

Two promising under-utilized grains: A Review

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Underutilized grains are obtained from those plant species whose ability to safeguard food security, revenue generation, better human health and ecological sustainability have been under-exploited. There is a dire need to utilize these underutilized grains of plant species as they can contribute appreciably towards the improvement in overall human nourishment, stable environmental services, fighting hunger and offering medicinal and income generation options. In this review, two grains, viz. *gorgon nut* and *job's tears* have been discussed. Both of these grains possess antifungal, antibacterial and antioxidant activity and have high phytochemical content. Growth requirements of these grains are specific and distinct and their high nutritional content indicates their potential application as nutraceutical. The utilization of these species is limited because there is a lack of awareness, relevant capacity within the research community and the land they are grown on is increasingly under global and local pressures. Underutilized species have not attracted enough attention of policy makers because they cannot compete with major commodity crops, commanding larger economic interests. Timely investment and research into these species can save food for the next generations arriving on an already ailing earth.

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Underutilized grains are obtained from the plant species whose potential has not been fully realized. Such orphan or neglected crops are a part of a larger biodiversity which have been ignored for various agronomic, monetary, genetic, cultural and social reasons. Underutilized plant species have been found to ameliorate environmental sustainability and combating land degradation. The different products are utilized as indigenous medicines, animal fodder and raw material for construction purposes. They can diversify vulnerable livelihoods by providing better opportunities for improvement in family income¹. The global population is reliant for over 50% of the basic requirement of proteins and calories on just three cereal crops – maize, wheat and rice². Ethno-botanic surveys indicate that, worldwide, more than 7,000 plant species are cultivated or harvested from the wild, but on the other hand, only 150 crops are commercialized on a significant global scale³. Underutilized species find application in agro biodiversity and have enormous potential leading to economic improvement, deteriorating malnutrition caused due to lack of micronutrients thus establishing

food security in developing nations^{4,5}. Distribution, cultivation and their uses are not studied and seed supply system is either weak or not formal. Moreover, they are highly nutritious and have many medicinal properties. However, they have received very little attention from the researchers, farmers, policy makers, decision makers, technology providers and consumers. In recent years, the true potential of underutilized crops in terms of rural development has been partially realized⁶. The worth of indigenous biodiversity needs to be realized by the policy makers, funding agencies, scientific researchers and farmers for a better farming system, which would go a long way in future in curbing the risks of environmental and economic disasters.

Gorgon nut- 'Foxnut' or 'gorgon nut' (*Euryale ferox* Salisb.) belongs to the family Nymphaeaceae and is mostly cultivated due to its edible seeds which resemble popcorn. The edible seed consists of the popped kernel of the *gorgon nut* (*Euryale ferox* Salisb.), black and round hard seed coat (shell) which has a diameter of 4.5 to 15 mm. The plant produces starchy white seeds, and the seeds are edible⁷. *Euryale ferox* Salisb. is a seasonal or perennial giant, stemless, spiny water lily spiny hydrophyte. It has

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large, oblong and orbicular leaves, flat aquatic, leaves (submerged) which have a quilted texture and flowers which are reddish green on upper surface and purple on the lower surface (float on the water surface) rooted to the mucky bottom with tough fibrous roots⁸. It is also cultivated in different parts of China⁹. It prefers tropical and sub-tropical climate, temperature between 20-35°C, humidity between 50-90%, rainfall between 100-250 cm¹⁰. *Gorgon nut* is an aquatic weed growing in the stagnant fresh water pools (1-5 m deep) of the North and northeastern states of India. In North Bihar, the seed is consumed in popped form, but in Manipur, other parts (leaves and stalks) are consumed as vegetables. Its cultivation and harvesting is also distributed in West Bengal, Manipur, Orissa, Assam and Kashmir. Wild populations are also found in Nepal, Bangladesh, Korea, China, Japan, Russia and North America¹¹.

Chemical constituents

Gorgon nut possesses significant antioxidant activity associated with medical applications such as inhibition of proteinuria or diabetic nephropathy. A study has revealed the presence of the 3 new sesquiterpene lignans named euryalins and 16 other known compounds. The 3 glucosylsterols identified by high resolution NMR and MS are 24-methylcholest-5-enyl-3 beta-O-pyranoglucoside, 24-ethylcholest-5-enyl-3 beta-O-pyranoglucoside, and 24-ethylcholesta-5, 22E-dienyl-3 beta-O-pyranoglucoside¹². Two new cerebrosides and tocopherol trimers; and two known tocopherol trimers were also isolated from the seeds of *Euryale ferox* Salisb. These compounds showed cytotoxicity in the brine shrimp lethality bioassay¹³. Precipitation technique was used to fractionate starch, which revealed the average length of unit amylose and amylopectin chain to be 22 and 380 glucose units, respectively¹⁴. The total phenolic, flavonoid and flavonol content of water extract of *E. ferox* were found to be 28.16 ± 0.49 (μg catechin/mg), 3.28 ± 0.21 (μg rutin/mg) and 1.93 ± 0.02 (μg catechin/mg), respectively¹⁵.

Antioxidants

Euryale ferox Salisb. extracts show high levels of DPPH radical scavenging activity, Trolox-equivalent antioxidant capacity (TEAC), reducing power, SOD activity, CAT activity and inhibits lipid peroxidation, hence a potent antioxidant. Additionally, it promotes cell viability, protects

against H₂O₂-induced apoptosis and ameliorates the effects of various antioxidant enzymes^{9,15}.

Nutritional value

Gorgon nut is a storehouse of macro- and micro-nutrients. It is one of the most popularly consumed dry fruit owing to its low fat content and high nutritional value. The nutritional profile of popped kernels when estimated as (gm/100gm), show the values to be moisture: 12.8; carbohydrate: 76.9; proteins: 9.7; fat: 0.1; total minerals: 0.5; calcium: 0.02; phosphorus: 0.9; iron: 0.0014. The seeds contain edible perisperm constituting 80% starch. In spite of the fact that the protein content is less (10-12%), its higher amino acid indices (89-93%) and high arginine+lysine/ proline ratio makes it superior to most plant and animal based diets. The ratio of leucine and isoleucine is also high in *makhana*. *Gorgon nut*, whether raw or fried contains appreciable amounts of essential amino acids and contains no cholesterol¹⁶. The calorific value of raw seeds (362 kcal/100gm) and puffed seeds (328 kcal/100gm) are tantamount to the staple crops and other carbohydrate rich cereals like wheat and rice. The percentages of micro-nutrients are estimated to be 0.5% minerals, 0.02% calcium, 0.9% phosphorous and 0.0014% iron²². Potassium, sodium and zinc content in fruits of various sizes ranged from 159 - 240 mg/kg, 180 - 240 mg/kg and 42.9 - 66 mg/kg, respectively. The copper content is nearly 8.3 mg/kg. Various grades of fruits contain 105 - 678 mg/kg of iron, hence an indicator that it is a rich source of iron. The manganese content in *makhana* fruits lies between 25 - 35 mg/kg. *Gorgon nut* is investigated to possess a better nutritional profile when compared to dry fruits such as almond, walnut, cashew nut and coconut in contents of sugar, proteins, ascorbic acid and phenol¹¹.

Use as traditional medicine

Euryale ferox Salisb. has been a popular traditional medicine used for various therapeutic purposes¹⁷. Ayurveda (the Indian system of medicine) suggests *gorgon nut* to possess healing properties in *Tridosas* (the seminal Ayurvedic theory of diagnosing diseases on the basis of three principal defects of the body). It particularly describes *gorgon nut* to be effective in *Vata* (rheumatic disorders) and *Pitta* (bile disorders). *Euryale* seeds are used against dysmenorrhea and spermatogenic properties according to the Unani system of medicine. The principles of Chinese

medicine recommend its benefits in tonifying spleen and curb diarrhea, to strengthen the kidneys and control the essence, or jing; and to dispel dampness. It is known as “*Chien-Shih*” in China, an effective constituent of a traditional Chinese medicine “*Su-Shin*” which is a tonic that enhances growth in young children. The edible seeds also exhibit astringent, deobstruent, anti-rheumatic, anti-diuretic and roborant properties¹¹. The fiber in the *makhana* seeds aids the body to expel waste and blocks the accumulation of toxins¹⁶. It acts as an expectorant and emetic¹¹. The seeds are low in calories & fats, and high in fiber, therefore, beneficial to diabetic people. It helps to maintain blood pressure and alleviate numbness. Some of the curing properties of *gorgon nut* include inhibiting insomnia, palpitations and irritability, strengthening the heart, treating anaemia, restoring the normal functions of the spleen and kidneys. It also improves the quality and quantity of semen, therefore, serves as an aphrodisiac. It arouses libido and prevents chances of premature ejaculation. Besides these, it can also be helpful in reducing infertility in females¹⁸. *Euryale ferox* Salisb. is found to be effective in the treatment of pyoderma, hernia and leucorrhea¹⁷. *Gorgon nut* is a storehouse of powerful antioxidant bioactive compounds which hinder aging, an adverse effect caused by free radicals in the body and can reduce myocardial ischemic reperfusion injury¹⁹. The total extracts of *Euryale ferox* Salisb. stimulated humoral immunity to a greater extent than cell-mediated immunity²⁰. International associations like “The American Herbal Products Association” recommend *Euryale* seed consumption to be safe giving it class one rating¹¹.

Gorgon nut as food

The seeds are sold at market and used as a farinaceous food. Several ready-to-eat products are prepared using sorted and graded *Gorgon nut* as an ingredient. It is also used in preparation of various milk-based dishes such as *kheer* and pudding²¹. In Mithila culture, it is used as an auspicious ingredient in offerings to the Goddesses during festivals and preparing porridge/pudding called *kheer* of *makhana* or ‘*makhaanak kheer*’ or ‘*makhaanak payasam*’ and ‘*makhane ka rayta*’ (*makhana* yogurt blend). It is also used in worshipping ceremonies (*puja*, *hawan*) and during fast²². After frying the seeds are used as snacks as well as in the preparation of vegetable dishes and curries¹¹. Roasted and fried *Gorgon nuts* sprinkled with oil and spices are consumed as popular snacks.

Makhana along with *Paan* (betel leaf), *Maachh* (fish) is symbolic to Maithil culture²². Nutritious and easily digestible bread is prepared from the *Gorgon nut* seed flour²¹. The fruits of *Euryale ferox* Salisb. are also consumed in parts of Kashmir. In Manipur, the seeds are taken raw in a salad and chutney forms¹¹.

Harvesting and processing

Collection

Makhana harvesting is mostly done between 10 am to up to 3 pm. Four to five people together collect seeds from bottom, one at a time by fixing a bamboo pole, locally known as *Kaara* and transfer it to the crescent shaped container, locally known as *Gaanja*^{10,11}.

Cleaning and Storage

Gaanja containing the *makhana* seeds is shaken simultaneously such that the seeds become free of mud and wastes. This is followed by packaging of clean seeds. The clean seeds are transferred to a cylindrical container, called *Auka* or *Khanjhi*. In order to rub the seed coat off, *Auka* or *Khanjhi* is rolled over the ground and then stored overnight in the huts and sun-dried for 2-3 hrs^{10,11}.

Gradation

The processed seeds are graded according to the size of sieving devices, locally known as *Jharna*, a rectangular thin iron plate bounded by wooden frame. Gradation initially starts by using number 1 sieve, followed by sieve number 2-10 in order^{10,11}. It is followed by processing of white puff.

Pre-heating

In order to avoid the dry seeds from spoilage, frying or pre-heating is done in an aluminum pot heated above earthen hot oven at a temperature of 230-335°C for 5 minutes at a time (continuous and fast stirring using a bamboo or iron stick called *Larna*)^{10,11}.

Tempering

It is done by storing fried nuts in special containers for a period of 40-50 hrs. This leads to loosening of the kernels within the seed coat, thus increasing the yield of the popped seeds^{10,11}.

Roasting

200 gm of fried nuts are heated for a period of 2-3 minutes in aluminum or iron pot above earthen hot oven (at a temperature of 230 -335°C) to get,

ready to eat puff called as *Bhaja/Lava*. The fried nuts are then thrashed with a wooden hammer, called *Pitna/Thapa* which causes the fried nuts to expand by about 3 times and white puff is formed^{10,11}.

Popping, packaging and marketing

Finally, the black seed coat adhering to the puffs is completely removed by putting a haul of white puffs in a container and rubbing them with palm or against the bamboo baskets (polishing). The popped kernels are again graded according to whiteness and size of the puffs and stored in polythene-lined gunny bags^{10,11}.

Potential for food industry

Makhana has the potential to turn into an important cash-crop, but due to lack of awareness among the rural folks, unused marshy areas are left fallow, which can be used for cultivation of *makhana* and earn more revenue for the poor farmers. Due to the high nutritive value of *Gorgon nut*, food industries find it as a pertinent raw material for value-added products. But the overall cost (involving raw material collection and further marketing) soars up due to its volumetric expansion and high transportation cost to and from distant places⁷. Endeavour to curtail volume of *Gorgon nut* by different methods can prove beneficial to the industries. This can be achieved only by application of proper machinery and dissemination of traditional knowledge²¹.

Job's tears

Coix lacryma-jobi L. (Common names are *job's tears*, *adlay*, *mayuen*, *chinese pearl barley* and *hatomugi*) belongs to family Poaceae and usually grows 1-2 m tall. It is a tall grain bearing tropical plant native to Southeast Asia²⁵. Mainly two varieties of this species exist, the wild type *Coix lacryma-jobi* L. var. *stenocarpa* and var. *monilifer* and the cultivated type is *Coix lacryma-jobi* L. var. *ma-yuen*. The latter has a soft shell and is harvested as a cereal crop. The wild variety has harder shell pseudocarp, pearly white, oval in structures and is used in form of beads for making rosaries and necklaces²⁴. It has upright stems which are moderately thick and produces prop roots from their lower joints. Leaves are alternately arranged, 10-50 cm long and 2-5 cm wide, mostly hairless but margins have fine hairs and have a stem-clasping base^{25,26}. The plant was grown in the remote past as the minor cereal and fodder crop and has been referred as one of the staple crop in

North eastern region of India. They are also seen run wild in many parts. Various ethnic groups of Mongolian origin in South Asia grow *job's tears* cultigens of great antiquity. Tribal people grow various soft-shelled races which are the result of folk domestication, easy hulling and good kernel type. In Arunachal Pradesh India the plant is cultivated by *Adi* tribe. The grains are used for making local brew also. *Job's tears* is a native of Southeast Asia where it is mostly designated as a weed. It is counted as one of the serious weed in Polynesia, a principal weed in Italy and Korea, a common weed in Hawaii, Iran, Iraq, Japan, Australia, Cambodia, China, Fiji, Ghana, Hong Kong, India, Nepal, Pakistan, Peru, Philippines, South Africa, Thailand and United States²³.

Chemical constituents

The seeds of *job's tears* are composed of different fatty acids and proteins (predominantly prolamins) that influence human physiological and biochemical processes^{26, 27, 28, 29}. The seeds of *job's tears* also contain a number of benzoxazinones that exhibit anti-inflammatory activity^{30,31}. The unsaponifiable fraction of seeds of *job's tears* contains various beneficial compounds including squalene³² and phytosterols³³. Six compounds in *job's tears* which show antimutagenic properties have been identified as p-hydroxybenzaldehyde, vanillin, syringaldehyde, trans-coniferylaldehyde, sinapaldehyde, and coixol by spectroscopic methods. Trans-coniferylaldehyde is found to be cytoprotective in action against tert-butyl hydroperoxide-induced DNA double-strand breaks in cultured cells. It has chemo preventive potential derived from trans-coniferylaldehyde induced through the activation of kinase signals, including p38, ERK1/2, JNK, MEK1/2, and MSK1/2³⁴.

Antioxidants

Methanolic extracts of *job's tears* has been studied for antioxidant property and found to be moderate. The methanolic extract of its hull demonstrates greater antioxidant potential as compared to the other parts of its seeds³⁵. The analysis of total phenolic content (TPC) of black and white husk for whole as well as degermed flours shows that black husk has a greater (~8.055 mg GAE/g) phenolic content than the white husk (~7.19 mg GAE/g), both in whole grain and degermed flour. TPC is found to be higher than cereals like black rice (3.13 mg/gm), brown rice (0.54 mg/gm), barley (0.50 mg/gm). The DPPH scavenging activity did not show much of a difference

for the black and white cultivar of *job's tears* and hence comparable. However, the whole grain extract (~5.94%) exhibited lower activity in comparison to degermed flour (~7.04%). The reducing power assay for the two cultivars again showed similar results, but greater compared to cereals like brown rice, white rice, mungbean³⁶.

Nutritional value

Job's tears seed has a protein content of 15.4-18%, fat content 6.2 %, carbohydrate 65.3%, fiber 0.8%, ash 1.9%, moisture content 11.2% and contains 380 calories per 100gm. Mineral composition includes Calcium: 25mg; Phosphorus: 435mg; Iron: 5mg. No traces of magnesium, sodium, potassium and zinc are found. The vitamin composition includes Thiamine (B1): 0.28mg; Riboflavin (B2): 0.19mg; Niacin: 4.3mg³⁷.

Use as traditional medicine

According to Hartwell, the fruits are used in folk remedies for abdominal tumors, oesophageal, gastrointestinal, lung cancers, various tumors, as well as excrescences, warts, and whitlows⁶⁷. Studies have shown coixenolide has antitumor activity³⁸. *Job's tears* is a popular indigenous medicine mostly used for treating abscess, anodyne, anthrax, appendicitis, arthritis, beriberi, bronchitis, catarrh, diabetes, dysentery, dysuria, edema, fever, goitre, halitosis, headache, hydrothorax, metroxenia, phthisis, pleurisy, pneumonia, puerperium, rheumatism, small-pox, splenitis, strangury, tenesmus, and worms³⁹. *Coix* seeds possess numerous functions as they stimulate the function of spleen and lung, helps in drainage of pus, induce diuresis according to traditional Chinese medicine. Symptoms of diarrhea and arthritis are also treated by *Coix* seeds. The dosage amount of *Coix* seeds varies from 10-30 gm, which is dependent on the preparation of the medicine either in the form of decoction or as powder⁴⁰.

Job's tears as food

As compared to rice seeds, *job's tears* seeds are high in protein and fat content but low in mineral content. Cooked seeds give pleasant mild flavor, thus can be used in soups. It can also be used to make bread or any other product when grounded into the flour. The minced kernels are also used to make sweet dishes by frying or coating with sugar. It can also be eaten like a peanut by removing its coat with hand. Its hard seed coat makes the process of extraction

difficult, but the potential of this grain is very useful as it has higher protein to carbohydrate ratio. Parched seeds are used to make tea and roasted seeds are used to make coffee, while beers and wines are made from fermented/pounded grains by the *Garo*, *Karbi* and *Naga* tribes⁴¹.

Other uses

The hard bony fruits of *job's tears* occur in different colors and are used as ornaments for women such as rosaries, necklaces, draperies. However, once the seeds become ripe they turn soft and can no longer be utilized for making ornaments⁴². At the time of harvesting, when the plants are cut at the base, the stubble is in the field and it tillers again. The fresh green leaves grow, which find excellent application as fodder for cattle and at the same time preventing soil erosion and drying-out of the soil by sun⁴³. The dried seeds make an excellent forage and fodder for cattle with protein content higher than that of corn. The plant can be used as silage when the plant has dried completely, but most of the seed is ripe. Even the dry plant can be used as compost⁴².

Harvesting and processing

Collection

The seeds are sown in the months of May-June, following which the plant slowly matures (with greyish leaves) within a period of 4-6 months (depending upon cultivar and season) and becomes ready for harvesting. The plant laden with ripe grains is cut right at the base manually, by the farmers or hired workers using sharp sickle or knives. The cut plants are tied in bundles and carried away from the fields to the house of farmers where threshing is normally done^{43,44}.

Threshing

Bunches of cut plants stacked on the plot are threshed either manually or a mechanical thresher. Mostly farmers prefer manual threshing in which the plant is beaten against a hard element (e. g., a wooden bar, bamboo table or stone) or with a flail. It can also be threshed by being trodden by human or animal foot⁴².

Winnowing

In order to separate the trash (foreign seeds or kernels, chaff, stalk, empty grains, etc.) from the grains, winnowing is performed by either using a sieve or mechanized cleaning can be done using a cereal winnower⁴⁴.

Sundrying

The excess moisture from the grains is removed by spreading the grains on a dry surface such as mats, plastic sheet or floor mostly outside the farmer's hut to dry naturally under the sun⁴³.

Hulling

The hulls can be removed both manually, by a human pressing the grain over a sieve to remove the softer hulls or by mechanical dehuller. Manual hulling is better as it preserves the vitamin content of the grains and polishing is avoided⁴². The hulling percentage is 30-50%⁴³.

Storage

The final dehulled grains become ready for storage mostly for home consumption. The grains must be stored in air-tight plastic bags away from heat and light as the grains are subject to rancidity on being stored for a long period of time at room temperature. Under humid conditions, the storability of the grain is limited, but is better for whole than the husked grain⁴³.

Potential for food industry

Protein content in *job's tears* was found to be comparable to that of wheat and hulled grains can be used as rice is used for human utilization. Usage of jobs tears has an advantage over other cereals as it can be consumed directly without processing. Baked products like biscuits were appreciated by consumers made from *job's tears*⁴⁵.

Conclusion

Recently, the Food and Agriculture Organization (FAO) has been raising the point of under-nutrition in the developing countries. It also emphasizes that developed countries are stricken by the problem of over-nutrition and micronutrient deficiencies⁴⁶. As a result, there has been an increasing interest in consumption of plant based foods including traditional, unexplored crops which are perceived to possess health promoting benefits. Worldwide exploration of such crops will not only help to fulfill the daily nutritional requirements of the population of the world but also to develop an epidemiological link to find new nutraceuticals⁴⁷. This review highlights two underutilized grains which have all the nutritional potential required to become "superfood" in near future. *Gorgon nut* and *job's tears* have remained unexplored and used only for local consumption. But their excellent nutritional profile and medicinal

properties give reasons to further exploit and utilize them as staple crops. These grains can be good, economic alternatives to present staple crops whose production is declining due to environmental conditions. Scientific community and food industries should join hands to concentrate their activities on such better alternatives. Timely investment and research focused on these species can provide food security to the present population and future generations.

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