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Review Article

Unlocking The Power of Herbs: Modern Extraction and Processing Techniques

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ABSTRACT

The culinary and health industries make extensive use of herbs. Because they contain active phytochemical compounds that have some efficacy in treating diseases and improving health and appearance, they have been shown to have positive impacts on the human body. The demand for herbal items also grown as a result of public knowledge of the negative consequences of synthetic chemical products. In order to meet the growing demand for herbal products and extract the maximum quantity of active components from herbs, highly effective technologies for processing and extracting herbs have been created. The most recent advancements in herbal extraction and processing techniques are reviewed in this article. After providing a brief overview of the history of herbal usage, we go on to discuss the various extraction methods and critically evaluate their relative benefits and drawbacks.

INTRODUCTION

Herbs serve as a major natural source of various bioactive compounds. Since ancient times, numerous diseases have been treated with different herbs-based remedies in traditional medicine. Natural phytochemicals and herb extracts are growing progressively more prominent in the dietary supplement, pharmaceutical, and cosmetics markets in recent years. By 2022, the market for herb preparation is expected to rise to a worth of around USD 86.74 billion, with the pharmaceutical sector accounting for the greatest share and the nutraceutical sector. Notably, the use of herbs preparations in cosmetics, beverages,

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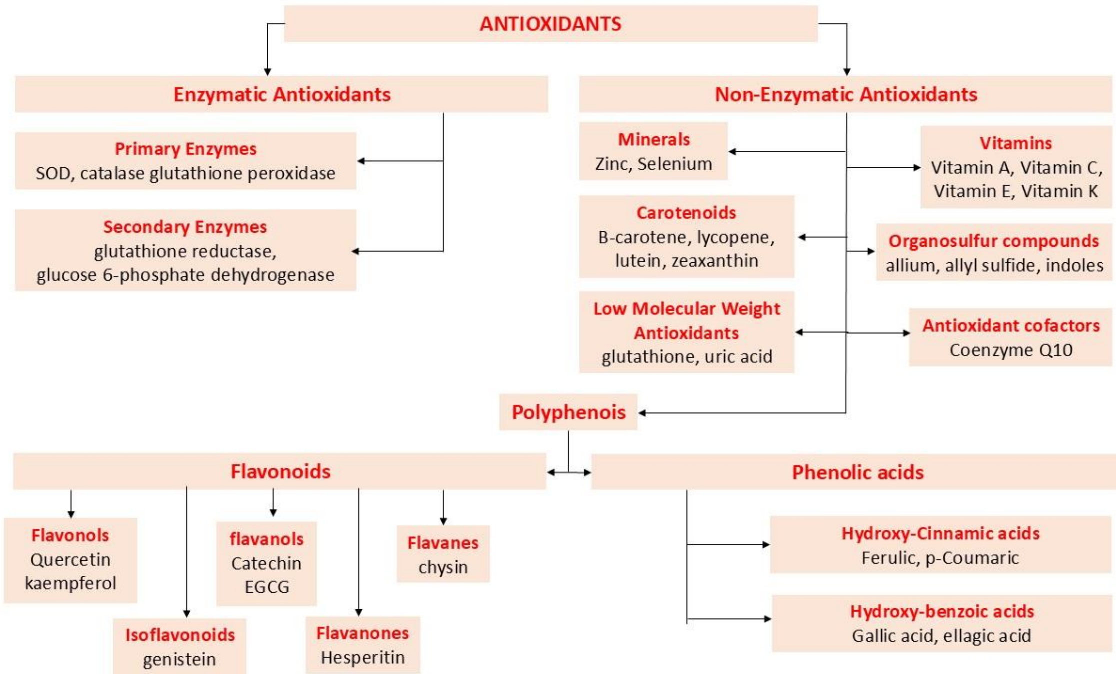
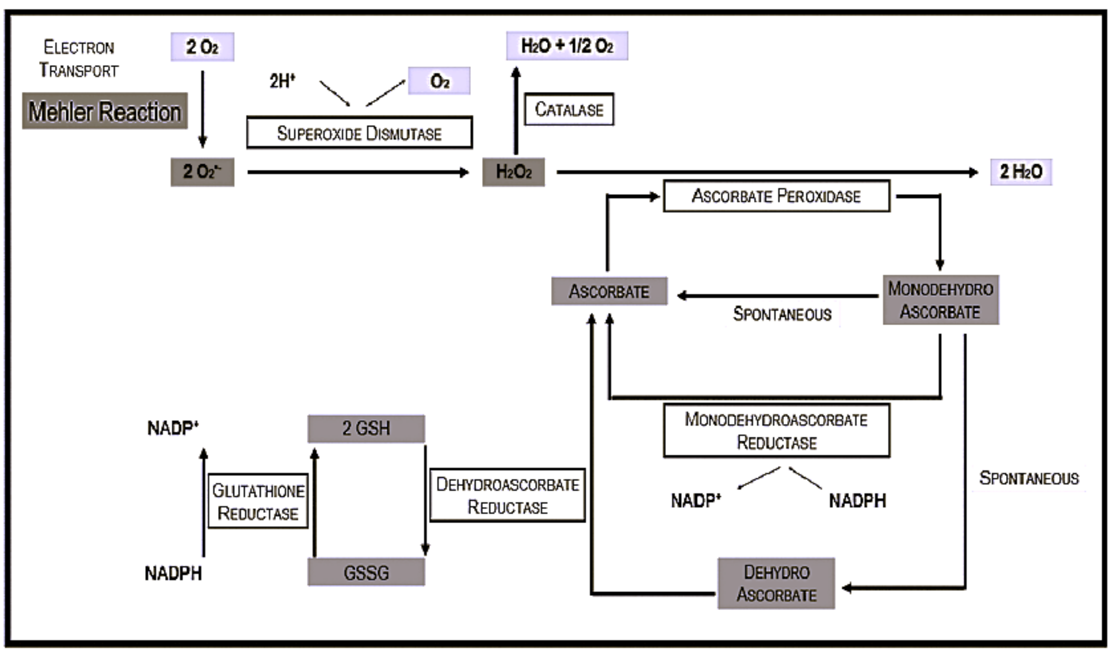
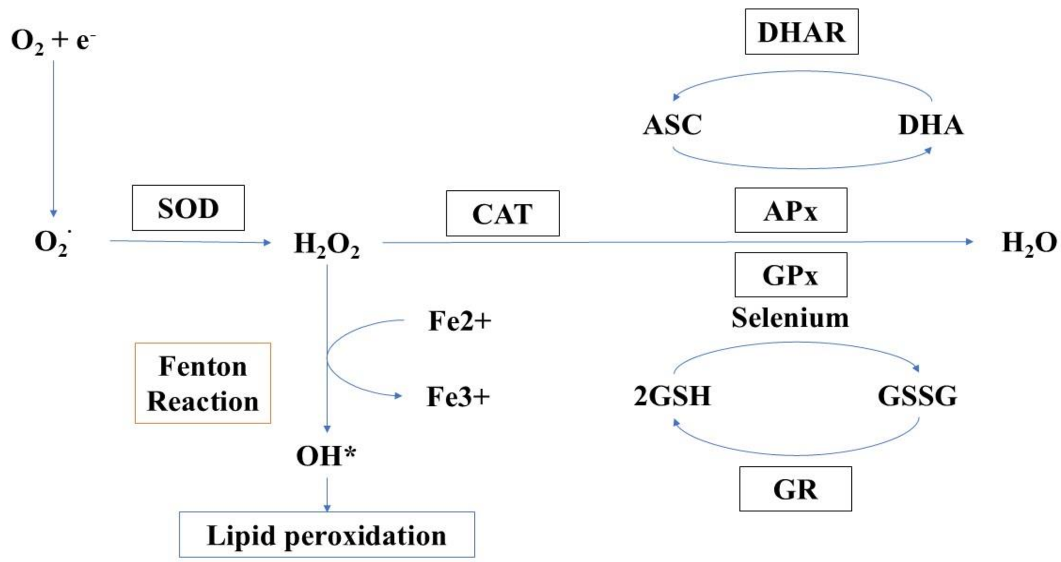
food, and medicine primarily relies on herbs leaves. Among all parts of herbs, leaves are the most significant reservoirs of bioactive compounds, including secondary metabolites. Recent research has highlighted the phytochemical compositions and biological effects of leaf extracts from various cultivated herbs. Therefore, even though herb leaves are often regarded as agricultural waste, they actually represent a valuable source of high-quality nutra-pharmaceutical compounds. Herbs are regarded as safe and natural remedies for humans, leading to the exploration of various medicinal and health-enhancing products. For centuries, herbs and spices sourced from plants have been utilized in both culinary and pharmaceutical applications. In recent decades, there has been an increase in research aimed at examining the protective benefits of herbs in treating chronic diseases in humans, such as cancer, heart disease, arthritis, neurological disorders, obesity, and diabetes. Spices are known to possess antioxidant, immunomodulatory, and anti-inflammatory effects. The active compounds, mainly polyphenols, are linked to various health benefits by influencing specific signalling pathways. While numerous treatments are available, most are synthetic, and adverse effects are common with all therapies, including those for kidney issues. Therefore, the search for a natural remedy with fewer side effects is increasingly important.After a lengthy history of developing herbal medicines, it has become evident that a combination of drugs often produces the desired effects more effectively than a single herb. The practice of using two or more herbs together is known as polyherbal, and their formulation is referred to as a polyherbal formulation. This approach is a fundamental principle in Ayurvedic and herbal medicine. The concept of synergism in polyherbal formulations is highlighted in the Sarandghar Samhita. The selection of herbs in these combinations is based on the specific disease or disorder they aim to treat, as they exhibit unique therapeutic activities through synergistic effects. Additionally, other herbs may be included in a polyherbal formulation to mitigate any side effects that may arise from the primary herb. Numerous studies have demonstrated that various herbal formulations, each with different potencies, operate through distinct mechanisms. Consequently, polyherbal formulations are increasingly preferred for treating complex diseases or disorders, as they offer synergistic therapeutic benefits. With advancements in scientific research, many therapeutically effective polyherbal formulations have been identified today. The current phytoconstituents found in herbs, such as alkaloids, tannins, saponins, phenolic compounds, flavones, flavonoids, glycosides, terpenoids, and sesquiterpene lactones, contribute to the effectiveness of the selected herbal combinations.



IMG 01. Classification of Antioxidant



IMG 02. Pathway of Antioxidants



Img 03. Genes Of Plants Involved as Antioxidant

(SOD): Superoxide Dismutase, (CAT): Catalase, (ASC): Apoptosis-associated speck-like protein , (DHA): Docosahexaenoic acid , (DHAR): Dehydroascorbate reductase , (APx): Ascorbate peroxidase , (GPx): Glutathione peroxidase , (GR): Glutathione reductase , (GSSG): Glutathione disulfide. Enzymes called antioxidants prohibit oxidation, a type of chemical reaction that may end in the formation of free radicals damaging cells. They play a role in guarding the body towards oxidative stress, which is linked to aging and a variety of disorders. Antioxidants are typically classified into two main categories: enzymatic and non-enzymatic.

1. Enzymatic Antioxidants:

These are enzymes produced by the body that neutralize free radicals through specific biochemical reactions. Key enzymatic antioxidants include:

- Superoxide Dismutase (SOD): Converts superoxide radicals into hydrogen peroxide.
- Catalase: Decomposes hydrogen peroxide into water and oxygen.
- Glutathione Peroxidase: Reduces hydrogen peroxide and lipid peroxides, utilizing glutathione as a substrate.

These enzymes are essential for maintaining cellular health by mitigating oxidative damage.

2. Non-Enzymatic Antioxidants:

These are small molecules that can donate electrons to free radicals, neutralizing them. They can be further divided into:

- **Vitamins:**
  - *Vitamin C (Ascorbic Acid):* A water-soluble antioxidant found in fruits and vegetables.
  - *Vitamin E (Tocopherols and Tocotrienols):* Fat-soluble antioxidants present in nuts, seeds, and vegetable oils.

- *Vitamin A (Retinol and Carotenoids):* Fat-soluble antioxidants found in colorful fruits and vegetables.

- **Minerals:**
  - *Selenium:* A trace element that is a component of antioxidant enzymes.
  - *Zinc:* Essential for the activity of certain antioxidant enzymes.

- **Other Compounds:**
  - *Flavonoids:* Plant-derived compounds with antioxidant properties.
  - *Phenolic Acids:* Found in various plant-based foods, contributing to antioxidant activity.

These non-enzymatic antioxidants are obtained through diet and are vital for neutralizing free radicals in the body. Understanding the classification of antioxidants helps in recognizing their diverse roles in protecting the body from oxidative damage and underscores the importance of a balanced diet rich in these compounds. Antioxidant enzymes in plants play a critical role in protecting plant cells from oxidative stress caused by reactive oxygen species (ROS). These enzymes are part of the plant's defense system, helping to mitigate the harmful effects of environmental stressors like UV radiation, drought, and extreme temperatures. The production and activity of antioxidant enzymes are often regulated by various genes in plants.

Here are some key antioxidant enzymes in plants and the associated genes:

1. Superoxide Dismutase (SOD)

- **Function**: SOD enzymes catalyze the dismutation of superoxide radicals (O_2^-) into oxygen and hydrogen peroxide (H_2O_2). This is the first line of defense against oxidative stress.

- **Genes**: The major types of SOD in plants are encoded by genes such as **Cu/Zn-SOD**, **Mn-SOD**, and **Fe-SOD**, which correspond to different metal cofactors (copper, zinc, manganese, and iron).
  - **Cu/Zn-SOD**: The gene *CSD1* and *CSD2* encode for copper/zinc superoxide dismutase.
  - **Mn-SOD**: The gene *MSD1* is responsible for manganese-dependent SOD.
  - **Fe-SOD**: The gene *FSD1* encodes iron-dependent SOD.

2. Catalase (CAT)

- **Function**: Catalase enzymes break down hydrogen peroxide (H_2O_2) into water and oxygen, thus preventing the toxic accumulation of hydrogen peroxide in cells.

- **Genes**: The genes encoding catalase are typically referred to as *CAT1*, *CAT2*, etc. Different isoforms are found in different cellular compartments, such as peroxisomes or chloroplasts.

3. Glutathione Peroxidase (GPX)

- **Function**: GPX enzymes reduce hydrogen peroxide and lipid peroxides using glutathione (GSH) as a reducing agent. They play an essential role in maintaining cellular redox balance.

- **Genes**: The gene **GPX** encodes this enzyme, and several isoforms exist, including cytosolic and chloroplastic versions.

4. Ascorbate Peroxidase (APX)

- **Function**: APX enzymes use ascorbate (vitamin C) to reduce hydrogen peroxide to water, making them essential for scavenging ROS in the cytoplasm and chloroplasts.
- **Genes**: In Arabidopsis, the gene APX1 encodes the major ascorbate peroxidase, but additional isoforms like APX2 and APX3 are also present in different tissues.

5. Glutathione Reductase (GR)

- **Function**: Glutathione reductase plays a crucial role in maintaining the reduced state of glutathione (GSH) in the cell, which is essential for the activity of several antioxidant enzymes, including GPX.
- **Genes**: The genes GR1, GR2, etc., are responsible for encoding glutathione reductase enzymes.

Regulation of Antioxidant Enzyme Genes:

The expression of antioxidant enzyme genes is highly regulated by various factors, including:

- **Environmental Stress**: Stressors like drought, heat, and UV radiation can induce the expression of these genes to protect plants from oxidative damage.
- **Hormonal Signals**: Plant hormones like abscisic acid (ABA), ethylene, salicylic acid (SA), and jasmonic acid (JA) can regulate the antioxidant defense system.
- **Transcription Factors**: Several transcription factors (e.g., **DREB**, **AP2/ERF**, **MYB**, **NAC**) bind to antioxidant gene promoters, triggering their activation in response to stress.
- **Epigenetic Regulation**: DNA methylation and histone modifications can influence the expression of antioxidant genes under different environmental conditions.

In summary, plant antioxidant enzymes are encoded by a wide variety of genes, each responsible for tackling specific ROS and ensuring plant survival under stress. Their activity is crucial for maintaining cellular integrity, growth, and development under challenging environmental conditions. Here's an innovative flowchart illustrating how plant enzymes act as antioxidants in the human body:

Plant Enzymes Enter the Body (via food, supplements)

Antioxidant Enzymes Identified

- 🧬 **Superoxide Dismutase (SOD) →** Converts superoxide radicals to oxygen & hydrogen peroxide
- 💧 **Catalase** → Breaks down hydrogen peroxide into water & oxygen
- 🛡 **Peroxidases (Glutathione Peroxidase) →** Neutralizes harmful peroxides

Enzyme-Activated Defense Pathways

- **NRF2 Pathway** → Triggers body's natural antioxidant production
- ⚡ **Quinone Reductase** → Detoxifies harmful quinones

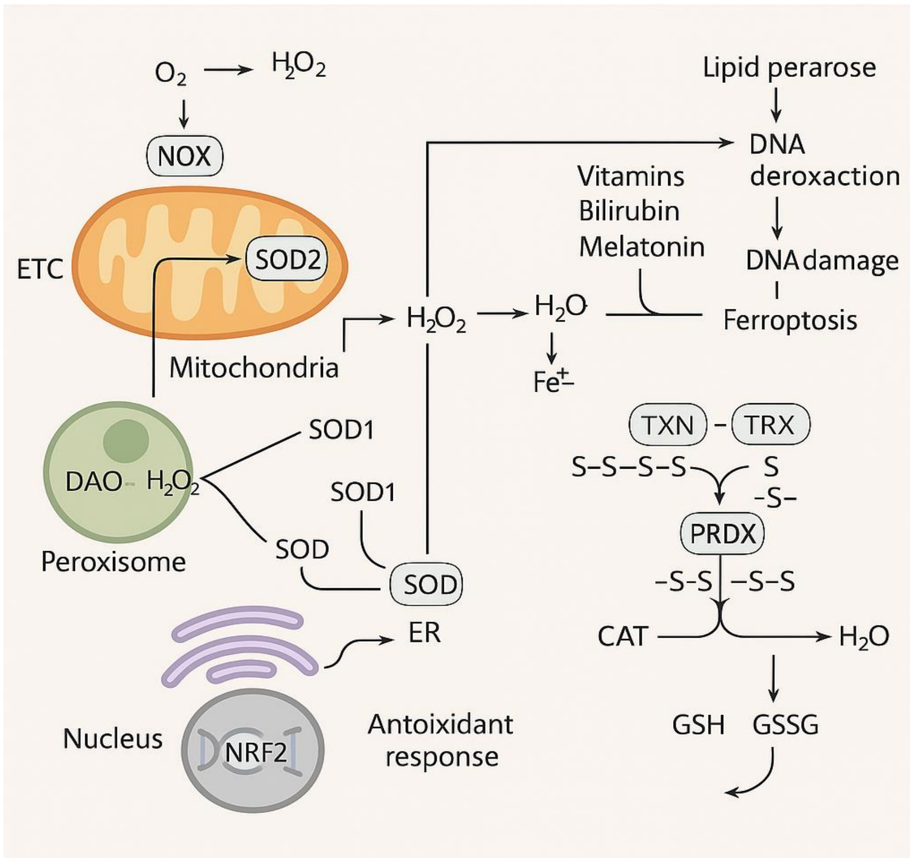
Enzyme Precursors Supporting Antioxidant Activity

- 🍍 **Bromelain (Pineapple) & Papain (Papaya)** → Reduce inflammation, aiding antioxidant balance

- **Polyphenol Oxidase** → Activates polyphenols for better free radical scavenging
- **Vitamin C, E, Flavonoids, Polyphenols** → Work together for enhanced defense

Synergy with Other Antioxidants

Plant enzymes can act as antioxidants in the human body by neutralizing free radicals and reducing oxidative stress.

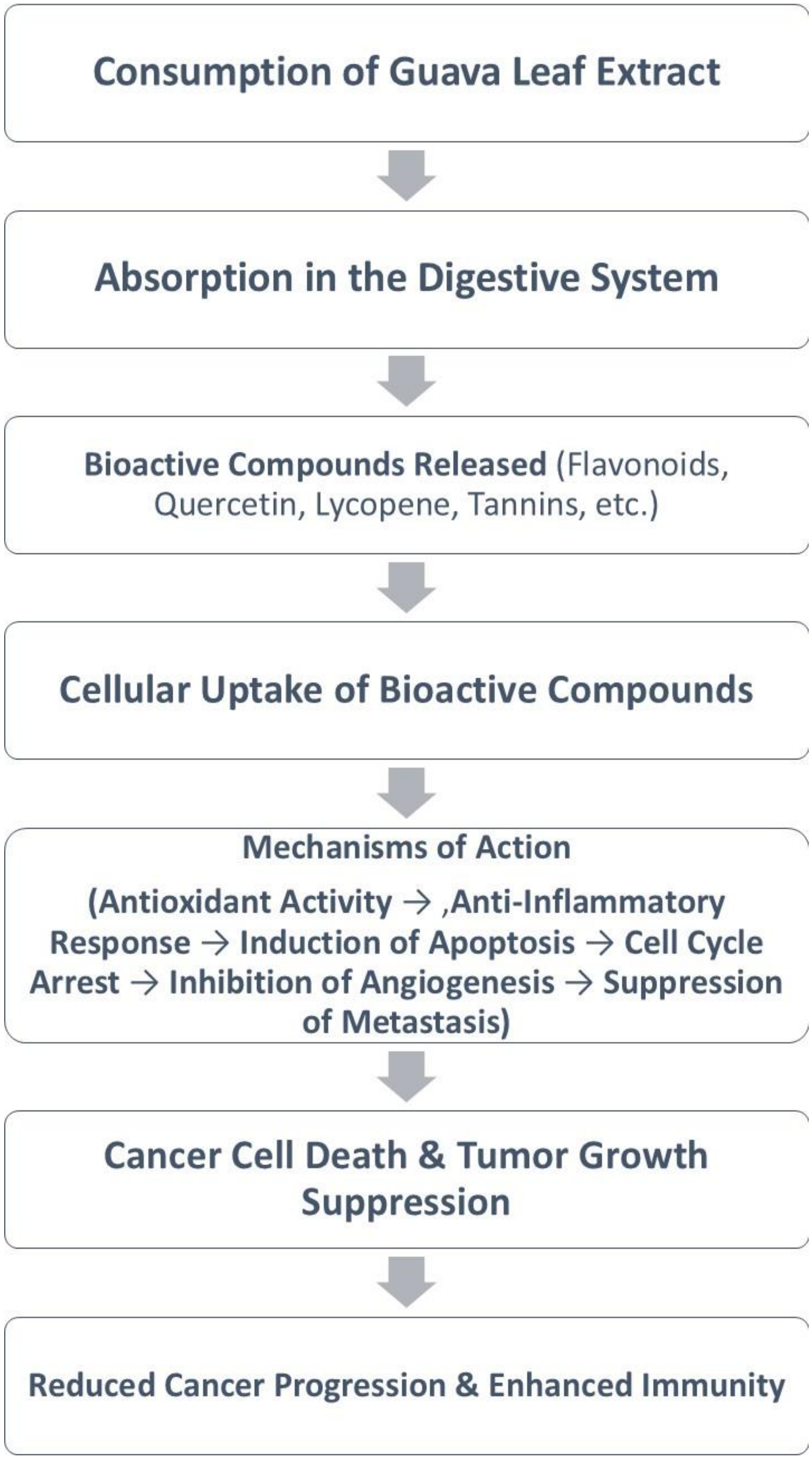


IMG. Oxidative cell death in Cancer: mechanisms and therapeutic opportunities

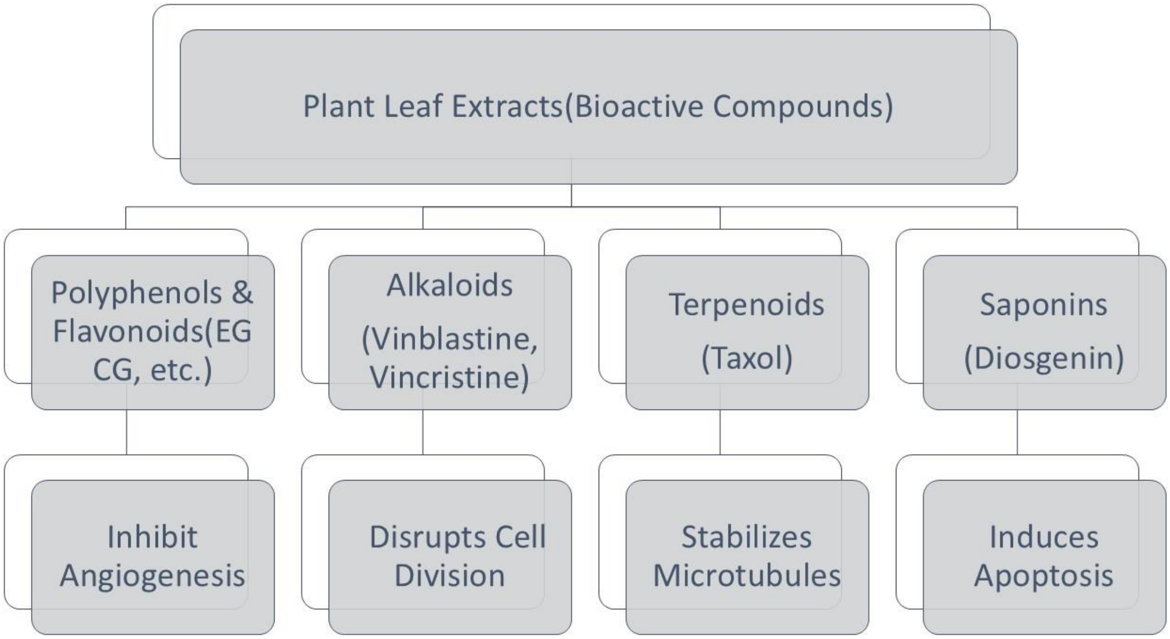
Herbs

Psidium guajava L. (GUAVA)

The Myrtaceae class contains the guava tree (Psidium guajava L.), a particular and traditional plant acknowledged for its numerous dietary and medicinal uses. In tropical regions which include Bangladesh, Pakistan, Indonesia, India, and South America, this fruit is commonly cultivated and eaten. Different nations use different portions of the guava tree, including its roots and leaves. The leaves of the guava tree (Psidii guajavae GL) are dark green, elliptical, and oval-shaped, featuring a blunt tip. Guava leaves, along with the fruit's pulp and seeds, are employed in the treatment of specific respiratory and gastrointestinal issues, as well as to boost platelet counts in individuals with dengue fever. Additionally, Guava leaves are commonly recognized for their antispasmodic, cough-relieving, anti-inflammatory, antidiarrheal, antihypertensive, anti-obesity, and anti-diabetic effects. Research involving animal models has also demonstrated that Guava leaves extracts can serve as effective antitumor, anticancer, and cytotoxic agents.



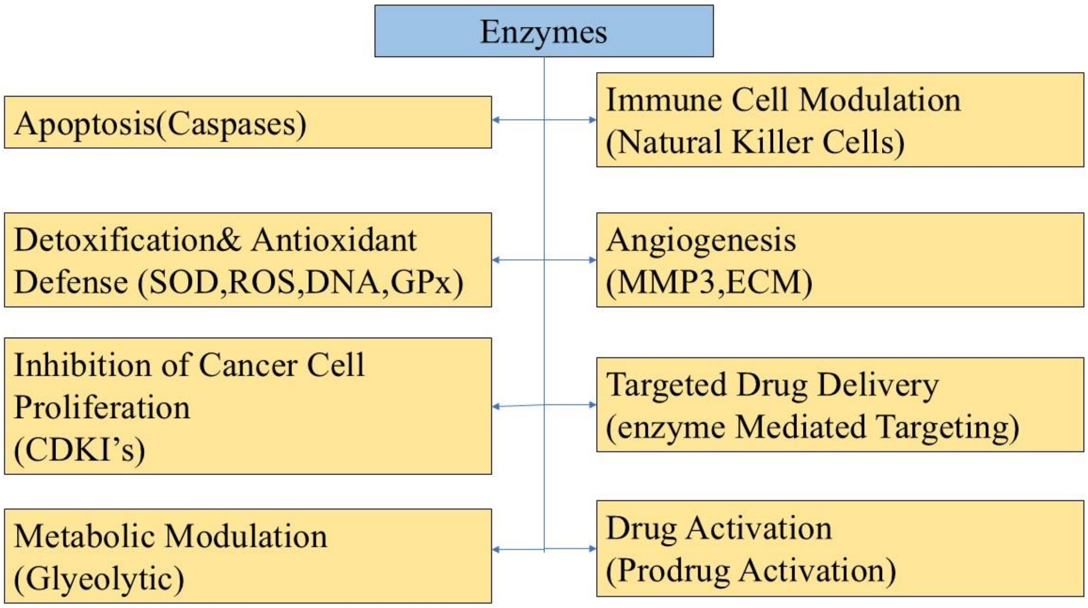
Anticancer Mechanism of Plant Leaf Extracts



Plant leaf extracts contain bioactive compounds that have shown potential as anticancer agents. These compounds interact with human cells through various mechanisms, including apoptosis (programmed cell death), inhibition of cancer cell proliferation, and suppression of metastasis. Some of the key bioactive compounds in plant leaves that contribute to anticancer effects include:

Citrus Limon (LEMON)

Citrus plants have been cultivated globally since ancient times. Although the exact location of the natural habitat of Citrus limonis is not precisely identified, it is believed to be indigenous to either North-Western or North-Eastern India. The introduction of Citrus limon to Spain and North Africa occurred sometime between the years 1000 and 1200 CE. It was later spread across Europe by the Crusaders, who discovered it growing in Palestine. By 1494, lemon cultivation was taking place in the Azores, with a significant amount being exported to England. Citrus limon is a tree that typically grows to a height of 2 to 3 meters. It features shiny, leathery, alternate leaves that are generally evergreen and lanceolate in shape, along with bisexual flowers that are predominantly white with a hint of purple at the petal edges. The fragrance of the flowers is strong and sweet, and they grow in small clusters. Lemon trees tend to bloom year-round, with fruit being harvested between six to ten times annually. The lemons are yellow and ellipsoidal, starting as pointed green berries that turn yellow as they ripen. The edible fruit contains a juicy interior divided into 8 to 14 segments, each with broad white or greenish seeds. Oval, oblong, and tapering to a point on the non-stem end, lemon leaves range in size from small to medium. The vivid green leaves, which have finely serrated edges and a faint rippling, grow alternately along the branches. Additionally, there is a noticeable center stem with a few tiny veins extending throughout the leaf. The underside of these leaves is a lighter shade of green, while the topside is glossy. Lemon leaves are crimson while they are young and turn a deep green as they get older. Additionally, citrus limon leaves have a vivid green, fragrant flavor with a hint of oil. Additionally, they are accessible all year long.Numerous scientific studies have recently examined the possible impacts of different sections, such as flowers, leaves, roots,peels, fruits, and essential oils, etc. Citrus limon is also used to treat a number of illnesses, including cancer, respiratory conditions, anxiety, and depression.

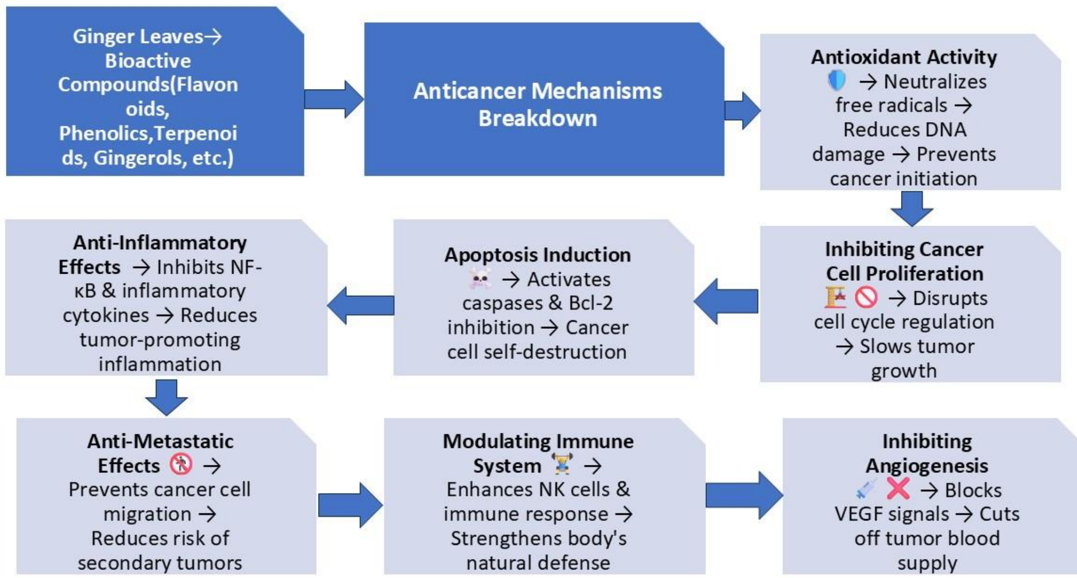


Enzymes play crucial roles in the body's defense against cancer through various mechanisms. They can act directly on cancer cells or indirectly influence the tumor microenvironment and the immune system.

Zingiber officinale (Ginger)

Around the world, ginger (Zingiber officinale) is frequently used as a spice in a variety of dishes and drinks. Ginger has long been used as a traditional medicine, especially in Southeast Asia, to cure fevers, coughs, sore throats, and stomach issues . It is regarded as a herbal plant that is extensively utilized in traditional Chinese medicine . Ginger has a long history in Indonesia, where it is used as a spice, a medicinal plant, and to provide taste and perfume to a variety of meals and drinks. The rhizome plant known as ginger has been used in traditional herbal treatment and as a scent. Young ginger is used as a beverage ingredient, pickled, and consumed as a fresh vegetable . Ginger is an erect, pseudo-trunked, seasonal herbaceous plant that ranges in height from 30 cm. The ginger plant is made up of stems, leaves, rhizomes, roots, and blossoms. The long-lasting rhizome roots of ginger can generate new shoots to replace withered leaves and stems. The ginger rhizome extended flat and was pale yellow inside, with uneven branches and coarse fibrous tissue. Shoots emerge from the top of the rhizome, whereas roots emerge from the base . According to its type, ginger actually comes in a variety of shapes and flavors. Many active substances, including terpenoids and phenolics, are found in ginger. Phenolic components found in ginger include paradol, zingerone, shogaol, and gingerol. Gingerols are the main polyphenols found in fresh ginger. Additionally, it contains a range of terpenoid and phenolic compounds, which are thought to be main constituents of ginger essential oil. In addition, it contains fiber, organic acids, lipids, carbs, and other nutrients.

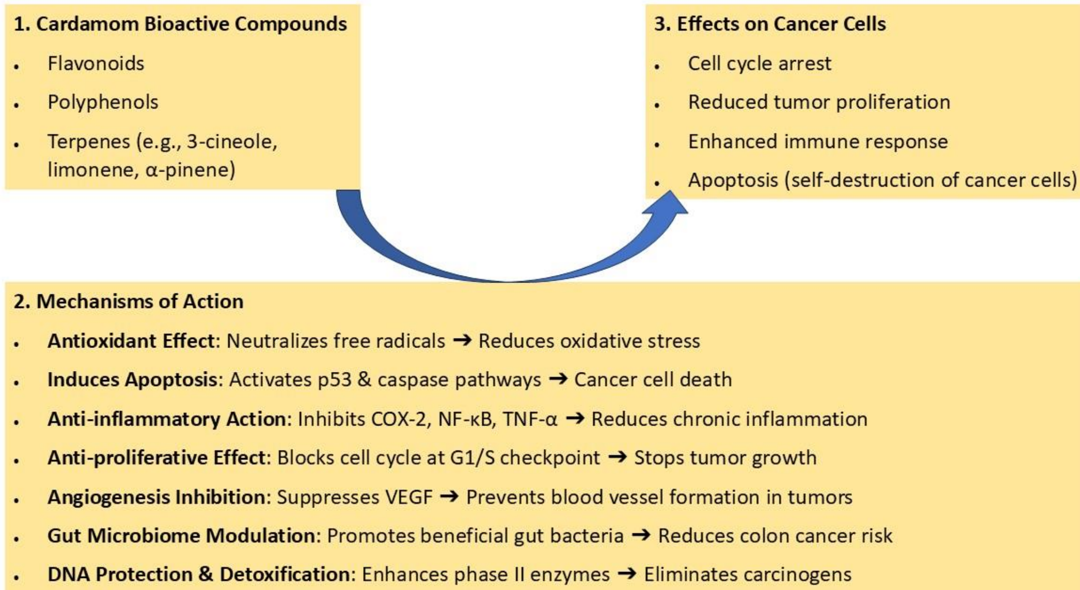
Zingiber officinale Anticancer Mechanisms in the Human Body



Elettaria Cardamomum (Elaichi)

The fragrant shrub known as green cardamom (E. cardamomum L. Maton), which belongs to the Zingiberaceae family, can reach a height of two to five meters. Originally from southern India and Sri Lanka, cardamom (E. cardamomum) is now widely naturalized in Tanzania and Guatemala. Nepal, Thailand, Myanmar, Vietnam, Cambodia, Morocco, Malaysia, and Central America are among the other countries in the world where this spice is abundantly grown . Elettaria cardamomum is a herbaceous perennial plant that has two rows of alternating black or green leaves on tall branches. The leaves have an acuminate tip, are lanceolate, glabrous on both surfaces, and are long (about 40–60 cm). Several plants belonging to the Zingiberaceae family's genera Elettaria and Amomum are referred to as cardamom. Both of these genera' plants are identified by their distinctive scent and spindle-shaped pods with tiny black seeds. True cardamom, green cardamom, or little cardamom (Elettaria cardamomum) and large cardamom, or black cardamom (Amomum subulatum), are the two varieties of cardamom that correspond to the aforementioned two genera . From India to Malaysia, green cardamom (E. cardamomum) grows throughout Asia. This perennial herb's dried fruits, or seed pods, are sold as one of the priciest and most valuable spices. Cardamom's tiny black seeds, which are enclosed in a thin, papery shell or pod, have a distinct, somewhat acrid flavor and a pleasant scent. Around the world, green cardamom has been utilized for both traditional medicinal and culinary purposes. In addition to being used as a flavoring and spicy ingredient in a number of food products, this spice has long been utilized as a folk treatment to cure pulmonary tuberculosis, digestive and kidney diseases, gum and tooth infections, and more Cardamom seed's high-value gastroprotective and antioxidant bioactives, including volatile oils, are primarily responsible for their distinctive scent, its use as a functional food, and its medicinal and nutraceutical properties.

Cardamom's Anticancer Mechanisms in the Human Body



Conventional extraction techniques

Maceration

Maceration is a simple and easy extraction method that involves soaking the powdered plant-prepared raw material in an appropriate solvent for three days at room temperature, with stirring. Following the extraction process, the mixture is filtered using sieves or a tiny-holed net. The marc is then compressed, and after standing, the liquid extract is cleaned by decantation or filtration. To reduce solvent loss by evaporation, maceration is best performed in a stoppered container. When the solvent evaporates during the extraction process, an already concentrated extract is produced, which is undesirable. A common method for concentrating the product is vacuum evaporation. Selecting the appropriate solvent is important the kinds of phytochemicals that were extracted from the samples. The solvents may also facilitate the extraction of thermolabile phytochemicals.

Digestion

Digestion is a form of extraction that makes use of heat, similar to maceration. The biologically active phytochemicals in the chosen plant material are shielded from fluctuations in temperature, always. Consequently, heat results in a higher extraction solvent efficiency. Temperatures are typically maintained between 35 and 40 °C, although for harder plant materials, like barks and materials with poorly soluble phytochemicals, they may be raised to as much as 50 °C. The suitable solvent is preheated to the specified temperatures before the necessary plant parts are added to a container for extraction. By shaking the container frequently, the ideal temperature is maintained for a duration that could be anything from 30 minutes to 24 hours.

Soxhlet

The Soxhlet extraction method combines the advantages of percolation and reflux extraction by continuously extracting the herb with fresh solvent through the use of reflux and siphoning principles. In contrast to percolation or maceration, the Soxhlet extraction method is an automatic continuous extraction technique that uses less time and solvent and has a high extraction efficiency. The Soxhlet extraction process's high temperature and lengthy extraction period will raise the risk of thermal deterioration. Because of the high extraction temperature used in Soxhlet extraction, the breakdown of tea's catechins was also noted. When compared to the maceration method used at 40 °C, the concentrations of total polyphenols and total alkaloids from the Soxhlet extraction method at 70 °C dropped.

Percolation

It is among the most widely used conventional techniques for acquiring active components for liquid extract manufacturing. A glass object called a percolator, which is shaped like a thin cone and has openings on both ends, is used in the percolation process. A dried plant sample that has been crushed. After that, the plant material is combined with the extraction solvent in a sterile container and soaked for four hours. After four hours, the mixture is moved to a sealed percolator and let to sit at room temperature for a full day. After adding solvent to completely saturate the mixture, the percolator's bottom is opened to let the liquid drip gradually. By adding solvent until a significant portion of the extract is still present, gravity is used to remove the solvent from the mixture. After that, the extract is separated using a filtration technique.

Accelerated solvent extraction (ASE)

This method's advantages—such as its high output, low solvent requirement, and very short time required—have made it extremely popular.. Significant ASE performance is supported by certain examples. For example, ASE outperformed Supercritical Fluid Extraction (SFE) in the recovery of hydrophilic and lipophilic phytochemicals from raspberry pomace. In contrast to the 15% yield in SFE, the effects of temperature and extraction time on extraction yield were far smaller in ASE, while 25% of lipophilic and hydrophilic chemicals were recovered. The procedure involves placing the sample into a stainless steel extraction cell, injecting it with solvent, and enclosing it between layers of inert silica that have been separated by bacterial cellulose filter paper. Due to the higher diffusion coefficient and lowered viscosity, the system is heated at greater temperatures and pressure for a specific period of time, resulting in extraction. After gathering the extract in vials, the cell is cleaned by functioning nitrogen and fresh solvent. The plant matrix is kept from accumulating into particles that could obstruct the system by the inert packing material.

Supercritical fluid extraction (SFE)

A supercritical fluid (SF) is used as the extraction solvent in supercritical fluid extraction (SFE). SF is capable of dissolving a variety of natural goods and is comparable to gas diffusion and liquid solubility. Near critical points, slight variations in temperature and pressure caused their solvates to vary significantly. Due to its popular advantages, which include low critical temperature (31 °C), selectivity, motion, cheap cost, non-toxicity, and the capacity to extract thermal compounds, low critical carbon dioxide (S-CO2) was widely used in SFE. S-CO2 is perfect for extracting non-polar natural materials like lipids and volatile oil because of its low polarity. S-CO2's solver properties can be greatly improved by adding a modifier.

Extraction Process

Plants Name	**Extraction Method**	**Yield %**	**Comparison**
Guava Leaves	Maceration	11.28 ± 0.90	(Ultrasound-assisted show high yield) due to its ability to rapidly extract high yield of desired compound while minimum heat damage & solvent usage compared to traditional method
	Stirring-assisted	14.17 ± 0.86	
	Heat and stirring-assisted	15.71 ± 0.67	
	Homogenizer-assisted (HAE)	15.21 ± 0.27	
	Boiling	16.49 ± 0.27	
	Soxhlet	15.74 ± 0.58	
	Microwave-assisted	15.42 ± 0.96	
	Ultrasound-assisted	16.98 ± 0.6	
	Ultrasound and microwave-assisted (UMAE)	21.33 ± 1.15	
Lemon Leaves	Maceration	4.5%	(Steam-distillation show high yield) it effectively extracts the more essential oils without causing significant degradation due to high temp
	Soxhlet	1.586%	
	Hydro distillation	0.946%	
	Steam distillation	2.492%	
	Hydro-distillation method	80%	
	Microwave Assisted Hydro-distillation	1.37%	
	Microwave hydro-distillation(MHD)	1.817%	
	Ultrasonic assisted extraction (UAE)	0.92%	
	Ultra-sonication	26.7%	
Ginger Leaves	Maceration	3.6%	(Ultrasonic-assisted show high yield) because of its high efficiency, flexibility, faster extraction time. IT requires less time to extract bioactive compound
	Soxhlet	5.5%	
	Supercritical fluid extraction	5.95%	
	Microwave-assisted extraction (MAE)	28.4%	
	Supercritical fluid extraction	3.3%	
	Ultrasound assisted extraction	16.62 ± 1.82%	
	Pressurized liquid extraction (PLE)	70%	
	Solvent Extraction Method	6.83%	

	Hot water extraction	12.13 ± 1.15%	
	Ultrasonic-assisted extraction(UAE)	8.29 ± 0.31%	
	Simultaneous distillation extraction	3.68%	
Cardamom	Steam distillation	2.50%	(Ultrasonic-assisted show high yield) due to its high extraction efficiency, improved quality of extracted oil & faster extraction time
	Hydrodistillation	2.52%	
	Soxhlet	7.3%	
	Microwave-assisted extraction (MAE)	2.27%	
	Supercritical fluid extraction	5.5%	
	Ultrasonic-assisted extraction (UAE)	7.16 ± 0.21	
	Solvent Extraction	7.6%	
	Enzyme-assisted hydrodistillation	7.8%	
	Solar energy-based extraction	4.4%	

Guava Leaves

Author Name	Observed Studies	What I have understood
1.Karunakar Shukla	Hypoglycemic Activity.	How the % reduction of blood glucose level in alloxan induced diabetic albino rats.
2.Tannaz Birdi	A single plant for multiple health problems.	Antiobesity is not observed in multiple health problems
3.Emmanuel Anyachukwu Irondi	Polyphenolic compostion and inhibitory effect on Xantine (XO) & Angiotensin-Converting Enzyme(ACE).	Only flavonoids & phenolic acids composition is observed not the others.
4.Amita Verma	Guava leaf oil has strong anti-cancer and antioxidant properties.	Validate through GC-MS , DPPH , & MTT assay.
5.Seung – Weon Jeong	Anti-inflammatory effects in vitro & in vivo.	Detection of anti-inflammatory potential with the help of cell line RAW -2647.

Lemon Leaves

Author Name	Observed Studies	What I have understood
1.Muhammad Attique Khan	Automatic identification and categorization of plant diseases by image processing.	Detection steps Segmentation, Preprocessing, Feature extraction & Classification of plant disease.

2.Javid Ghazizadeh	Effect of Lemon balm on depression and anxiety in clinical trials.	Lemon balm is well to lerated and may improve the anxiety depressive symptoms
3.Santa Cirmi & Michele Navarra	Citrus fruit trash has a second life and is a significant source of bioactive chemicals.	How the waste part is reuse as food, packaging, cosmetics and pharmaceutical industries of lemon waste.
4.Ankit Pandey	The bioactivity & chemical composition of lemon grass.	How many phytochemical composition &chemical composition is present and which activity is showed by the lemon grass.
5.Mohajira Begum	Treatment on the nutrient content &microbial properties of dried chanda (Fish).	Lemon leaves extract treat more helpful in fish preservation.

Ginger Leaves

Author Name	Observed Studies	What I have understood
1.Mohammad.S. Mubarak	Protective & Therapeutic potential of ginger extract & [6] gingerol in cancer.	It shows a lot of promise in cancer prevention & therapy but further research needed to fully understand their potential.
2.Suzana Makpol	Ginger in the prevention of Ageing & Degenerative disease.	No study has discussed the effect of ginger on muscular disease.
3.Emad M Abdallah	Antibacterial activity of ginger rhizome.	It highlight the antibacterial property of ginger reported 38 out of 40 positive result against all tested bacteria.
4.Sahdeo Prasad	Role in prevention & Treatment of Gastrointestinal cancer.	Effective against various GI cancers such as gastric cancer, pancreatic cancer, liver cancer, colorectal cancer.
5.Noureen Zafar	Mobile based system for detecting ginger leaf disorders.	The VGG-16 and CNN models produced the best results, as demonstrated by the performance indicators.

Cardamom

Author Name	Observed Studies	What I have understood
1.Nahead Aryaeian	Effect of cardamom consumption on inflammation & blood pressure in adults	The meta-analysis provides convincing evidence like effect of cardamom on SBP, DBP & hs-CRP etc in improving inflammatory markers & blood pressure

2.Samir Qiblawi	Therapeutic intervention of cardamom in cancer & other human disease	Extract found many health-enhancing effects,including antioxidant stress properties, free radical scavenging ability,prevention of coronary heart disease,anti-inflammatory gastroprotective,antimicrobial&anti cancer activities.
3.Ravinder Singh	Antibacterial activity of cardamom extract in food products	It is used in most of the Indian sweet dishes to give a good flavour.It is also used widely in pharmaceutical sector
4.M.N.Venugopal	Viral diseases of cardamom & their management	The research gives information available on distribution of viral diseases, symptomatology ,crop loss,transmission,etiology,host range & disease management.
5.Ravi Kumar	Elettaria cardamom with their pharmacological activity.	It act`s as anti-inflammatory, As Antidote, Anti-ulcerogenic, Analgesic, Laxative & Anti-depressant, Antioxidant, Antimicrobial activity.

DISCUSSION

Reactive oxygen species and free radicals can be captured by flavonoids and other plant phenolic compounds, which also have potent antioxidant properties. The extraction process is one of the most important factors in acquiring natural antioxidants. It is best to use quick, easy, and environmentally friendly methods. However, the chosen extraction method should be highly effective at eliminating the most potent compounds without causing the harm. The ideal method has the following benefits: it may shorten the extraction time, use less solvent, increase extraction yield, and improve the quality of the extracts. According to the study, P. guajava leaves are a powerful source of phytocompounds that have antioxidant properties. Various extraction techniques have been used in this study to assess their impact on the antioxidant and phytochemical profile. Because of its great extraction efficiency for plant bioactives, the UMAE (Ultrasound-Microwave Assisted Extraction) approach has proven to be the most effective of all the extraction techniques. Due to a phenomenon called "cavitation," which occurs when high temperatures, high shear forces, and free radicals work to break down the cell wall and produce a high extraction yield, along with electromagnetic microwaves for uniform heating, the UMAE method was based on green extraction techniques that offer better efficiency and yields. Combining these two techniques has improved efficiency in terms of antioxidant activity, TPC (Total Phenolic Content) and TFC (Total Flavonoid Content), and extraction yield. Increased antioxidant activity has been associated with high levels of flavonoids and phenols. According to a study, the antioxidant activity of plant extracts was positively correlated with their total phenolic and flavonoid contents since higher antioxidant activity is often associated with higher phenolic content. Alcohols, alkanes, phenols, flavonoids, and aromatic chemicals were all detected in the FTIR spectrum. According to a study, the ultrasonication procedure provides higher extraction efficiency than both the Soxhlet method and traditional maceration. As a result, UMAE was suggested as the best extraction technique. It is anticipated that the information acquired from this study will be helpful for both commercial and microscale extraction of guava leaf natural antioxidants. Molecules known as antioxidants slow down the oxidation process. Free radicals, which are created by oxidation events, can harm cells by initiating a number of chain reactions. Numerous illnesses, including cancer, are brought on by free radicals that harm cells. Antioxidants interrupt chain reactions and eliminate free radicals. Beta-carotene, lycopene, vitamins C, E, and A, among other compounds, are examples of antioxidants. One of the most significant damaging reactions is oxidative. Numerous human illnesses, including viral infections, inflammation, neurological problems, and arguments, are caused by the damage caused by free radicals. Free radicals are created when medications are processed in the body. Hormones and environmental factors can occasionally be the cause of the generation of free radicals. All oxidation reactions are caused by these free radicals. These herbs are rich in providing nutrients and antioxidants, which are necessary for life and also aid in reducing the activity of free radicals. Additionally, it has a range of phytochemicals that are good for human health, including high blood pressure, diabetes, and obesity. Antioxidants eliminate free radicals using two popular techniques: the DPPH and FRAP assays. Herbs extracts in organic solvents and water include a lot of antioxidants that can stop the oxidation process. As concentration rises, these chemicals' concentrations rise as well. Antioxidants, which are abundant in herbs, can help lower the prevalence of degenerative diseases such arthritis, cancer, heart disease, inflammation, cognitive dysfunction, and arteriosclerosis . Polyphenols and ascorbic acid are the most prevalent oxidants found in fruits. Flavonoids make up the majority of the polyphenols, which are primarily found in glycoside and ester forms. These herbs has been shown to contain the glycosides of myricetin and apigenin as well as free elagic acid. The DPPH method demonstrates that herbs has remarkable antioxidant contents that do not harm human neutrophils. Extracts in various solvents demonstrate that phenolic compounds, rather than flavonoids, are responsible for the antioxidant activity of herbs, with methanol and aqueous extraction exhibiting the highest activity. Ethanolic extract of herbs exhibits low activity in all antioxidant assays, including DPPH and FRAP assay. These herb's antioxidant activity allows it to control diabetes, as evidenced by a significant diabetic control in mice. It is possible to separate quercetin, quercetin-3-O-glucopyranoside, and morin from leaves. These substances exhibit antioxidant properties. Quercetin has the ability to balance free radicals. Compared to all other compounds, it has a significantly higher reducing power. It is thought to be the most potent and active antioxidant found in guava leaves. Herbs extracts' antioxidative properties have opened up a new therapeutic avenue for treating a variety of illnesses and difficulties. To determine the precise mechanism underlying herb's antioxidant and other pharmacological properties, more research is necessary in this area.

CONCLUSION

The effectiveness of polyherbal formulations against various illnesses should be investigated methodically in order to utilize them as herbal agents and to create effective medications by utilizing medicinal plant resources. This article aims to provide a scientific explanation of how valuable medicinal plant extracts are used in various ailments together with their polyherbal composition.

Future Perspectives

With advancements in extraction technologies and increasing consumer preference for natural antioxidants, herbs will continue to be a valuable resource for health and industry. Future research will focus on improving yield, bioavailability, and sustainable production methods.The future of herbal antioxidants is promising, with applications spanning multiple industries. As research continues to refine extraction methods and delivery systems, the demand for natural antioxidants will only grow. Their integration into pharmaceuticals, food, cosmetics, and nanotechnology not only benefits human health but also supports sustainability efforts, making them a key focus for innovation in the coming years. Research on practical extraction techniques is fueled by the ongoing need to extract plant bioactive components. These has led to the development of most non-traditional extraction techniques. However, since the majority of these methods rely on different mechanisms and extraction improvement is the result of multiple processes, it is crucial to understand each step of the conventional extraction process. Additionally, it is crucial to investigate the characteristics of the herbs material and the selection of compounds. There is still insufficient experimental evidence for some of the existing methods. The appropriate application of standard procedures has an impact on the evaluation of extraction efficiency. The growing economic importance of bioactive chemicals and the products made from them might faster the creation of increasingly sophisticated extraction methods in the future.

REFERENCES

1. Kumar, M., Tomar, M., Amarowicz, R., Saurabh, V., Nair, M. S., Maheshwari, C., Sasi, M., Prajapati, U., Hasan, M., Singh, S., Changan, S., Prajapat, R. K., Berwal, M. K., & Satankar, V. (2021). Guava (Psidium guajava L.) leaves: Nutritional composition, phytochemical profile, and health-promoting bioactivities. Foods (Basel, Switzerland), 10(4), 752. https://doi.org/10.3390/foods10040752
2. Seo, J., Lee, S., Elam, M. L., Johnson, S. A., Kang, J., & Arjmandi, B. H. (2014). Study to find the best extraction solvent for use with guava leaves (Psidium guajava L.) for high antioxidant efficacy. Food Science & Nutrition, 2(2), 174–180. https://doi.org/10.1002/fsn3.91
3. (N.d.). Researchgate.net. Retrieved April 13, 2025, from https://www.researchgate.net/publication/357912102_Pharmacological_Actions_of_Citrus_Limon_Leaves
4. Ashaq, B., Rasool, K., Habib, S., Bashir, I., Nisar, N., Mustafa, S., Ayaz, Q., Nayik, G. A., Uddin, J., Ramniwas, S., Mugabi, R., & Wani, S. M. (2024). Insights into chemistry, extraction and industrial application of lemon grass essential oil -A review of recent advances. Food Chemistry: X, 22(101521), 101521. https://doi.org/10.1016/j.fochx.2024.101521
5. Ayustaningwarno, F., Anjani, G., Ayu, A. M., & Fogliano, V. (2024). A critical review of Ginger’s (Zingiber officinale) antioxidant, anti-inflammatory, and immunomodulatory activities. Frontiers in Nutrition, 11, 1364836. https://doi.org/10.3389/fnut.2024.1364836
6. (N.d.). Researchgate.net. Retrieved April 13, 2025, from https://www.researchgate.net/publication/310897912_The_effect_of_different_methods_and_solvents_on_the_extraction_of_polyphenols_in_ginger_Zingiber_officinale
7. Andriyani, R., Budiati, T. A., & Pudjiraharti, S. (2015). Effect of extraction method on total flavonoid, total phenolic content, antioxidant

and anti-bacterial activity of zingiberis officinale rhizome. Procedia Chemistry, 16, 149–154. https://doi.org/10.1016/j.proche.2015.12.023

8. Anwar, F., Abbas, A., Alkharfy, K. M., & Gilani, A.-U.-H. (2016). Cardamom (Elettaria cardamomum Maton) Oils. In Essential Oils in Food Preservation, Flavor and Safety (pp. 295–301). Elsevier
9. Abdullah, Ahmad, N., Tian, W., Zengliu, S., Zou, Y., Farooq, S., Huang, Q., & Xiao, J. (2022). Recent advances in the extraction, chemical composition, therapeutic potential, and delivery of cardamom phytochemicals. Frontiers in Nutrition, 9, 1024820. https://doi.org/10.3389/fnut.2022.1024820
10. Anwar, S., Kausar, M. A., Parveen, K., Zahra, A., Ali, A., Badraoui, R., Snoussi, M., Siddiqui, W. A., & Saeed, M. (2022). Polyherbal formulation: The studies towards identification of composition and their biological activities. Journal of King Saud University. Science, 34(7), 102256. https://doi.org/10.1016/j.jksus.2022.102256
11. Bitwell, C., Indra, S. S., Luke, C., & Kakoma, M. K. (2023). A review of modern and conventional extraction techniques and their applications for extracting phytochemicals from plants. Scientific African, 19(e01585), e01585. https://doi.org/10.1016/j.sciaf.2023.e01585
12. Zhang, Q.-W., Lin, L.-G., & Ye, W.-C. (2018). Techniques for extraction and isolation of natural products: a comprehensive review. Chinese Medicine, 13, 20. https://doi.org/10.1186/s13020-018-0177-x
13. Mohammad Azmin, S. N. H., Abdul Manan, Z., Wan Alwi, S. R., Chua, L. S., Mustaffa, A. A., & Yunus, N. A. (2016). Herbal processing and extraction technologies. Separation and Purification Reviews, 45(4), 305–320. https://doi.org/10.1080/15422119.2016.1145395
14. Ghenabzia, I., Hemmami, H., Ben Amor, I., Zeghoud, S., Ben Seghir, B., & Hammoudi, R. (2023). Different methods of extraction of bioactive compounds and their effect on biological activity: A review. International Journal of Secondary Metabolite, 10(4), 469–494. https://doi.org/10.21448/ijsm.1225936
15. Sampath Kumar, N. S., Sarbon, N. M., Rana, S. S., Chintagunta, A. D., Prathibha, S., Ingilala, S. K., Jeevan Kumar, S. P., Sai Anvesh, B., & Dirisala, V. R. (2021). Extraction of bioactive compounds from Psidium guajava leaves and its utilization in preparation of jellies. AMB Express, 11(1), 36. https://doi.org/10.1186/s13568-021-01194-9
16. Oyeniran, O. H., Omotosho, O.-P. I., Ademola, I. I., Ibraheem, O., Nwagwe, O. R., & Onodugo, C. A. (2024). Lemon (Citrus limon) leaf alkaloid-rich extracts ameliorate cognitive and memory deficits in scopolamine-induced amnesic rats. Pharmacological Research - Modern Chinese Medicine, 10(100395), 100395. https://doi.org/10.1016/j.prmcm.2024.100395
17. Ashaq, B., Rasool, K., Habib, S., Bashir, I., Nisar, N., Mustafa, S., Ayaz, Q., Nayik, G. A., Uddin, J., Ramniwas, S., Mugabi, R., & Wani, S. M. (2024). Insights into chemistry, extraction and industrial application of lemon grass essential oil -A review of recent advances. Food Chemistry: X, 22(101521), 101521. https://doi.org/10.1016/j.fochx.2024.101521
18. Al-Areer, N. W., Al Azzam, K. M., Al Omari, R. H., Al-Deeb, I., Bekbayeva, L., & Negim, E.-S. (2023). Quantitative analysis of total phenolic and flavonoid compounds in different extracts from ginger plant (Zingiber officinale) and evaluation of their anticancer effect against colorectal cancer cell lines. Farmatsiia,

70(4), 905–919. https://doi.org/10.3897/pharmacia.70.e103936

19. Abdullah, Ahmad, N., Tian, W., Zengliu, S., Zou, Y., Farooq, S., Huang, Q., & Xiao, J. (2022). Recent advances in the extraction, chemical composition, therapeutic potential, and delivery of cardamom phytochemicals. Frontiers in Nutrition, 9, 1024820. https://doi.org/10.3389/fnut.2022.1024820
20. Dewage Dona, D. H. D., & Rajapakse, C. S. K. (2024). A review of the antioxidant and antimicrobial activities and photoprotective properties of Psidium guajava L. Oriental Journal of Chemistry, 40(5), 1240–1249. https://doi.org/10.13005/ojc/400505
21. Hu, W., Yu, A., Wang, S., Bai, Q., Tang, H., Yang, B., Wang, M., & Kuang, H. (2023). Extraction, purification, structural characteristics, biological activities, and applications of the polysaccharides from Zingiber officinale Roscoe. (ginger): A review. Molecules (Basel, Switzerland), 28(9). https://doi.org/10.3390/molecules28093855
22. Morsy, N. F. S. (2015). A short extraction time of high quality hydrodistilled cardamom (Elettaria cardamomum L. Maton) essential oil using ultrasound as a pretreatment. Industrial Crops and Products, 65, 287–292. https://doi.org/10.1016/j.indcrop.2014.12.012
23. Anand David, A. V., Arulmoli, R., & Parasuraman, S. (2016). Overviews of biological importance of quercetin: A bioactive flavonoid. Pharmacognosy Reviews, 10(20), 84–89. https://doi.org/10.4103/0973-7847.194044
24. Irondi, E. A., Agboola, S. O., Oboh, G., Boligon, A. A., Athayde, M. L., & Shode, F. O. (2016). Guava leaves polyphenolics-rich extract inhibits vital enzymes implicated in gout and hypertension in vitro. Journal of Intercultural Ethnopharmacology, 5(2), 122–130. https://doi.org/10.5455/jice.20160321115402
25. Daswani, P. G., Gholkar, M. S., & Birdi, T. J. (2017). Psidium guajava: A single plant for multiple health problems of rural Indian population. Pharmacognosy Reviews, 11(22), 167–174. https://doi.org/10.4103/phrev.phrev_17_17
26. Mandal, A. K., Paudel, S., Pandey, A., Yadav, P., Pathak, P., Grishina, M., Jaremko, M., Emwas, A.-H., Khalilullah, H., & Verma, A. (2022). Guava leaf essential oil as a potent antioxidant and anticancer agent: Validated through experimental and computational study. Antioxidants (Basel, Switzerland), 11(11), 2204. https://doi.org/10.3390/antiox11112204
27. Jang, M., Jeong, S.-W., Cho, S. K., Ahn, K. S., Lee, J. H., Yang, D. C., & Kim, J.-C. (2014). Anti-inflammatory effects of an ethanolic extract of guava (Psidium guajava L.) leaves in vitro and in vivo. Journal of Medicinal Food, 17(6), 678–685. https://doi.org/10.1089/jmf.2013.2936
28. Iqbal, Z., Khan, M. A., Sharif, M., Shah, J. H., ur Rehman, M. H., & Javed, K. (2018). An automated detection and classification of citrus plant diseases using image processing techniques: A review. Computers and Electronics in Agriculture, 153, 12–32. https://doi.org/10.1016/j.compag.2018.07.032
29. Russo, C., Maugeri, A., Lombardo, G. E., Musumeci, L., Barreca, D., Rapisarda, A., Cirmi, S., & Navarra, M. (2021). The second life of citrus fruit waste: A valuable source of bioactive compounds. Molecules (Basel, Switzerland), 26(19), 5991. https://doi.org/10.3390/molecules26195991
30. Ghazizadeh, J., Sadigh-Eteghad, S., Marx, W., Fakhari, A., Hamedeyazdan, S., Torbati, M., Taheri-Tarighi, S., Araj-Khodaei, M., & Mirghafourvand, M. (2021). The effects of

lemon balm (Melissa officinalis L.) on depression and anxiety in clinical trials: A systematic review and meta-analysis. Phytotherapy Research: PTR, 35(12), 6690–6705. https://doi.org/10.1002/ptr.7252

31. de Lima, R. M. T., Dos Reis, A. C., de Menezes, A.-A. P. M., Santos, J. V. de O., Filho, J. W. G. de O., Ferreira, J. R. de O., de Alencar, M. V. O. B., da Mata, A. M. O. F., Khan, I. N., Islam, A., Uddin, S. J., Ali, E. S., Islam, M. T., Tripathi, S., Mishra, S. K., Mubarak, M. S., & Melo-Cavalcante, A. A. de C. (2018). Protective and therapeutic potential of ginger (Zingiber officinale) extract and [6]-gingerol in cancer: A comprehensive review: Ginger extract and [6]-gingerol as anticancer agents. Phytotherapy Research: PTR, 32(10), 1885–1907. https://doi.org/10.1002/ptr.6134
32. Mohd Sahardi, N. F. N., & Makpol, S. (2019). Ginger (Zingiber officinale Roscoe) in the prevention of ageing and degenerative diseases: Review of current evidence. Evidence-Based Complementary and Alternative Medicine: eCAM, 2019, 5054395. https://doi.org/10.1155/2019/5054395
33. Prasad, S., & Tyagi, A. K. (2015). Ginger and its constituents: role in prevention and treatment of gastrointestinal cancer. Gastroenterology Research and Practice, 2015, 142979. https://doi.org/10.1155/2015/142979
34. Waheed, H., Akram, W., Islam, S. ul, Hadi, A., Boudjadar, J., & Zafar, N. (2023). A mobile-based system for detecting ginger leaf disorders using deep learning. Future Internet, 15(3), 86. https://doi.org/10.3390/fi15030086
35. Heydarian, A., Tahvilian, N., Shahinfar, H., Abbas-Hashemi, S. A., Daryabeygi-Khotbehsara, R., & Aryaeian, N. (2024). Effect of cardamom consumption on inflammation and blood pressure in adults: A systematic review and meta-analysis of randomized clinical trials. Food Science & Nutrition, 12(1), 3–12. https://doi.org/10.1002/fsn3.3738
36. Qiblawi, S., Kausar, M. A., Shahid, S. M. A., Saeed, M., & Alazzeh, A. Y. (2020). Therapeutic interventions of cardamom in cancer and other human diseases. Journal of Pharmaceutical Research International, 74–84. https://doi.org/10.9734/jpri/2020/v32i2230774.
37. (N.d.). Researchgate.net. Retrieved April 14, 2025, from https://www.researchgate.net/publication/358524479_A_Review_on_Amomum_subulatum_and_Elettaria_Cardamomum_with_their_Pharmacological_Activity
38. An, X., Yu, W., Liu, J., Tang, D., Yang, L., & Chen, X. (2024). Oxidative cell death in cancer: mechanisms and therapeutic opportunities. Cell Death & Disease, 15(8), 556. https://doi.org/10.1038/s41419-024-06939-5
39. Cai, Z.-M., Peng, J.-Q., Chen, Y., Tao, L., Zhang, Y.-Y., Fu, L.-Y., Long, Q.-D., & Shen, X.-C. (2021). 1,8-Cineole: a review of source, biological activities, and application. Journal of Asian Natural Products Research, 23(10), 938–954. https://doi.org/10.1080/10286020.2020.1839432
40. Ashokkumar, K., Murugan, M., Dhanya, M. K., & Warkentin, T. D. (2020). Botany, traditional uses, phytochemistry and biological activities of cardamom [Elettaria cardamomum (L.) Maton] - A critical review. Journal of Ethnopharmacology, 246(112244), 112244. https://doi.org/10.1016/j.jep.2019.112244
41. Parasuraman, S., Thing, G. S., & Dhanaraj, S. A. (2014). Polyherbal formulation: Concept of ayurveda. Pharmacognosy Reviews, 8(16), 73–80. https://doi.org/10.4103/0973-7847.134229

42. Tang, D., Kang, R., Berghe, T. V., Vandenabeele, P., & Kroemer, G. (2019). The molecular machinery of regulated cell death. Cell Research, 29(5), 347–364. https://doi.org/10.1038/s41422-019-0164-5.

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