Pharmacogn J. 2025; 17(3): 293-298
A Multifaceted Journal in the field of Natural Products and Pharmacognosy
www.phcogj.com

*Original Article*

# Comprehensive Analysis of *Brassica oleracea*: Phytochemical Composition, Radical Scavenging, and Anti-Proliferative Activity

**Nithya Venugopal[1]*, Radhika Jayaraman[4], Mohammed Junaid Hussain Dowlath[1], Ganesh Munuswamy Ramanujam[2], Sundarapandian Subramaniyan[1], Pratheepa Sivasankari Natarajan[1], Jayashri Seetharaman[3]**

## ABSTRACT

**Background:** Natural sources like plants, vegetables, and fruits contain vast micro and macro nutrients that are useful for livelihood and also act as a medicine for various health conditions. Brassica vegetable naturally contains high antioxidant property which aids in removing free radicals caused by organelles during cellular process. The study aims at preparing *Brassica oleracea* extracts using a range of polar and non-polar solvents and to evaluate its phytochemical, antioxidant and cytotoxicity properties. **Methods:** *Brassica oleracea* was extracted using hexane, ethyl acetate and ethanol. All the extracts were subjected to phytochemical analysis and antioxidant activity was performed using DPPH method. The antiproliferative activity was perfomed on THP-1 cells by MTT assay. The extract showing maximum activity was then characterized using FTIR and GCMS. **Results:** The extract study infers positive results for major secondary metabolites (alkaloids, glycosides, proteins, phenols, tannins, steroids, flavonoids, terpenoids and diterpenes) and negative for quinones and coumarins. DPPH radical scavenging assay showed high antioxidant activity for ethanol extracts 45-91% at 5µg/mL followed by ethyl acetate (37%-80%) and hexane extract (23%-73%). The anti-proliferative activity in THP-1 cells, revealed that the ethanolic extract significantly decreases cell viability relative to hexane and ethyl acetate extracts, indicating its potential as a natural anticancer drug. **Conclusion:** Cytotoxicity studies further demonstrated a concentration dependent effect on cell viability, indicating its potential bioactivity. The structural analysis performed with FTIR and GC-MS revealed important functional groups and bioactive compounds that could play a role in these effects.

**Keywords:** Antioxidants, Broccoli, DPPH, Flavonoids, FTIR, ROS, THP-1 Cells.

**Nithya Venugopal[1]*, Radhika Jayaraman[4], Mohammed Junaid Hussain Dowlath[1], Ganesh Munuswamy Ramanujam[2], Sundarapandian Subramaniyan[1], Pratheepa Sivasankari Natarajan[1], Jayashri Seetharaman[3]**

*[1]Department of Anatomy, SRM Medical College Hospital and Research Centre, Faculty of Medicine and Health Sciences, SRM Institute of Science and Technology, SRM Nagar, Kattankulathur, 603203, Kanchipuram, Chennai, Tamil Nadu, India.*

*[2]Interdisciplinary Institute of Indian System of Medicine, SRM Institute of Science and Technology, SRM Nagar, Kattankulathur, 603203, Kanchipuram, Chennai, Tamil Nadu, India.*

*[3]Department of Biotechnology, Faculty of Science and Humanities, SRM Institute of Science and Technology, SRM Nagar, Kattankulathur, 603203, Kanchipuram, Chennai, Tamil Nadu, India.*

*[4]Department of Anatomy, Vels Medical College and Hospital, Manjankaranai Village, Tiruvallur District -601102, Tamil Nadu, India.*

**Correspondence**

**V. Nithya**

Department of Anatomy, SRM Medical College Hospital and Research Centre, Faculty of Medicine and Health Sciences, SRM Institute of Science and Technology, SRM Nagar, Kattankulathur, 603203, Kanchipuram, Chennai, Tamil Nadu, *India*.

E-mail: nithya.venu83@gmail.com

**History**

- Submission Date: 23-04-2025;
- Review completed: 18-05-2025;
- Accepted Date: 30-05-2025.

**DOI : 10.5530/pj.2025.17.37**

**Article Available online**

http://www.phcogj.com/v17/i3



## INTRODUCTION

As a source of new drugs and with varying pharmacological potential, natural compounds with a variety of bioactivities are becoming more and more essential. Humans have long utilised plants to treat a variety of illnesses, and they continue to do so today either directly or indirectly as supplements[1]. Plants were utilised to treat nearly every illness before the invention of synthetic medications. Several investigations have revealed that plants possess therapeutic qualities, including antimicrobial, analgesic, antiphlogistic, free-radical scavenger, and antineoplastic agents. The occurrence of oxidative stress is due to the discrepancy among the generation of the level of reactive oxygen species (ROS) and the body's capacity to counteract with antioxidant defences. Although reactive oxygen species are crucial for cellular signalling and maintaining homeostasis, an overabundance can harm the proteins, fats, and the DNA molecule, leading to cellular dysfunction. This oxidative damage contributes significantly to the onset of numerous chronic conditions like cancer, cardiovascular disorders, metabolic disorders, as well as neurological disorders such as dementia and Parkinson's diseases[2]. Exposure to environmental toxins, can exacerbate oxidative stress by raising the generation of ROS and lowering the levels of antioxidants[3].

To take the place of artificial antioxidants, which are prohibited because of the carcinogenicity, natural antioxidants have recently drawn a lot more attention for usage in foods or pharmaceutical products[4]. Flavonoids and phenolic acid are secondary metabolites of plants that have been extensively researched for their anti-cancer and antioxidant properties. In many types of vegetables and herbs, phenolic compounds are present, and many of them have antioxidant qualities. Because of this, they can function as reduction agents, oxygen singlet suppressors, and hydrogen donors as well as metal ion chelators[5]. *Brassica oleracea* is a promising natural source of antioxidants, recognised for its powerful bioactive components that may alleviate oxidative stress. *Brassica oleracea* belongs to the family cruciferous is a biennial vegetable originated 2000 years ago from Italy[6]. The vegetable *Brassica oleracea* is largest and widely consumed in Europe and all parts of the world because of their varying class of nutrients. It is considered as an important food crop in India, Japan, China and European countries commonly known as Broccoli. Broccoli is a fast-growing plant, grows about 23-34 inches upright tall and branching, with dense clusters of flowers buds[7]. The green cluster of flowers at the centre of plant is referred to as "head" of broccoli. *Brassica* species are good sources of water soluble and insoluble vitamins and phytochemicals[8] which will reduce the oxidative damage risk caused by free radicals.

Phytochemical group of *Brassica oleracea* flavonoids, dietary phytoconstituents prevalent antioxidants

**Cite this article:** Venugopal N, Jayaraman R, Dowlath MJH, Ramanujam GM, Subramaniyan S, Natarajan PS, Seetharaman J. Comprehensive Analysis of *Brassica oleracea*: Phytochemical Composition, Radical Scavenging, and Anti-Proliferative Activity. Pharmacogn J. 2025;17(3): 293-298.

in plants and human diets, are increasingly important due to their antioxidative, estrogenic, antibacterial, anticancer, anti-inflammatory, antimutagenic, myocardial, vasodilator, and hepatoprotective properties[9]. Despite *Brassica oleracea*'s known benefits, limited data exist on its comparative solvent-based extraction efficiency, antioxidant potential, and anti-proliferative activity. The aim of this study is to evaluate the phytochemical composition, antioxidant activity and anti-proliferative effects of different solvent extracts of *Brassica oleracea*, along with characterization using FTIR and GCMS analysis.

## MATERIALS AND METHODS

### Materials

Plant samples of *Brassica oleracea (*Broccoli) florets were purchased from the supermarket at Guduvanchery, Chengalpet district, Tamil Nadu, India. The samples were authenticated by Siddha Central Research Institute, (B29032301C) Chennai. The THP-1 cell line was purchased from NCCS, Pune, Maharashtra, India. All the chemicals used in this study were of analytical grade and were purchased from Southern India Scientific Corporation. Chennai, Tamil Nadu, India.

### Preparation and extraction of the sample

The vegetable sample that was obtained was washed thoroughly using purified water to eliminate the debris. Then the sample was sliced into tiny pieces using a sterile blade and then allowed to dry in the shade for more than two weeks. Sample was coarsely grounded using motor and pestle and stored in an airtight container for further use. *Brassica oleracea* was extracted using hexane (BHE), ethyl acetate (BEAE) and ethanol (BEE) by cold maceration method. For 20g of sample (*Brassica oleracea)* 200mL of solvent was added in a screw capped bottle, in 1:10 ratio. The sample was incubated for 48hrs with constant stirring, filtered by using a Whatman No.1 filter paper, solvent was evaporated by rotavapor method, crude extracts were collected and used for further analysis.

### Phytochemical analysis

The phytochemical study of *Brassica oleracea* was carried out to determine whether phenolic chemicals, alkaloids, flavonoids, saponins, steroids, and tannins, terpenoids, coumarins, quinones and diterpenes are present in the crude extracts using test tube methods following the standard protocol prescribed by Upadhyay et al., (2016)[10] and Jahan et al., (2010)[11].

### Antioxidant activity

The radical scavenging activity of Hexane, ethyl acetate and ethanol extract of *Broccoli* was assayed using 2,2-diphenylpicrylhydrazyl (DPPH) method. It is a radical compound commonly used to evaluate the radical scavenging activity based on electron transfer[12]. The experiment was carried out using the methods described by Ligor et al., (2024)[13] with minor changes. Briefly, 100µL of extract was mixed with 100µL of0.1mM DPPH solution and incubated for 30 mins in dark. The absorbance was checked at 517nm. The anti-radical activity was calculated using the formula:

$$\text{Radical scavenging activity (\%)} = \frac{(\text{Abs Control} - \text{Abs Sample})}{\text{Abs Control}} \times 100\%$$

### Anti-proliferative activity

The THP-1 cell lines were cultured in DMEM medium with FBS, streptomycin, and penicillin, and raised in a $CO_2$ incubator at 37°C. The MTT assay is an indicator of cell viability, activity and proliferation of cells by measuring cellular metabolic activity in THP-1 cells. The cytotoxicity level of THP-1 cells against BHE, BEAE, BEE extracts was studied by a sensitive, reliable and colorimetric method based on the reduction of yellow tetrazolium salt (MTT) to purple formazan crystals by metabolically active NAD(P)H-dependent oxidoreductase enzymes[14]. Shortly, 96-well plates were seeded with THP-1 cells at a concentration of $1 \times 10^4$ cells/ well in 200µl culture medium and incubated for 1hr. After incubation, cells were treated with 10ml of extract (5mg/ml) followed by 24hr incubation with 10µl of MTT solution along with 5% FBS. Again, the plates were incubated for 3hrs, finally 100µl of DMSO was added and quantified. Insoluble formazan crystals are dissolved by adding solubilization and the absorbance were measured at 500–600nm. Number of live, metabolically active cells increases with darkness of the fluid. Formula to calculate cell inhibition percentage is:

$$\text{Percentage cell inhibition} = \frac{\text{Absorbance of treated cells}}{\text{Absorbance of control}} \times 100$$

### Fourier transform infrared spectroscopy (FTIR)

The functional group analysis of the ethanolic extract of *Brassica oleracea* plant components was conducted using Fourier transform infrared spectroscopy (FTIR) using a Shimadzu IRTracer-100 spectrophotometer with high sensitivity measurements and an SN ratio of 60,000:1[15]. An FTIR spectroscope was used to load each sample onto a plate and run it at a resolution of 4 $cm^{-1}$ over an infrared wave number range of 500 to 4000 $cm^{-1}$. The functional categories of secondary metabolites in each milligram of dried sample may have the ability to scavenge free radicals by compressing the sample with 100 milligrams of potassium bromide (KBr).

### Gas chromatography mass spectrometry (GC-MS) analysis

*Brassica oleracea* ethanolic extract was analysed for compound detection by GCMS. The sample was injected into Shimadzu, QP2010 SE single quadrupole GC-mass spectrometer in a column oven temperature 50°C during initial up till 280°C for final hold, injection temperature 250°C, total flow 54mL/min, hold time 2mins. Helium (99.95%) carrier gas was employed at a flow rate of 1mL/min[16], the initial oven temperature was set at 110°C and spectral masses were measured at 70 eV. For analysis one milligram of crude extract dissolved in suitable solvent to obtain a clear solution without any particles in it and injected into the splitless mode with a temperature set at 250°C.

## RESULTS AND DISCUSSION

### Phytochemical analysis

All three extracts of *Brassica oleracea* showed positive test results for phenols, flavonoids, alkaloids, tannins, terpenoids, glycosides, diterpenes and proteins. Steroids test positive for Hexane and Ethyl acetate and negative for ethanol. Coumarins and quinones are negative for all the three samples (Table 1). Phytochemicals are secondary metabolites which is produced mainly by plants, bacteria and fungi. They are low molecular weight molecules having diverse biological activities and chemical structures[17]. These metabolites help in plant growth, morphological differentiation and protecting the plants against various environmental constrains. Primary phytochemicals like phenols, alkaloids, proteins and glycosides play a major role in biological activity. Alkaloids compound contains nitrogen atom in a heterocyclic ring structure exhibiting antioxidant and antimicrobial activity. Among the phytochemicals group, phenols possess antioxidant activity containing large number of compounds with nearly greater than 8,000 compounds characterized by one aromatic ring with one or more hydroxyl groups attached.

**Table 1: Phytochemical analysis of *Brassica oleracea*.**

| Test | Samples | | |
|---|---|---|---|
| | BHE | BEAE | BEE |
| **Alkaloids** | + | + | + |
| **Glycosides** | + | + | + |
| **Proteins** | + | + | + |
| Terpenoids | - | - | - |
| Phenols and Tannins | + | + | + |
| Steroids | + | + | - |
| Flavonoids | + | + | + |
| Terpenoids | + | + | + |
| Coumarins | - | - | - |
| Quinones | - | - | - |
| Diterpenes | + | + | + |

**"+"** indicates presence and **"-"** indicates absence of the particular phytoconstituents.

## DPPH radical scavenging activity

It is one of the widely preferred and most employed methods for measuring radical scavenging activity in plant extracts. This is simple, standardized and relatively rapid method. DPPH is a nitrogen-centered, stable free radical that turns yellow to violet during a reduction process. Color change is dependent on the extract scavenging ability by donating a hydrogen atom. For every assay, ascorbic acid served as the positive control. All the 3 extracts showed strong radical scavenging activities in a concentration dependent manner. Scavenging activity was demonstrated by hexane extract at a variety of 23%-73%, Ethyl aetate extracts showed 37%-80%, Ethanol extracts showed 45% - 91% scavenging activity (Figure 1). These compounds exhibited concentration-dependent antioxidant properties that were significant ($p < 0.01$), greater the concentration levels raise the exhibition of activity related to radical scavenging. This was comparable to the 91%–95% antioxidant activity of the positive control ascorbic acid. Among the three tested extracts the ethanol extract showed the highest antioxidant activity. This is consistent with an earlier study showing that ethanol serves as a strong solvent for the extraction of phenolic compounds and flavonoids from Brassica species, which play a major role in their antioxidant properties[18]. This can be attributed to the existence of bioactive compounds that include flavonoids, Vit C, glucosinolates, polyphenols, quercetin and kaempferol which are more effectively extracted in polar solvents[19]. This highlights the potential application of *Brassica oleracea* in functional food and pharmaceutical formulations aimed at combating oxidative stress-related disorders.

## Anti-proliferative study of extracts

The anti-proliferative effects of extracts from *Brassica oleracea* were evaluated on THP-1 cell lines by measuring the proportion of viable cells after being treated with different solvent extracts. The findings (Figure 2) demonstrate a decrease in cell viability for all tested extracts in contrast with the control group. Among the extracts, the ethanolic extract (BEE) showed the most significant reduction in cell viability (96.48% ± 3.51), followed closely by the ethyl acetate extract (BEAE) (97.72% ± 0.20) and the hexane extract (BHE) (98.26% ± 0.72). The decrease in viability indicates that the phytochemicals found in *Brassica oleracea* extracts, such as flavonoids, glucosinolates, and polyphenols, may be responsible for the cytotoxic effects on THP-1 cells. Ethanol, being a polar solvent, tends to extract a higher abundance of bioactive compounds, which could clarify the more significant decline in cell viability seen with BEE compared to the other extracts. Likewise, the moderate cytotoxicity noted in BEAE may be linked to medium-polarity phytochemicals like flavonoids and specific glucosinolates. The hexane extract (BHE), having the lowest polarity, presented the smallest reduction in viability, probably due to the extraction of mainly non-polar compounds that have limited anti-proliferative effects[18].

The possible mechanisms behind the observed anti-proliferative effects might include the production of reactive oxygen species (ROS), an interruption of cell cycle, or the induction of programmed cell death. Prior research has indicated that phytochemicals derived from Brassica, especially glucosinolates and their hydrolysis products (isothiocyanates), can trigger apoptosis and cytotoxicity mediated by oxidative stress in cancer cells[20]. Additionally, the antioxidant properties of these extracts might affect cellular redox balance, thus influencing proliferation[19]. The results are consistent with earlier studies that have shown the anti-proliferative actions of compounds from broccoli. For example, methanolic extract of Brassica vegetables, has been documented to cause dose-dependent cytotoxic effects in lung adenocarcinoma cells[21]. Furthermore, the variations in cytotoxicity among the solvent extracts imply that the polarity of the solvent plays a vital role in extracting bioactive compounds with differing levels of effectiveness[22].

## FTIR

Ethanolic extract of *Brassica oleracea* FTIR analysis spectra results are displayed in (Figure 3). The analysis inferred the list of compound class (Table 2) present in the sample and the measurement of this energy will initiate the transition between the molecule's bond vibrational phases. The wide peak of absorption at 3200-3600 $cm^{-1}$ is associated with stretching vibrations of O-H, indicating the presence of hydroxyl-containing compounds such as flavonoids, phenols, and carbohydrates[23]. These compounds contribute significantly to the antioxidant properties of *Brassica oleracea*. The band at 3391.46 $cm^{-1}$ is

**Table 2: Compound class listed upon the wavenumber range in the infrared region.**

| Frequency range ($cm^{-1}$) | Appearance | Functional Group | Class |
|---|---|---|---|
| 3200-3600 | Broad | O-H stretching | Hydroxyl groups (Polyphenols, Flavonoids) |
| 3300-3500 | Medium | N–H stretching | Amine groups (Proteins, Alkaloids) |
| 3000-3100 | Weak | =C–H stretching | Alkenes (Flavonoids, Terpenoids) |
| 2850-2960 | Strong | C–H stretching | Aliphatic Hydrocarbons |
| 2100-2260 | Medium | C≡C stretching | Alkynes |
| 1600-1750 | Strong | C=O stretching | Carbonyl groups (Aldehydes, Ketones, Esters) |
| 1400-1600 | Variable | C=C stretching (Aromatic) | Phenolic Compounds |
| 1000-1300 | Variable | C–O stretching | Alcohols, Esters, Carboxylic acids |
| 600-900 | Strong | C–H bending (Aromatic) | Aromatic rings |

**Table 3: GC-MS compounds listed based on peak area percentage value.**

| Retention time | Area (%) | Compound name | Molecular Formula |
|---|---|---|---|
| 5.53 | 3.45 | Hexadecane | $C_{16}H_{34}$ |
| 9.27 | 4.12 | 9-Octadecenamide (Oleamide) | $C_{18}H_{35}NO$ |
| 12.79 | 5.86 | 2,2,2-Trifluoroethyl 2-methyltetrahydro-5-oxo-3-furancarboxylate | $C_8H_9F_3O_4$ |
| 15.68 | 6.32 | Phytol | $C_{20}H_{40}O$ |
| 18.92 | 7.25 | Octadecanoic acid (Stearic acid) | $C_{18}H_{36}O_2$ |
| 20.91 | 8.50 | Squalene | $C_{30}H_{50}$ |
| 23.14 | 4.75 | Stigmasterol | $C_{29}H_{48}O$ |

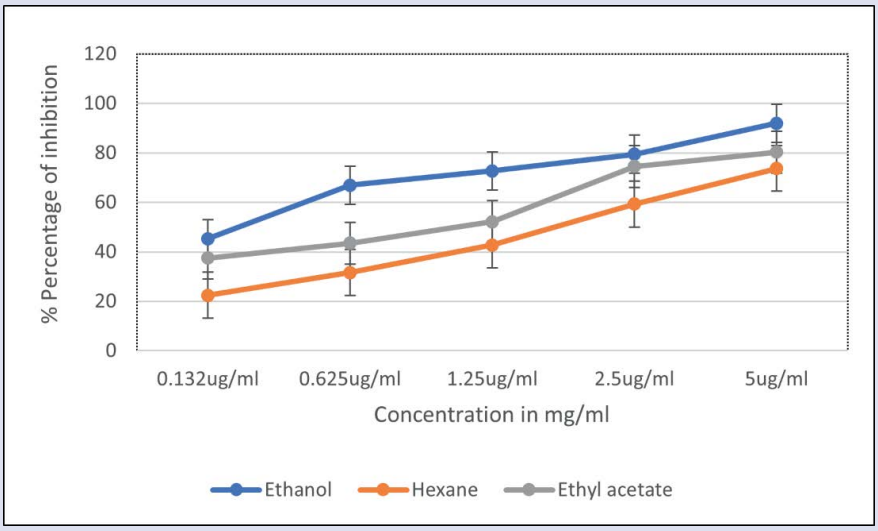


**Figure 1:** DPPH radical scavenging activity of BHE, BEAE and BEE.

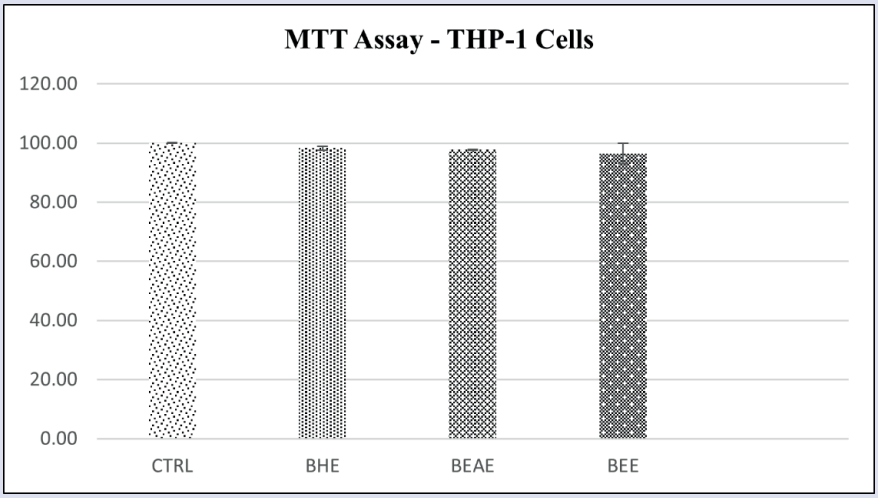


**Figure 2:** Anti-proliferative activity of hexane, ethyl acetate and ethanolic extracts of *Brassica oleracea* against THP-1 cell line at concentration 50µg/mL.

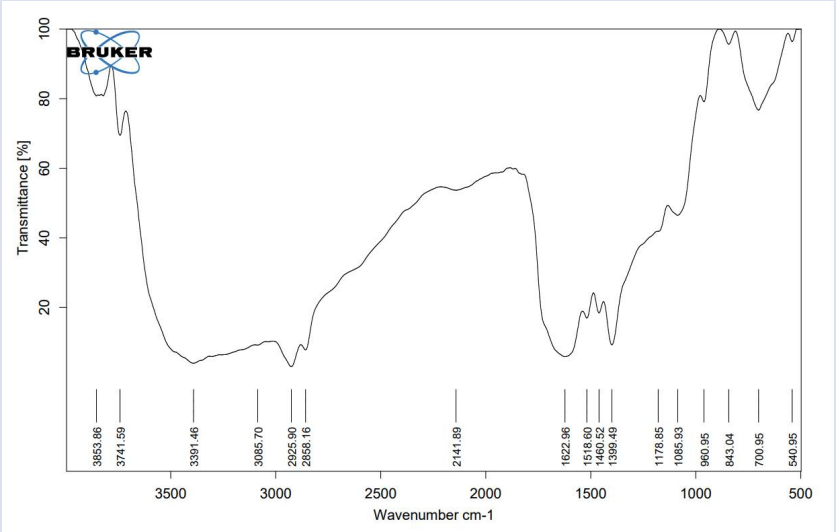


**Figure 3:** Determination of functional groups of ethanolic extract in the frequency range of 500 – 4000cm$^{-1}$.

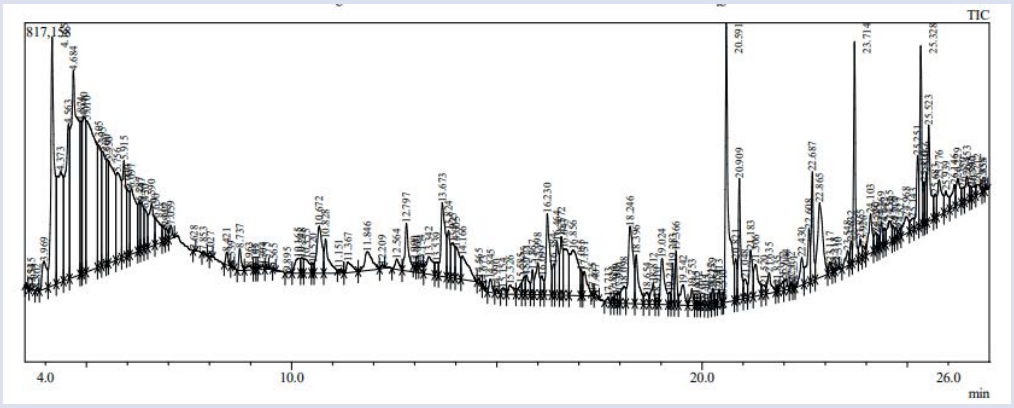


**Figure 4:** Identification of compound based on retention time duration by GCMS analysis in ethanolic extract.

associated with N–H stretching, which may be attributed to the presence of proteins, amines, or alkaloids in the extract. The existence of alkenes is suggested by the elevation at 3085.70 $cm^{-1}$, which is associated with =C–H stretch, likely found in terpenoids and flavonoids[24]. The peaks at 2925.90–2856.16 $cm^{-1}$ indicate C–H stretching vibrations, confirming the presence of aliphatic hydrocarbons, which are common in plant lipid fractions. The peaks in the range of 1516.80–1399.49 $cm^{-1}$ are characteristic of aromatic C=C stretching, confirming the existence of phenolic compounds, that contribute to the antioxidant potential of *Brassica oleracea*. The absorption bands in the 1178.85–1085.93 $cm^{-1}$ range correspond to C–O stretching, likely from alcohols, esters, and carboxylic acids. Peaks at 843.04–700.95 $cm^{-1}$ indicate aromatic C–H bending vibrations, confirming the presence of benzene rings in phenolic and flavonoid structures. These results align with previous research on *Brassica oleracea* and other cruciferous vegetables, wherein FTIR analysis has validated the existence of bioactive chemicals like flavonoids, glucosinolates, and polyphenols in the ethanolic extract. A study by Kim et al. (2022) indicated comparable absorption bands, suggesting that Brassica species are abundant in antioxidant and anti-inflammatory chemicals[18]. The existence of carbonyl and hydroxyl functional groups reinforces the function of these compounds in radical scavenging and cellular protection processes[19].

### Compound determination using GC-MS

Gas Chromatography-Mass Spectrometry (GC-MS) study was performed to detect the bioactive compounds in the ethanol extract of *Brassica oleracea* and was compared with The National Institute of Standard and Technology (NIST) database to interpret the results (Figure 4). The database will infer compound's name, molecular weight, structure and formula displayed in (Table 3). From the result analysis totally 162 compounds are identified in the ethanol extracts of *Brassica oleracea*. Abundance of a particular compound is identified by highest peak area percentage likewise 9-Octadecenamide, Hexadecane, 2,2,2-Trifluoroethyl 2-methyltetrahydro-5-oxo-3-furancarboxylate, etc. The identified compounds are known to possess biological activities such as like antimicrobial and antioxidants activities[25].

## CONCLUSION

This study highlights the phytochemical composition, antioxidant capacity, and anti-proliferative effects of *Brassica oleracea* extracts. The findings validate the existence of essential bioactive components, including flavonoids, phenols, and alkaloids, which enhance the plant's antioxidant properties. The DPPH assay revealed substantial radical scavenging capability, with ethanol extracts showing the greatest efficacy. Cytotoxicity studies further demonstrated a concentration dependent effect on cell viability, indicating its potential bioactivity. The structural analysis performed with FTIR and GC-MS revealed important functional groups and bioactive compounds that could play a role in these effects. The results indicate that *Brassica oleracea* may act as a potential naturally occurring antioxidant and anti-proliferative factor; however, additional mechanistic and *in vivo* research is necessary.

## ACKNOWLEDGEMENTS

The author would like to express their sincere gratitude to SRM Institute of Science and Technology for providing the facilities for the completion of this research work.

## REFERENCES

1. Lučić D, Pavlović I, Brkljačić L, Bogdanović S, Farkaš V, Cedilak A, et al. Antioxidant and antiproliferative activities of kale (Brassica oleracea L. Var. acephala DC.) and wild cabbage (Brassica incana Ten.) polyphenolic extracts. Molecules. 2023 Feb 15;28(4):1840.
2. Evans WC. Trease and Evans' pharmacognosy. Elsevier Health Sciences; 2009 May 27.
3. Kim JS, Cuong DM, Bae YB, Cho SK. Antioxidant and antiproliferative activities of solvent fractions of broccoli (Brassica oleracea L.) sprout. Applied Biological Chemistry. 2022 Dec;65(1):34.
4. Raja K, Nalini Uthaman, Saravanan R. Phytochemistry of methanolic extracts of brassica oleracea and its effect on anti-proliferative activity in human lung adenocarcinoma a549 cell line. International Journal of Current Research,2023;15(2), 23913-23917.
5. Nikolic G, Zlatkovic S, Cakic M, Cakic S, Lacnjevac C, Rajic Z. Fast fourier transform IR characterization of epoxy GY systems crosslinked with aliphatic and cycloaliphatic EH polyamine adducts. Sensors. 2010 Jan 19;10(1):684-96.
6. Wang J, Yang Z, Lin L, Zhao Z, Liu Z, Liu X. Protective effect of naringenin against lead-induced oxidative stress in rats. Biological trace element research. 2012 Jun 146:354-9.
7. Casuga FP, Castillo AL, Corpuz MJ. GC–MS analysis of bioactive compounds present in different extracts of an endemic plant Broussonetia luzonica (Blanco)(Moraceae) leaves. Asian Pacific Journal of Tropical Biomedicine. 2016 Nov 1;6(11):957-61.
8. Sannasimuthu A, Kumaresan V, Pasupuleti M, Paray BA, Al-Sadoon MK, Arockiaraj J. Radical scavenging property of a novel peptide derived from C-terminal SOD domain of superoxide dismutase enzyme in Arthrospira platensis. Algal research. 2018 Nov 1;35:519-29.
9. Cartea ME, Francisco M, Soengas P, Velasco P. Phenolic compounds in Brassica vegetables. Molecules. 2010 Dec 30;16(1):251-80.

10. Upadhyay R, Sehwag S, Singh SP. Antioxidant activity and polyphenol content of Brassica oleracea varieties. International journal of vegetable science. 2016 Jul 3;22(4):353-63.
11. Liu RH. Health benefits of fruit and vegetables are from additive and synergistic combinations of phytochemicals. The American journal of clinical nutrition. 2003 Sep 1;78(3):517S-20S.
12. Oo MT, Min M, Myo K, Tun M. Preliminary phytochemical screening and antioxidant activity of Brassica oleracea Linn.(broccoli). In3rd Myanmar Korea Conference Research Journal. 2015;3(4):1564-1569.
13. Ligor M, Szultka-Młyńska M, Rafińska K, Cwudzińska A. Comparative Studies of Extracts Obtained from Brassica oleracea L. Plants at Different Stages of Growth by Isolation and Determination of Isothiocyanates: An Assessment of Chemopreventive Properties of Broccoli. Molecules. 2024 Jan 20;29(2).
14. Al Talebi Z, Karhib MM, Taki MM, Salaam Abood E, Mubarak HA, Sahar Ahmed Ibrahim C. Chemical analysis, antioxidant, and antibacterial potential of aqueous extract of broccoli (Brassica oleracea) using GC-MS. Archives of Razi Institute. 2023 Apr 30;78(2):593.
15. Jahan IA, Mostafa M, Nimmi I, Hossain MH, Ahsan M, Chowdhury JU. Chemical and antioxidant properties of broccoli growing in Bangladesh. Dhaka University Journal of Pharmaceutical Sciences. 2010;9(1):31-7.
16. Roy A, Kordas K. The relation between low-level lead exposure and oxidative stress: a review of the epidemiological evidence in children and non-occupationally exposed adults. Current environmental health reports. 2016 Dec 3(4):478-92.
17. Dowlath MJ, Karuppannan SK, Gi DR, Sb MK, Subramanian S, Arunachalam KD. Effect of solvents on phytochemical composition and antioxidant activity of Cardiospermum halicacabum (L.) extracts. Pharmacognosy Journal. 2020;12(6).
18. Hostettman, K., Chinyanganga, F., Maillard, M., & Wolfende, J. L. Phytochemical studies of medicinal plants from Malawi. University of Zimbabwe (UZ) Publications, Zimbabwe, 1996:336.
19. Zafar I, Hussain AI, Fatima T, Abdullah Alnasser SM, Ahmad A. Inter-varietal variation in phenolic profile, sugar contents, antioxidant, anti-proliferative and antibacterial activities of selected Brassica species. Applied Sciences. 2022 Jun 8;12(12):5811.
20. Hameed M, Sultana B, Anwar F, Aslam M, Mushtaq M, Munir H. Changes in proximate composition, biochemical and antioxidant attributes of Broccoli (Brassica oleracea L.) in relation to foliar application of selected plant growth regulators. Pak J Bot. 2015 Oct 1;47:1685-91.
21. Teoh, E.S. Secondary metabolites of plants. In Medicinal Orchids of Asia; Teoh, E.S., Ed.; Springer International Publishing: Cham, Germany, p. 59–73; 2016. https://doi.org/10.1007/978-3-319-24274-3_5.
22. Shang M, Zhong H, Gao X, Shen M, Cai Y, Yang Z. Investigation of the Synergistic Protective Effect of Natural Antioxidants on DNA Damage. Pharmaceutical Chemistry Journal. 2023 Aug 57(5):663-8.
23. Ferreira L, Machado N, Gouvinhas I, Santos S, Celaya R, Rodrigues M, et al. Application of Fourier transform infrared spectroscopy (FTIR) techniques in the mid-IR (MIR) and near-IR (NIR) spectroscopy to determine n-alkane and long-chain alcohol contents in plant species and faecal samples. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2022 Nov 5;280:121544.
24. Jomova K, Alomar SY, Alwasel SH, Nepovimova E, Kuca K, Valko M. Several lines of antioxidant defense against oxidative stress: Antioxidant enzymes, nanomaterials with multiple enzyme-mimicking activities, and low-molecular-weight antioxidants. Archives of Toxicology. 2024 May 98(5):1323-67.
25. Sajid, M, Singh Prabjeet, Munir Hassan Samoon, A. K. Balange. Effect of dietary chitosan on non-specific immune response and growth of Cyprinus carpio challenged with Aeromonas hydrophila. Int Aquat Res. 2010;2(2):77–85.


**Cite this article:** Venugopal N, Jayaraman R, Dowlath MJH, Ramanujam GM, Subramaniyan S, Natarajan PS, Seetharaman J. Comprehensive Analysis of Brassica oleracea: Phytochemical Composition, Radical Scavenging, and Anti-Proliferative Activity. Pharmacogn J. 2025;17(3): 293-298.