Applied Biological Research 27(4): 515-521; (2025)
DOI: 10.48165/abr.2025.27.01.51

GC-MS PROFILE AND CHEMOPROTECTIVE EFFECT OF *Cinnamomum zeylanicum* BARK ESSENTIAL OIL AGAINST TRIPLE-NEGATIVE BREAST CANCER CELL LINE MDA-MB-231

Javed Ahamad

Department of Pharmacognosy, Faculty of Pharmacy, Tishk International University, Erbil - 044 001, Kurdistan Region (Iraq)
e-mail: *jas.hamdard@gmail.com; javed.ahamad@tiu.edu.iq*

(Received 7 September, 2025; accepted 9 November, 2025)

ABSTRACT

***Cinnamomum zeylanicum* Blume (Lauraceae) bark is one of the most important spices used to enhance the taste and flavour of Indian foods. *C. zeylanicum* bark, besides its use as a spice, has potential antioxidants, antimicrobial, antifungal, anti-inflammatory, and chemoprotective potential. The present study was aimed to characterize key chemical constituents of *C. zeylanicum* bark essential oil and determine its chemoprotective effect against triple-negative breast cancer cells (TNBC). The chemical composition of *C. zeylanicum* bark essential oil was determined by gas chromatography mass spectroscopy (GC-MS). The analysis identified 29 chemical compounds, amongst which (*E*)-cinnamaldehyde (69.89%), eugenol (14.27%), δ-cadinene (2.80%), and (*Z*)-caryophyllene (2.33%) were the key constituents. *C. zeylanicum* bark essential oil produced concentration- and time-dependent inhibition of TNBC (MDA-MB-231) cells. *C. zeylanicum* bark essential oil at 15.62 μL mL^{-1} concentration produced maximum inhibition of MDA-MB-231 cells which was about 90.6%. The aroma profile of *C. zeylanicum* bark essential oil and *in vitro* anticancer activity provide a scientific basis for its possible use as a cancer remedy.**

Keywords: Aroma profile, breast cancer, *Cinnamomum zeylanicum*, cinnamon, essential oil, TNBC

INTRODUCTION

Cinnamon has been used as a culinary herb and spice since ancient times due to its pleasant aroma and sweet taste (Rao and Gan, 2014). The *Cinnamomum* genus consists of many species, with *C. zeylanicum (C. verum)*, *C. cassia*, *C. loureiroi,* and *C. burmannii* as prominent species (Ranasinghe *et al.*, 2013). *Cinnamomum zeylanicum* Blume (family: Lauraceae) is preferred as a spice due to its characteristic aroma and taste. *C. zeylanicum* bark is a rich source of bioactive essential oil compounds responsible for its aroma (Kazemi and Mokhtariniya, 2016; Anand *et al.*, 2016). *C. zeylanicum* essential oil has been reported as a potent antioxidant, antimicrobial, and antifungal (Jayaprakasha *et al.*, 2003; Alizadeh Behbahani *et al.*, 2020; Tran *et al.*, 2020). Many studies have shown that *C. zeylanicum* essential oil has a potential chemoprotective effect against certain types of human cancer (Varalakshmi *et al.*, 2014; Aggarwal *et al.*, 2022; Cappelli *et al.*, 2023). *In vitro* and *in vivo* studies have shown the potential of *C. zeylanicum* essential oil against breast cancer cell lines (Abd Wahab *et al.*, 2017; Kubatka *et al.*, 2020).

Triple-negative breast cancer (TNBC) is an aggressive type of breast cancer with a high mortality rate. Traditional chemotherapy and hormonal therapies are ineffective against TNBC because this type of breast cancer lacks estrogen, progesterone, and HER2 receptors (Foulkes *et al.*, 2010; Ahmad *et al.*, 2024). A thorough literature review has revealed that *C. zeylanicum* essential oil is effective against many types of human cancers, including breast cancer. In recent decades, preclinical studies have shown that essential oils from many plants have potential against TNBC (Zito *et al.,* 2019; Lauricella *et al.*, 2022; Zhang *et al.*, 2022; Benedetti *et al.*, 2023;). Hameed *et al.* (2016) have explored the chemical composition of the methanolic extract of *C. zeylanicum* bark by GC-MS and reported the presence of many volatile and non-volatile chemical constituents but did not explore the major well-known chemical compounds of *C. zeylanicum* bark, like (*E*)-cinnamaldehyde, eugenol, benzaldehyde, and (*Z*)-caryophyllene. Another GC-MS study by Al-fekaiki *et al.* (2017) on the essential oil of *C. zeylanicum* bark from Basra (Iraq) also did not explore its major chemical compounds, and the results showed that the essential oil consists of cinnamaldehyde (57.83%), cyclohexane carboxylic acid (9.29%), and 6-octadecanoic acid (8.41%). The above studies did not accurately explore the chemical composition in the essential oil of *C. zeylanicum* bark as reported by many workers (Unlu *et al.,* 2010; Alizadeh Behbahani *et al.,* 2020). Hence, the present study was designed to characterize the aroma constituents present in the essential oil of *C. zeylanicum* bark available in Erbil (Iraq). The present study aimed to determine the key chemical constituents using GC-MS and evaluate the cytotoxic activity of the essential oil of *C. zeylanicum* bark against MDA-MB-231 TNBC cell lines.

MATERIALS AND METHODS

Plant material and chemicals

Cinnamomum zeylanicum bark (500 g) was procured in April 2024 from Majidi Hyper Market, Erbil, Kurdistan (Iraq). The plant sample was authenticated based on its organoleptic characteristics. *C. zeylanicum,* commonly called Ceylon cinnamon, has a sweet taste and characteristic aroma as compared to *C. cassia*, which has a slightly bitter taste, and a voucher specimen of plant sample was kept in the Department of Pharmacognosy, Faculty of Pharmacy, Tishk International University, Erbil, Iraq (PRL/2025/03). Triple-negative breast cancer (MDA-MB-231) cell lines were purchased from NCCS, Pune (India). Fetal bovine serum (FBS), Dulbecco's modified eagle medium (DMEM), and antibiotic solution were obtained from Gibco (USA). MTT (3-4,5 dimethylthiazol-2yl-2,5-diphenyl tetra-zolium bromide) at 5 mg mL^{-1} concentration was purchased from Sigma (USA); dimethyl sulfoxide from Himedia (India). Wash beakers and 96-well tissue culture plates were procured from Tarson (India).

Isolation of essential oil

For isolation of essential oils from *C. zeylanicum* bark, hydro-distillation method was followed (Ahamad *et al.,* 2019). Small pieces of *C. zeylanicum* bark (250 g) were kept with distilled water in a Clevenger apparatus. The apparatus was run for 4 to 6 h to isolate maximum essential oils. After separation of essential oils from bark, the oil was collected in a glass bottle and passed through anhydrous sodium sulphate to remove the traces of water. The pure essential oil was stored at 4ºC till further use.

GC-MS analysis and identification of chemical constituents

The bench-top Agilent GC-MS (Agilent Technologies, USA) was used to analyse the key chemical constituents present in *C. zeylanicum* bark. The essential oil was analysed on a non-polar DB-G glass column (30 m length × 0.25 mm internal diameter and 0.25 µm film thickness), and helium was used as carrier gas @ 1 mL min^{-1}. The operating temperature of oven was kept at 50ºC for 1 min and then isothermally kept for 2 min at 320ºC, and the injector port temperature was set at 280ºC. Split ratio of 1:5, data was captured at 70 eV, and scanning time was 1.5 sec. The chemical compounds were monitored in mass range of 50 to 1000 atomic mass units, and the total run time was 42 min. The ChemStation (Agilent Technologies, USA) was used to monitor all the processes. For identification of individual peaks (chemical constituents), the data from GC-MS was compared with the reported Kovats index (Unlu *et al.,* 2010; Alizadeh Behbahani *et al.,* 2020) and with mass fragmentation patterns obtained by GC-MS analysis, and compared with those stored in databases like NIST, Wiley8 libraries, and published literature (Unlu *et al*., 2010; Babushok *et al.,* 2011; Alizadeh Behbahani *et al.,* 2020).

Determination of cell viability by MTT assay

The cell viability assessed was performed by MTT assay as per Ahamad (2024) with slight modification. Briefly, the MDA-MB-231 cells were cultured in RPMI 1640 medium, and the medium was supplemented with 10% FBS and 1% penicillin. Cells were cultured at 37°C in a humidified 5% CO_2 incubator. For cell viability, cells were seeded in 96-well plates (10^4 cells $well^{-1}$) and incubated at 37°C. After 24 h, the cell culture medium was removed and replaced with fresh medium containing different concentrations (0.98 to 500 µL mL^{-1}) of *C. zeylanicum* essential oils, which had previously dissolved in DMSO. After 24 h exposure, MTT solution (5 mg mL^{-1} PBS) was added to each well. After 4 h, the formazan crystals were dissolved in DMSO, and optical density was read using a plate reader at 570 nm. GraphPad Prism (version 8) was used for statistical analysis and plotting data. Data is presented as mean ± standard deviation. One-way ANOVA was used to examine the significance between different groups, followed by Tukey's post hoc test. *p*-values < 0.05 were considered statistically significant (for $p > 0.05$; *$p \leq 0.05$, **$p \leq 0.01$, ***$p \leq 0.001$).

RESULTS AND DISCUSSION

GC-MS profile of Cinnamomum zeylanicum essential oil

The *C. zeylanicum* bark essential oil was analysed by GC-MS and revealed the presence of 29 chemical constituents (Table 1; Fig. 1). GC-MS analysis enabled the identification of 99.4% of the chemical

Table 1: Chemical composition of *C. zeylanicum* bark essential oils determined by GC-MS

S. No.	Chemical constituents	M.F.	R.T. (min)	K.I.	Content (%)
1.	Benzaldehyde[f]	C_7H_6O	8.254	936	0.22
2.	2-Methyl-1-benzofuran[f]	C_9H_8O	15.955	1109	0.06
3.	α-Terpineol[e]	$C_{10}H_{18}O$	16.969	1175	1.37
4.	(Z)-Cinnamaldehyde[a]	C_9H_8O	19.549	1182	0.94
5.	(*E*)-Cinnamaldehyde[a]	C_9H_8O	23.141	1268	69.89
6.	α-Terpinyl acetate[e]	$C_{12}H_{20}O_2$	25.239	1334	0.13
7.	Eugenol[a]	$C_{10}H_{12}O_2$	25.963	1339	14.27
8.	α-Copaene[b]	$C_{15}H_{24}$	26.354	1375	1.31
9.	(*Z*)-Caryophyllene[b]	$C_{15}H_{24}$	28.180	1407	2.33
10.	Cinnamyl acetate[d]	$C_{11}H_{12}O_2$	28.759	1408	0.05
11.	*cis*-α-Bergamotene[b]	$C_{15}H_{24}$	29.512	1451	0.61
12.	(*E*)-Caryophyllene[b]	$C_{15}H_{24}$	29.607	1454	0.21
13.	Viridiflorene[b]	$C_{15}H_{24}$	30.463	1488	0.26
14.	Cadina-1(6),4-diene[b]	$C_{15}H_{24}$	30.776	1442	0.15
15.	α-Muurolene[b]	$C_{15}H_{24}$	31.103	1491	0.06
16.	*β*-Bisabolene[b]	$C_{15}H_{24}$	31.359	1499	0.12
17.	γ-Cadinene[b]	$C_{15}H_{24}$	31.476	1505	0.88
18.	γ-Bisabolene[b]	$C_{15}H_{24}$	31.873	1511	0.27
19.	*β*-Curcumene[b]	$C_{15}H_{24}$	32.290	1512	1.83
20.	δ-Cadinene[b]	$C_{15}H_{24}$	32.405	1513	2.80
21.	Eugenyl acetate[a]	$C_{12}H_{14}O_3$	32.612	1524	0.34
22.	*trans*-Cadina-1,4-diene[b]	$C_{15}H_{24}$	32.790	1532	0.32
23.	(*E*)-α-Bisabolene[b]	$C_{15}H_{24}$	33.146	1534	0.30
24.	Tetradecanal[f]	$C_{14}H_{28}O$	34.467	1594	0.05
25.	Humulol[c]	$C_{15}H_{26}O$	36.057	1618	0.09
26.	*β*-Caryophyllene alcohol[c]	$C_{15}H_{26}O$	36.487	1625	0.21
27.	α-Muurolol[c]	$C_{15}H_{26}O$	37.161	1627	0.20
28.	α-Cadinol[c]	$C_{15}H_{26}O$	37.254	1652	0.13
29.	α-Bisabolol[c]	$C_{15}H_{26}O$	38.799	1668	0.15

Where MF (molecular formula), RT (retention time, minutes), and KI (Kovats index); [a]Phenylpropanoids (04), [b]Sesquiterpenes (14), [c]Sesquiterpenoids (05), [d]Styrenes (01), [e]Monoterpenoids (02), and [f]Miscellaneous (03).

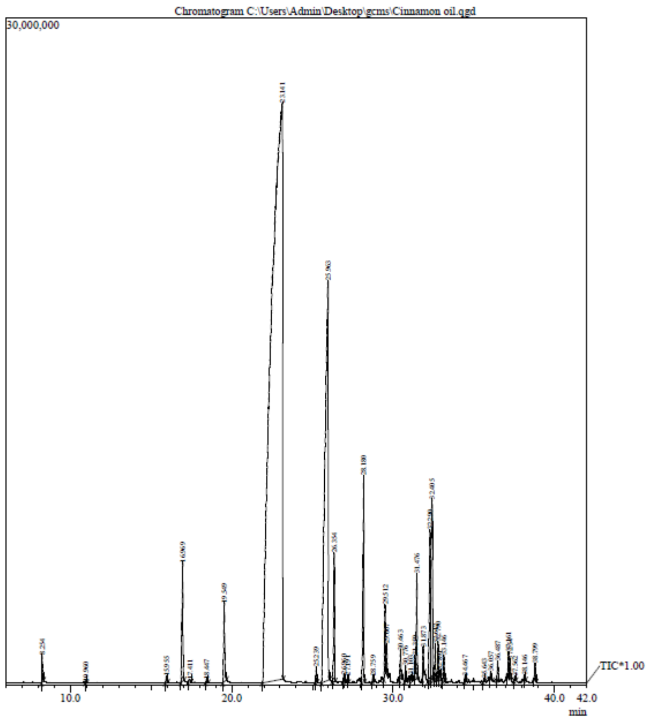

Fig. 1: GC-MS chromatograph of *Cinnamomum zeylanicum* bark essential oil

compounds present in *C. zeylanicum* essential oil. The key chemical compounds identified were (*E*)-cinnamaldehyde (69.89%), eugenol (14.27%), δ-cadinene (2.80%), and (*Z*)-caryophyllene (2.33%).

Phenylpropanoids (~ 85.44%) were found as the key class of compounds present in *C. zeylanicum* essential oil, in which (*E*)-cinnamaldehyde (69.89%) and eugenol (14.27%) make major contributions. The second most predominant class was sesquiterpene; the GC-MS analysis identified 14 chemical compounds belonging to this class. Sesquiterpenoid compounds (05), monoterpenoids (02), and styrene (01) compounds were also identified in *C. zeylanicum* essential oil. Unlu *et al.* (2010) have explored the chemical composition of *C. zeylanicum* bark essential oil by GCMS, and reported (*E*)-cinnamaldehyde (68.95%), benzaldehyde (9.94%) and (*E*)-cinnamyl acetate (7.44%) as major chemical compounds. Alizadeh Behbahani *et al.* (2020) also characterized *C. zeylanicum* bark essential oil by GC/MS and identified (*E*)-cinnamaldehyde (71.5%), linalool (7.0%), *β*-caryophyllene (6.4%), eucalyptol (5.4%), and eugenol (4.6%) as key chemical compounds. The present findings revealed a similar pattern of chemical composition in *C. zeylanicum* bark essential oil, especially concerning key chemical constituents like (*E*)-cinnamaldehyde and eugenol. There are some variations in other chemical compounds that may be due to geographical variation, storage, drying, and isolation methods (Najibullah *et al.*, 2022; Ahamad *et al.*, 2021)

Cell cytotoxicity activity of C. zeylanicum essential oil on TNBC cells

The cell cytotoxicity activity of *C. zeylanicum* bark essential oil was examined against MDA-MB-231 cell lines by MTT assay, and the study results were presented in Fig. 2 and 3. The treatment with *C. zeylanicum* bark essential oil at the concentrations varying from 1.95 to 500 µL mL^{-1} for 24 h significantly reduced the cell viability of MDA-MB-231 cell lines in a concentration- and time-dependent manner (Fig. 2 and 3). It is clearly evident that at a concentration of 0.98 µL mL^{-1}, *C. zeylanicum* bark essential oil did not affect the MDA-MB-231 cell lines. The maximum cytotoxicity was observed at a concentration of 15.62 µL mL^{-1}, which was about 90.60%. After that peak, there is no significant variation in cell viability.

The present study showed that *C. zeylanicum* bark essential oil significantly (***$p \leq 0.001$) inhibits the cell viability of MDA-MB-231 cell lines as compared to the

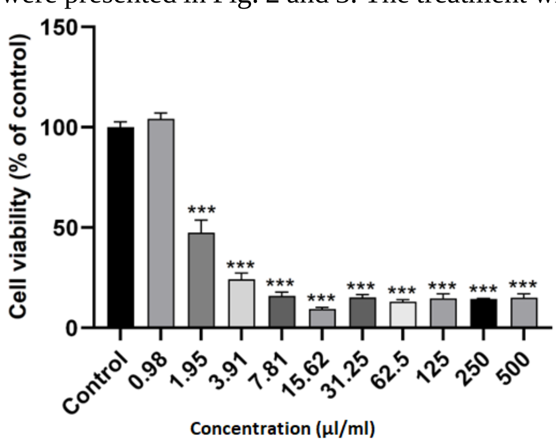

Fig. 2: Cell viability after treatment with *C. zeylanicum* bark essential oil against MDA-MB-231 cell lines

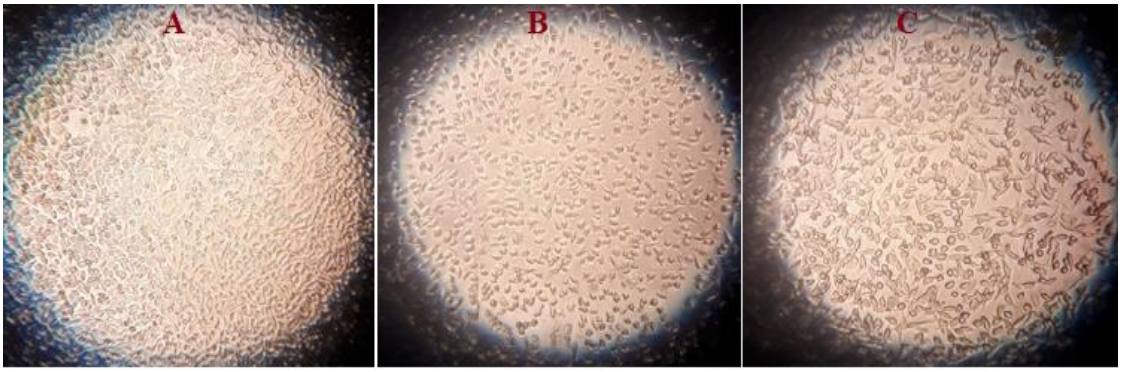

Fig. 3: Cell viability after treatment with *C. zeylanicum* bark essential oil against TNBC (MDA-MB-231) cell lines: A) Control, B) *C. zeylanicum* bark essential oil @ 3.91 μg mL^{-1}, and C) *C. zeylanicum* bark essential oil @ 15.62 μg mL^{-1}.

control. The study revealed that *C. zeylanicum* bark essential oil is a potential anticancer remedy. Our findings are in close agreement with previous studies performed on cinnamon. Abd Wahab and Adzmi (2017) showed that *C. zeylanicum* bark essential oil significantly produces cell toxicity with an IC_{50} value of 58 μg mL^{-1} against MCF-7 breast cancer cell lines. Husain *et al.* (2018) studied the anticancer activity of ethanolic extract of *C. zeylanicum,* and the study shows that its extract significantly inhibits cell viability of MDA-MB-231 cell lines with an IC_{50} value of 25 μg mL^{-1}. Kubatka et al. (2020) explored that *C. zeylanicum* bark powder can significantly inhibit MCF-7 and MDA-MB-231 cell lines.

Conclusion: *C. zeylanicum* bark is a well-known traditional medicinal plant used as a spice and condiment. Its bark is a household remedy as it has carminative, stomachic, stimulant, and stringent properties. GC/MS analysis explores the chemical composition of *C. zeylanicum* bark available in local market of Iraq. The key constituents in essential oil were found as (*E*)-cinnamaldehyde and eugenol. The MTT assay revealed the potential chemoprotective effect of *C. zeylanicum* bark essential oil. The present study's finding on *C. zeylanicum* provides a scientific basis for further use as a possible remedy for breast cancer, especially TNBC.

Acknowledgement: We greatly appreciate the research facility provided by the Department of Pharmacognosy, Faculty of Pharmacy, Tishk International University, Erbil, Iraq.

Ethical statement: In the present study, there is no use of animals or humans, so we do not need ethical approval.

Conflict of interest: The author declares that there is no conflict of interest.

REFERENCES

Abd Wahab, W. and Adzmi, A.N. 2017. The investigation of cytotoxic effect of *Cinnamomum zeylanicum* extracts on human breast cancer cell line (MCF7). *Science Heritage Journal,* **1**(2): 23-28.

Aggarwal, S., Bhadana, K., Singh, B., Rawat, M., Mohammad, T., Al-Keridis, L.A., *et al.,* 2022. *Cinnamomum zeylanicum* extract and its bioactive component cinnamaldehyde show anti-tumor effects via inhibition of multiple cellular pathways. *Frontiers in Pharmacology,* **13**: 918479. [*doi: 10.3389/fphar.2022.918479*].

Ahamad, J. 2021. Aroma profile and α-glucosidase inhibitory activity of essential oil of *Mentha* spicata leaves. *Journal of Essential Oil Bearing Plants,* **24**(5): 1042-1048.

Ahamad, J. 2024. Anticancer potential of cardamom (*Elettaria cardamomum*) essential oil against TNBC, Glioma and kidney cancer *in vitro*. *Integrative Biomedical Research*, **8**(9): 1-7.

Ahamad, J., Uthirapathy, S., Mohammed Ameen, M.S. and Anwer, E.T. 2019. Essential oil composition and antidiabetic, anticancer activity of *Rosmarinus officinalis* L. leaves from Erbil (Iraq). *Journal of Essential Oil Bearing Plants*, **22**(6): 1544-1553.

Ahmad, J., Ahamad, J., Algahtani, M.S., Garg, A., Shahzad, N., Ahmad, M.Z., *et al.*, 2024. Nanotechnology-mediated delivery of resveratrol as promising strategy to improve therapeutic efficacy in triple negative breast cancer (TNBC): Progress and promises. *Expert Opinion on Drug Delivery*, **21**(2): 229-244.

Al-fekaiki, D.F., Niamah, A.K. and Al-Sahlany, S.T.G. 2017. Extraction and identification of essential oil from *Cinnamomum zeylanicum* barks and study the antibacterial activity. *The Journal of Microbiology, Biotechnology and Food Sciences*, **7**(3): 312. [*https://doi.org/10.15414/jmbfs.2017/18.7.7.312-316*].

Alizadeh Behbahani, B., Falah, F., Lavi Arab, F., Vasiee, M. and Tabatabaee Yazdi, F. 2020. Chemical composition and antioxidant, antimicrobial, and antiproliferative activities of *Cinnamomum zeylanicum* bark essential oil. *Evidence-Based Complementary and Alternative Medicine*, **2020**(1): 5190603. [*doi: 10.1155/2020/5190603*].

Anand, V., Kumar, S. and Hedina, A. 2016. *Cinnamomum zeylanicum* Linn. The spice with multi potential. *Systematic Reviews in Pharmacy*, **7**(1): 24-29. [*doi: 10.5530/srp.2016.7.3*].

Babushok, V.I., Linstrom, P.J. and Zenkevich, I.G. 2011. Retention indices for frequently reported compounds of plant essential oils. *Journal of Physical and Chemical Reference Data*, **40**(4): 043101-47. [*doi: 10.1063/1.3653552*].

Benedetti, S., Nasoni, M.G., Luchetti, F. and Palma, F. 2023. New insights into the cytotoxic effects of *Thymus vulgaris* essential oil on the human triple-negative breast cancer cell line MDA-MB-231. *Toxicology in Vitro*, **93**: 105705. [*doi: 10.1016/j.tiv.2023.105705*].

Cappelli, G., Giovannini, D., Vilardo, L., Basso, A., Iannetti, I., Massa, M. and Mariani, F. 2023. *Cinnamomum zeylanicum* blume essential oil inhibits metastatic melanoma cell proliferation by triggering an incomplete tumour cell stress response. *International Journal of Molecular Sciences*, **24**(6): 5698. [*doi: 10.3390/ijms24065698*].

Foulkes, W.D., Smith, I.E. and Reis-Filho, J.S. 2010. Triple-negative breast cancer. *New England Journal of Medicine*, **363**(20): 1938-1948.

Hameed, I.H., Altameme, H.J. and Mohammed, G.J. 2016. Evaluation of antifungal and antibacterial activity and analysis of bioactive phytochemical compounds of *Cinnamomum zeylanicum* (Cinnamon bark) using gas chromatography-mass spectrometry. *Oriental Journal of Chemistry*, **32**(4): 1769. [*http://dx.doi.org/10.13005/ojc/320406*].

Husain, I., Ahmad, R., Chandra, A., Raza, S.T., Shukla, Y. and Mahdi, F. 2018. Phytochemical characterization and biological activity evaluation of ethanolic extract of *Cinnamomum zeylanicum*. *Journal of Ethnopharmacology*, **219**: 110-116.

Jayaprakasha, G.K., Jagan Mohan Rao, L. and Sakariah, K.K. 2003. Volatile constituents from *Cinnamomum zeylanicum* fruit stalks and their antioxidant activities. *Journal of Agricultural and Food Chemistry*, **51**(15): 4344-4348.

Kazemi, M. and Mokhtariniya, S. 2016. Essential oil composition of bark of *Cinnamomum zeylanicum*. *Journal of Essential Oil Bearing Plants*, **19**(3): 786-789.

Kubatka, P., Kello, M., Kajo, K., Samec, M., Jasek, K., Vybohova, D. and Mojzis, J. 2020. Chemopreventive and therapeutic efficacy of *Cinnamomum zeylanicum* L. bark in experimental breast carcinoma: Mechanistic *in vivo* and *in vitro* analyses. *Molecules*, **25**(6): 1399. [*https://doi.org/10.3390/molecules25061399*].

Lauricella, M., Maggio, A., Badalamenti, N., Bruno, M., D'Angelo, G.D. and D'Anneo, A. 2022. Essential oil of *Foeniculum vulgare* subsp. *piperitum* fruits exerts an anti-tumor effect in triple-negative breast cancer cells. *Molecular Medicine Reports*, **26**(1): 243. [*doi: 10.3892/mmr.2022.12759*].

Najibullah, S.N.M., Ahamad, J., Sultana, S. and Zafar, A. 2022. Chemical characterization and evaluation of anticancer activity of *Pistacia terebinthus* Linn. fruits essential oil. *Journal of Essential Oil Bearing Plants,* **25**(1): 180-187.

Ranasinghe, P., Pigera, S., Premakumara, G.S., Galappaththy, P., Constantine, G.R. and Katulanda, P. 2013. Medicinal properties of 'true'cinnamon (*Cinnamomum zeylanicum*): A systematic review. *BMC Complementary and Alternative Medicine*, **13**(1): 275. [*doi: 10.1186/1472-6882-13-275*].

Rao, P.V. and Gan, S.H. 2014. *Cinnamon*: A multifaceted medicinal plant. *Evidence-Based Complementary and Alternative Medicine*, **2014**(1): 642942. [*doi: 10.1155/2014/642942*].

Tran, H.N., Graham, L. and Adukwu, E.C. 2020. *In vitro* antifungal activity of *Cinnamomum zeylanicum* bark and leaf essential oils against *Candida albicans* and *Candida auris*. *Applied Microbiology and Biotechnology*, **104**(20): 8911-8924.

Unlu, M., Ergene, E., Unlu, G.V., Zeytinoglu, H.S. and Vural, N. 2010. Composition, antimicrobial activity and *in vitro* cytotoxicity of essential oil from *Cinnamomum zeylanicum* Blume (Lauraceae). *Food and Chemical Toxicology,* **48**(11): 3274-3280.

Varalakshmi, B., Anand, A.V., Karpagam, T., Bai, J.S. and Manikandan, R. 2014. *In vitro* antimicrobial and anticancer activity of *Cinnamomum zeylanicum* Linn. bark extracts. *International Journal of Pharmacy and Pharmaceutical Science,* **6**(1): 12-18.

Zhang, M., Qiu, B., Sun, M., Wang, Y., Wei, M., Gong, Y. and Yan, M. 2022. Preparation of black pepper (*Piper nigrum* L.) essential oil nanoparticles and its antitumor activity on triple negative breast cancer *in vitro*. *Journal of Food Biochemistry,* **46**(12): e14406. [*doi: 10.1111/jfbc.14406*].

Zito, P., Labbozzetta, M., Notarbartolo, M., Sajeva, M. and Poma, P. 2019. Essential oil of *Cyphostemma juttae* (Vitaceae): Chemical composition and antitumor mechanism in triple negative breast cancer cells. *PLOS One,* **14**(3): e0214594. [*https://doi.org/10.1371/ journal.pone. 0214594*].