Value addition and nutritional fortification of finger millet \([Eleusine coracana (L.) Gaertn.]\) using bark of \(Gethi\) (\(Boehmeria regulosa\) Wedd.) tree

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Finger millet \([Eleusine coracana (L.) Gaertn.]\), an important coarse cereal of Indian Subcontinent and Africa, is devoid of gluten and, therefore, lacks the bread making quality of wheat. A traditional method of imparting finger millet the bread making quality of wheat using bark of a tree locally known as \(Gethi\) (\(Boehmeria regulosa\) Wedd.) and, the physical properties and nutritional composition of the bark are reported in the present study. The method has been found effective with other coarse cereals such as maize, sorghum, pearl millet and barnyard millet, and pseudo-cereals, viz. buckwheat and amaranth. Preliminary phytochemical analysis of the bark showed presence of appreciable amounts of phenolics, flavonoids and antioxidant activity, besides high viscosity. The bark is also rich in iron and zinc, signifying its potential efficacy in nutritional fortification of coarse cereals and pseudo-cereals apart from improving their bread making quality.

**Keywords:** Finger millet, Value addition, Nutritional fortification, Roti, Indian flatbread, Gethi, Boehmeria regulosa

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Coarse cereals constitute an important component of diet of millions of people across the world. In India, a sizable population particularly in arid, hilly and tribal regions is dependent mainly on coarse cereals for their food and nutritional security. ‘Coarse cereals’ is a generic term referring to cereals other than wheat and rice, which are used as food. The coarse cereals cultivated in India include maize (\(Zea mays\) L., makka), sorghum (\(Sorghum bicolor\) L. Moench., jowar), pearl millet (\(Pennisetum glaucum\) (L.) R. Br., bajra], finger millet (\(Eleusine coracana\) (L.) Gaertn.), \(mandua/ragi\), barnyard millet \(Echinocloa frumentacea\) (Roxb.) Link.] and \(E. esculenta\) (A. Braun) H. Scholz, \(madira/sawa\)), kodo millet (\(Panicum scrobiculatum\) L., kodo), little millet (\(Panicum miliare\) Lam., kutki), proso millet (\(Pancium miliaceum\) L., cheena) and foxtail millet (\(Setaria italica\) Beauv., \(kauni/kakun\))\(^1\). Besides coarse cereals, pseudocereals such as buckwheat (\(Fagopyrum esculentum\) L. and \(F. tataricum\) L., \(kuttu/ugal\)) and amaranth (\(Amaranthus hypochondriacus\) L., \(ramdana/chaulai\))\(^1\), and many other less known and underutilized crops are also cultivated for food. The coarse cereals and pseudocereals are used much in the same manner as rice (cooked after dehusking) and/or wheat (ground into flour and used for making Indian flatbread, vernacularly called roti). The flour of coarse cereals lacks gluten, the protein composite that imparts wheat dough elasticity and renders rotis prepared from wheat flour puffy and soft.

Finger millet is an important coarse cereal of Indian Subcontinent and Africa and is cultivated in over 40 countries globally. India is the largest producer of finger millet accounting for 40 % of the total global production from 25 % of the total global finger millet area\(^2\). The state of Uttarakhand is among the leading producers and consumers of finger millet. However, over the last few decades, the area and production of finger millet has declined steeply due to reduced household and local consumption. A major reason behind declining popularity of finger millet is poor roti making quality of its flour due to lack of gluten. Absence of gluten makes rolling out dough of finger millet into round shape difficult. The absence of gluten also prevents finger millet rotis from puffing up like rotis prepared from wheat flour. Popularly this problem is answered by adding wheat flour to the flour of finger millet in a fixed proportion to impart it elasticity; or by placing the finger millet dough ball between two plastic sheets and then rolling the dough

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ball out into round shape by gently moving the rolling pin over the plastic sheet (traditionally banana leaves were used in place of plastic sheets). A possible alternative to these methods is the incorporation of commercially available pure gluten into finger millet flour to impart it properties of wheat flour. The use of any such external supplement, however, seems unlikely to become popular among hill people who generally are wary of using external supplements of any kind in their food. Besides, the cost involved is too high. It will, therefore, be worth to try locally obtainable alternatives which are available in plenty, are cheaper and known to be acceptable as food or food supplement.

Background

During a visit to Gram Sabha Mudiyani (District Champawat, Uttarakhand) in July 2012, it was learnt in the course of interaction with the farmers that the dried bark of older trees of a particular tree species, locally known as Gethi, was traditionally mixed with finger millet grains before milling to render finger millet rotis soft and puffy like rotis prepared from wheat. This knowledge was learnt to be age old and in common practice among the members of the farming community. The tree referred to by the farmers was identified as Boehmeria regulosa Weddell belonging to Urticaceae family (Figs. 1-3). The tree is primarily known for its wood which is used for making traditional bowls/vessels (theki, dwak) and traditional measures of weight/volume (mana, paseri). The bark of this tree is also referred to have medicinal properties and food utility (the powder of its bark is used to make bread soft and tasty). The method of using the bark powder and the crops in which the bark powder is used for making their bread soft and tasty, however, is not specified. The information on its physical properties and nutritional composition is also lacking. The present study, therefore, aimed to ascertain the efficacy of the bark powder in improving bread making properties of coarse cereals, viz. finger millet, maize, sorghum, pearl millet and barnyard millet, and pseudocereals, viz. amaranth and buckwheat, besides identifying optimum bark powder-crop flour combinations for the aforementioned crops. Further, as tree barks are storehouses of plant secondary metabolites and contain a variety of health promoting/retarding phytochemicals, the present study also aimed to analyze the phytochemical composition and nutrition profile of the bark powder to ascertain its suitability as a food additive.

Methodology

The analysis was carried out at VPKAS Experimental Farm, Hawalbagh, Almora during 2012-13.

Collection of bark

A sample of bark was collected from a Gethi (Boehmeria regulosa) tree at Mudiyani village with due consent of the owner of the tree. After removing the outer corky layer, the bark was sundried for 10 days and then ground into fine powder (Figs. 2 a-c). Conventionally, the bark of the tree is removed during winter season only. This is because it is the time when the fresh harvest of finger millet is milled. The bark is so removed as not to damage the deeper vital tissues of the plant, thereby enabling its regeneration over a period of 3-4 months.

Effect of Gethi bark powder on different crops’ flour

Preparation of bark powder incorporated flour

Following the proportions recommended by the farmers (250 gm dried Gethi bark per 10.0 kg finger millet grain), finger millet sample was prepared by incorporating 25 gm Gethi bark powder in 1.0 kg finger millet flour. Generally, 100 gm flour is sufficient for making 3-4 rotis of normal size. Apart from the recommended ratio, higher ratios (30 gm and 35 gm Gethi bark powder per 1.0 kg finger millet flour) were also prepared to observe the effect of higher proportion of Gethi bark powder on bread making properties of finger millet. Similarly, samples of maize, sorghum, pearl millet, barnyard millet, amaranth and buckwheat flour were prepared. In these crops, the sample size was 500 gm per crop.

Evaluation of dough for roti quality

The parameters taken for evaluation of quality of dough and roti were (1) elasticity of dough (2) ease in rolling out dough (3) puffiness of rotis (4) softness of rotis, and (5) taste of rotis. Normal crop flour (without Gethi powder) was used as the standard control.

Methodology for analysis of physical properties and nutritional composition of Gethi bark powder

For analysis of physical properties and nutritional composition, the bark was removed using a wedged wooden tool and collected in sterile plastic bag using surgical gloves, and ground with the help of mortar and pestle to avoid any contamination.
Extraction
Powdered air dried samples were extracted in methanol\textsuperscript{5,6}.

Viscosity
Viscosity of Gethi bark powder was measured using Viscometer (Newport Scientific Corp., Australia). Wheat flour was used for comparison.

Crude fiber content
Crude fibre, calcium, iron and phosphorous were analyzed following standard procedures\textsuperscript{7,8}.

Total phenolic content
Total phenolic content was determined using Folin-Ciocalteu method\textsuperscript{9}.

Total flavonoid content
Total flavonoid content was determined by colorimetric method\textsuperscript{10}.

DPPH scavenging assay
The stable DPPH was used for determination of free radical scavenging of extracts\textsuperscript{9}.

Results and discussion
The dough of Gethi bark powder-incorporated-finger millet flour was higher in cohesiveness and elasticity. The dough was easy to roll out into round shape and did not tear during rolling. The rotis puffed up well upon baking and remained soft upon cooling (Figs. 3a, b). In contrast, the dough of normal finger millet flour (without Gethi bark powder) got torn during the rolling out process and, therefore, rolling the dough out into round shape was not possible (Fig. 3c). Even with the use of plastic sheets, rolling out dough of normal finger millet flour was difficult and the puffing of rotis was poor.

For further confirmation and validation of the ITK, ten individuals known to be taking finger millet rotis on a daily basis were selected for obtaining feedback on the claimed property of the bark powder. These individuals were very well familiar with the difficulties faced in preparation of finger millet rotis and also with the quality of finger millet dough and rotis. One 100 gm packet each of Gethi powder-
incorporated-finger millet flour and normal finger millet flour was provided to each of ten respondents along with an evaluation sheet covering various quality aspects of finger millet dough and rotis. 100 gm finger millet flour is sufficient for making four rotis of normal size. The feedback obtained from the respondents was compiled and analyzed (Table 1). The results of the experiment conducted in the laboratory and the feedback obtained from the respondents to test the efficacy of Gethi bark powder on roti-making properties of finger millet dough showed that incorporation of bark powder not only rendered the dough of finger millet elastic and easy to roll out but also caused the rotis to puff up like wheat rotis. The feedback obtained from the respondents also suggested improved softness and taste of rotis of Gethi bark powder-incorporated-finger millet flour.

Further, it was observed that higher proportion of Gethi bark powder (> 3.0 gm Gethi bark powder/100 gm flour) failed to bring about any significant improvement in the roti making properties of finger millet compared to 2.5 gm Gethi bark powder/100 gm flour. On the contrary, higher proportion of Gethi bark powder imparted a slightly disagreeable gummy flavour to the rotis.

The evaluation of effect of Gethi bark powder on the dough and rotis of other coarse cereals, viz. maize, sorghum, pearl millet and barnyard millet, and pseudocereals, viz. buckwheat and amaranth showed similar effects. The bark powder improved properties of dough and rotis of these crops in the same manner as that of finger millet. For barnyard millet and amaranth 2.5 gm Gethi bark powder/100 gm flour was effective, whereas in case of maize, sorghum and buckwheat, 3.0 mg Gethi bark powder/100 gm flour gave better results over 2.5 gm. These observations suggest a wider application range of the bark powder of Gethi, extending to a host of other food crops.

**Nutritional value of Gethi bark**

Preliminary phytochemical analysis of methanolic extract of Gethi bark powder showed presence of significant amount of minerals (Fe, Zn), phenolics, flavonoids and antioxidant activity (DPPH, ABTS, FRAP value), besides high viscosity. The viscosity of Gethi bark powder was 20.2 % higher than wheat (RUV 238.5 compared to 198.5 of wheat). The improved cohesiveness and elasticity of different crop flours, therefore, can reasonably be attributed to high viscosity of Gethi bark powder. The bark powder

![Fig. 3](image_url)

**Table 1**—Comparative evaluation of Gethi bark powder-incorporated and ordinary finger millet flour based on feedback of respondents

<table>
<thead>
<tr>
<th>Quality parameter</th>
<th>Respondents’ rating of Gethi bark powder-incorporated finger millet flour compared to ordinary flour</th>
<th>Observed only in Gethi bark powder-incorporated finger millet flour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity of dough</td>
<td>Higher: 10 At par: 0 Lower: 0</td>
<td>-</td>
</tr>
<tr>
<td>Ease in rolling out</td>
<td>Higher: 10 At par: 0 Lower: 0</td>
<td>-</td>
</tr>
<tr>
<td>Puffiness of rotis</td>
<td>Higher: 6 At par: 4 Lower: 0</td>
<td>10</td>
</tr>
<tr>
<td>Softness of rotis</td>
<td>Higher: 6 At par: 4 Lower: 0</td>
<td>-</td>
</tr>
<tr>
<td>Taste of rotis</td>
<td>Higher: 6 At par: 4 Lower: 0</td>
<td>-</td>
</tr>
</tbody>
</table>
is also a good source of micronutrients like iron (91-98 ppm) and zinc (25-28 ppm) (Table 2). Its incorporation, therefore, will serve to enrich micronutrient profile of coarse and pseudo-cereals flour, particularly of calcium rich finger millet. Presence of high amount of iron and zinc, and high viscosity makes Gethi bark powder good for daily intake as food additive.

The phytochemicals found in plants such as flavonoids, tannins and phenolic acids are potential source of natural antioxidants \(^{12}\) and also possess other biological properties. Plant phenolics have been recognized to be a therapeutic target for cancer treatment and cardiovascular disease in the next decade \(^{11,12}\) and as a natural source of antioxidants. Due to their antioxidant property, phenolic compounds are potentially health promoting. The total phenolic content (40.38 mg/2.5 gm) and total flavonoid content (41.01 mg/2.5 gm) of Gethi bark powder was found to be substantially higher than that of finger millet (TPC 15.3 mg/gm) (Table 3). Similarly, the total antioxidant activity (74.60 mg/2.5 gm) was also much higher as compared to finger millet (25.6 mg/2.5 gm). The flavonoid content (47.60 mg/2.5 gm) and antioxidant activity (34.03 mg/2.5 gm) of roti of Gethi bark incorporated finger millet roti was 28.3 and 6.7 % higher, respectively, than that of roti of finger millet flour alone. However, there was a decrease in phenolic content (7.95 mg/2.5gm) in the roti of Gethi bark incorporated finger millet, which may be due to binding of phenolic compounds with other organic substances and proteins, or from alterations in the chemical structure of phenolic compounds. Decrease in polyphenol content due to cooking has been noticed in some legume seeds also \(^{14}\).

The high antioxidant activity and higher content of health-promoting phenolics and flavonoids in Gethi bark powder, therefore, make it beneficial as a food ingredient as well. The bark powder also contained tannins (0.72 mg/2.5 gm) and trace amounts of phytic acid (0.02 mg/2.5 gm). The quantity of these anti-nutritional factors (ANFs), however, is too small to pose any health hazard. Moreover, overnight soaking of the bark powder was found to decrease tannins by 40.92 % and phytic acid by 9.62%.

**Medicinal value of Gethi bark**

The juice of Gethi bark is applied to treat cuts and wounds, and to treat body pain \(^4\). The paste of bark is applied on the bone fracture \(^{13}\).

**Significance of the study for the traditional community and researchers**

Biological resources and associated traditional knowledge (TK) bear enormous significance in the lives of traditional communities and hold vast commercial potential as well. Adequate documentation of TKs is essential to prevent their misappropriation and to ensure fair sharing of benefits arising out of their commercial use with the TK holders. The TK validated and documented in the present study has potential commercial applications as the bark of Gethi powder not only renders the flour of gluten lacking crops elastic and their rotis puffy, but contains health promoting nutritional factors as well. The use of this TK on commercial scale can play a potential role in livelihood enhancement of the holders of this TK. The study also presents avenues for further research to identify and characterize the principal component(s) of Gethi bark powder that impart the improved roti making quality to crop flours. Though Gethi tree is a common tree in the mid hills of Uttarakhand, the knowledge on the use of its bark for improving roti quality is very limited. The present study will also serve to disseminate this knowledge to a wider section of the traditional finger millet consumers. The TK will also be useful for populations having maize, jowar, bajra and small millets as their staple food.

| Table 2—Micronutrient contents in Gethi bark powder |
|--------------------------|--------------------------|--------------------------|
| Zn (ppm) | Fe (ppm) | Nitrogen (%) |
| 25-28 | 91-98 | 6 |

| Table 3—Total phenolic acid, flavonoid content and antioxidant activity of Gethi bark powder, finger millet roti and roti of Gethi powder incorporated finger millet dough |
|--------------------------|--------------------------|--------------------------|
|                          | Total phenolic acid (mg/g tannic acid equivalents/2.5g bark powder) | Total flavonoid content (mg/g tannic acid equivalents/2.5g bark powder) | Total antioxidant activity (mg/g trolox equivalents/2.5g bark powder) |
| Gethi bark powder       | 40.39±2.10               | 49.02±0.76               | 74.61±4.92               |
| Finger millet roti      | 26.63±2.16               | 34.03±0.01               | 47.60±0.00               |
| Roti of Gethi powder    | 7.95±1.30                | 36.60±0.01               | 61.08±0.60               |
| incorporated finger millet |                          |                          |                          |
Conclusion
Poor bread making quality of coarse and pseudo-cereals is an important factor contributing to the declining production of these crops, especially in states such as Uttarakhand where they are traditionally consumed in the form of bread. Use of pure gluten to impart elasticity and puffability to coarse cereals’ flour is not a viable option, especially for the traditional consumers. The present study demonstrates the effectiveness of *Gethi* bark powder in improving bread making property of finger millet and shows its wider application as a natural and viable alternative to pure gluten and/or other external supplements for enhancing the bread making properties of coarse cereals and pseudo-cereals. Furthermore, *Gethi* powder-incorporated iron and zinc fortified flour of coarse and pseudo-cereals has the promise to serve as a potential means to enhance nutritional security of the populations dependent on these crops as their staple food.

Acknowledgement
The authors duly acknowledge the farmers of Gram Panchayat Mudiyan (Dist. Champawat, Uttarakhand) for providing valuable information on the traditional use of bark of *Boehmeria regulosa* and extending cooperation during the course of this study.

References