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REVIEW ARTICLE

# Pharmacognosy, physicochemistry, phytochemistry, pharmacological and ethnomedicinal profiles of *Bambusa arundinacea* (Retz.) Willd. seeds: a scoping review

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## Abstract

Bamboo-plants popularly known for their industrial uses are now been in attention for their therapeutical as well as food/nutraceutical utilities. The plant is intricately associated with humans from time immemorial. *Bambusa arundinacea* (Retz.)Willd. is an important species among the bamboo community. Research works on this species of bamboo have yielded crucial data regarding its phyto-constituents and biochemical parameters. Seeds of *B. arundinacea* are known to possess several therapeutical as well as nutritional properties and they are traditionally used by many tribal populations across the globe. The present review article is an attempt to critically analyse the comprehensive information from the research works carried out on pharmacognostical and physicochemical profiles, to evaluate the phytochemical , pharmacological and ethnomedicinal properties of the seeds of *B. arundinacea.* This attempt of review revealed the characteristic pharmacognostical as well as physicochemical features possessed by these seeds. The phytochemical analysis revealed vital information regarding the bio-constituents present in the seeds of *B. arundinacea* which implies their possible therapeutic potential. The bioactivities of some constituents present in the seeds can ensure the possibility of utilizating these seeds in the manufacturing of medicines, in future. Though the seeds are in use as food and medicine by several tribes since ancient times, very few researches were done on their bio-ingredients and their activities. Therefore, the studies in future should be oriented to further explain the biological activities of the bi constituents present in the seeds of *B. arundinacea*.

## Keywords

*Bambusa arundinacea*; bamboo rice; bamboo seeds; ethno-medicine; *Moongil arisi;* phytochemistry

## Introduction

Herbal medicines have proved their utility and importance in the healthcare systems in practice across the globe. A plant exhibits various biological activities depending on the part used such as leaves, flowers, fruits, barks, roots and seeds as they contain different functional elements(1). Bamboos are perennial grasses belonging to the subfamily Bambusoideae of the grass family Poaceae. Research studies conducted on bamboo have proved its immense potential as a medicinal plant. Abundant references regarding therapeutic properties of bamboo can also be seen in traditional systems of medicine like Ayurveda, Chinese medicine and Unani (2, 3). Several scientific

studies have obtained the evidences about the therapeutic potentials of many bamboo species which were being used since ancient times (4).

Bamboo plants are intricately associated with humans and have contributed a lot to human civilization since centuries. They are also of enormous economic importance with their uses in a wide arena like food, fuel, paper pulp, scaffolding, construction of houses, and making of many household articles of everyday use. Though bamboos are found growing worldwide, these plants are seen abundantly in India, Sri Lanka, China, Japan, Korea, Asia-Pacific region and East Asia. India, having nearly about ten million hectares of bamboo-forests, is one among the leader countries in the world in the production of bamboos (5). Total number of wild and cultivated species of bamboo ranges between one hundred to one hundred and fifty in India (6). The species, *Bambusa arundinacea* (Retz.) Willd., locally known as *Bamboo* or *Bans* is normally known for their industrial uses but nowadays the nutraceutical profile of this plant is also getting much more attention from global pharamaceutical industry (7). Several studies on this species of bamboo have yielded crucial data regarding its phyto-constituents and biochemical parameters. Parts of *B. Arundinacea* that are being used traditionally in the treatment of various ailments include its sap, leaves, shoots, *Bamboo-manna* (*Tabasheer*/*Banshlochan*) and seeds. 'Bamboo rice' is milled from bamboo seeds and it is rich in nutrients and traditionally used as chief food grain by many tribal populations across the globe. The present review is an attempt to explore the comprehensive information on pharmacognostical and physicochemical profiles, phytochemistry, pharmacological properties and ethnomedicinal uses of the seeds of *B. arundinacea.*

Published literature on *B. Arundinacea* was strategically searched through various platforms to collect the optimum available literature. Electronic databases such as PubMed, Google scholar, AYUSH Research portal, AYUSHDHARA, J-GATE, Research Gate and Preprints were searched. Relevant research papers and review articles were short listed. This list included published as well as unpublished researches on pharmacognosy, physicochemistry, phytochemistry, pharmacology and ethno-medicinal properties carried out on the seeds of *B. Arundinacea.* Information was rigorously retrieved, critically analysed and systematically summarized in the framing the present article.

## General characteristics and distribution

*B. arundinacea* is an important species of bamboo extensively used as a renewable natural resource and thus it is being planted extensively, both as plantations and in agroforestry across India (8,9). This is the commonest bamboo occurring in the southern part of India and is known as *Moongil* in Tamil language. It reaches the height of 8-30 m and has a diameter up to 18 cm while inter-node length ranges up to 45 cm. The plant has two structures; the rhizome and the culm. The stem which remains underground is called rhizome from which several culms emerge from the ground. These culms attain their full diameter and height in a single growing season which generally lasts for 3-4 months. Most of the woody material in bamboo comes from this portion(10). Colour of culms is green initially which later turns into a straw yellow colour. Thorns and large yellow culm sheaths are the characteristic features of *B.arundinacea* (Fig. 1a). Scientific classification of this species is given below (11,12) -

Kingdom- Plantae

Phylum- Angiosperms

Subphylum- Monocotyledons

Order- Poales (Graminales)

Family- Poaceae (Graminae)

Sub Family- Bambusoideae

Genus- *Bambusa*

Species- *arundinacea*

Masses of seeds which are suspended from the ends of the branches can be seen in flowering of *B. Arundinacea* (Fig. 1b-c). In general, bamboo flowers both gregariously and sporadically. Different bamboo species exhibit distinctive flowering and seed characteristics which are helpful in their identification . General observation denotes that size of seeds is smaller in large-sized bamboos when compared to small sized bamboos (13). In view of conservation, *ex-situ* conservation using seeds has been the easiest and cheapest method for bamboos. Only difficulty in this method was the short viability period of bamboo seeds as the seeds start to lose their germination vigour over time. The viability period of bamboo seeds varies from species to species. In *Bambusa tulda* Roxb., it ranges from 30 to 35 days while *Dendrocalamus longispathus* (Kurz) Kurz and *B. arundinacea,* the viability period is reported to be 55 and 65 days respectively (14).

Species *B. arundinacea* is seen dispersed all through the clammy places in India up to a height of 1250 m, especially close to waterway banks. It is found ascending upto 1100 m on the Nilgiris in Central and South India and is also cultivated in many places in North-East India and Bengal (15-18). This species also occurs in Sri Lanka, Malaya, Peru and Myanmar (19-21).

## Pharmacognostical profile

Studies conducted on pharmacognostical profile of *B. arundinacea* seed revealed striking macroscopic, microscopic and powder microscopic characteristics which are helpful as a diagnostic tool for its correct identification (22).

### *Macroscopic characteristics*

The morphological term denoting the fruit of *B. arundinacea* is caryopsis which is 5-8 mm long and oblong in shape. It is covered with a thick seed coat with a groove on one side (Fig. 1d). A basal bowl-shaped stalk called rachilla is there in which two perianth lobes called lemma and palea are present. The bamboo rice or seed is elliptically oblong, smooth and brown in colour which is enclosed within the lemma and palea (Fig. 2a-c). On one side of the grain, a longitudinal groove is seen (Fig. 2d).

### *Microscopic characteristics*

On microscopic examination, an embryo is seen on lower lateral part of grain surrounded by the starchy endosperm. Folded cotyledons appearing as thin curved leaf like structures are also seen enclosing the embryo proper (Fig. 3a). A bowl-shaped structure called *rachilla* is composed of lemma and palea which encloses the grain (Fig. 3b).Transverse section of the grain shows three layers- the epidermis, hypodermis and endodermis. Epidermis is a thick-walled layer of epidermal cells while hypodermis and endodermis are composed of large, compact square-shaped cells (Fig. 3c). Inner to the cell layers is the endosperm in which dense disassociated starch grains are present.


**Fig. 1**.Morphological characteristics a) *B.arundinacea* in its natural habitat; b & c) Flowering-fruiting; d) Husked grains

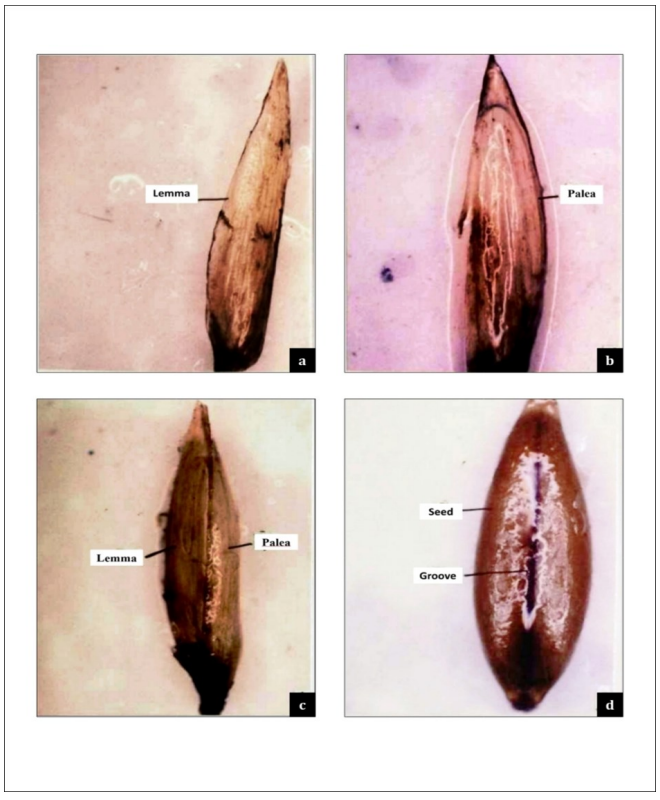


**Fig. 2.** Macroscopic characteristics a)Lemma; b) Palea; c) Caryopsis with lemma and palea enclosing the grain; d) The grain in surface view with longitudinal groove

### *Powder microscopy*

The powder microscopy shows small pieces of epidermal cells of the perianth membranes of the grains. From the surface view, compactly arranged thick

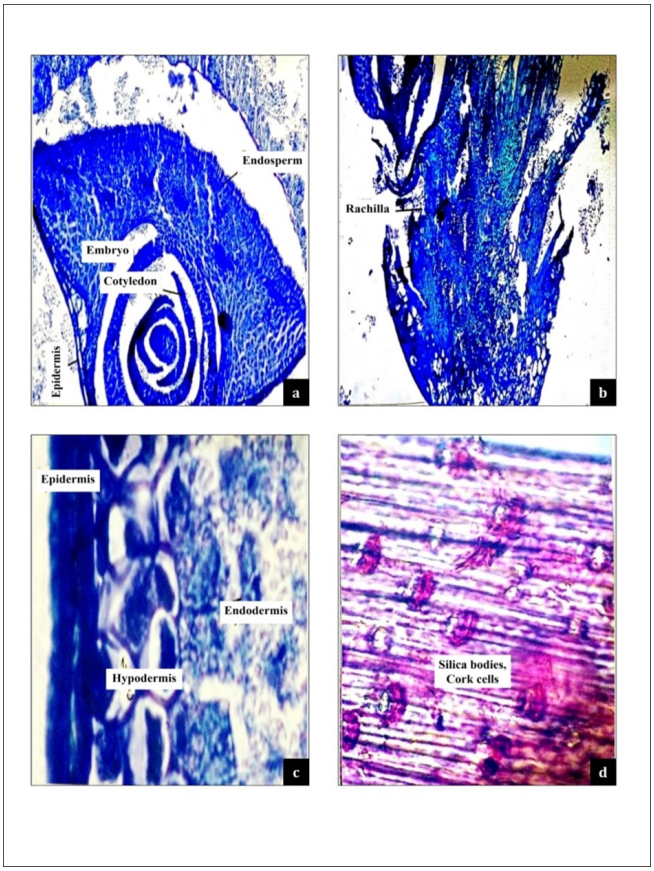


**Fig. 3**. Microscopic characteristics a) Embryo located within the embryonic chamber of the grain; b) Rachilla bearing perianth members; c) Surface view of the perianth with silica bodies and cork cells; d) L.S. of seed showing the seed coat cell layers

-walled narrow fibers are seen in perianth membranes. Diffusely distributed pairs of silica bodies and cork cells can also be seen on the surface. Silica bodies are white and transparent while cork cells are darkly striated (Fig. 3d). Trichomes that are thick walled in nature, triangular-conical in shape with pointed ends and curved echinate spines are also seen scattered. (Fig. 4a). Starch grains which are of simple type, spherical or square in shape are seen abundant in the powder (Fig. 4b). Long dense trichomes which are thick walled and lignified and directed towards the tip are also seen along the margins of lemma and palea. Similar types of trichomes are also seen along the margin of the rachilla (Fig. 4c-d). Pointed fibers which are long, narrow and thick walled are also present in the powder. Thick

lignified walls and narrow lumen are the characteristics of these fibers (Fig. 4e). Branchy sclereids, polygonal or rectangular in shape are seen abundantly in the powder. Elongated cylindrical sclereids also can be seen (Fig. 4f).

## Physicochemical profile

Analytical studies carried out in order to establish the physical and physicochemical properties of

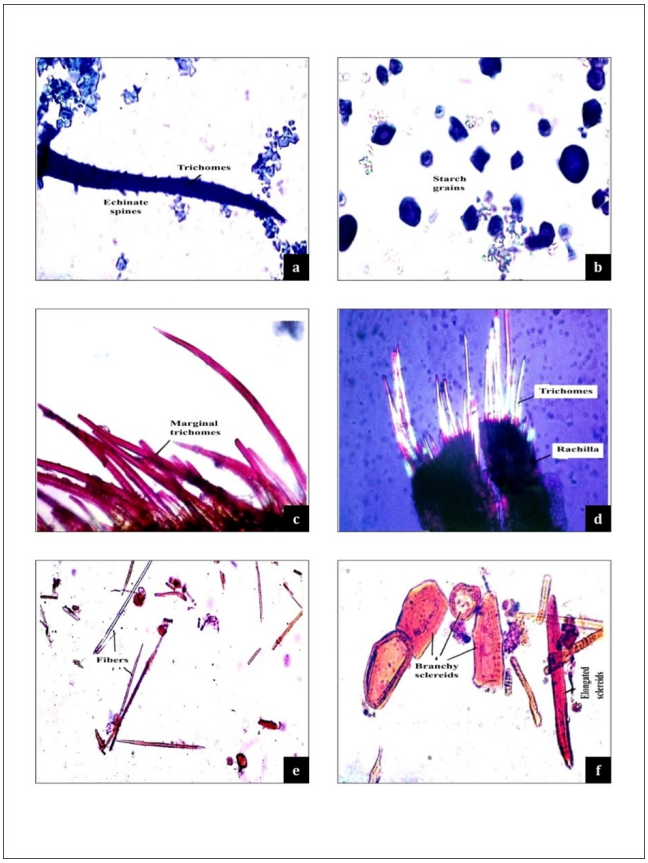


**Fig. 4.** Powder microscopy a) Epidermal trichomes with echinate spines; b) Starch grains stained with iodine; c) Marginal trichomes on the perianth; d) Trichomes along the outer margin of the rachilla as seen under polarized light; e) Fibers in the perianth; f) Sclereids of different types

*B. arundinacea* seeds revealed several characteristic features (23). The seed resembles like wheat in appearance naturally while the dehusked and milled seed *i.e.,* bamboo rice appears like milled and polished rice of *Jeeraga Sala* variety. Physical properties of dehusked and milled seeds are shown in table 1. The weight of 1000 grains was high in the case of dehusked grains, as it contains bran along with the endosperm. However, as expected, the weight of the milled grains was reduced, as it was made free of aleurone, pericarp and the seed coat layers, which in combination form the bran, where about 10.7% bran was removed while polishing in the Minghetti polisher.

Physicochemical profile of *B. arundinacea* seeds revealed moisture content as 12.5% in both dehusked (dehusking done by hand pounding with wooden pestle and mortar) and milled seeds. The equilibrium moisture content on soaking at room temperature (EMC-S at RT) of un-dehusked bamboo seeds was around 34% which was high by about 1.2% compared

**Table 1**: Physical properties of *B. arundinacea* seeds

| Parameter | Dehusked seed | Milled seed |
|---|---|---|
| Grain weight* (mg) | 12.9 | 11.5 |
| Length (mm) | 5.9 | 5.2 |
| Thickness (mm) | 2.1 | 1.4 |

*Based on 1000 kernels weight

to the dehusked seeds. A combination of lemma and palea that make up for the husk and that consist of hemicelluloses that can absorb moisture significantly compared to the dehusked seeds may account for this difference. In the case of milled bamboo seeds, the EMC-S was around 31% which was mainly because of starch granules or starch molecules along with the cell wall material and protein bodies in the grain. This shows a peculiar gradation of EMC-S values from the un-dehusked to milled grains.

The fat content in the dehusked bamboo seed was around 1% which is 50 to 60% less than that of ordinary dehusked brown rice in which fat content varies from 2 to 3%. The fat content of about 0.5% retained in the milled bamboo seed suggests that only up to about 50% of fat is present in the milled seed. At two-minute polishing, the bran obtained being pure, the fat content was relatively high (6.96%) and at five-minute polishing the bran being mixed with starch from the endosperm, the fat content was, as expected, down to 5.98%.

Starch and proteins are the main components of normal brown rice and also of bamboo-seeds. Starch in

**Table 2**: Physico-chemical properties of B.arundinacea seeds

| Parameter | Dehusked seed | Milled seed |
|---|---|---|
| Moisture (%) | 12.5 | 12.5 |
| Equilibrium moisture content(%) | 33.60[@]<br>32.40 | 31.20<br>0.46 |
| Fat (%) | 1.0 | 6.96*<br>5.98** |
| Protein (%) | 11.2 | 9.6 |
| Starch content (%) | - | 80.80 |
| Amylose content (%) | - | 27.3 |

*Fat content of the bran obtained after two minutes of polishing; **Fat content of the bran obtained after five minutes of polishing; [@]Value for the un-dehusked grains.

these, includes amylose and amylopectin. Starch accounts for 80-85%, protein accounts for 6-8% while average amylose content is found to be 17.39% in the chemical composition of brown rice (24). In this particular study, protein content in the bamboo-seed was found to be very high compared to varieties of normal brown rice. Depending on the degree of removal of the bran, the protein content in the milled seed varied as expected. The dehusked bamboo-seeds showed a protein content of around 11% which on milling reduced to 9.6%, indicating the loss of protein through the bran layers. The total starch content was

80.8% while the amylose content in the bamboo-seed flour was found to be 27.3%. It may be recalled that in normal rice the amylose content varies from less than 5% to up to a value in excess of 26%, the former being named as waxy rice and the later as high amylose rice (Table 2).

## Phytochemistry

Phytochemical analysis studies of *B. arundinacea* seeds revealed several phytoconstituents.t. Qualitative phytochemical tests were carried out on the aqueous and alcoholic extracts and powdered samples using standard procedures described by Sofowora (1993), Trease and Evans (1989), Harborne (1973) and Obadoni *et al* (2001) (25, 26). The phytochemical profile of *B. Arundinacea* seeds illustrating the status of various phytoconstituents is depicted in table 3.

Phytochemical analysis of *B. a rundinacea* seed extract showed the presence of elements like phenols, flavonoids, tannins, phlobatannins, cardiac glycosides, reducing sugar, quinines, sterols, carbohydrates and amino acids while the presence of alkaloids, saponins, terpenoids and anthraquinines could not be established in the sample. The phenolic compounds or phenols are one of the largest and most ubiquitous groups of plant metabolites (27). Many pharmacological properties such as anti-aging, anti-carcinogen, anti-inflammation, anti-atherosclerosis, cardiovascular protection and improvement of endothelial function, as well as inhibition of angiogenesis and cell proliferation activities can be attributed to these compounds (28). Antioxidant properties of medicinal plants rich in phenolic compounds have been established by many research trials conducted on such plants. (29, 30). Also, phenolic compounds such as phenolic acids, flavonoids, tocopherols etc., are the rich source of natural antioxidants (31). Flavanoids and tannins have proven their antimicrobial properties against wide array of micro-organisms *in-vitro*. Probable reason for this may be the ability of these compounds to complex with extracellular and soluble proteins and to complex with bacterial cell wall. Researchers have also discovered that flavonoids are hydroxylated phenolic substances known to be synthesized by plants in response to microbial infection and tannins have the capacity to bind with proline rich protein and interfere with protein synthesis in microbes (32). The presence of antioxidants, phenolic compounds add to its strong anticancer quality also (33-35). Phlobatannins, another phyto-constituents in seeds are known for their anti-inflammatory and analgesic effects along with wound healing properties. Cardiac glycosides are used for ulcer and diabetic treatments (36, 37). Thus, it becomes evident that the seed extracts of *B. arundinacea* possess several therapeutic properties and can be researched further to be a source for the drugs requiring potent anti-microbial and antioxidant activities.

**Table 3:** Phytochemical study of *B. arundinacea* seed extract

| Sr. No. | Phytoconstituents | *B. arundinacea*seed extract |
|---|---|---|
| 1 | Flavonoids | + |
| 2 | Tannins | + |
| 3 | Phlobatannins | + |
| 4 | Cardiac glycosides | + |
| 5 | Reducing sugar | + |
| 6 | Phenols | + |
| 7 | Quinines | + |
| 8 | Sterols | + |
| 9 | Carbohydrates | + |
| 10 | Amino acids | + |
| 11 | Alkaloids | - |
| 12 | Saponins | - |
| 13 | Terpenoids | - |
| 14 | Anthraquinines | - |

In addition to this, *B. arundinacea* seeds contain essential amino acids like histidine, leucine, isoleucine, lysine, methionine, threonine and valine as well as conditionally essential amino acids like arginine, cysteine and tyrosine (Table 4)(38-40). These amino acids are necessary for normal metabolism and growth and development of various tissues in human body.

The quantitative percentage compositions of some of the micro-nutrients in husked bamboo-seeds are enumerated in table 5 (41). *B. arundinacea* seeds are well enriched with mineral elements like calcium, phosphorus and iron. In human physiology, mineral salts of calcium and phosphorus are responsible for regulatory functions including neuromuscular transmission, blood clotting, oxygen transport and enzymatic activity as well as for structural functions involving the skeleton and soft tissues. Iron, as a constituent of haemoglobin and myoglobin, plays a vital role in the transport of oxygen. *B. Arundinacea* seeds also contain vitamins like Thiamine (B1), Riboflavin (B2), Niacin (B3) and carotene (precursor of vitamin A). Chief proteins observed in the seeds in fractionation experiments were glutelins with isoelectric point at *p*H 4.6. Chromatography conducted on two-dimensional paper revealed the presence of nearly all the essential amino acids in bamboo-seeds (42).

**Table 4:** Amino acids present in *B.arundinacea* seed extract

| Sr. No. | Amino acids | *B. arundinacea* seed extract |
|---|---|---|
| 1 | Histidine | + |
| 2 | Leucine | + |
| 3 | Isoleucine | + |
| 4 | Lysine | + |
| 5 | Methionine | + |
| 6 | Threonine | + |
| 7 | Valine | + |
| 8 | Arginine | + |
| 9 | Cysteine | + |
| 10 | Tyrosine | + |

## Pharmacological properties

Avery few studies have been carried out on pharmacological activities of the *B. arundinacea* seeds. In one of the experimental trials conducted, seeds were

**Table 5:** Quantitative percentage compositions of micro-nutrients in husked seeds of *B.arundinacea*

| Sr. No. | Micro-nutrients | Husked seeds of *B. arundinacea* |
|---|---|---|
| 1 | Calcium (macro-mineral) | 25 mg% |
| 2 | Phosphorus (macro-mineral) | 218 mg % |
| 3 | Iron (micro-mineral) | 9.2 mg % |
| 4 | Thiamine (Vit. B1) | 0.1 mg% (33.3 IU) |
| 5 | Riboflavin (Vit. B2) | 36.3 µg% |
| 6 | Niacin (Vit. B3) | 2.03 mg% |
| 7 | Carotene (precursor of Vit. A) | 12.0µg % (20 IU of Vit. A) |

evaluated for their blood glucose lowering effect using glibenclamide as a standard comparator. Alloxan induced diabetic rats were subjected to aqueous ethanolic solvent extracts of seeds and compared with standard. Significant reduction in blood glucose along with safety and efficacy was observed in the experiments conducted on rats using aqueous ethanolic extracts of bamboo seeds. The study was concluded with the finding that the *B. Arundinacea* seeds possess statistically significant anti-diabetic activity in comparison to the standard glibenclamide (43).

### Ethnomedicinal uses

In South-East Asia, bamboo-seeds are a popular ingredient in the local cuisine. In India, seeds are traditionally used as food by several tribal communities like *Kani*-tribes of Southern Western Ghats of Kanyakumari district in Tamil Nadu. According to general beliefs of the *Kani*-tribe, seeds of *B. arundinacea* increase the fertility and reproducing capacity in humans. Hence seeds of this species are always in a great demand from pharmaceutical industries as they use these seeds in the manufacturing of anti-infertility drugs(44). There is a need to conduct more studies to evaluate the fertility enhancing effects of the seeds in order to recognise its therapeutic potential in the management of infertility.

These tribals call the grains of this bamboo as *Moongil arisi* which means bamboo rice in Tamil language. They follow a traditional method for the storage of *Moongil arisi* in which the collected seeds are sun-dried first. *Kulukkai* is the term used for the big earthen pots used to store the bamboo rice for longer durations. Leaves of *Pongamia pinnata* Vent. and *Azadirachta indica* A. Juss. are mixed with the bamboo rice so as to prevent spoiling due to bugs and other insects. The opening of the storage earthen pot is sealed with the mixture of cow dung and mud. Tribals sell the surplus seeds in the nearby urban areas and markets. Some are the regular vendors of bamboo seeds to the local offices of state forest department(41, 45). Thus, bamboo seeds harvesting has helped a lot in empowering the economy of the tribal and rural population.

Seeds are also traditionally known to be beneficial in the conditions like strangury and abnormal urinary discharges (38). Other uses by the tribals include use of seeds in the treatment of fractures. For this bamboo seeds along with its terminal buds and young leaves are grounded together with *Aloe vera* pulp and turmeric. The obtained paste is used for external application on the fractured sites for about two weeks duration which leads to easy healing and speedy joining of bones (46).

Results obtained from the phytochemical and nutritional analysis, clearly indicate that *B. Arundinacea* seeds have high nutritional value than that of ordinary rice. Looking at the protein content, bamboo-seeds are seen equivalent to wheat and exceeds the protein content in normal rice. Some historical evidences are there mentioning the fact that bamboo seeds were the only source for living for thousands of people in times of scarcity in the past (47). Present days studies also put *B. Arundinacea* seeds ahead of wheat and rice in terms of overall nutritive value.

## Conclusion

In the present study, several relevant scientific works were gathered and reviewed in order to provide the information related to pharmacognostical and physicochemical profiles, phytochemistry, pharmacological properties and ethnomedicinal uses of *B. arundinacea* seeds. The review showed that seeds of *B. arundinacea* possess several characteristic identifying features in their pharmacognostical as well as physicochemical profiles. Phytochemical analysis exhibited vital information regarding the bio-constitutents present in the seeds which implies their possible therapeutic potential. The bioactivities of some constituents present in the seeds can ensure a likely utilization of the seeds in the manufacturing of medicines in future. Though the seeds are in use as food and also as medicine by several tribes since ancient times, very few researches on bio-ingredients along with their actions are available for seeds of *B. arundinacea*. Therefore, studies in future should be oriented to further explain the biological activities of bio-constituents present in the seeds. Moreover, well-designed RCTs should be conducted to support its therapeutic use.

## Authors contributions

SP participated in data search, wrote the original draft and served as a corresponding author. DS and SP contributed to conception and designing of article and reviewed the

original draft. AB and SP interpreted the data, reviewed and edited the original draft critically. All the authors have read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** The authors declare that they have no conflicts of interest

**Ethical issues:** None.

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