THERAPEUTIC AND NUTRITIONAL VALUE OF BRASSICA OLERACEA L. VAR. ITALICA (BROCCOLI): A REVIEW

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ABSTRACT
Brassica oleracea L. var. italica (Broccoli) belonging to family Brassicaceae probably evolved in Roman times from wild or primitive cultivated forms of Brassica oleracea from the eastern Mediterranean region. Brassica oleracea has been reported to contain Alkaloids, Saponins, Glycosides, Cardiac glycosides, Anthraquinones, Proteins, Carbohydrates, Steroids, Terpenoids and Flavonoids. Brassica oleracea also contain highest amount of glucosinolates known till date in plants and its derivatives which could be used in various cancer therapy. Scientifically various part of plant like leaves, flower, fruits, seeds and fresh juice has been evaluated for its various activity like antibacterial activity, antihelminitic activity, antimicrobial activity, anticancer activity, anti-nociceptive effect, antioxidant activity, relaxation of rat uterine, hepatoprotective activity, anti-inflammatory activity, antitrypanosomal effect and weight loss. In the present review nutritional value of plant and medicinal properties of plant has been discussed to provide collective on this multipurpose herb and must be consider to be consumed as daily nutrition.
INTRODUCTION:
The family *Brassicaceae* includes about 400 genus and 4,000 species. Through the genetic improvement several horticultural varieties that present economic interest, mainly *B. oleracea* var. *acephala* (kale), *Brassica oleracea* var. *capitata* (cabbage), *Brassica oleracea* var. *geminifera* (Brussels sprouts), *Brassica oleracea* var. *borytis* (cauliflower) and *Brassica oleracea* var. *italica* (broccoli). Other species economically important are *Brassica nigra* and *Sinapis* spp. (mustards), *Raphanus sativus* (radish), *Armoracia rusticana* (horseradish), *Rorippa nasturtium-aquaticum* (watercress) and *Eruca sativa* (rocket) \(^1\). The family *Brassicaceae* has been studied due to the pharmacologic properties of its main metabolite, the glucosinolates (GLS). These metabolites, as well as, their hydrolysis products (isothiocyanate and nitriles) are powerful antioxidants and anti-carcinogenic agents \(^2,3\).

All the varieties of cabbage, cauliflower, broccoli and nolecole are produced from the wild cabbage- the Colewort which grows wild on hills. Total world production of broccoli in 2012 was estimated at 21,266,789 tonnes. Major broccoli producing country is China 9,500,000 tonnes, India 7,000,000, Italy 414,142. In the production of broccoli India comes on number second followed by the China which is the top most producer of broccoli \(^4\).

Introduction to plant profile
Plant profile of *Brassica oleracea* L. var. *italica* (Broccoli) is shown in figure 1.

![Broccoli](image1)

**Figure 1.** *Brassica oleracea* L. var. *italica* (Broccoli): Flower vegetable & Whole plant

**Taxonomical Classification**
Vernacular names

Distribution
Brassica oleracea is commonly found in Italy, Central and northern Europe, West Africa. Plant mainly distributed in China, India, Mexico, France, Poland, United States, Pakistan, Germany and Egypt.

In India Brassica oleracea grow in high places like Khandala, Mahabaleshwar and Bandel area of district Ranchi.

Description
Erect, glabrous, annual or biennial herb up to 80 cm tall at the mature vegetative stage, up to 150 cm when flowering, with unbranched stem thickening upwards; root system strongly branched. Leaves alternate but closely arranged and more or less erect, forming a rosette surrounding the young inflorescence especially in cauliflower, usually simple; stipules absent; leaves almost sessile, but often shortly petiolate in broccoli; blade ovate to oblong, up to 80 cm × 40 cm, undulate or irregularly incised to almost entire, coated with a layer of wax, blue-green with whitish veins. Inflorescence a terminal paniculate raceme up to 70 cm long, when young (curd or head) composed of more or less densely arranged branching partial inflorescences and fleshy peduncles, in cauliflower up to 30 cm in diameter, very solid and globular to rather loose and flat, white to green, in broccoli less densely arranged with longer peduncles, green to purple. Flowers bisexual, regular, 4-merous; pedicel up to 2 cm long, ascending; sepals oblong, c. 1 cm long, erect; petals obovate, 1.5–2.5 cm long, clawed, pale to bright yellow or whitish; stamens 6; ovary -superior, cylindrical, 2-celled, stigma globose. Fruit a linear silique 5–10 cm × c. 5 mm, with a tapering beak 5–15 mm long, dehiscent, up to 30-seeded. Seeds globose, 2–4 mm in diameter, finely reticulate, brown. Seedling with epigeal germination, with a taproot and lateral roots; hypocotyl 3–5 cm long, epicotyl absent; cotyledons with petiole 1–2 cm long, blade cordate, 1–1.5 cm long, cuneate at base, notched at apex.
Traditional Uses
Antiatherosclerotic, Antibacterial, Antimaculitic, Antinitrosaminic, Antinyctalopic, Antiproliferant, Antioxidant, Antiradicular, Antiretinitic, Antitumor, breast, Antitumor, colon, Antitumor, lung, Antitumor, skin, Antiviral, Detoxicant, Estrogenic, Glucuronidase Inhibitor, Goitrogenic, Hypocholesterolemic, Prooxidant, Quinone-Reductase-Inducer \(^{10}\) and Anticonvulsant \(^{11}\).

**PHYTOCHEMICAL CONSTITUENTS**

The phytochemical screening was carried on the leaves extracts of *Brassica oleracea* L. var. *italica* revealed the presence of some active ingredients such as Alkaloids, Saponins, Glycosides, Cardiac glycosides, Anthraquinones, Proteins, Carbohydrates, Steroids, Terpenoids and Flavonoids. The principle component present is glucosinolate. Glucosinolates are known to possess antibacterial, antifungal as well as anticancerous activity \(^{12}\).

<table>
<thead>
<tr>
<th>Phytochemicals</th>
<th>Solvents</th>
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<tbody>
<tr>
<td></td>
<td>Pet Ether</td>
</tr>
<tr>
<td>Alkaloids</td>
<td>-</td>
</tr>
<tr>
<td>Flavonoids</td>
<td>+</td>
</tr>
<tr>
<td>Glycosides</td>
<td>-</td>
</tr>
<tr>
<td>Phenols</td>
<td>-</td>
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<td>Saponins</td>
<td>+</td>
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<tr>
<td>Steroids</td>
<td>-</td>
</tr>
<tr>
<td>Tannins</td>
<td>-</td>
</tr>
<tr>
<td>Terpenoids</td>
<td>+</td>
</tr>
</tbody>
</table>

(+) presence; (-) absence

Pet Ether: petroleum ether; Eta: ethyl acetate

**Thin layer chromatography (TLC)**

TLC was performed to separate the glucosinolates (glucoraphanin, glucobrassicin, glucoiberin, progoitrin, sinigrin, gluconapin, glucoerucin and neo-glucobrassicin) and its hydrolysis products (isothiocyanates, nitriles) from *Brassica oleracea* extract.
Three extracts were used for TLC i.e. defatted soxhlet extract, defatted cold macerated extract and defatted fresh *Brassica oleracea* extract. For defatted Soxhlet and cold macerated extract, ground *Brassica oleracea* was defatted with diethylether (in soxhlet, and on rotary shaker), then extracted with 80 % methanol and further utilized for TLC. For fresh *Brassica oleracea* extract, 30 gm of fresh *Brassica oleracea* with diethyl-ether was kept for 2 days followed by 80 % ethanol for 3 days on rotary shaker (same as for cold macerated extract). The supernatant obtained was utilized for TLC. After spraying and heating the TLC plates (as described above) the plates were checked for the development of spots. The spots obtained were then calculated for Rf values so that the compound can be identified.¹³
The Rf values were calculated by:

\[ R_f = \frac{\text{Distance travelled by solute}}{\text{Distance travelled by solvent}} \]

**Table 2.** Detected glucosinolates in extracts and their Rf values

<table>
<thead>
<tr>
<th>Extract</th>
<th>Phytochemical</th>
<th>Rf-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soxhlet Extract</td>
<td>Glucobrassicin</td>
<td>0.6</td>
</tr>
<tr>
<td>Cold extract</td>
<td>Glucobrassicin</td>
<td>0.6</td>
</tr>
<tr>
<td>Fresh <em>Brassica oleracea</em>   extract</td>
<td>Glucobrasicin-1-sulphonate</td>
<td>0.3</td>
</tr>
</tbody>
</table>

**NUTRITIONAL VALUE**

Broccoli can provide cholesterol-lowering benefits and positive impact on our body’s detoxification system. Because broccoli is one of the very low calorie vegetables; provides just 34 calories per 100 g. Nevertheless, it is rich in dietary fibres, minerals, vitamins, and anti-oxidants that have proven health benefits.

Fresh Broccoli contains many phyto-nutrients such as thiocyanates, indoles, sulforaphane, isothiocyanates and flavonoids like beta-carotene cryptoxanthin, lutein, and zeaxanthin.

Broccoli contains Vitamin C and Vitamin A in high amount.

Flower vegetable is rich source of Vitamin K and B-complex group of vitamins like niacin (Vit. B-3), pantothenic acid (Vit. B-5), pyridoxine (Vit.B-6), and riboflavin. The flower heads also have some amount of omega-3 fatty acids.

It is also a good source of minerals like calcium, manganese, iron, magnesium, selenium, zinc and phosphorus\(^{14,15}\).

**PHARMACOLOGICAL ACTIVITIES**

The plant *Brassica oleracea* has been proved for various medicinal activities like antibacterial activity, antihelminitic activity, anti-microbial activity, anticancer activity, anti-nociceptive effect, antioxidant activity, relaxation of rat uterine, hepatoprotective activity, anti-inflammatory activity, antitrypanosomal effect and weight loss.

1. **Antibacterial Activity**

Various extract of *Brassica oleracea* L. showed the antibacterial activity against six food borne bacteria viz., *Bacillus cereus ATCC 10876*, *Bacillus subtilis ATCC 6633*, *Staphylococcus aureus ATCC 6538*, *Escherichia coli ATCC 8739*, *Salmonella typhimurium MTCC 3224* and *Shigella flexneri ATCC 12022*. In acetone and methanolic extract Minimum inhibitory concentration (MIC) values of 10 - 320 µg/ml were recorded against most of the pathogens. *B. subtilis ATCC*
6633 (15.4 mm) and Bacillus cereus ATCC 10876 (16.3 mm) were found to be the most sensitive organisms among the pathogens tested.

In another study various extracts of Brassica oleracea were investigated against a few drug resistant uropathogens. This showed the antibacterial activity against both gram positive and gram negative bacteria. The extracts showed significant zones of inhibition ranging from 4 to 14 mm respectively, whereas the minimum inhibitory concentration (MIC) against them ranged from 6.25 to 200 µg/ml concentrations. The lowest activity of MIC was shown against Proteus mirabilis at 6.25 µg/ml by ethyl acetate extract.

1. Antihelmintic Activity

Aqueous and hydroalcoholic extracts of seeds of Brassica juncea and flower of Brassica oleracea showed the antihelminitic activity. The various concentrations of the extract (100, 150, 200,300,500 mg/ml) respectively were screened for their anthelmintic activity using Pheretima posthuma and activities were comparable with the standard drug Albendazole. This showed dose dependent activity. The determination of time of paralysis (P) and time of death (D) of the worms was carried out. Hydroalcoholic extract of Brassica juncea and Brassica oleracea showed more prominent anthelmintic activity.

2. Anti-microbial Activity

Various extract of the Brassica oleracea (aqueous, acetone, petroleum ether and chloroform) showed the anti-microbial activity against the bacterial (Pseudomonas aeruginosa, Shigella flexneri, E.coli and Klebsiella pneumoniae) and fungal (Aspergillus niger, Aspergillus flavus, Aspergillus fumigatus and Cladosporium species) isolates. Among the four extracts tested, acetone extract exhibited maximum activity against Pseudomonas aeruginosa, Shigella flexneri, E.coli and Klebsiella pneumoniae and a narrow range of activity was exhibited against aqueous, petroleum ether and chloroform extracts. Aspergillus flavus and Aspergillus niger was found to be sensitive to acetone extracts when compared with Aspergillus fumigatus and Cladosporium species.

3. Anticancer Activity

Sulforaphane (SFN) an isothiocyanate formed by hydrolysis of glucosinolates found in Brassica oleracea was reported to possess anticancer and antioxidant activities and was evaluated by MTT assay in human epithelial carcinoma Hep-2 and Vero cells. Results showed that standard SFN and purified SFN concentration found to have closer IC50 which is equal to 58.96
microgram/ml (Hep-2 cells), 61.2 microgram/ml (Vero cells) and less than the extract which is found to be 113 microgram/ml (Hep-2 cells) and 125 microgram/ml (Vero cells)\(^3\).

4. **Anti-nociceptive Effect**

Hydroalcoholic extract of *Brassica oleracea* exhibited the anti-nociceptive activity against Formalin test induced pain model. The Animals were pre-treated with the *Brassica oleracea* extract (500, 1000, 2000 mg/kg/p.o.). Data shows there is decreased pain in formalin test in the group that received 2000 mg/kg/p.o. dose of extract in comparison to other groups\(^19\).

5. **Antioxidant Activity**

Various extract of *Brassica oleracea* were evaluated for their total phenolic contents and antioxidant activity using DPPH radical scavenging assay and reducing power assay. The study showed that the ethanolic leaves extract of *Brassica oleracea* L. var. *capitata* which contains highest amount of phenolic compounds exhibited the greatest anti-oxidant activity than Petroleum Ether, ethylacetate, chloroform and aqueous extracts\(^2\).

6. **Relaxation of rat uterine**

Fresh juice of *Brassica oleracea* var. *capitata* showed the H\(_2\) receptor antagonistic action. Two sets of experiments consisted of recording the responses of the uterine horn preparations (precontracted with potassium chloride, KCl) to histamine (4.5; 9; 17.99; 35.99; 71.98 \(\times\) 10\(^{-4}\) and 14.40\(\times\) 10\(^{-3}\) mol/L, 2 minute each concentration) in absence and presence of S-Chlorpheniramine, ranitidine and BOCJ. Results indicated that histamine (EC50 = 19.05 ± 1.76 \(\times\) 10-4 mol/L, \(p < 0.001\)) produces relaxation of potassium chloride precontracted isolated rat uterus. This effect of histamine is abolished by ranitidine, a selective H2 histamine receptor antagonist and BOCJ in a concentration dependent manner\(^20\).

7. **Hepatoprotective activity**

Ethanolic leaves extract of *Brassica oleracea* L. var. *capitata* possessed the significant hepatoprotective activity against simvastatin (20 mg/kg p.o. for 30 days) induced hepatotoxicity. *Brassica oleracea* L. var. *capitata* (300 mg/kg/p.o. and 500 mg/kg/p.o.) showed the protective effect which was identified by increased in Serum Glutamate Pyruvate Transaminase (SGPT), Serum Glutamate Oxaloacetate Transaminase (SGOT), Alanine Phosphatase (ALP), Serum bilirubin and decreased in Total proteins content and in oxidative stress markers such as GPx, GST, SOD and CAT in simvastatin treated rats\(^21\).
8. Anti-inflammatory activity
Methanolic extracts of different cabbage heads showed different anti-inflammatory activity values. All tested extracts showed high anti-inflammatory value in a range 0–100 μg concentration where Chinese, Savoy and Green heads had the highest anti-inflammatory activity; while Red heads had the lowest anti-inflammatory activity value. Anti-inflammatory activities were analyzed by spectrophotometer 22.

9. Antitrypanosomal Effects
Methanolic plant extracts (MPES) of Brassica Oleracea fruits and leaves at different concentrations (250-1000 µg/ml) were tested against Trypanosoma evansi on Vero cell line. In-vivo infectivity test of incubated MPES of Brassica Oleracea fruits, leaves and medium with trypanosomes were done in mice. In-vitro cytotoxicity of the test extracts at concentrations (1.56-100 µg/ml) was performed on Vero cells. Both MPES of Brassica Oleracea fruits and leaves demonstrated trypanocidal activity, which ranged from immobilization, reduction and to the killing of trypanosomes. MPES of Brassica oleracea fruits, leaves and diminazine aceturate (Berenil) were cytotoxic to Vero cells at all concentrations except at 1.56, 1.56 and 6.25-1.56 µg/ml, respectively 23.

10. Weight loss
Chloroform extract, combined ethyl acetate and ethanol and the crude extract of Brassica oleracea showed significant loss in the body weight of female rats at 5% and 1%. Water extract of Green tea showed the 117 g total loss in body weight while chloroform extract showed higher total loss in the body weight i.e. 180 g 24.

11. Hypocholesterolemic Activity
Methanolic and aqueous extracts of Brassica oleracea leaves reported to have the hypocholesterolemic activity when tested against Cu²⁺- induced oxidation model for its susceptibility of isolated lipoproteins- very low density lipoproteins (VLDL) and low density lipoproteins (LDL). This study showed that both extracts inhibited lipid peroxidation in both isolated VLDL and LDL. So Brassica oleracea consumption may play an important protective role in the cardiovascular and other related diseases resulting from imbalance of oxidant and antioxidant status 25.
ACUTE TOXICITY STUDY
The toxicity of *Brassica oleracea* extract study did not show any toxic effects in albino mice. No death was observed up to the oral administration of extract dose concentration 200-2000 mg/kg body weight during the 72 hours of study period.\(^{21}\)

CONCLUSION
The extensive literature survey revealed that broccoli is an important medicinal plant due to its high nutritional value and traditional uses to treat diseases and presence of many active chemical constituents which are responsible for various medicinal and pharmacological properties. Broccoli is also consumed worldwide as fresh vegetables (in salad), in cooked form and as boiled form. Further evaluation needs to be carried out on broccoli in order to confirm its medicinal uses and development of formulations containing this plant for their practical clinical applications, which can be used for the welfare of mankind.

REFERENCES

