Source : Jha, *et al.*,(1991).

Makhana is a good source of carbohydrate. Edible perisperm constitutes 80 per cent starch. Nath and Chakraborty (1985) revealed 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
Yield (%) from seed meal	52.5	n.d
Moisture (%)	14.4	13.5
Ash (%)	15	0.15
N (%) by kjedahl method	1.36	Nil
Protein (%) by amino acid analysis	7.32	Trace
Total carbohydrate (%)	77.33	86.85
Amylose (%),potentiometrically	n.d.	25.30
Amylopectin (%) with respect to amylose	n.d.	74.7

Source :Nath & Chakraborty (1985), 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 lengthby methylation	-	395	20
intrinsic viscosity [h](dl/g)	1.15	0.78	1.2

Source :Nath & Chakraborty (1985) 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 (1985) , n.d., not determined.

Dutta (1984) state that *Euryale ferox* is a store house of macro- and micro-nutrients. 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 (Belavady and Subramanian, 1959). 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) was investigated by (Dutta, 1984). According to Dutta, (1984), 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. Singh and Arora (1978) 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. 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 (CSIR, 1952). According to Singh, *et al.*, (1988), *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.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.

Table 7: Amino acids in the seeds of *Euryale ferox*

Amino acid	% of dry weight
Aspartic acid	0.33
Threonine	0.60
Glutamic acid	0.92
Alanine	0.46
Valine	0.82
Methionine	0.36
Isoleucine	1.07
Leucine	1.44
Tyrosine	0.83
Histidine	1.60
Lysine	0.88
Arginine	0.60

Source : Read (1946)

Thus, seeds of *E. ferox* during present investigation contained a total of 12 amino acids (Table 7).Das et al. (2006) reported cardioprotective properties of *E. ferox* and suggested that such cardioprotective properties may be linked with the ability of *E. ferox* to induce thioredoxin-related protein-32 (TRP32) and thioredoxin-1 (Trx-1) proteins and to scavenge reactive oxygen species (ROS). The seeds are also of great traditional medicinal value. Biochemical analysis of the seeds revealed 61% carbohydrate, 15.6% protein, 12.1% moisture, 7.6% fibre, 1.8% ash and 1.35% fat. The seeds were found to contain 12 amino acids, which are histidine, leucine, isoleucine, glutamic acid, lysine, tyrosine, valine, aspartic, threonine, alanine, methionine and arginine. It is also observed that the carbohydrate content of the E. ferox (61.2%) is higher than that of Spirulina (13 - 25%). (Md. Almujaddade *et. aL.*, 2008). Read (1946) reported biochemical composition of E. ferox and found to be composed of carbohydrate (75.7%), protein (9.9%), fat (0.3%), and ash (0.6%). In the present material protein content was 1.6 times higher while fat content was about 5 times higher than that reported by Read (1946).It is mainly cultivated as a source of starch and protein (Puste, 2004).Although the related works particularly on scientific culture of makhana as well as more details in analysis of seed quality is practically very less, however, some of works have been done on qualitative aspects of makhana seeds (Nadkarni 1970; Nath and Chakraborty 1985; Anonymous 1989; Jha and Prasad 1993). With number of uses, starch extracted from makhana, is used in textile industries. Because of its economic, social and religious importance, some early studies on its economics were made by Lakhmani (1978).Pramanik *et. al.*, (2013) reveal that seed yield as well as nutritional value of makhana seeds (starch, sugar, protein and minerals) vary significantly by different integrated nutrient management (INM) packages applied on the crop and fishes. The result exhibited highest value (75.04, 2.37, 9.45 and 0.52%) with N4 treatment (plants and fishes both received a well-balanced organic and inorganic sources of plant nutrients along with fish-feed including zinc spray).

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. According to these literatures, all the plant parts have tonic, astringent

and non-obstructing properties (Dragendroff, 1898).The leaves are effective against rheumatism which may be attributed to the presence of an alkaloid "drummine" (Sokolov,1952) and fusion of leaves was found to be effective against difficult parturition. Leaf ash cooked with fermented rice was found to have the capacity to restrain seminal gleets. Diseases of spleen, polyuria, spermatorrhoea, gonorrhoea, articular pains, micturition, and seminal loss are also treated with it. Stuart, (1911) & Kariyone and Kimura (1949) were reported the seeds to be effective in increasing the secretion of hormones. It acts as an expectorant and emetic (Nadkarni, 1976). Ethnomedicinal uses for weakness, spermatorrhoea, leucorrhoea, aphrodisiac, retard aging, as well as astringent, oxytocic and analgesic in action. The seeds are eaten raw or roasted (Han, 1998).Sharma (2005)observed 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, antidiuretic and roborant properties. Jha *et al.*, (1991) was noted that it is also utilized to overcome postnatal weaknesses in women. In case of men its aphrodisiac and spermatogenic potential is utilized. 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) (Hsu H, 1951). The seeds contain sufficient amount of vitamins so, used to treat beriberi, a disease caused by deficiency of Vitamin B1 (Ho *et al.*,1953). Quadrat-I-Khuda *et al*., (2000) 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.*, (2000) 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 (McGuffin, *et a.*, 1997).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 8: 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.

INDUSTRIAL IMPORTANCE:

Makhana is used as starch for coating on the quality fabrics like Benarsi sarees etc (Jha and Barat, 2003).

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