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Exploring the Impact of Rosemary Extracts on Biological Activity and Food Applications: A Comprehensive Review

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ABSTRACT :

Researchers have extensively researched the Mediterranean herb rosemary (Rosmarinus officinalis) for its wide range of biological advantages, including its anti-inflammatory, anti-cancer, antioxidant, and antibacterial qualities. The bioactive chemicals carnosic acid, rosmarinic acid, and carnosol are mostly responsible for these qualities, which make rosemary a perfect choice for food preservation and the creation of functional foods. The biological activities of rosemary extracts, their modes of action, and their many uses in the food business are all thoroughly examined in this review, which also highlights the advantages and disadvantages of standardisation, safety, and consumer acceptability.

Keywords: Rosemary, Antioxidant activity, Antimicrobial Properties, Food preservation, Function food.

Introduction :

Increased proliferative and diminished apoptotic capabilities are among the most basic characteristics of cancer cells [1]. The synthesis and release of growth factors, which govern cell growth and proliferation and maintain cellular homeostasis and proper tissue architecture, are strictly regulated by normal cells. Because these signals are dysregulated in cancer cells, the cell's homeostasis is upset. There are several techniques to promote the growth of cancer cells. The production of appropriate receptors allows cancer cells to react to growth stimuli that they may manufacture. Additionally, higher levels of receptor proteins on the surface of cancer cells can make them more sensitive to growth stimuli; changes to the receptor molecules that promote the activation of downstream; Modifications to receptor molecules that promote downstream signalling pathway activation lacking growth factor binding can have the same impact [2].

Plant-based natural materials have been screened to find several medicinal compounds. Cancer is being effectively treated with several of these medications, including the chemotherapeutics paclitaxel and docetaxel, which were separated from the wood and bark of the Musaceae tree, and etoposide, which was isolated from the mandrake plant and Queen Anne's lace [2].

A Mediterranean native, Rosmarinus Officinalis L. is a member of the Lamiaceae mint family and is used in a variety of culinary and therapeutic applications. Carnosic acid (CA) and rosmarinus acid (RA), two diterpenes, are the primary polyphenols in rosemary extract (RE). Recent research has demonstrated the strong anticancer effects of rosemary extract and its polyphenols CA and RA (reviewed recently in [3,4,5]).

Interest in plant-based additions like rosemary extracts has increased as a result of the global movement towards sustainable and natural food solutions. Beyond their conventional culinary use, rosemary's bioactive components offer strong defence against inflammatory processes, oxidative damage, and microbiological spoiling. These qualities make rosemary a key component of clean-label products because they improve sensory qualities, prolong shelf life, and promote health advantages in food systems.

Rosemary extracts' biological activities include:

1. Antioxidant qualities Extracts from rosemary are among the best natural antioxidants; they can be used to stabilize fats and stop oxidative deterioration. The extraction technique and solvent type are the most crucial factors to consider when testing a new rosemary extract because they will have an impact on its antioxidant qualities.

2. In the scientific literature, several extraction techniques for the selective extraction of rosemary leaves have been identified. Water with an alkaline pH, mechanical pressing techniques, solvent extractions employing vegetable or animal fat, and organic solvents (such as hexane, ethyl ether, chloroform, ethanol, methanol, dioxane, and ethylene dichloride) are all included in this. The industry no longer uses the antiquated extraction methods.(6,7)

Primary Compounds:

Carnosic acid and carnosol are lipid-soluble antioxidants that prevent the spread of free radicals.
Rosmarinus acid is a water-soluble phenolic acid that has a strong capacity to scavenge free radicals.

Mechanisms of Action:
Reactive oxygen species scavenging (ROS).Transition metals are chelated.
oxidative enzymatic pathways and lipid peroxidation inhibition.
Numerous articles have addressed these compounds' mode of action in great detail. For instance, it was found by Houlihan et al. [8] and Wu et al. [9] that rosemary's antioxidant qualities are due to its abundance in isoprenoid quinones, which function as chelators of reactive oxygen species (ROS) and chain terminators of free radicals. The phenolic components included in commercial rosemary extracts also function as main antioxidants by interacting with lipid and hydroxyl radicals to produce stable products, according to Gordon [10]. Following this, Fang and Wada [11] noted that these substances may function as metal ion chelators (Fe+2 essentially).

Applications in Foods:

- revents meat, dairy, and oil items from going rancid.
- Improves the durability of baked and fried foods while being stored.

1.2 Antimicrobial Activity

Extracts from rosemary have broad-spectrum antibacterial properties that target spoilage organisms and foodborne pathogens. Using the microdilution method, the essential oils' antimicrobial activity was examined. One fungus species, Candida albicans ATCC 14053, and four bacterial species Escherichia coli ATCC 25922 (American Type Culture Collection), Pseudomonas aeruginosa ATCC 27853, Staphylococcus aureus ATCC 25923, and Bacillus cereus ATCC 11778 were used in the experiment.
Nutrient agar was utilised for fungal growth and Mueller-Hinton agar and broth (Difco Laboratories, Detroit, USA) for bacterial growth (11). In addition to the use of antibiotics and antimicrobial medications, antibiotic-resistant bacteria are becoming more common, particularly in infections. Treatment has become more challenging and prolonged as a result of the patient epidemic of these resistant diseases. Even though antibiotic output is growing daily, bacterial resistance has become a significant global issue. Escherichia coli and Pseudomonas aeruginosa are opportunistic, Gram-negative Enterobacteriaceae pathogens. In hospitals, Staphylococcus aureus and Bacillus cereus are also significant Gram-positive pathogens [12].
Control of Pathogens: Effective against Salmonella species, Listeria monocytogenes, E. Coli, and fungi such as Aspergillus.

Mechanisms of action:
membrane disruption in microorganisms. Using MIC or MBC, rosemary's antibacterial activity has been assessed in a variety of assay types. The antibacterial properties of rosemary (Rosmarinus officinalis, L.) and basil (Ocimum basilicum, L.) were presented by Sienkiewicz et al. [17]. These authors published the MIC values for the two essential oils' ability to inhibit microbial growth. To test for antibiotic susceptibility, disc diffusion was used. The findings demonstrated the effectiveness of both tested essential oils against every clinical strain of Escherichia coli. With MIC values ranging from 0.025 µL/mL to 0.78 µL/mL based on the broth microdilution method, Mihajilov-Kristev et al. [18] demonstrated the effectiveness of essential oils that mostly included carvacrol (67.0%) and γ-terpinene (15.3%) against Gram-negative bacteria, including Escherichia coli. [19], verified that E. coli ATCC 25922 is significantly inhibited by rosemary essential oil. More than 6.4 mg/L was the minimum inhibitory concentration of rosemary oil against E. coli.

Anticancer Activity

In preclinical research, rosemary compounds—specifically, carnosol and carnosic acid—have shown anticancer properties. Colony formation was significantly reduced at 30 µg/mL (24 h) when CaCo-2 colon cancer cells were exposed to RE [17]. At an IC50 of around 71.8 µg/mL, Yi et al. (2011) investigated the anti-tumorigenic activity of various culinary and medicinal herbs on SW480 colon cancer cells and discovered that RE considerably reduced cell proliferation at a dosage of 31.25 µg/mL (48 h) [18]. In HT-29 and SW480 cells, extracts standardised to CA (25%–43%) or to total polyphenol content (10 µM) significantly reduced cell proliferation and caused cell cycle arrest [18,19,20].
With an IC50 as low as 34.6 µg/mL, RE dramatically suppressed the proliferation of DLD-1 and SW620 colon cancer cells at 30 µg/mL (48 h). In addition, RE sensitised cells that were resistant to 5-fluorouracil (5-FU) and increased the chemotherapeutic drug's inhibitory effects on proliferation [21].

Mechanisms of action :
induction of tumour cell apoptosis. Treatment with RE was found to drastically reduce the viability of many cancer cell lines, which many studies attributed to increased cell death and apoptosis. Following treatments with RE, colon [22,23], pancreas [24], breast [25], and lung [26] cancer cell lines showed increased poly ADP ribose polymerase (PARP) breakage, a known sign of accelerated apoptosis. Conversely, RE boosted the generation of TNFα and nitrate buildup (i.e., increased nitric oxide synthesis) in pancreatic [27] and liver [28] cancer cells, which is suggestive of improved nitric oxide-induced apoptosis and cell killing capabilities. in cancer cells of the ovaries .[29]
Enhanced apoptosis was linked to higher gene expression of the mitochondrial-regulated apoptosis proteins heat shock protein 70 (hsp70), which is involved in protein folding and shields the cell from harmful substances and heat stress, and cytochrome c, which is involved in the electron transport chain. Enhanced expression of pro-apoptotic proteins Bax and cleaved-caspase 3 [30,31], binding immunoglobulin protein (BiP) and CCAAT/-enhancer-

binding protein homologous protein (CHOP) proteins that cause endoplasmic reticular stress [32,33], and the unfolded protein response [34,35,36] in prostate and colon cancer cells are additional mechanisms of apoptosis by RE.

The endoplasmic reticular stress-related protein PRKR-like endoplasmic reticulum kinase (PERK) was found to decrease in normal prostate epithelial cells after receiving RE treatment. This suggests that RE selectively causes endoplasmic reticular stress in prostate cancer cells while sparing normal prostate cells [37].

The Food Industry's Use of Rosemary Extracts

Food preservation

Foods lose quality, odour, and texture due to oxidative deterioration caused by free radicals; however, this process can be postponed by adding antioxidants. Antioxidants, both natural and synthetic, are employed in the food business to increase the product's storage stability. The high degree of activity compared to natural antioxidants is the source of synthetic antioxidants' advantages [38]. Nevertheless, certain artificial antioxidants have demonstrated possible negative consequences. Toluene hydroxyl For instance, butylated hydroxyanisole (BHA) and butylated butylated (BHT) have been widely utilised as artificial antioxidants in food.

However, restrictions were placed on these synthetic antioxidants after studies revealed a possible carcinogenic effect [39, 40]. However, recent studies that suggest a possible anti-carcinogenic impact [41,42] contradict this. In recent years, the usage of natural antioxidants has grown as a result of the contradiction and the general consumer demand for natural products. Extracts from rosemary are widely utilised in food preservation as natural antimicrobials and antioxidants.

Key Applications: Meat and Poultry: Reduces lipid oxidation and microbial spoilage. Seafood: Delays spoilage in fish and crustaceans. Oils and Fats: Prolongs shelf life by preventing rancidity.

Oil storage

Furthermore, fried dishes can have their sensory quality greatly enhanced by the use of rosemary extracts. investigated the impact of rosemary antioxidant on the quality of potato chips fried in soybean oil. The findings demonstrated that the antioxidant rosemary could be added to soybean oil to effectively increase antioxidant activity. This effect was more pronounced than that of TBHQ, which significantly affected the stabilisation of the oil colour change. It was anticipated that it will be widely employed in the frying food sector and replace synthetic antioxidants.(43).

Flavor Enhancement

The fragrant character of rosemary improves sensory qualities and provides a clean-label substitute for artificial flavour enhancers. Because of its ability to enhance flavour, rosemary extract is a natural component that is frequently used in food. It has a unique, fragrant flavour that is frequently characterised as slightly minty and piney. The rosemary plant's leaves, which include essential oils and other flavor-enhancing substances, are the source of the extract.(45).

Technological Advancements in Extract Processing :

Stirring Extraction (STE) Technique

The first extraction method being studied is stirring extraction (STE), a traditional method [28]. A1 is the solvent composition (either water or ethanol), A2 is the solvent-to-solid ratio, A3 is the extraction time, A4 is the rosemary sample particle size, A5 is the extraction temperature, A6 is the stirring speed, A7 is the size of the magnetic bar, A8 is the number of extraction cycles, and A8 is the solvent-to-solid ratio. Two of the most researched factors in extraction optimisation are the extraction solvent and the solvent-to-solid ratio since they both affect the quantity of bioactive chemicals recovered [26]. An further crucial element influencing the extraction procedure is the quantity of extraction cycles. Consequently, increasing the number of extraction cycles may improve the recovery of bioactive chemicals; nevertheless, given the expense and environmental impact of this procedure, it is crucial to look into whether repeat extractions are necessary to boost efficiency [29].

Pulsed Electric Field (PEF)-Assisted Extraction Technique

Sustainable methods of using food and food waste have been the subject of much recent research. These methods can successfully minimise pollution and harness the potential of bioactive compounds for a wide range of uses in the food industry, pharmaceuticals, and other industries [30]. Utilising non-thermal extraction methods, particularly pulsed electric field (PEF)-assisted extraction, offers a promising and environmentally responsible way to extract significant bioactive compounds from food. This opens the door for food processing to become more efficient and sustainable in the future [31, 32]. PEF is one of the green techniques that this study looks at in this context. The electric field strength (B5), the pulse period (B6), and the pulse duration (B7) are among the other PEF parameters that have been studied; some of them are the same as those that were studied for STE (A1–A4 and A8, B1–B4 and B8). PEF works well at modest electric fields, like 0.5 and 1 kV/cm, which makes it ideal for recovering thermolabile materials [33]. However, field strength and pulse width are inversely correlated; greater field strength with narrower pulses can yield comparable outcomes to lower field strength with wider pulses [34]. Therefore, the conditions under which the PEF-assisted extraction will occur must be optimised.

Ultrasonic Probe-Assisted Extraction (UPAE) Technique

Technology aided by ultrasound is said to be a simple method that increases yield and shortens extraction times. The probe system, specifically the ultrasonic probe tip, has a greater energy intensity over a smaller surface area. By reducing energy dissipation, it can increase the effectiveness of ultrasonic therapy in the extraction process [35]. The tip geometries, probe diameters, and lengths of ultrasound probes can differ. In the ultrasonication process, the particular properties and amount of the sample used dictate the choice of probes [36]. The UPAE parameters that were examined were identical to those of PEF and STE (X1-X4 and X8), with the exception that the ultrasonic power (C5), pulsation (C6), and the probe were included.

Ultrasonic Bath-Assisted Extraction (UBAE) Technique

In contrast to employing an ultrasonic bath system, for example, immersing the probe directly in the sample will cause a faster temperature increase during the extraction process since less energy is lost to the environment [40,41]. In order to determine whether distinct extraction yields finally occur and, if so, which of the two approaches is more effective, it is crucial to also investigate UBAE. The parameters under investigation that target UBAE include ultrasonic power (D5) and ultrasonic sound waves, which, like other sound waves, propagate through the molecules of the material they come into contact with in a series of compression and rarefaction waves [42]. At high intensities, the rarefaction cycles overwhelm the attraction interactions between the medium's molecules, leading to When the intensity is high, cavitation bubbles arise because the cycles of rarefaction overwhelm the attraction interactions between the molecules in the medium. During the collapse, cavitation bubbles produce swift jets that cause cellular structures to break down and allow solvents to enter [38]. Cavitation depends on the physical characteristics of the solvent, such as its viscosity, surface tension, and saturation vapour pressure [39]. The principle governing both UPAE and ultrasonic bath-assisted extraction (UBAE) is same. The ultrasonic probe system does, however, have some disadvantages. Hz (D6) and ultrasonic (D7) modes.

Safety and Regulatory Considerations :

The FDA has granted GRAS (Generally Recognised as Safe) regulatory approval. authorised for particular applications in the EU and other areas.
Standardisation Requirements: Because extract composition varies, consistent quality control procedures are required. Difficulties and Prospects Epidemiologic studies have been used to assess the potential of carnosol and carnosic acid, polyphenolic diterpene compounds found in rosemary, as preventive agents against prostate cancer. Research has been done to determine how carnosi acid and carnosol work to prevent cancer. According to the pathways that have been clarified, rosemary may be used as a chemopreventive medication to treat prostate malignant neoplastic disease. Rosemary extracts have been shown in experiments to have anticancer effects against a range of cancer types.
The application of rosemary extract alone was said to produce synergism, despite the fact that its activity was linked to the main compounds in its content. The FDA and EFSA assessed rosemary extract as having strong human health benefits, and they endorsed the use of the extract overall. The effectiveness of employing rosemary extract as a tumour type-specific treatment should be the focus of clinical research without sacrificing effectiveness. Difficulties Standardization of Extracts: Differences in the amounts of bioactive compounds in different batches of manufacture.

Conclusion :

In terms of natural food preservation methods and innovative functional foods, rosemary extracts are at the forefront. Their diverse biological activity and attractive clean-label qualities make them essential components of contemporary food systems. Even if there are still issues with consumer perception and standardization, further developments in extraction techniques and legal frameworks should enable rosemary to reach its full potential in the food sector.

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