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RESEARCH ARTICLE

# Unlocking the potential: A comprehensive study of nutritional, phytochemical antioxidant and antibacterial activity of selected underutilized seeds

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## Abstract

Tremendous changes have happened in the food choices and dietary practices globally and in the current scenario, where health concerns are on the rise and sustainability is a pressing issue, adopting a healthy, seed-based diet offers a range of benefits. Incorporating diverse seeds into our daily diets is a promising solution to improve individual health outcomes foster environmental sustainability and strengthen local economies. Underutilized seeds refer to seeds from plants that are not widely cultivated or consumed but have significant nutritional and economic potential. Research studies on these seeds are gaining traction, as they provide insights into their nutritional significance, potential health effects and environmental sustainability. Seed-based diets focusing on underutilized seeds represent a sustainable nutrition, ecology and cultural preservation approach. We can create resilient food systems that honor tradition and innovation by promoting the importance of underutilized seeds and empowering local communities to cultivate and consume them. Many underutilized seeds are integral to traditional cuisines and cultural identities and preserving these crops helps maintain cultural heritage and culinary diversity. The study revealed that the six selected underutilized seeds possess significant nutritional potential. Phytochemical, antioxidant and antibacterial assessments further highlighted their value as healthy dietary alternatives. The findings support the inclusion of these seeds in daily diets and emphasize the need to promote their cultivation, production and processing and building awareness among people for better nutrition at an affordable cost.

**Keywords:** alkaloids; antioxidant; nutritional; phenol content; seeds; underutilized

## Introduction

In an era where global food systems are increasingly dominated by a limited number of crops, preserving and promoting underutilized seeds and seed-based recipes have become critical to sustaining biodiversity and regional food security. Specific regions are known for their seed heritage and offer a wealth of nutritional, cultural and ecological benefits. Underutilized seeds refer to the seeds of crops that have not been fully exploited for their potential benefits in agriculture, nutrition and ecosystem services. These seeds often come from indigenous plants or traditional varieties that are resilient, nutrient-rich and adapted to local conditions. Due to mainstream agricultural practices like high-yield, industrial crops, farming and consumption practices of these seeds are sidelined. This research paper explores the potential use of underutilized seeds as a contributing source for sustainable agricultural practices, preserving natural nutritional resources and fostering regional economic development. Documenting and promoting the use of these seeds for consumption as a regional plant food resource thus creates pathways to enhance food diversity, reduce dependency on monocultures and support local farmers and communities. Previous studies report that the significance of various underutilized legume seeds, their nutritional profiles and their potential health benefits, including antioxidant properties (1). The present study aimed to identify, analyse the nutritional and biochemical properties of the selected locally available underutilized seeds for broader goals like biodiversity preservation, food security and sustainable agricultural practices of local communities. The major objectives included -the identification of locally available underutilized seeds and the assessment nutritive value of selected seeds. Estimation of phytochemical, antioxidant and antibacterial properties of underutilized seeds constituted the second major objective of the study. The second major objective of the study is the estimation of phytochemical, antioxidant and antibacterial properties in underutilized seeds. This research is vital for promoting agrobiodiversity, food security and climate-resilient agriculture in regions that rely heavily on a few staple crops. Many studies reported (2, 3) the importance of studying these properties in underutilized crops. These seeds, often derived from indigenous or traditional plant varieties, offer superior nutritional profiles, adaptability to local ecosystems and ecological benefits (4). However, industrial agricultural systems continue to marginalize them, risking the erosion of cultural heritage and genetic diversity. This study is imperative to explore, document and evaluate underutilized seeds' nutritional and bioactive properties to revitalize sustainable food systems and empower local communities.

## Materials and Methods

The present study was carried out in two distinct phases to evaluate the nutritional and bioactive potential of locally available underutilized edible seeds.

### Phase I: Identification and nutritional assessment of underutilized seeds

The initial phase focused on identifying six underutilized edible seed varieties based on regional availability and traditional knowledge. The selected seeds were evaluated for their nutritional composition. Parameters such as moisture, protein, fat, carbohydrate, fiber and ash content were assessed using standardized methods outlined in the Nutritive value of Indian foods published by the Indian Council of Medical Research (ICMR) (5). The data obtained were used to compare the selected seeds' nutritive values and highlight their potential as alternative nutritional resources.

### Phase II: Extraction and biochemical analysis

During the study's second phase, seeds were collected, washed and homogenized using distilled water and methanol to prepare aqueous and organic extracts, respectively. The extracts were then centrifuged at 2000 rpm for 10 min and the supernatant was used for further study. Methanolic extracts were used for the determination of total antioxidant activity, total phenol content, for the detection of alkaloids and antibacterial analysis.

The antioxidant activity was determined using radical scavenging activity of diphenyl picryl hydrazyl (DPPH) (5). Concentration of extracts of 0.05, 0.1, 0.5, 1.0, 2.0 and 5 mg/mL in methanol was prepared. Vitamin C was used as the standard. The test solution consisted of 1 mL of the extract, 3 mL of methanol and 0.5mL of 1mg of DPPH in methanol. The blank comprises of the above solution devoid of extract. The optical density of the test solution and blank were measured at 517 nm with a UV-Vis spectrophotometer (UVmini1240 model, Shimadzu, Japan). The radical scavenging activity was calculated using the formula,

Percentage of inhibition = ((Ab-Aa)/Ab) x 100,

Where,

Ab - absorption of the blank sample

Aa- absorption of the extract.

The total phenol content was estimated by the Folin Ciocalteu assay (6). To 0.1 mL of sample extract 3 mL of distilled water and 0.5 mL of Folin Ciocalteu reagent were added. After 3 min 2 mL of 20 % sodium carbonate was added and mixed thoroughly. The tubes were kept in boiling water bath for 1 min. The absorption was measured at 650 nm in a spectrophotometer against the reagent blank after the tubes were cooled. The standard graphs were plotted using the different concentration of gallic acid (0.01 - 0.1 mm) and total phenolic content was expressed as mg of gallic acid equivalents per gram of extracts.

The presence of alkaloids was detected using Mayer's reagent (7, 8)-1 mL of Mayer's reagent was added to 5 mL of seed extract and the presence of alkaloids was confirmed by the formation of a cream precipitate.

## Results and Discussion

### Phase 1: Identification of underutilized seeds and nutritive value assessment

An extensive literature survey and market survey were done to identify the underutilized seeds. Six underutilized seeds that are locally available and not much included as a dietary source were collected for the analysis, recipe development and documentation. All the selected seeds were less commonly consumed by people, but at the same time, locally available in plenty. People were mostly unaware of its nutritional value and therefore did not include it in their daily diet to enhance overall diet quality. The details of the seeds selected are given in Table 1.

### Nutritive value of selected underutilized seeds and their comparison

The comparative nutritional profiling of six underutilized seeds-sunflower, watermelon, pumpkin, tamarind, pomegranate and lotus-revealed significant variations in macro- and micronutrient content, underscoring their potential as alternative nutritional sources. Nutrient composition was assessed per 100 g of edible seed portion and values for energy, carbohydrates, protein, calcium, fiber, iron, potassium and sodium were analyzed and compared and given in Table 2.

Among all the seeds studied, sunflower seeds had the highest energy content (584 kcal), followed closely by watermelon seeds (557 kcal) and pumpkin seeds (446 kcal), indicating their calorific richness and potential use as high-energy dietary components. Conversely, pomegranate seeds recorded the lowest energy value, making them less significant as energy-dense foods. Carbohydrate content was highest in pumpkin (54 g) and tamarind seeds (53.66 g), making them suitable for energy replenishment. In contrast, watermelon seeds had a remarkably low carbohydrate content (11.03 g), suggesting their utility in low-carb or ketogenic diets. Protein analysis revealed watermelon (28.33 g) and pumpkin seeds (23.06 g) as excellent plant-based protein sources, suitable for vegetarian and vegan diets. Pomegranate seeds, on the other hand, had the lowest protein content (1.67 g), limiting their role in protein-based applications.

In terms of micronutrients, sunflower (78 mg) and tamarind seeds (74 mg) were relatively rich in calcium, a key mineral for bone health. The fiber content was highest in pumpkin (6 g) and tamarind (5 g) seeds, indicating their potential for digestive health support and satiety enhancement. The iron content was highest in sunflower (5.3 mg) and tamarind seeds (4.3 mg), positioning them as good sources for addressing iron-deficiency anemia. Potassium was found in the highest concentration in pumpkin seeds (919 mg), followed by sunflower seeds (645 mg), both supporting cardiovascular health. Sodium levels remained generally low across all seeds, with pumpkin seeds showing a relatively higher sodium content (18 mg), but still within healthy dietary limits.

**Table 1.** List of selected underutilized seeds with their scientific name

| Seeds selected | Scientific name | Images of selected underutilized seeds |
|---|---|---|
| Lotus seed | Nelumbo Nucifera |  |
| Pumpkin seed | Cucurbita maxima |  |
| Pomegranate seed | Punica granatum |  |
| Watermelon seed | Citrullus lanatus |  |
| Sunflower seed | Helianthus annuus |  |
| Tamarind seed | Tamarindus indica |  |

**Table 2.** Nutritive value of selected underutilized seeds

| Name of selected seeds | Nutritive value of selected seeds | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Energy (Kcal) | CHO (g) | Protein (g) | Fat (g) | Calcium (mg) | Sodium (mg) | Potassium (mg) | Fibre (g) | Iron (mg) |
| Lotus seed | 89 | 17 | 4.1 | 0.5 | 44 | 1 | 367 | 4 | 0.95 |
| Pumpkin seed | 446 | 54 | 19 | 19 | 55 | 18 | 919 | 18 | 3.3 |
| Pomegranate seed | 83 | 18.70 | 1.67 | 1.17 | 10 | 3 | 236 | 4 | 0.31 |
| Watermelon seed | 557 | 11.03 | 28.33 | 47.37 | 54 | 10 | 648 | 3.6 | 7.28 |
| Sunflower seed | 584 | 20 | 21 | 51 | 78 | 9 | 645 | 9 | 5.3 |
| Tamarind seed | 354 | 53.66 | 23.06 | 4.30 | 286.66 | 12.63 | 30.53 | 7 | 3.3 |

These findings align with an earlier nutritional study (9), emphasizing the health-promoting potential of underutilized seeds in functional food development and diversified diets. Overall, pumpkin, sunflower and watermelon seeds emerged as the most nutritionally valuable among those assessed, demonstrating strong potential for broader incorporation into local and global food systems.

## Phase II: Extraction and biochemical analyses

**a) Phytochemical screening for alkaloids in selected seeds**

Among the six seeds analyzed, pumpkin and watermelon showed the presence of alkaloids, indicating their potential pharmacological relevance. The total phenolic content was highest in sunflower seeds (1.739 mg/mL) followed by watermelon seeds (1.711 mg/mL), suggesting a strong correlation between phenolic concentration and antioxidant capacity are given in Table 3.

**b) Estimation of total phenol content of selected seeds:**

The total phenolic content was found to be highest in sunflower seeds (1.739 mg/mL) followed by watermelon seeds (1.711 mg/mL). The results obtained for the other seeds were tamarind (0.807 mg/ mL), pomegranate (0.778 mg/mL), lotus (0.575 mg/mL) and pumpkin (0.485 mg/mL) (Fig. 1).

**c) Antioxidant activity of selected seeds**

The DPPH radical scavenging assay revealed that pumpkin seeds exhibited the highest antioxidant activity (96 %), while tamarind seeds showed the lowest (57.6 %). Interestingly, the antioxidant response of certain seeds such as lotus, pomegranate and watermelon, decreased with increasing extract concentration, suggesting a possible saturation effect or interaction of extract components at higher volumes. In contrast, seeds like pumpkin, sunflower and tamarind showed a positive dose-response, indicating their suitability for functional food formulations is noted and given in Table 4.

**d) Antibacterial activity of selected seeds**

The antibacterial activity varied significantly among the tested seeds. Pomegranate seeds exhibited the broadest-spectrum activity, with a maximum zone of inhibition of 10 mm against *Staphylococcus* and 9 mm against *Bacillus* species, highlighting their strong antimicrobial efficacy. Lotus, pumpkin and tamarind also showed consistent antibacterial effects against multiple pathogens including *E. coli*, *Proteus* and *Salmonella*, whereas sunflower seeds exhibited no activity, indicating seed-specific bioactivity profiles and results are given in Table 5. Analysis indicates that the growth of *Staphylococcus sp.* can be controlled by seeds of lotus, pumpkin, pomegranate and tamarind, the most effective being pomegranate with a zone of inhibition of 10 mm. (Plate 1). *Bacillus sp.* is sensitive to pumpkin, pomegranate and watermelon seed extracts, with the highest inhibitory effect demonstrated by pomegranate (9 mm) (Plate 2). The seeds of lotus, pumpkin and tamarind inhibited the growth of *E. coli* (Plate 3). *Proteus sp.* can be controlled by lotus, pumpkin and tamarind seeds (Plate 4). Growth of *Salmonella sp.* was inhibited by lotus and pomegranate seeds (Plate 5).

## Conclusion

In summary, the integration of underutilized seeds into local food systems could enhance both public health and agricultural sustainability. The statistical trends indicate that underutilized seeds with higher phenolic content generally exhibited stronger antioxidant and antibacterial effects. Further in-depth statistical modeling and in vivo studies are recommended to validate these findings and explore synergistic effects among bioactive compounds of selected underutilized seeds.

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**Table 3.** Results of the Mayer's test for alkaloids

| Name of the sample | Presence of cream precipitate | Presence of alkaloids |
|---|---|---|
| Lotus seed | Absent | - |
| Pumpkin seed | Present | + |
| Pomegranate seed | Absent | - |
| Watermelon seed | Present | + |
| Sunflower seed | Absent | - |
| Tamarind seed | Absent | - |

( '+' denotes positive and '-' denotes negative)

**Table 4.** Antioxidant activity of selected seeds

| Lotus seed | | Pumpkin seed | | Watermelon | | Watermelon seed | | Sunflower seed | | Tamarind seed | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Vol. of extract (mL) | % | Vol. of extract (mL) | % | Vol. of extract (mL) | % | Vol. of extract (mL) | % | Vol. of extract (mL) | % | Vol. of extract (mL) | % |
| 0.1 | 95.3 | 0.1 | 79.2 | 0.1 | 86.6 | 0.1 | 85.4 | 0.1 | 92.2 | 0.1 | 57.6 |
| 0.2 | 93.6 | 0.2 | 90.2 | 0.2 | 85.2 | 0.2 | 85.2 | 0.2 | 92.5 | 0.2 | 62.2 |
| 0.3 | 92.9 | 0.3 | 94.5 | 0.3 | 84.1 | 0.3 | 82.4 | 0.3 | 93.0 | 0.3 | 64.8 |
| 0.4 | 86.7 | 0.4 | 96 | 0.4 | 82.0 | 0.4 | 81.6 | 0.4 | 93.7 | 0.4 | 65.6 |

(% indicates the percentage of inhibition of DPPH)

**Table 5.** Antibacterial analysis of methanolic extract of selected seeds

| Seed Sample | *Staphylococcus sp.* | | *Bacillus sp.* | | *E. coli* | | *Proteus sp.* | | *Salmonella sp.* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Zone of inhibition (mm) | Antibacterial activity | Zone of inhibition (mm) | Antibacterial activity | Zone of inhibition (mm) | Antibacterial activity | Zone of inhibition (mm) | Antibacterial activity | Zone of inhibition (mm) | Antibacterial activity |
| Lotus | 5 | + | - | - | 2 | + | 3 | + | 3 | + |
| Pumpkin | 1 | + | 3 | + | 4 | + | 4 | + | 0 | - |
| Pomegranate | 10 | + | 9 | + | 0 | - | 0 | - | 5 | + |
| Watermelon | 0 | - | 1 | + | 0 | - | 0 | - | 0 | - |
| Sunflower | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| Tamarind | 1 | + | 0 | - | 1 | + | 5 | + | O | - |

('+' indicates positive antibacterial activity and '-' indicates negative antibacterial activity)

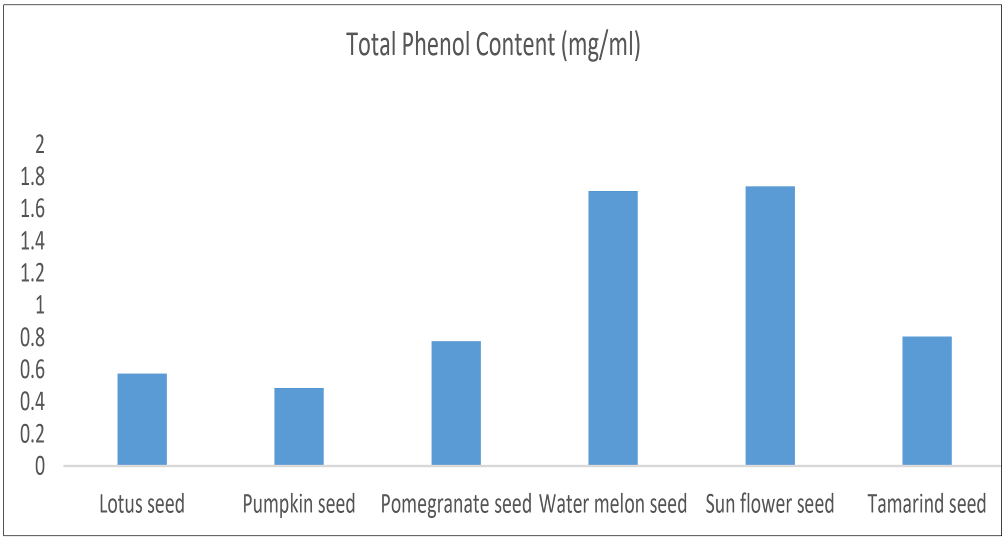


**Fig. 1.** Estimation of total phenol content in selected seeds.

**Plate 1.** Antibacterial activity of selected seed extracts on *Staphylococcus sp*.

1. Lotus 2. Control 3. Pumpkin 4. Pomegranate 5. Watermelon 6. Sunflower 7. Tamarind


**Plate 2.** Antibacterial activity of selected seed extracts on *Bacillus sp*.

1. Lotus 2. Control 3. Pumpkin 4. Pomegranate 5. Watermelon 6. Sunflower 7. Tamarind


**Plate 3.** Antibacterial activity of selected seed extracts on *E. coli*.

1. Lotus 2. Control 3. Pumpkin 4. Pomegranate 5. Watermelon 6. Sunflower 7. Tamarind


**Plate 4.** Antibacterial activity of selected seed extracts on *Proteus sp*.

1. Lotus 2. Control 3. Pumpkin 4. Pomegranate 5. Watermelon 6. Sunflower 7. Tamarind


**Plate 5.** Antibacterial activity of selected seed extracts on *Salmonella sp*.

1. Lotus 2. Control 3. Pumpkin 4. Pomegranate 5. Watermelon 6. Sunflower 7. Tamarind

antioxidant activity, phenol content and alkaloid presence of samples studied in the present work.

## Authors' contributions

LL and RPV identified the research problem, conducted a literature survey and designed the experimental study. LL and RPV conducted the nutrient analysis and recipe development, experimental study for the antioxidant activity, phenol content and alkaloid presence in selected underutilized seeds was done by AVJ. LL, RPV and AVJ carried out data analysis. LL and RPV wrote the initial draft of the manuscript. All authors approved the final draft of the manuscript.

## Compliance with ethical standards

**Conflict of interest:** The authors declare that there exists no conflict of interest.

**Ethical issues:** None

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