Annals of Phytomedicine 14(1): 44-53, 2025

DOI: http://dx.doi.org/10.54085/ap.2025.14.1.5

Annals of Phytomedicine: An International Journal
http://www.ukaazpublications.com/publications/index.php

Print ISSN : 2278-9839 Online ISSN : 2393-9885

Review Article : Open Access

Anticancer and antimicrobial properties of extracted bioactives of Rosemary (*Rosmarinus officinalis* L. syn., *Salvia rosmarinus* Spenn.)

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Article Info

Article history
Received 5 January 2025
Revised 21 February 2025
Accepted 22 February 2025
Published Online 30 June 2025

Keywords
Rosemary
Cancer
Antimicrobial
Extraction
Chemical constituents

Abstract

Rosemary is one of the potential herbs being exploited by various industries worldwide. It has been used in the treatment of cancer, in aromatherapy, and psychological treatments, and as an antimicrobial agent. The major constituents of the essential oil are 1,8-cineole, a pinene, camphene, β pinene, carnosol, and carnosic acid which are attributable to all the important properties of the essential oil. Many novel extraction procedures such as microwave assisted steam distillation, multistage steam distillation, CO_2 supercritical extraction, microwave hydrodiffusion and gravity, solvent free microwave extraction, controlled Instantaneous decompression have emerged apart from the conventional hydrodistillation and steam distillation, by realizing the advantages over the traditional ones. Hence, this present study focuses on novel and profitable extraction techniques, chemical constituents, anticancer and antimicrobial properties of *Rosmarinus officinalis* L.

1. Introduction

Medicinal and aromatic plants have recently gained a wide scope to be exploited for their valuable essential oils, extracts for varied purposes like additives in food, plant protection, and also for their research interest due to their bioactive secondary metabolites, which offer promising medicinal applications (Mathe, 2018; Sokhibjon *et al.*, 2024).

Rosemary (*Rosmarinus officinalis* L. syn., *Salvia rosmarinus* Spenn.) is one of the important herbs belonging to the family Lamiaceae. It is an evergreen perennial shrub grown across the world for its health benefits and therapeutic potential derived from its oil. It is also referred to as the "Dew of the sea" due to its aroma and fragrance (Selavaraj *et al.*, 2022). The leading exporters of rosemary are India, Turkey, and South Africa. India exports rosemary to the United States, Australia and Germany. From India, the yearly export is gaining an increase of 3% (Volza Grow Global, 2024). Besides the whole plant, there is a growing demand for the oil and extract of the herb**.** This has been used anciently by the tribes in treating splitting headaches, relieving muscle spasms, and in psychotherapy (Abu-Al-Basal, 2010; Rahbardar and Hosseinzadeh, 2020; Manville *et al.*, 2023). This herb is noticed for its unique taste and pleasant smell. It not only possesses antibacterial and anti-fungal properties but also has beneficial effects on human health. Its potential is being exploited across various industries and pharmaceuticals (Pawowska *et al.*, 2020). Cosmetics is one of the growing industries, that explores this valuable plant to treat cellulite, as an antioxidant to reduce ageing and can be used in the treatment of skin cancers (Macedo *et al.*, 2020). As it contains polyphenols such as carnosic and rosemarinic acid, its use has also been exploited in treating type 2 diabetes in humans (Naimi *et al.*, 2017). Rosemary extracts, essential oil, and hydrosols have been found to have antimicrobial (Abozid and Asker, 2013), antinociceptive (Beltrán-Villalobos *et al.*, 2017), anticancer (Jaglanian *et al.*, 2020a), antioxidant (Saini *et al.*, 2020), antidiabetic (Kabubii *et al.*, 2024), antidepressant (Guo *et al.*, 2018), anti-inflammatory (Habtemariam, 2023), antispasmodic (Ai-Sereiti *et al.*, 1999) properties. It is also used to enhance memory and increase sleep quality (Nematolahi *et al.*, 2018).The evaluation of essential oils after the process of distillation, are separated and analyzed majorly through gas chromatography (GC) or gas chromatography mass spectrometry (GC-MS) (Pintore *et al.*, 2002; Tschiggerl and Bucar, 2010). Thorough GC-MS, 15 to 80 chemical constituents have been identified after distillation procedures (Socaci *et al.*, 2009; Rajeswara Rao *et al.*, 2010; Amin *et al.*, 2017; Abozid and Asker., 2013). The major constituents identified were α-pinene, 1,8-cineole, camphor, verbenone, borneol, linalool, eucalyptol, and borneol under various conditions and growth factors (Gachkar *et al.*, 2007; Tschiggerl and Bucar, 2010; Hcini *et al.*, 2013; Tomi *et al.*, 2016; Mwithiga *et al.*, 2022). The essential oil consists of neutral lipids, monounsaturated, polyunsaturated, and saturated fatty acids, oxygenated monoterpenes, monoterpene hydrocarbons, tocochromanols, and phenols (Tigrine-Kordjani *et al.*, 2012; Elbanna *et al.*, 2018; Doozakhdarreh *et al.*, 2022;). The percentage of major constituents present in majority

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of the genotypes include 1,8-cineole (20.1 to 37.5%), camphor (12.35 to13.55%), α pinene (8.58 to 11.8%), β pinene (6.7 to 6.10%), borneol (4.0 to 5.61%), camphene (5.07 to 5.85%), α terpineol (4.30 to 8.17%), limonene (3.19 to 3.04%), *p* cymene (2.42 to 3.11%), verbenone (6.20 to 8.14%) (Rajeswara Rao *et al.*, 2010; Tavassoli *et al.*, 2011; Hcini *et al.*, 2013; Amin *et al.*, 2017). Upon polyphenol analysis diterpenoids and flavonoids were the major classes. Carnosic acid was the predominant polyphenol present in it (Mena *et al.*, 2016).

Rosemary extracts have also been used in the food industry to preserve various natural food products through their antibacterial, antifungal, and antioxidant properties. Its use has been mainly exploited in the preservation of meat and meat products due to its aroma (Al-Hijazeen and Al-Rawashdeh, 2019; Lorenzo *et al.*, 2021; Boukhari and Fatimi, 2023).

Though plants in this world are part of curing diseases and in rural healthcare (Majeed, 2017) and in the modern world, the usage of chemical drugs and medication plays a major part in the treatment of all diseases and disorders. However, the awareness of the side effects and the chemical toxicity in humans has shown light upon traditional and herbal medicines. There is also a scope widened for combination treatments with medicinal plants (Rathore *et al.*, 2017). This review highlights the major constituents of rosemary extract, and the procedures to extract them. The anticancer effects on breast cancer, prostate cancer, colon cancer, and skin cancer have been presented. Antimicrobial effects for bacteria and fungi have also been discussed in this review.

2. Extraction procedures

Rosemary oil extraction carried out by steam distillation (SD) and hydrodistillation (HD) revealed that steam distillation is found to have more oil recovery than hydrodistillation. 1.2% of essential oil yield was obtained through steam distillation and 0.44% from hydrodistillation which was very low. 80% of the oil was recovered in 10 min in steam distillation rather than 30 min in hydrodistillation (Boutekedjiret *et al.*, 2003; Presti *et al.*, 2005; Arafa, 2019). The maximum yield of oil was obtained through steam distillation. Spadi *et al.* (2021) stated that the optimum time for greater oil yield was 120 min, with no increase in yield after this point.

Multistage steam distillation proved advantageous for industrial applications. Steam had more contact time with the leaves, so the yield obtained was also greater in a shorter duration of 30 min, 85% of the oil was recovered through multistage steam distillation. (Malekydozzadeh *et al.*, 2012).

Microwave assisted hydrodistillation (MAHD) is one of the new emerging methods in extraction procedures. Unlike hydrodistillation, this process is a solvent-free extraction procedure. The time taken for extraction is 20 min. The oil yield and the characteristics are like those obtained from steam or hydrodistillation but had major advantages proving to be environmentally friendly by emitting less CO_2 into the atmosphere, decreasing energy consumption, and reducing the cost of production (Karakaya *et al.*, 2014; Elyemni *et al.*, 2019; Ferreira *et al.*, 2020). By increasing the microwave generation by 50%, more oxygenated compounds are obtained with decreased monoterpenes. Hence, the obtained oil quality was superior under microwave assisted hydrodistillation (Fazlali *et al.*, 2015).

CO_2 supercritical extraction gives greater yields of essential oil than hydrodistillation and steam distillation. The essential oil extracted through this method shows 14 times greater antioxidant activity than that obtained through other methods of extraction (Conde-Hernández *et al.*, 2017). Superheated water which is about 125% and 175% under pressure was found to extract oxygenated aroma compounds, but this leaves behind some monoterpenes, higher hydrocarbons, lipids and waxes. The oxygenated compounds obtained are more when compared to steam distillation (Basile *et al.*, 1998). Microwave hydrodiffusion and gravity (MHG), proves to have many advantages of using no water or solvent which is environmentally safer, reducing the operational time from 3 h of hydrodistillation to 15 min, with lesser energy costs and essential oil with more antimicrobial and antioxidant activity (Bousbia *et al.*, 2009).

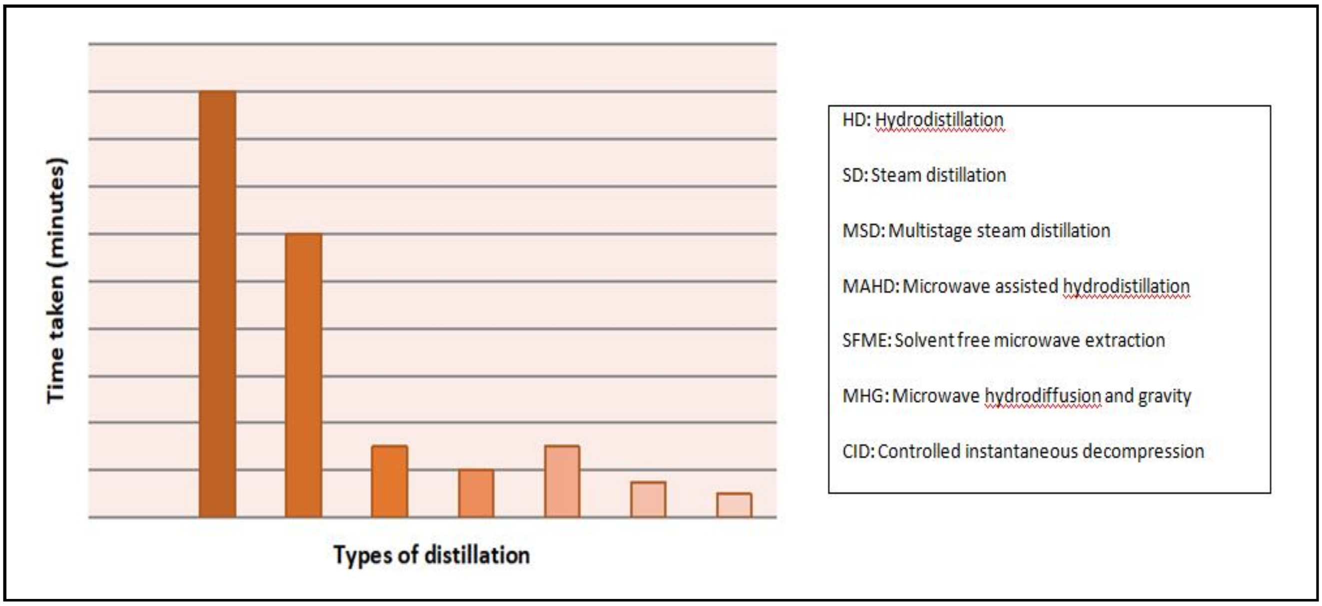

Figure 1: Distillation types and time taken.

Solvent free microwave extraction (SFME) is a combination of microwave heating and dry distillation. The yield and oil quality were the same in both the solvent free microwave extraction and hydrodistillation, except for the time taken (30 min and 180 min). SFME is found to be an alternative environmentally friendly technique to be used in industries for extraction (Filly *et al.*, 2014). Enzyme assisted extraction with cellulase and hemicellulase and in combinations gave a higher yield of essential oil (Hosni *et al.*, 2013). Controlled instantaneous decompression, an emerging method, can be used to extract 97% of essential oil in about 10 min by applying a steam pressure of about three bar (Rezzoug *et al.*, 1998). Subjecting rosemary leaves with a moisture content of 0.40 g H_2O/g of dry material, subjecting to a short period of steam pressure of 410 kPa and then dropping pressure instantaneously to vacuum to 50 kPa, with an operational time of 16 min is effective in extracting 96% of essential oil through polynomial equation (Rezzoug *et al.*, 2005).

3. Classification of essential oil

Rosemary oil is classified into four categories based on the major component. These variations are found in different genotypes, varied agroclimatic conditions, and differences in extraction methods. In India, the essential oil is cineoliferous and camphoriferous type (Rajeswara Rao *et al.*, 2010; Borges *et al.*, 2019; Sadeh *et al.*, 2019) (figure 2).

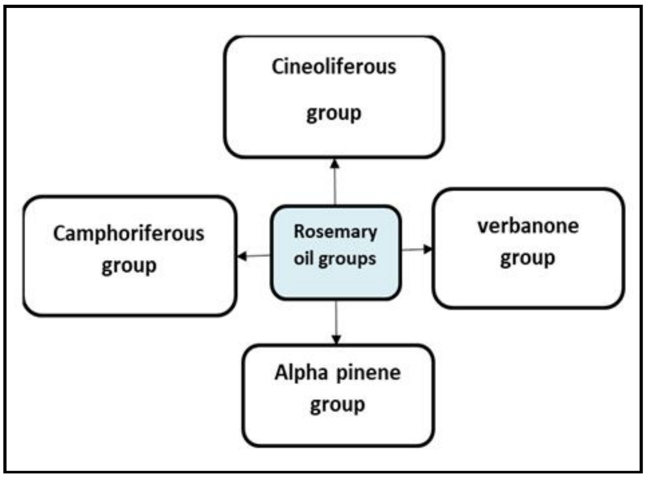

Figure 2: Rosemary essential oil based on the major component present.

The components of the extracts are classified into various classes. This may include groups like monoterpenes, monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpenes, diterpenes, phenolic acids, and flavonoids (Almela *et al.*, 2006; Borges *et al.*, 2019).

Table 1: Classes of predominant constituents present in rosemary

Class	Components	Chemical formula	Reference
Monoterpenes	α-pinene	$C_{10}H_{11}$	Borges *et al.*, 2019
	Camphene	$C_{10}H_{16}$	Kadri *et al.*, 2011
	Verbenone	$C_{10}H_{14}O$	Borges *et al.*, 2019
	α-thujone	$C_{10}H_{16}O$	Kadri *et al.*, 2011
Monoterpene hydrocarbons	Limonene	$C_{10}H_{16}$	Borges *et al.*, 2019
	β-pinene	$C_{10}H_{16}$	Yosr *et al.*, 2013
	terpinolene	$C_{10}H_{16}$	Borges *et al.*, 2019
	β-myrcene	$C_{10}H_{16}$	Yosr *et al.*, 2013
	p-cymene	$C_{10}H_{14}$	Borges *et al.*, 2019
Oxygenated monoterpenes	1,8-cineole	$C_{10}H_{18}O$	Borges *et al.*, 2019
	Camphor	$C_{10}H_{16}O$	Tavassoli *et al.*, 2011
	Borneol	$C_{10}H_{18}O$	Mena *et al.*, 2016
	Linalool	$C_{10}H_{18}O$	Borges *et al.*, 2019
Phenolic acids	Rosemarinic acid	$C_{10}H_{16}O_8$	Almela *et al.*, 2006
	Hydrobenzoic acid	$C_7H_6O_3$	Mena *et al.*, 2016
Sesquiterpenes	Caryophyllene	$C_{15}H_4$	Borges *et al.*, 2019
	α-humulene	$C_{15}H_{24}$	Kadri *et al.*, 2011
Flavonoides	Apigenin	$C_{15}H_{10}O_5$	Almela *et al.*, 2006
	Lutenin	$C_{40}H_{56}O_2$	
Diterpenes	Carnosic acid	$C_{20}H_{28}O_4$	Almela *et al.*, 2006

4. Anticancer properties

The essential oil of rosemary is found to have no cytotoxic effects on cells and hence can be used in the treatment of cancer (Al-Maharik *et al*., 2022). The three main active ingredients found in rosemary extract carnosol, carnosic acid, and rosemarinic acid have been found to increase the effectiveness of CDDP (cis diamminedi-chloroplatinum), a drug used in cancer treatments (Tai *et al*., 2012). Chloroformic rosemary extract and ethanolic oats extract bring about condensation of chromatin, which leads to cell death (Alzaharna *et al*., 2020). Carnosic acid in rosemary extract showed the most effective control of cell multiplication (13 to 30%), with a 19 µM dosage concentration within 48 h of treatment (Yesil-Celiktas *et al*., 2010).

4.1 Colon and prostate cancer

The components such as carnosic acid, carnosol, 1,2-methoxy carnosic acid, taxodione, and betulinic acid are responsible for the anti-proliferative effects in human colon cancer (Borrás-Linares *et al*., 2015). Ethanolic rosemary extract had growth inhibition effects against the growth of Caco-2 lines of colon cancer cells (Alzaharna *et al*., 2020). Administration of rosemary extracts *in vitro* for colorectal cancer increased the reactive oxygen species leading to death of cancer cells. Oral administration in athymic nude mice with grafted human colon cancer cells reduced tumor formations (Pérez-Sánchez *et al*., 2019).

It has been found that rosemary essential oil prevents proliferation, survival, and the spread of the androgen sensitive PC 3 and 22VR1 prostate cancer cells. Significantly, there is no impact of rosemary essential oil on the normal epithelial prostate cells (Jaglanian *et al*., 2020b). Reduced cell viability was observed by testing rosemary against prostate cancer cells LNCaP with IC_{50} values (Bourhia *et al*., 2019). *In vitro*, administration of carnosol has been shown to inhibit the G2 cycle and cyclin production. Carnosol targets the AMPK pathway and brings down cancer cell proliferation (Johnson *et al*., 2008). Testing five rosemary extracts with high carnosic acid in both *in vivo* and *in vitro* conditions has confirmed that the combination of carnosic acid with carnosol was more effective than their individual effects (Dilas *et al*., 2012). Rosemary extract had a similar effect on HDAC 2 as SAHA suberoylanilide hydroxamic acid which is used in PCa cancer treatment, which brings about apoptosis of cell lines (Jang *et al*., 2018)

4.2 Breast cancer

Extract with the highest amount of carsonic acid, 42.2% (Inolens50) is found to have a maximum antiproliferative effect against breast adenocarcinoma (González-Vallinas *et al*., 2014). Rosemary extract showed moderate antiproliferative effects on cancer cells and with Bleomycin, but radio-mimetic bleomycin treatment showed better results on breast cancer cells (Mrðanoviæ *et al*., 2019). Carnosol in rosemary extracts has been found to alter chromatin structure in MDA-MB-1231 and Hs578T breast cancer cells which brought down the functional ability (Alsamri *et al*., 2021). Rosemary extract has been found to reduce cell multiplication, activation of AkT, and mTOR signaling of MDA-MB-231 breast cancer cells (Jaglanian and Tsiani, 2020). Essential oil at 500 µg/ml was effective (81 to 89%) on MCF7 breast cancer cells (Hussain *et al*., 2010). Petroleum ether extract had anticancer activities on MCF7 breast cancer cells and HCT 11 human colon cancer cell lines at IC_{50} rates of 3.77 µg/ml and 3.09 µg/ml, respectively (Ali, 2021). Mrðanoviæ *et al.* (2019) stated that rosemary extract with the drug BLM (bleomycin) was more effective than their individual treatment.

4.3 Skin cancer

Application of methanolic extract from rosemary leaves has been found to prevent the tumor formation induced by the application of Benzo (α) pyrene [B (α) P], 7,12-diethylene (α) anthracene (DMBA) treatment in mice. The covalent bond formations between [B (α) P] and epidermal DNA causing the tumor was disrupted when 1.2 or 3.6 mg of rosemary extract was topically applied before [B (α) P] treatment (Wang *et al*., 1994). Cattaneo *et al*. (2015) observed that 65% of the hydroalcoholic extract of rosemary controls human melanoma, A375 group of cells by cytological effects.

4.4 Treatment for other cancers

Treating NSCLC H1299 (nonsmall cell lung cancer) cells at IC_{50} 19 µg/ml of rosemary extract showed antiproliferative cell properties, induced cleavage of PARP markers of apoptosis, and prevented cancer spread (Neill *et al*., 2022). MDA-MB-231, triple negative human lung cancer cells that had no recovery with hormonal treatments, showed antitumor activities as there was increased cleavage of PRAP (proline rich acidic protein), leading to apoptosis (Jaglanian and Tsiani, 2020). Wang *et al*. (2012) compared essential oil and its constituents α pinene, β pinene, and 1,8-cineole on human ovarian cancer lines SKOV3, HO-8910, and Bel-7402 and found that the essential oil of rosemary had more anticancer properties than individual constituents.

Treatment with rosemary essential oils revealed that there was maximum control towards the cell multiplication in human pancreatic cancer cell lines SW1990 and gastric epithelial cancer cell line NCI-N87 (Huang *et al*., 2023). Jang *et al*. (2018) suggested that when then cancerous keratinocytes were cultured with rosemary extract at a concentration of 1.25% helps in the control of cell multiplication of keratinocytes HaCaT by regulating cell death. Carnosic acid proved to be a potential agent in enhancing the effects of sestrin2 and MRP2 for increasing the effects of Nrf2 genes in HepG2 liver cancer cells (Tong *et al*., 2017). In human non-small cell lung cancer lines H441, H520, and H661 the IC_{50} for carnosic acid through MTT(3-(4,5-dimethylthiazolyl-2)-2,5-diphenyltetrazolium bromide assay) method was found to be 20 µM, 40 µM, 40 µM for the lines respectively. In the cell lines, the controlled death expressions were elevated, by changes in the genes such as Bax, Bak, caspase-3, and p53 mediating apoptosis (Duran *et al*., 2024). In cell lines H1299 and H460, carnosic acid as a potential anticancer agent inhibited cell multiplication and induced death through the control of over-expressed AMPK (adenosine monophosphate activated protein kinase) activity. Sestrin 2 involved in the expression of cancer activity was also controlled by the recycling process by degradation of the organelles (Neill *et al*., 2024).

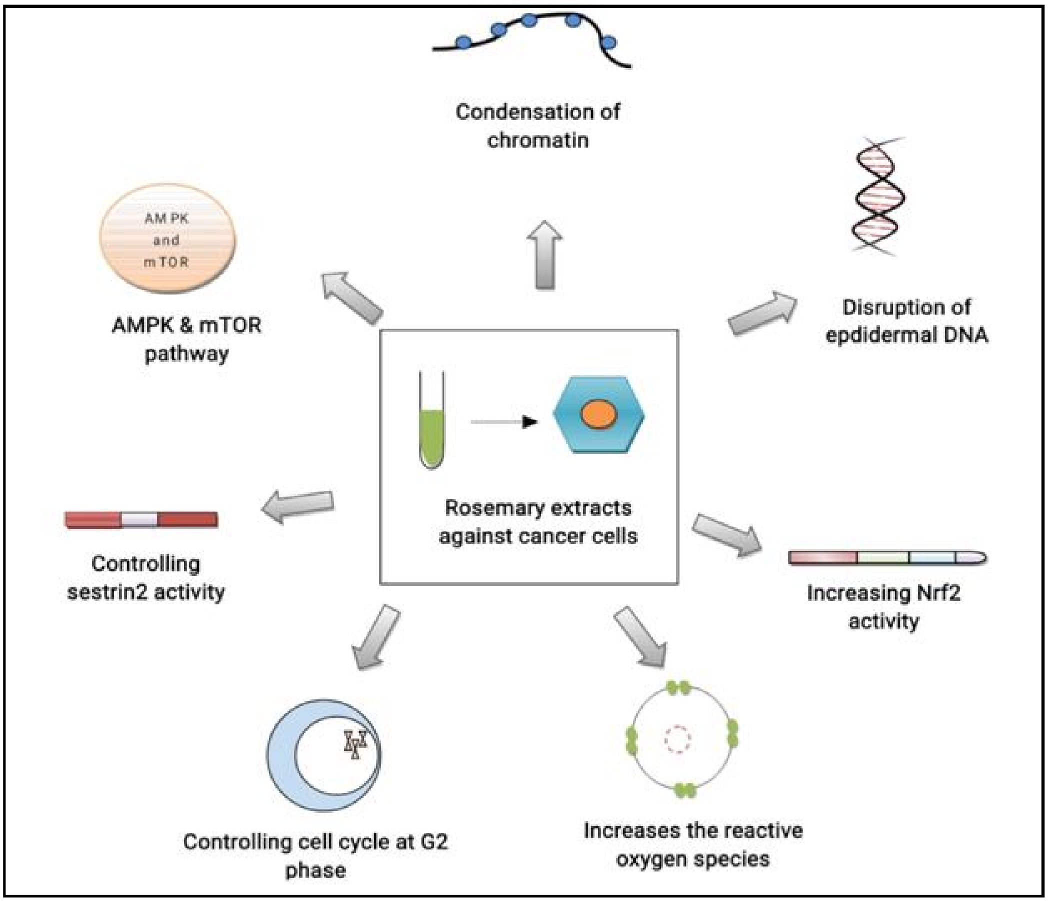

Figure 3: Mechanism of action of rosemary extracts against cancer cells.

Table 2: Anticancer properties of Rosemary extract and its constituents

Cancer type	Type of dose	Effect	Reference
Colon cancer			
	Carnosic acid, carnosol, 1,2-Methoxy Carnosic acid	Antiproliferative	Borrás-Linares *et al.*, 2015
Caco-2, colon cancer cell lines	Ethanolic extract	Growth inhibition	Alzaharna *et al.*, 2020
Colorectal cancer	Rosemary extract	Increases ROS and leads to death of cells	Pérez-Sánchez *et al.*, 2019
Prostrate cancer			
PC-3 and 22VR1 cell line	Rosemary essential oil	Prevented proliferation, survival and spread	Jaglanian *et al.*, 2020
LNCaP	Extract	Reduced cell viability	Bourhia *et al.*, 2019
	Carnosol administration	Inhibits G2 stage in cell cycle and reduces cell multiplication	Johnson *et al.*, 2008
HDCA2 cell line	Rosemary extract	Similar effect as Suberoylanilide hydroxamic acid	Jang *et al.*, 2018
	Carnosic acid+carnosol	Decreased cell proliferation	Dilas *et al.*, 2012

Breast cancer			
	Rosemary extract + Bleomycin	Antiproferative effects	Mrðanoviæ *et al.*, 2019
	Carnosol	Alters chromatin structure	Alsamri *et al.*, 2021
	Rosemary extract	Activation of AkT and mTOR pathways	Jaglanian and Tsiani, 2020
MCF-7	Petroleum ether extracts	Anticancer activities	Ali, 2021
Skin cancer			
	Methanolic rosemary extracts	Prevents The covalent bond formation between [B (α) P] and epidermal DNA	Wang *et al.*, 1994
A375	65% hydro alcoholic extract	Cytological effects	Cattaneo *et al.*, 2015
Non small cell lung cancer NSCLC	Rosemary extract	Showed anti proliferative cell properties, induced cleavage of PARP markers	Neill *et al.*, 2022
Pancreatic SW1990 and NCI-N87 Gastric cancer	Essential oil	Cancer control	Wang *et al.*, 2012
Keratinocytes-HaCaT	Rosemary cell culture	regulation of cell death	Jang *et al.*, 2018
HepG2 liver cancer	Carnosic acid	Increases the effects of Nrf2 genes	Tong *et al.*, 2017

5. Antimicrobial activity

5.1 Antibacterial activity

Rosemary extracts have been found to have great antibacterial potential. The main components that cause the inhibitory action of bacteria are carnosol, rosmanol and isorosemanol. The inhibitory action of the extract is due to phenotypic and genotypic changes in the bacteria cells (Walid *et al.*, 2022). Rosemary oil as a whole proved to be a better antibacterial agent when compared to its major constituents like 1,8-cineole, α pinene, and β pinene when tested individually. Hence, the use of rosemary essential oil as a whole is widely preferred. Methanolic extracts also had a lesser effect than the actual extract (Abdoul-Latif *et al.*, 2021; Wang *et al.*, 2012).

The minimum value for bacterial growth inhibition (MIC) was 0.625 and 1.25% and the minimum antibacterial effect was 1.25 and 2.5% for *Staphylococcus aureus* and *Escherichia coli,* respectively. Studies suggest that the use of rosemary oil and basil or rosemary oil and amyloglycosides was effective against *E. coli* (Barreto *et al.*, 2014; Sienkiewicz *et al.*, 2013). This oil showed potent control over Gram-positive bacteria than the Gram-negative bacteria. Higher minimum inhibition concentration (MIC), 2-5 µg/ml of rosemary oil was observed in gram negative bacteria which indicates lesser colony control upon treatment (Moreno *et al.*, 2006; Hussain *et al.*, 2010; Jafari-sales and pashazadeh, 2020). Antibacterial activity with different polar extracts was tested and they proved to be effective for all the bacteria except *Bhrocotrix* sp. (Fernández-López *et al.*, 2005). Antibacterial activity was caused by organelles damage, increase in cell elasticity, vacuole segregations, increase in ROS in cells, depolarization of mitochondria, and cell membrane damage leading to lyses (Stojanoviæ-Radiæ *et al.*, 2010; Shahina *et al.*, 2022).

Rosemary extracts showed antibacterial activities against *Shigella sonei* and *Salmonella typhi* (Bozin *et al.*, 2007). Maximum antibacterial activity was seen against *Rodotorula species* and *Scytalidium dimidiatum* through varied inhibition control mechanisms (Al-Bader, 2019) Rosemary oil extract at 100% concentration, showed inhibition of growth through clear areaformation in *Bacillus subtilis* (Elabass *et al.,* 2021). Inhibitory actions were more towards bacteria than yeasts at a minimal value of 0.5 to 1.5 mg/ml (Tavassoli *et al.*, 2011).

According to Gómez-Estaca *et al.* (2010), the essential oil of *R. officinalis* inhibited *Salmonella cholerasuis*, *S. sonei*, *Yersinia enteroclitica*, *S. aureus*, *Bacillus cereus, Clostridium perfringens, Aeromonas hydrophila, Photobacterium phosphereum* species growth completely. *Pseudomonas aeruginosa, Shewannella putrefaciens* growth were not inhibited.

5.2 Antifungal activity

The antifungal mechanism of rosemary extended towards fungal as well as yeast strains. This has proved to control *Aspergillus niger*, *Aspergillus fluves, Saccharomyces cervicis*e and *Candidia albicans* (Abozid and Asker, 2013). Antagonistic activity on *C. albicans* was more predominant among the fungi group (Bozin *et al.*, 2007). Extract concentration from 60 to 80% had the maximum control over *C. albicans* (Matsuzaki *et al.*, 2013; Abozid and Asker, 2013). Individual treatment with cineole a major component showed control over the colonies (Matsuzaki *et al.*, 2013). The extract obtained in the later part of the distillation process, suppressed the growth in a better way (Genena *et al.*,2008).

Twenty percent extract had an inhibition value of 32.31% against *A. niger*. The main antifungal activity was due to benzene and 1-methoxy-4-(1-propenyl) (Salih *et al.*, 2017). The suppression of the *Alternaria alternata* strain was due to the high 1,8-cineole content (Affes *et al.*, 2022). Mechanisms like physical changes in mycelium, increase in digestion activity of the cell wall, and changes in the chemical composition of the cells, might be the reason for control in the growth of *Coletortichum gleosporoides* (Yuan *et al.,* 2024).

Extracts had shown great control over the plant pathogenic fungi also. Rosemary hydrosol was found to be an environmentally friendly antagonist source for *Fusarium* sp. as it inhibits growth up to 15% and does not show adverse effects on growth of plant species (Mravlje *et al*., 2022). Essential oil combination of rosemary and sweet marjoram at a concentration of 100 and 125 and 15 µl/l of air hindered *Gleotrichum candidum* which causes potato rubbery rot disease (Kara, 2024).

6. Future prospects

In this growing world, importance is given majorly to efficiency and energy consumption of the process, due to growing demands all over the world. Hence, the right method of extraction for a better yield and quality oil will be an important criterion in the upcoming years. Exploration in the field of ethnopharmacology is on the run for the use of rosemary essential oil and the extracted constituents for the treatment of cancer as a main dose or supplementation is one of the interesting fields waiting for extensive research. Exploration for its use against various other pathogenic and non-pathogenic bacteria could be a great potent field to explore about. Hence, there are diverse fields to be explored, waiting for the scientific community to engage as an important medicinal and aromatic herb with its many hidden values.

7. Conclusion

Rosemary is an important crop medicinal plant division and has enormous potential in diverse fields. Though the usage of rosemary as a drug has been evolving, the basic requirements for deriving the compounds are the extraction procedures. Identification of the constituents with their respective class can give insight into the specification of these constituents. Emerging utilization of rosemary as a drug in pharmaceuticals for the supplementation in cancer and for the use as an antimicrobial agent is opening up new ventures. From this discussion, insights into the extraction methods, important constituents, and antimicrobial and anticancer properties have been provided as a framework.

Acknowledgments

The authors acknowledge the Department of Medicinal and Aromatic Crops, Tamil Nadu Agricultural University, Tamil Nadu, India.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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Citation **Subiksha Naveenkumar Bhuvaneswari, Saraswathi Thiruvenkatasamy, Karthikeyan Muthusamy, Visalakshi Manickam, Saranya Nallusamy and Selvi Durisamy(2025). Anticancer and antimicrobial properties of extracted bioactives of Rosemary (*Rosmarinus officinalis* L. syn., *Salvia rosmarinus* Spenn.). Ann. Phytomed., 14(1):44-53. http://dx.doi.org/10.54085/ap.2025.14.1.5.**