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An Updated Review on Extraction, Isolation, and Identification of Bioactive Compounds from Plant Extracts

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Abstract **Original Research Article**

Plant extracts have long been used for their medicinal qualities and as sources of bioactive chemicals. In recent years, there has been a surge in interest in investigating the possibilities of plant extracts in a variety of disciplines, including medicine, cosmetics, and food. This abstract presents an up-to-date assessment of methods for extracting, isolating, and identifying bioactive chemicals from plant extracts, highlighting advances and problems in this field. The first stage in acquiring bioactive chemicals from plant sources is extraction. Maceration, infusion, decoction, solvent extraction, supercritical fluid extraction, and microwave-assisted extraction are among the extraction procedures used. These approaches strive to extract the target molecules as efficiently as possible while keeping their chemical integrity and bioactivity.

Keywords: Methods for extracting, identifying bioactive chemicals, Maceration, supercritical fluid extraction, microwave-assisted extraction.

1. INTRODUCTION

Fruits and vegetables include a variety of antioxidant chemicals, including phenolics, carotenoids, anthocyanins, and tocopherols [1]. Approximately 20% of known plants have been used in pharmacological investigations, positively improving the healthcare system by treating cancer and other ailments [2]. Plants are capable of producing a wide range of bioactive chemicals. Fruits and vegetables have high amounts of phytochemicals, which may protect against free radical damage [3]. Plants that contain beneficial phytochemicals may complement the human body's needs by functioning as natural antioxidants [4]. Several studies have demonstrated that several plants are high in antioxidants. Plants, for example, include antioxidants such as vitamins A, C, and E, as well as phenolic compounds such as flavonoids, tannins, and lignins [3]. Fruit and vegetable eating has been related to a number of health benefits as a result of their therapeutic characteristics and high nutritional content [5]. Antioxidants prevent and minimise oxidative damage in foods by delaying or suppressing oxidation produced by reactive oxygen species (ROS), resulting in increased shelf- life and quality [6]. Beta carotene, ascorbic acid, and numerous phenolics all play important roles in anti-aging, inflammation reduction, and cancer prevention [7]. Many organisations and health-care systems around the world have advocated for increased intake of fruits and vegetables [8]. The purpose of this work is to give a review of phytochemical research that has addressed the extraction, measurement, and identification of plant bioactive chemicals. This review includes an overview of the lipid oxidation process, details on plants known to be antioxidant and antimicrobial sources, phenolic compounds, antioxidants from vegetables and fruits, cancer prevention, phenolic compound extraction techniques, isolation and purification of bioactive molecules, and structural classification of bioactive molecules.

2. Bioactive Compound Extraction, Isolation, and Purification Methods

2.1. Phenolic Compound Extraction Making Use of Solvents

Scientists have investigated and analysed the effects of various solvents, such as methanol, hexane, and ethyl alcohol, on antioxidant extraction from diverse plant parts, such as leaves and seeds. Various solvents with varying polarity must be employed to extract different phenolic chemicals from plants with great precision [9]. Furthermore, scientists have discovered that highly polar solvents, such as methanol,

are extremely potent antioxidants. Anokwuru *et al.*, discovered that acetone and N,N dimethylformamide (DMF) are particularly successful in extracting antioxidants, but Koffi *et al.*, discovered that methanol was more effective than ethanol at extracting a substantial amount of phenolic compounds from walnut fruits [10-12].

In comparison to acetone, water, and methanol, ethanolic extracts of Ivorian plants extracted higher concentrations/amounts of phenolics [11]. Multiple solvents have widely been used to extract phytochemicals, and scientists typically used a dried powder of plants to extract bioactive components while also eliminating the interference of water. The polarity of the solute of interest is used to select solvents for the extraction of biomolecules from plants. A solvent with identical polarity to the solute will dissolve the solute properly. To minimise the amount of similar chemicals in the desired yield, multiple solvents might be utilised successively. The polarity of a few common solvents is as follows, from least polar to most polar: Hexane, chloroform, ethylacetate, acetone, methanol, and water are all examples of solvents.

2.2 Microwave-Assisted Extraction (MAE)

MAE has piqued the interest of researchers as a method for extracting bioactive chemicals from a wide range of plants and natural leftovers [12]. Microwaves emit electromagnectic radiation with frequencies ranging from 300 MHz to 300 GHz and wavelengths ranging from 1 cm to 1 m. These electromagnetic waves have both an electrical and magnetic field. Two perpendicular fields are described. Microwaves were first used to heat up items that could absorb some of the electromagnetic energy and convert it to heat. The frequency 2450 MHz is extensively used in commercial microwave instruments, and corresponds to an energy output of 600-700 Watts [13]. Recently, improved strategies for reducing bioactive component loss without increasing extraction time have been available. As a result, microwave-assisted extraction has been shown to be a good technique in a variety of sectors, particularly medicinal plants. Furthermore, this approach minimised biological component extraction losses [14]. Because of its potential to minimise both time and extraction solvent volume, microwave-assisted extraction (MAE) has been employed as an alternative to conventional procedures for the extraction of antioxidants [15]. Indeed, the primary goal of employing MAE is to heat the solvent and extract antioxidants from plants with a lower concentration of these solvents [13]. According to Li *et al.*, conventional techniques using various solvents yielded lower antioxidant activity and phenolic content than MAE [16]. By assessing ferric reducing antioxidant power (FRAP), oxygen radical absorbance capacity (ORAC), and total phenolic content (TPC), the researchers confirmed that MAE was more effective at enhancing antioxidant activity. Some parameters, such as extraction temperature, solvent composition, and extraction time, can alter the efficacy of microwave extraction. Because of its ability to boost the effectiveness of microwave extraction, the extraction temperature was usually examined more than other aspects. Tsubaki *et al.*, discovered that 170 °C was the best temperature for extracting phenolic components from Chinese tea. Furthermore, raising the extraction temperature above this point resulted in a lower extraction yield [17]. Recently, Christophoridou *et al.*, used a unique microwave-assisted extraction (MAE) approach to extract a specific molecule by converting energy to heat and cooperating with solvents [18]. MAE has various advantages, according to Williams *et al.*, including decreased solvent usage, shorter extraction periods, and higher sensitivity to target compounds [19]. Table 1 provides a comparison of several antioxidant techniques used.

Table 1: Methods for measuring antioxidant capacity are compared based on mechanism, endpoint, quantification method, and whether the assay can detect lipophilic and hydrophilic antioxidants

Antioxidant Assay	Mechanism	Endpoint	Quantification	Lipophilic and Hydrophilic AOC
ORAC	HAT	Fixed time	AUC	Yes
TRAP	HAT	Lag phase	IC50 lag time	No
FRAP	SET	Time varies	ΔOD fixed time	No
TEAC	SET	Time varies	ΔOD fixed time	Yes
DPPH	SET	IC50	ΔOD fixed time	No
LDL oxidation	SET	Lag phase	Lag time	No

2.3. Extraction Assisted by Ultrasound

Ultrasound-assisted extraction (UAE) has been used to extract bioactive chemicals from plant materials in a variety of food-processing applications [19]. Ultrasound at frequencies greater than 20 kHz is used to damage plant cell walls, allowing the solvent to permeate the cells and produce a larger extraction yield. Through processing, UAE can use a low operating temperature while retaining a good extract quality for chemicals. UAE is regarded as one of the simplest extraction methods since it employs basic laboratory equipment such as an ultrasonic bath. A shattered sample is mixed with the appropriate solvent and deposited in an ultrasonic bath, while temperature and extraction duration are regulated [20]. A wide number of solvents can be used in the UAE of various organic and inorganic materials. An ultrasonic bath and an ultrasonic probe system are common pieces of equipment used in ultrasound-assisted extraction. Unfortunately, ultrasonic probes have two major

drawbacks, both of which are connected to experimental repeatability and reproducibility [21].

Green technology, according to Tabaraki *et al.*, is required to safeguard the environment from hazardous pollutants [22]. As a result of its function in lowering the amount of solvent and energy consumed, ultrasonic extraction of phenolic compounds has expanded in recent years. Corrales *et al.*, demonstrated that UAE can efficiently break down plant tissue and perform well during the production process, as well as release active chemicals in solvents [21]. The results revealed that employing UAE as an effective approach to extract antioxidants from various sources increased antioxidant activity from 187.13 mol TE g1DM to 308 mol TE g1DM. Albu *et al.*, have investigated and used the use of ultrasound to extract phenolic components from rosemary [23]. To determine the most efficient approach, multiple factors were tested, including ultrasonic bath extractions, an ultrasonic probe system, a shaking water bath at various temperatures, and different solvents. The application and use of ultrasonic bath and probe systems significantly reduced operation time in all cases. Cho *et al.*, observed a similar pattern when extracting resveratrol from grapes [24]. In another study, Barbero *et al.*, proposed using ultrasound in various industries due to its beneficial effects in the extraction of capsaicinoids from hot peppers [25]. Furthermore, the ultrasonic technique showed the capacity to reduce phenolic degradation [26]. Mulinacci *et al.*, examined the extraction time of phenolic components from strawberries using solid-liquid, subcritical water, and microwave-assisted techniques [27]. The findings revealed that the UAE approach was the most successful.

2.4 Techniques for Isolating and Purifying Bioactive Molecules from Plants

Purification and isolation of bioactive chemicals from plants is a technology that has seen recent advancement [28, 29]. This current technique allows for the parallel development and availability of various complex bioassays on the one hand, while also providing precise isolation, separation, and purification procedures on the other. When looking for bioactive chemicals, the goal is to design a method that can screen the source material for bioactivity such as antioxidant, antibacterial, or cytotoxicity while also being simple, specific, and fast [27]. Animal experiments are more expensive, require more time, and are prone to ethical problems, hence in vitro methods are frequently used. Some variables make it impossible to develop final techniques or protocols for isolating and characterising certain bioactive compounds. This could be due to the plant's various components (tissues), many of which create very distinct molecules, as well as the variable chemical structures and physicochemical properties of the bioactive phytochemicals [30]. Plant material selection and collection are both regarded essential processes in isolating and characterising a bioactive phytochemical. The next stage is to gather ethnobotanical information in order to identify potential bioactive compounds. Extracts can then be created. Using different solvents, the active molecules responsible for bioactivity are isolated and purified. Column chromatography techniques can be used to isolate and purify bioactive substances. High Pressure Liquid Chromatography (HPLC), for example, has been developed to speed up the process of purifying the bioactive chemical. The purified chemicals can be identified using several spectroscopic techniques such as UV-visible, infrared (IR), nuclear magnetic resonance (NMR), and mass spectroscopy [31].

2.5 Purification of the Bioactive

Molecule Using paper thin-layer and column chromatography technologies, several bioactive compounds have been identified and purified. Because of their ease, economy, and availability in diverse stationary phases, column chromatography and thin-layer chromatography (TLC) are still widely employed [32]. The highest value for phytochemical separation is found in silica, alumina, cellulose, and polyamide. Plant materials include a high concentration of complex phytochemicals, making separation difficult [32]. As a result, increasing polarity with many mobile phases is advantageous for highly valued separations. Thin-layer chromatography has long been employed in column chromatography to analyse compound fractions. With some analytical methods, silica gel column chromatography and thin-layer chromatography (TLC) have been employed to separate bioactive compounds [32].

2.6. Bioactive Molecule Structural Clarification

The structure of particular molecules is determined using data from a variety of spectroscopic techniques, including UV-visible, infrared (IR), nuclear magnetic resonance (NMR), and mass spectroscopy. The basic idea of spectroscopy is to send electromagnetic radiation through an organic molecule, which absorbs some but not all of the light. A spectrum can be created by measuring the amount of electromagnetic energy absorbed. The spectra are tailored to certain bonds in a molecule. The structure of an organic molecule can be determined using these spectra. For structural clarity, scientists mostly use spectra obtained from three or four regions: ultraviolet (UV), visible, infrared (IR), radio frequency, and electron beam [31].

2.7. UV-Visible Spectroscopy

UV-visible spectroscopy can be used to undertake qualitative analysis and to identify certain classes of substances in pure and biological mixtures. Because aromatic compounds are potent chromophores in the UV range, UV- visible spectroscopy is preferred for quantitative study. UV-visible spectroscopy can be used to identify natural substances [33]. Anthocyanins, tannins, polymer dyes, and phenols create complexes

with iron, which have been discovered using ultraviolet/visible (UV-Vis) spectroscopy [34]. Furthermore, it was discovered that spectroscopic UV-Vis techniques are less selective and provide information on the composition of the total polyphenol content. The total phenolic extract (280 nm), flavones (320 nm), phenolic acids (360 nm), and total anthokyanids (520 nm) were all determined using UV-Vis spectroscopy.

2.8. Spectroscopy in the Infrared

When infrared light travels through a sample of an organic molecule, some frequencies are absorbed; yet, some frequencies are transmitted through the sample without absorption. The vibrational changes that occur within a molecule when exposed to infrared radiation are connected with infrared absorption. As a result, infrared spectroscopy is essentially a vibrational spectroscopy. The vibrational frequencies of various bonds (C-C, C=C, C-O, C=O, O-H, and N- H) differ. If such bonds exist in an organic molecule, they can be recognised by measuring the characteristic frequency absorption band in the molecule the spectrum of infrared light [35]. Fourier Transform Infrared Spectroscopy (FTIR) is a high-resolution analytical technique used to determine chemical components and structural compounds. To fingerprint herbal extracts or powders, FTIR provides a quick and nondestructive analysis.

2.9 NMR (Nuclear Magnetic Resonance) Spectroscopy

NMR is largely concerned with the magnetic characteristics of specific atomic nuclei, most notably the nucleus of the hydrogen atom, the proton, the carbon, and a carbon isotope. Many researchers have used NMR spectroscopy to examine molecules by recording the differences between the various magnetic nuclei and therefore providing a clear picture of where these nuclei are in the molecule. Furthermore, it will show which atoms are present in neighbouring groups. It can eventually determine how many atoms are present in each of these environments [33]. Several attempts have been made in the past to isolate individual phenols using preparative or semi-preparative thin-layer chromatography, liquid chromatography, and column chromatography, the structures of which are then identified off-line by NMR [34].

2.10 Chemical Compound Mass Spectrometry Identification

In mass spectrometry, organic molecules are blasted with either electrons or lasers, resulting in very energetic charged ions. A mass spectrum is a visualisation of a fragmented ion's relative abundance versus its mass/charge ratio. Mass spectrometry can calculate relative molecular mass (molecular weight) with high accuracy and provide an accurate molecular formula where the molecule is fragmented [18]. Bioactive compounds from pith have previously been identified and purified using bioactivity-guided solvent extraction, column chromatography, and HPLC [36]. To characterise the structure of the bioactive molecule, UV-visible, IR, NMR, and mass spectroscopy techniques were used. In addition, compounds can be hydrolyzed and their derivatives identified. When tandem mass spectrometry (MS) is used, mass spectrometry provides a wealth of information for the structural elucidation of the molecules. As a result, combining HPLC with MS allows for the rapid and reliable identification of chemical components in medicinal herbs, particularly when a pure standard is unavailable [37-40]. Recently, LC/MS has been widely employed for phenolic compound analysis. Because of its high ionisation efficiency, electrospray ionisation (ESI) is a favoured source.

3. Oxidation of Lipids

Many foods can experience lipid oxidation during production, shipping, and storage. When exposed to an oxidative environment, lipids (such as triglycerides, sterols, and phospholipids) readily oxidise [41]. Lipid molecules, particularly those containing polyunsaturated double bonds (i.e., linolenic acids), are easily oxidised within meals. Highly saturated seed oil (palmitic acid and stearic acid) would be excellent for this end use because it is oxidatively stable and has a high melting temperature [42]. Soybeans account for 56% of global oilseed production. However, when compared to unsaturated oil (approximately 90%), the percentage of saturated oil in seed plants is quite low (about 10%) [43]. The oxidative stability of palmitic acid is improved. Soybean oil is also used to make trans-fat-free shortening, margarine, and cosmetics. This saturated short-chain fatty acid, however, is unsuitable for feeding because it causes an unfavourable lipoprotein profile in blood serum [44]. Stearic acid has no cholesterolemic impact on human health [45]. Stearic acid is less likely to be incorporated into cholesterol esters and has no effect on blood serum LDL cholesterol levels [46, 47]. Extensive study has been conducted in attempt to boost stearic acid content oil production in soybeans, the world's most extensively consumed legume crop. Seed stearic acid content was enhanced by up to 7 times using induced mutagenesis [48]. Oxygen free radicals or reactive oxygen species can cause lipid oxidation in food systems. Free radicals are compounds with one or more unpaired electrons that oxidise on their own [49]. Oxygen free radicals are exemplified by reactive oxygen species. Reactive oxygen species contain both free radical molecules and non-free radicals that can impact lipid oxidation. Hydrogen peroxide (H2O2), hydrochloric acid (HCl), ozone (O3), and molecular oxygen (O2) are examples of non-free radical reactive oxygen species [42]. Molecular oxygen reacts 1450 times faster with linoleic acid than triplet oxygen. Molecular oxygen is a key cause of oil rancidity. Three diagrams depict lipid oxidation caused by a chain reaction of free radicals.

(1) Initiation: RH+initiator R ROOH+initiator ROO•
(2) Propagation: R + O2 ROO ROO + RH ROOH + R
(3) Termination: R + R R-R ROO• + R ROOH

Heating, radiation, temperature, metal ion catalysts, reactive oxygen species, and photosensitizers such as chlorophyll all cause the processes described above to occur. The beginning phase, depicted in Equation (1), frequently occurs at an allytic methylene group of an unsaturated fatty acid (RH) or a lipid-hydroperoxide (ROOH). The produced free radical (R•) then interacts with oxygen to form a peroxy radical (ROO•). This product can combine immediately with another lipid molecule to form a lipid hydroperoxide (ROOH) and, as a result, a lipid free radical (R•). This results in a constant cascade of chain reactions until the free radicals are neutralised by other free radicals. Equation (2) depicts the entire stage. According to Equation (3), two radicals have transformed into non-free radical products at the termination phase, which will stop the chain reaction's cascade mode. Furthermore, some antioxidants or free radical scavengers can stop the chemical cascade. Metal ions, particularly iron and copper ions, effectively catalyse these reactions [50].

Lipoxygenases (EC 1.13.11) can also act, triggering oxidation to create peroxides in lipid-containing foods. One of the principal products of oxidation is hydrogen peroxide, which is highly unstable and readily changes to secondary compounds. Oxidation can produce a variety of chemical groups, including aldehydes, ketones, alcohols, acids, and hydrocarbons. These chemicals can have a negative impact on the look, quality, and edibility of a food product by altering the texture, colour, flavour, and safety of meals, as well as causing unpleasant off odours or off tastes, and even lowering nutritional content [50].

4. Plants as an Antioxidant Source

Antioxidants are bioactive substances that suppress or postpone the oxidation of molecules [42]. Antioxidants are classified as either natural or synthetic. BHT, BHA, propyl gallate, and tertbutylhydroquinine are examples of synthetic antioxidants that are routinely utilised. Many experts are concerned about safety because synthetic antioxidants, due to their toxicity and carcinogenicity, have lately been demonstrated to cause health problems such as liver damage. As a result, there has been a surge in the creation of safer antioxidants from natural sources, and plants have been employed as a good source of traditional medicines to treat many disorders. Many of these therapeutic plants are rich in compounds that have antioxidant properties. Tamarind, cardamom, lemon grass, and galangal basil are some examples of frequent ingredients used in ethnic foods. Antioxidants have been found in several spices or herbs [51]. Food deterioration caused by bacterial or fungal infection has always been a serious concern, generating massive losses to food industry and societies around the world [51]. Furthermore, the proliferation of microorganisms in food has become a major public health concern. As people become more aware of the harmful consequences of synthetic preservatives, there is a greater desire for nontoxic, natural preservatives, many of which are likely to have antioxidant or antibacterial properties [52, 53]. Herbs have long been utilised in the food business for flavour and aroma, and some have been discovered to have antibacterial characteristics [54]. As a result, there is a greater need for screening and using plant resources for antioxidant and antibacterial characteristics.

4.1. Antioxidant Content of Red Algae

Red algae are aquatic plant species that are thought to be among the oldest families of eukaryotic algae [55]. Palmaria palmate, a red alga, has been researched for its antioxidant activity. According to the findings, 9.68 g of ascorbic acid and 10.3 g of total polyphenol can both diminish activity in 1 mg of dulse extracts. The presence of functional groups such as hydroxyl, carbonyl, and others, which lead to reduced or inhibited oxidation, was found to be associated to reducing activity in aqueous/alcohol soluble compounds [56].

4.2. Monocot Antioxidants

Ashawat *et al.,* investigated the antioxidant activities of Areca catechu ethanolic extracts, discovering that Areca catechu exhibited the highest antioxidant activity when compared to other eudicots such as Centella asiatica, Punica granatum, and Glycyrrhiza glabra [57]. Londonkar and Kamble investigated the antioxidant activity of Pandanus odoratissimus L. [58]. Zahin *et al.,* investigated the antioxidant activity and total phenolic content of Acorus calamus [59]. The findings revealed the existence of a substantial relationship between phenolic content and antioxidant activity. Another monocot, O. sanctum, demonstrated that the prevention of lipid peroxidation in vivo and in vitro increased proportionally with extract concentration.

4.3. Vegetable Antioxidants

Vegetable consumption has been related to a lower risk of numerous diseases, including cancer and cardiovascular disease, in epidemiological studies [59]. Several studies have been conducted to test vegetables for antioxidant activity utilising various oxidation systems. Carrots, potatoes, sweet potatoes, red beets, cabbage, Brussels sprouts, broccoli, lettuce, spinach, onions, and tomatoes are among these veggies. In addition to the succinct research that used various strategies to release bioactive compounds, it is becoming increasingly difficult to ignore new extraction technologies that have paved the way for quick extraction of bioactive compounds. Despite scientists' advances in demonstrating the action of bioactive chemicals found in vegetables, there is little known

about the activity of the antioxidant components isolated from these veggies. Advanced methods for isolating and measuring the activity of antioxidant substances such as flavonoids, phenolic acids, tocopherols, carotenoids, and ascorbic acid have been prioritised by researchers [60].

4.4 Fruit Antioxidants

Fruit eating has also been associated to a lower risk of a variety of diseases [61]. In many nations, peaches (Prunus persica L.) are a commercially important fruit. According to research, phenolic compounds present in distinct peach genotypes are a significant source of potential antioxidants [60]. Peaches, on the other hand, have shown a significant reduction of low density lipoprotein (LDL) oxidation, with a percentage of antioxidant activity ranging from 56 to 87%. This antioxidant action can be linked to its essential chemical content, which includes hydroxycinnamic acids, chlorogenic, and phenolic acids. carotenoids such as b-carotene and b-cryptoxanthin, but not neochlorogenic acids. Furthermore, peach peel has limited antioxidant activity. Plumb *et al.,* on the other hand, found that hydroxycinnamic acids do not contribute to the suppression of lipid peroxidation in the liver utilising plums and peaches because they have a low ability to scavenge hydroxyl radicals [62]. Grape (Vitis vinifera L.) is a fruit crop that is grown all over the world [62] recently investigated grapes and their juices. Fresh grapes and commercial grape juice both had high levels of phenolic chemicals. When standardised at 10 mg gallic acid equivalents (GAE), the proportion of inhibition of LDL oxidation ranged from 22% to 60% for fresh grapes and 68% to 75% for commercial grape juices. According to [63], both grapes and their juices had a high oxygen radical absorbance capacity (ORAC), with the anthocyanin pigment malvidin-3,5-diglucoside being a significant component identified from grapes. Common chemicals isolated from wild grapes (Vitis coignetiae) were anthocyanins with the malvidin nucleus, malvidin 3-O-(6-O-p-coumaroylglucosido)-5-glucoside, and phenolics. Wangensteen *et al.,* evaluated the action of various bioactive compounds by releasing them from grape pomace, and found that bioactive chemicals can considerably decrease LDL oxidation in humans [64]. Grape seeds are high in polyphenol chemicals, including monomerics like catechin, epicatechin, and gallic acid, as well as polymerics like procyanidins [65]. The main phenolic chemicals found in apples (Malus domestica L.) are polyphenols and carotenoids, as well as caffeic, quinic, and p-coumaric acids. These polyphenols have antioxidant properties. Flavanol monomers and oligomers, as well as quercetin, contribute to fruits and vegetables' health benefits [65]. Apple pomace has mostly been utilised to supplement polyphenols such as chlorogenic acid [66, 67]. Furthermore, phenolics such as caffeic, p-coumaric acid, arbutin, and p-coumaric acids, as well as flavonol procyanidins, have been identified as constituents of apple pomace [68]. Procyanidins' ability to act as oxygen radical scavengers, superoxides, and hydroxyl radicals was calculated. Despite the low total phenol content achieved by employing acetone 70%, apples have shown excellent antioxidant activity against linoleic acid oxidation. The main bioactive components discovered in this case were chlorogenic acid and phloretin glycosides; nevertheless, vitamin C was only a tiny fraction in apple juice [69]. The antioxidant and antibacterial activity of Punica granatum peel extracts in various solvents (ethyl acetate, acetone, methanol, and water) were investigated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method. The results showed that methanol extracts had much higher reducing power and acetone extracts had significantly higher antibacterial activity. Soong and Barlow studied the antioxidant activity and phenolic content of several fruit seeds [70]. Petroleum ether was utilised to remove excess fat from the seeds, and methanol was used for extraction. The antioxidant activity was investigated using the 2,2-azino-bis-3-ethylbenzthiazoline-6-sulfonic acid (ABTS), DPPH, and ferric reducing ability of plasma (FRAP) techniques. Abdille *et al.,* investigated the antioxidant activity of Dillenia indica fruit using DPPH, phospho-molybdenum, and carotene bleaching techniques [71]. The maximum antioxidant activity was found in methanol extracts, followed by ethyl acetate and water extracts. In vitro antioxidant activity of Syzygium cumini fruit has been examined [71]. Methods for measuring antioxidant activity included DPPH, superoxide, lipid peroxidation, and hydroxyl radical scavenging activities. The findings revealed a strong relationship between the concentration of the extract and the percentage of free radical inhibition. The inclusion of antioxidant vitamins, anthocyanins, phenolics, and tannins may contribute to the fruit's antioxidant properties. It has been found that antioxidant activity in blackberry (Rubus fruticosus L.) fruit extracts prepared in different climatic locations was determined by genotype rather than climate or season [10]. Juntachote and Berghofer used DPPH, superoxide, carotene bleaching, reducing power, and iron chelation methods to assess the stability of antioxidant activity in ethanolic extracts of Holy basil and galangal [72]. They discovered that antioxidant activity was stronger at neutral pH than at acidic pH. Extracts of holy basil and galangal demonstrated high iron chelation activity, superoxide anion scavenging activity, and reducing power proportional to extract concentration. Using in vitro methods such as superoxide, DPPH scavenging activity, and inhibition of LDL oxidation, Liyana-Pathirana *et al.,* evaluated the antioxidant activity of cherry laurel fruit (Laurocerasus officinalis Roem) and its concentrated juice (Pekmez) [73]. The findings indicated that pekmez has much stronger antioxidant activity than cherry laurel fruit. Orhan *et al.,* investigated the antioxidant activity of Arnebia densiflora Ledeb using in vitro methods such as DPPH and superoxide scavenging activities and

discovered that polar extracts had higher antioxidant activity than nonpolar extracts [74]. Rathee *et al.*, investigated the antioxidant activity of Mammea longifolia buds extracted in methanol as well as aqueous ethanol. The results revealed that aqueous ethanol has significantly stronger antioxidant activity than methanol. In vitro antioxidant activity of Annona species leaf extracts demonstrates that Annona muricata has stronger antioxidant activity than Annona squomosa [75].

4.5. Cooking Herbs as an Important Antioxidant Source

The antioxidant activity of 32 plants from 21 distinct families has been investigated [76]. The discovery verified the existence of a positive relationship between total antioxidant activity and total phenolic content. Lu and Yeap Foo investigated the antioxidant activity and polyphenol content of Salvia officinalis (L.) and discovered that rosmarinic acid and different catechols were responsible for the radical scavenging action, while caffeic acid was responsible for the inhibition of xanthine oxidase (EC 1.17.3.2) [77]. The antioxidant activity of Salvia miltiorrhiza and Panax notogensing was examined by Zhao *et al.*, [78].

Salvia miltiorrhiza displayed a higher reducing power and scavenging activities against free radicals, including superoxide and hydroxyl radicals, but only a modest hydrogen peroxide scavenging activity.

Furthermore, Javanmardi *et al.*, evaluated the antioxidant activities and total phenolic contents of Iranian Ocimum sp. accessions and found that the antioxidant activity rose in tandem with the total phenolic content [51].

Pomegranate peel extracts were evaluated for antioxidant and antimutagenic activity using various solvents such as ethyl acetate, acetone, methanol, and water [51]. Dried extracts were tested for anti-mutagenic and antioxidant activity using the Ames test and the phosphorus-molybdenum technique. The results revealed that the had the strongest anti-mutagenic activity and the lowest antioxidant activity in the water extract.

Furthermore, the phenolic content and antioxidant activity of parsley (Petroselinum crispum) and cilantro (Coriandrum sativum) were studied [79]. The total phenolic content of parsley and cilantro leaves and stems, as well as methanol and water extracts, was shown to differ. Methanol leaf extracts were found to have strong antioxidant activity against both lipid- and water-soluble radicals. In vitro methods such as DPPH scavenging activity and FRAP were also used to study the antioxidant activity of aqueous plant extracts. The findings demonstrated a substantial relationship between overall antioxidant activity and phenolic content, but only a weak relationship between cupric ion chelators and polyphenols. Using hydroxyl radical scavenging, preparations of Satureja montana L. subsp. Kitaibelii were investigated for antioxidant activity and lipid peroxidation inhibition. . The observed results revealed a strong connection with total phenolic content [9].

4.6. Antioxidant derived from legumes

The DPPH radical scavenging method was used to study the antioxidant properties of methanol extracts of Mucuna pruriens L. (Fabaceae) seed extracts. The findings revealed a positive relationship between antioxidant activity and total phenolic compounds [80]. Siddhuraju and Manian investigated the antioxidant and free radical scavenging activity of horsegram (Macrotyloma uniflorum Lam.) seeds [81]. Acetone extracts demonstrated approximately 70% more activity [81]. Samak *et al.*, investigated Wagatea sp. to determine its superoxide and hydroxyl radical scavenging properties and discovered that it has a strong oxidation inhibition due to its high phenolic and flavonoid content. The scientists also discovered that Wagatea sp. bark and leaf extracts have a high scavenging activity against super radicals [82].

4.7. Tree Antioxidants

Tree antioxidants have also been measured. Various procedures were used to extract phenols from almond hulls (Prunus amygdalus L.) and pine sawdust (Pinus pinaster L.) in order to investigate the gramme fresh yield of polyphenol compounds and antioxidant activity [83]. The DPPH radical scavenging method was used to assess antioxidant activity. The results revealed that ethanol was the best choice for extracting phenolics or any bioactive components, whereas methanol was more selective for extracting polyphenolics. In vitro antioxidant activity of juniper (Juniperus communes) fruit extracts has been studied [84]. The findings demonstrated that both the water and ethanol extracts had high antioxidant activity.

Using a methanolic solvent to extract the bioactive components from Anacardium occidentale yielded higher antioxidant activity values, but other solvents, such as ethyl acetate, yielded lower antioxidant activity values [85]. Kaur *et al.*, investigated the Chickrassy Chukrasia tabularis A. Juss leaves to validate their capacity to reduce lipid peroxidation and discovered a significant inhibition despite their high phenolic component content [86]. Finally, the antioxidant activity of Acacia nilotica L. has been evaluated using ethyl acetate as a solvent to extract phenolic components [86]. When the concentration of extracts was relatively high, the results showed the highest antioxidant activity.

4.8. Antioxidant from Shrubs

Many bushes have been demonstrated to have antioxidant properties. Singh *et al.*, investigated the antioxidant properties of several plant extracts.

Peroxide value, thiobarbituric acid, DPPH radical scavenging activity, and reducing power were used to calculate antioxidant activity. The antioxidant activity of Coriandrum sativum L. and Sarcolobus globosus L. was shown to be strong when utilising acetone as a solvent, and it was comparable to synthetic antioxidants [87].

Using the ABTS method, the phenolic component content and antioxidant activity of eleven Algerian medicinal herbs were determined. Antioxidant activity was detected in the plants studied. Artemisia campestris L. outperformed caffeic acid and tocopherol in terms of antioxidant activity. Furthermore, HPLC tests revealed a strong relationship between antioxidant efficacy and hydroxycinnamic derivative concentration.

The antioxidant activity of Vitex negundo Linn seed has been evaluated utilising several methods such as superoxide, hydroxyl, and DPPH scavenging activities [87]. The highest antioxidant activity was found in both raw and dry heated seed extracts, while hydrothermally processed samples had decreased antioxidant activity.

4.9. Antioxidant Characterization in Other Eudicots

Nakagawa and Yokozawa [88] investigated the nitric oxide and superoxide scavenging activity of green tea and discovered that specific tannins had the ability to demonstrate good antioxidant activity. Using several solvents such as methanol and ethyl acetate, Zin *et al.*, calculated the antioxidant activity of extracts from various components of Mengkudu (Morinda citrifolia L.), including the leaves, fruits, and roots [89]. To monitor and analyse antioxidant activity, ferric thiocyanate and thiobarbituric acid were utilised as models. The methanol extract of Mengkudu root had increased antioxidant activity, although it was not substantially different from tocopherol and BHT extracts. Methanol extracts of the fruits and leaves had modest efficacy.

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The antioxidant activity of fennel (Foeniculum vulgare) seed extracts in vitro has been reported to increase proportionally to extract concentration [89]. Using the DPPH and carotene bleaching techniques, nine additional extracts of Bolivian plants were tested for radical scavenging and antioxidant activity [90]. The ethyl acetate fractions were shown to have stronger radical scavenging and antioxidant activity than the other extracts. It has been observed that Rhodiola rosea bioactive components extracted in methanol yielded a considerable yield of phenolics, approximately (153 2 mg/g). Wangensteen *et al.*, evaluated the antioxidant activity of Ss globosus by DPPH scavenging and lipoxygenase inhibition [64]. Coriander exhibited a high oxidation inhibitory capacity. There was also a link between total phenolics and antioxidant activity. Furthermore, it was discovered that the coriander leaves had stronger antioxidant activity than the seeds [91].

Phyllanthus niruri's antioxidant activity was determined using methanol and water as a solvent. The antioxidant activity of leaf and fruit extracts was demonstrated by inhibiting lipid peroxidation and DPPH scavenging [64]. The results also revealed that the aqueous extract had better superoxide scavenging activity than the methanol extract. Furthermore, the antioxidant and free radical scavenging activity of Phyllantus species from India in an aqueous extract was assessed [92]. DPPH, carotene, superoxide, nitric oxide scavenging, and reducing power techniques were used to calculate antioxidant activity. Coleus aromaticus extract inhibited DPPH and nitric oxide scavenging activities somewhat.

Panax demonstrated high iron chelation but poor superoxide scavenging. Bioactive components and antioxidant activity of mango peel extract were investigated by Ajila *et al.*, [93]. The ripe peel had a higher concentration of anthocyanins and carotenoids than the raw peel, but the raw peel had a larger polyphenol content. The IC50 values for lipid peroxidation and DPPH ranged from 1.39 to 5.24 g of gallic acid equivalent. Chen and Yen looked into the antioxidant activity and free radical scavenging ability of dried guava leaves and fruit [94]. At a concentration of 100 g/mL, the results revealed that guava leaf and guava tea extracts inhibited oxidation by 94-96%. Fruit extracts were less active than leaf extracts, but the scavenging action improved as concentration increased. In addition, there was a link between antioxidant activity and phenolic substances. Dastmalchi and colleagues analysed the chemical composition. The discovery revealed that polar molecules like caffeic acid and rosmaric acid were responsible for the observed antioxidant action.

The antioxidant activity of mulberry leaves was examined using various solvents [95]. The procedure evaluated its activity using DPPH and suppression of lipid peroxidation methods. According to the findings, the methanolic extract had the largest yield of total phenolics and was the most important antioxidant in all of the procedures tested. After eliminating a fat fraction from the samples, the antioxidant activity of kale (Brassica obraceae L.) was tested [96]. Methanol was employed in the extraction procedure to study its antioxidant activity, with DPPH scavenging activity as the investigated method. Using HPLC and MS, the researchers successfully extracted nine phenolic acids and verified that total phenolic concentration was related to DPPH scavenging activity.

In another investigation, ethanol was employed to calculate the antioxidant activity of the skin of sun-dried cashew nuts (Anacardium occidentale L.) [97]. To test the ability to suppress oxidation, bioactive substances were extracted using a technique that included lipid peroxidation, ABTS, and DPPH assays. According to the findings, epicatechin was the primary polyphenol in the extract responsible for antioxidant action. In vitro antioxidant and antiradical activity of fenugreek (Trigonella foenum ssp. graecum) seeds was examined by Kaviarasan *et al.*, the results revealed a good association between antiradical activity and phenolic component level in the extract [98]. The bioactive components were extracted with hexane and methanol, and the antioxidant activity of Pueraria tuberosa was determined using ABTS, lipid peroxidation, and superoxide and hydroxyl scavenging activities. An independent investigation found that lipid peroxidation was inhibited [99]. The antioxidant activity of the lotus rhizome (Nelumbo nucifera Gaertn.) has been evaluated in various solvent extracts using carotene bleaching and DPPH techniques [99]. Methanol extraction outperformed acetone in terms of DPPH scavenging activity. The antioxidant activity and total phenolic and flavonoid content of Helichrysum pedunculatum have been determined [100]. The results showed that increasing the amount of phenolic and flavonoid content resulted in enhanced antioxidant activity. Meot-Duros and Magn screened the leaves of Crithmum maritmum to see if there was any link between antioxidant activity and phenolic content and discovered a substantial correlation when methanol was employed as the solvent [101]. Tricholepis glaberrima L. (Asteraceae) has also been studied for antioxidant activity using various extracts [101]. Methanol had higher antioxidant activity, while chloroform and aqueous extracts had reduced antioxidant activity. Sakat *et al.*, used methanol as a solvent to test the antioxidant and anti-inflammatory activities of Oxalis corniculata L. DPPH and nitric acid had IC 50 values of around 93 and 73.07 g/mL, respectively [102]. Jain *et al.*, investigated the phytochemical and free radical scavenging properties of Tabernaemontana divaricata L. in vitro. The antioxidant activity was the same in both ethanol and water extracts, but lower in petroleum ether [103].

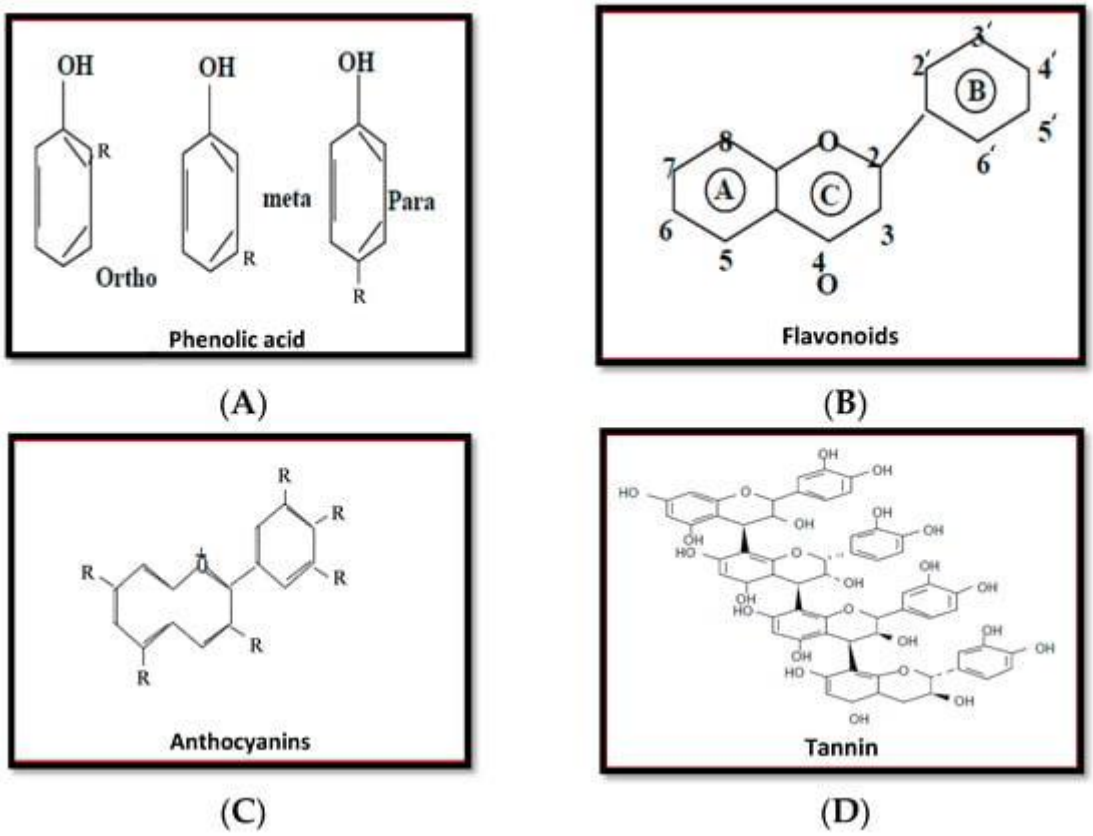
Ascleipiadaceae and Periplocoideae were found to have high antioxidant activity, with a good link between antioxidant activity and phenolic content [103]. By extracting the flavonol glycoside and steroidal saponin, which showed strong antioxidant activity, Laitonjam and Kongbrailatpam examined the chemical composition and antioxidant activities of Smilax lanceafolia [104]. Spinach (Spinacea oleracea L.) is one of the world's most popular vegetables. It was first domesticated and farmed in West Asia. According to analytical chemistry, spinach contains violaxanthin and neoxanthin antioxidants that are not commercially available [105]. Carotenoids, for example, can be disguised by chlorophyll in greenish plants like spinach, despite their presence [106]. The primary carotenoids in fresh spinach are b-carotene, lutein, violaxanthin, and neoxanthin [107]. Pumpkins are members of the Cucurbitaceae family. This family is divided into several species based on the texture and shape of their stems, such as Cucurbita pepo, Cucurbita moschata, Cucurbita maxima, and Cucurbita mixta. Nowadays, the market offers a broad variety of vegetables, with pumpkin being one of them due to its many nutritional and decorative purposes [108].

5. Antioxidant Properties of Plant Vitamins and Phenolic Compounds

5.1. Phenolic Compounds

5.1.1. Phenols and Phenolic Acids

Phenolic acids are chemically composed of carboxylic acid. According to Figure 1A, the primary pillars of phenolic acids are hydroxycinnamic and hydroxybenzoic acids. Furthermore, scientists have discovered that hydroxycinnamic acids are primarily composed of p-coumaric, caffeic, ferulic, and sinapic acids (Figure 1A).



The chemical structures of phenolic acid (A), flavonoids (B), anthocyanins (C), and tannins (D) are shown in Figure 1.

5.1.2. Flavonoids

The molecular weight of flavonoids is low (Figure 1B). Flavane is one kind of flavonoid. Flavane's molecular structure includes two benzene rings (Figure 1A,B). These two rings are linked together by a pyrane ring (Figure 1C). Flavones, isoflavones, flavonoids, flavonols, flavanones, anthocyanins, and proanthocyanidins are all classified as flavonoids (Figure 1B).

5.1.3. Anthocyanins

Anthocyanidins are a basic kind of anthocyanin. Anthocyanidins are made up of an aromatic ring connected to a heterocyclic ring (Figure 1C). Furthermore, the heterocyclic ring is linked to the third aromatic ring by a carbon bond [109]. Anthocyanins are frequently discovered in glycoside form, according to scientists. Furthermore, many different types of anthocyanins are present in nature, making these phenolic compounds extremely complicated. Anthocyanins, which are found in several types of fruit, are thought to be an essential element that can enrich and boost antioxidant activity (Figure 1C).

5.1.4. Tannin

Tannins are natural compounds found in a variety of plant groups that include a high concentration of phenolic rings. Tannins are divided into two categories: hydrolyzable and condensed. Flavonoids units with varying degrees of condensation are found in condensed tannins. Hydrolyzable tannins are a complex mixture of simple phenols with ester bonds. Many variables, including alkaline substances, mineral acids, and enzymes, can hydrolyze tannins (Figure 1D) [110].

5.2. The Role of Vitamins in Cancer Prevention

Cancer has been on the rise all around the world. It is the leading cause of death from year to year. In 2015, 10.4 million new cancer cases were reported, and scientists anticipate that the number of cancer cases per year will more than quadruple by 2030 [111]. Many recent investigations have found convincing evidence that hydroxyl radicals (OH•) and superoxide anion (O2 •) are implicated in cancer formation since they are biological reactive oxygen species. Compounds with significant reactive oxygen species reduction activity are anticipated to be capable of preventing cancer [112]. As previously demonstrated, fruits and vegetables are the primary source of natural antioxidants, which include a variety of antioxidant molecules such as Vitamin C, Vitamin E, carotenoids, lutein, and lycopene. Some researchers have confirmed that phenolic compounds and polyphenols are secondary plant metabolites that are regarded the best free radical scavengers. The plant species variety in the United States is astounding. Because of their varied desired activities, some of them have `been utilised for traditional medicines for a long time. The cytotoxic effects of kiwi and pomegranate plant extracts on two tumour cell lines (L20B and RD) were investigated. The results showed that the means of both L20B and RD cultures were significantly different (p 0.05), and

kiwi and pomegranate plant extracts inhibited the growth rate of both L20B and RD cell lines significantly. At 1000 g/mL doses, both extracts demonstrated a high ability to reduce the number of L20B and RD cells as compared to the control [113].

Plant natural product mixes have been examined in order to study their influence on human leukaemia cells [114]. The discovery confirmed that natural product mixes were a good source of human leukaemia cell inhibition. Nassr-allah *et al.*, studied the chemical diversity of natural plant products in order to test their anticancer and antioxidant properties [115]. The antioxidant activity for plant extraction was measured using the DPPH assay, while the anticancer activity was measured using in vivo and vitro methods. The findings revealed that some natural compounds derived from Egyptian flora have the potential to be used as cancer treatments [116]. An aqueous extract of willow leaves (Salix safsaf, Salicaceae) was evaluated in vivo and in vitro against human cancer cells [115]. According to the research, willow extract metabolites could suppress tumours, increasing apoptosis and causing DNA damage. Different extracts from the leaves of the drumstick tree (Moringa oleifera) were tested in vitro for anticancer efficacy against leukaemia and hepatocarcinoma cells. Hot water and ethanol extracts effectively destroyed primary cells taken from 10 patients with acute lymphoblastic leukaemia (ALL) and 15 individuals with acute myeloid leukaemia (AML). As a result, Moringa oleifera has the potential to be used as a natural treatment for disorders like cancer [117]. According to Altemimi [118], phenolic extracts from olive leaf extract could be employed as a source of potential antioxidant and antibacterial agents.

6. Plants as a Source of Antimicrobials

Various solvents were used to examine the antibacterial activity of Punica granatum extracts [119]. The water extract inhibited the growth of Bacillus subtilis and Staphylococcus aureus, whereas the organic solvents inhibited the development of all the organisms examined. The antibacterial activity of Rauvolfia tetraphylla and Physalis minima leaves was assessed by Shariff *et al.*, The chloroform extract was more effective at inhibiting pathogenic microorganisms [120]. Antimicrobial activity of Indian medicinal herbs has been demonstrated [120]. Approximately 77 extracts from these plants were evaluated for antibacterial activity against eight types of bacteria and four species of pathogenic fungi. Water extracts of Lantana camara L., Saraca asoca L., Acacia nilotica L., and Justicia zeylanica L. inhibited the growth of all examined microorganisms the most. The antibacterial activity was the highest, ranging between 9.375 and 37.5 g/mL for bacterial pathogens and 75.0 to 300.0 g/mL for fungal pathogens. Devi *et al.*, studied the phytochemical composition and antibacterial activity of Achyranthes bidentata Blume [121]. The ethanol extract inhibited Bacillus subtilis, Salmonella typhi, and Klebsiella pneumoniae well, but was less efficient against Pseudomonas species and Staphylococcus aureus [122]. Gymnema montanum L. ethanolic extracts have been tested for antibacterial activity against Salmonella typhi, Pseudomonas aeruginosa, and Candida albicans [121]. The results showed that the leaf extract of G. montanum contained the most antibacterial capabilities, which corresponded to its phenolic component content. Piper ribesoides L. methanolic root extract has been shown to have antibacterial action against Staphylococcus aureus [123]. Surprisingly, a low concentration of 3.125 mg/mL was sufficient to prevent dangerous microorganisms. Caesalpinia pulcherrimma (L.) leaf extracts demonstrated increased antioxidant activity in water and ethanol extracts but reduced antioxidant activity in petroleum ether extracts [124]. Torilis japonica L. fruit was found to have less spores and a lower concentration of vegetative cells than the detection level. Ghosh *et al.*, investigated Stevia rebaudiana Bertoni's antibacterial activities against ten diseases [125]. Staphylococcus aureus was shown to be more sensitive than others [24]. Mahesh and Satish tested several key medicinal herbs for antibacterial efficacy against human pathogenic microorganisms [126]. To extract the phenolic components, water and methanol were utilised as solvents. The results confirmed that the methanol extract outperformed the aqueous extract in terms of antibacterial activity [125].

Moreover, leaf extracts of Acacia nilotica L., Sida cordifolia L., Tinospora cordifolia L., Withania somnifera L., and Ziziphus mauritiana L. have been studied to determine the antibacterial activity against Bacillus subtlis, Escherichia coli, Staphylococus aureus, and Pseudomonas fluorescens, as well as studying the antifungal activity against Aspergillus flavus, Dreschlera turcica, and Fusarium verticilloides [126]. Acacia nilotica and Sida cordifolia leaves had the highest antibacterial activity, whereas Acacia nilotica bark had the best antifungal activity. Water and methanol extracts of Samanea saman (Jacq.) were found to be effective against Xanthomonas spp. as well as human pathogenic bacteria. The antibacterial activity of Pseudarthria viscida root has been measured using ethanol as a solvent. When compared to common medications such as ciprofloxacin and griseofulvin, the results demonstrated high antibacterial activity. Hopea pariviflora Beddome extracts were found to have strong antibacterial activity against Staphylococcus aureus by Ehsan *et al.*, [127]. Antimicrobial activity of ethanolic extracts of Bryonopsis laciniosa against several Gram-positive and Gram-negative bacteria has been studied. Staphylococcus aureus, Micrococus luteus, and Bacillus cereus growth was inhibited, as evidenced by a decrease in the growth zone. Plumbago zeylanica L. has been tested for antibacterial activity in chloroform extracts against Escherichia coli, Salmonella typhi, and Staphylococcus aureus [127]. Bacillus subtilis and Klebsiella, on the other hand, were resistant. Khond *et*

al., investigated the antibacterial activity of 55 medicinal herbs [128]. When compared to the other plants tested, extracts of Madhuca longifolia L., Parkia biglandulosa L., and Pterospermum acerifolium L. had the highest antibacterial activity. Pavithra *et al.,* tested Evolvulus nummularius L. for antibacterial activity and discovered that an ethanolic extract inhibited Escherichia coli and B. subtilis the most [129]. The plant Hygrophila spinosa when harvested between September and October, Andre's leaves had substantial antibacterial action, with less activity observed in other months [129]. Antimicrobial activity of Artemisia pallens L. against seven bacteria species has been investigated [130]. Bacillus cereus was shown to be more sensitive to A. pallens extracts. A methanolic extract also shown greater antibacterial activity than the other solvents tested. Some Algerian plants have antibacterial properties, according to Akroum [131]. Methanolic extracts of Linum capitatum, Camellia sinensis, Allium schoenoprasum, Vicia faba, Citrus paradise, Lippia citriodora, Vaccinium macrocarpon, and Punica granatum demonstrated increased antibacterial activity. Bajpai *et al.,* used methanol and ethyl acetate extracts to test the antibacterial activity of Pongamia pinnata leaves against several pathogenic bacteria [132]. When compared to streptomycin, the results showed considerable inhibition. Memecylon edule has been shown to have stronger antibacterial activity in chloroform extracts than other extracts [132]. Gram-negative bacteria were more sensitive to crude extracts than Gram-positive bacteria. Bansal *et al.,* investigated the antibacterial effectiveness of plants found in arid zones [133]. Bacillus cereus and Staphylococcus aureus were suppressed by an ethanolic extract of Tinospora cordifolia L. Kumar *et al.,* found substantial antibacterial activity against tested species in methanol extracts of both aerial parts and root of Andrographis serpyllifolia L. [134].

The antibacterial activity of Memecylon malabaricum, Cochlospermum religiosum, and Andrographis serpyllifolia has been studied [135, 136]. There showed moderate action against both Gram-positive and Gram-negative bacteria. An ethanolic extract of Anethum graveolens had higher antibacterial activity than an aqueous extract. When an ethanolic extract of Smyrnium cordifolium Boiss was employed, Khanahmadi *et al.,* [137] discovered that it has greater antibacterial action against Gram-positive bacteria than Gram-negative bacteria [136, 137]. Koperuncholan *et al.,* investigated some medicinal plants from the Western Ghats' south-eastern slopes [138]. Gram-positive bacteria were more susceptible to plant extracts than Gram-negative bacteria. Niranjan *et al.,* tested Schrebera swietenioides Roxb for antibacterial activity against human pathogenic microorganisms [139]. All of the dangerous bacteria examined were most effectively inhibited by water and methanol extracts. Several research [139, 140] extracted tannins and saponins from certain Indian medicinal herbs and tested their antibacterial efficacy against Klebsiella pneumoniae. Tinospora cordifolia ethanol extracts inhibited Bacillus cereus and Staphylococcus aureus. Additionally, ethanolic preparations of Coleus aromaticus L. have been shown to have strong antibacterial activity. The highest effective concentration range for inhibition was 25-39 g/mL. Vinothkumar *et al.,* investigated the efficacy of an Andrographis paniculata L. leaf extract to suppress the growth of Gram-positive and Gram-negative bacteria. According to the findings, aqueous extracts reduced dangerous microorganisms [134]. Pumpkin's antibacterial action against Staphylococcus aureus, Bacillus subtillus, Escherichia coli, and Pseudomonas aeruginosa has been found to be beneficial. The extracts were prepared using three distinct solvents: water, chloroform, and alcohol. The alcohol extract was shown to be more potent than both the water and chloroform extracts. All extracts were toxic to Staphylococcus aureus. Recently, the antibacterial activity of ultrasonicated spinach leaf extracts against Gram-positive and Gram-negative bacteria was discovered utilising random amplification of polymorphic DNA (RAPD) markers and electron microscopy [134]. RAPD is a new approach for detecting diagnostic mutations inside a genome. The isolated leaf spinach antibacterial compounds' minimum inhibitory concentrations (MICs) against Escherichia coli and Staphylococcus aureus ranged between 60 and 100 mg/mL. The best extraction parameters were 45 °C, 44% ultrasonic power, and a 23-minute extraction period. According to the findings, the treated bacterial cells appeared to be harmed by a decrease in cell number. In fact, it was hypothesised that spinach leaf extracts kill bacteria by producing DNA mutations and disrupting cell walls.

7. Final Thoughts

7.1 Future prospect of extracting technique:

The future of extracting bioactive compounds from plant extracts lies in the integration of various techniques to enhance selectivity and efficiency. Combination approaches such as solid-phase microextraction (SPME) coupled with high-performance liquid chromatography (HPLC), solid-phase extraction (SPE) coupled with gas chromatography-mass spectrometry (GC-MS), and liquid-liquid extraction combined with nuclear magnetic resonance (NMR) spectroscopy are being explored. These integrated methods enable the targeted extraction, isolation, and identification of specific bioactive compounds from complex plant matrices.

8. CONCLUSIONS

In conclusion, plant extracts shown significant antioxidant capacity in vitro and in vivo, and the extracts can be considered a good source of natural antioxidants and antimicrobials. Polyphenol extraction from plants using rapid and appropriate methodologies is a low-cost method because the amount of solvent needed is reduced, and lengthier extraction durations

are avoided compared to the usual extraction method. Furthermore, natural bioactive substances have been shown to inhibit and prevent all types of cancer. Flavonoids have been demonstrated to be anti-tumor (benign and melanoma) agents by a free radical quenching mechanism (i.e., OH, ROO). Many studies have demonstrated that flavonoids perform a variety of activities, including mutagenic, cell-damaging, and carcinogenic, due to their acceleration of many ageing factors. In addition to antioxidant activity, phenolic substances suppress cancer formation through a variety of basic cellular pathways. More extensive research into these chemicals will aid pharmaceutical development in the realm of carcinogenic illness prevention.

REFERENCES

1. Jakubowski, W.; Bartosz, G. Estimation of oxidative stress in saccharomyces cerevisae with fluorescent probes. *Int. J. Biochem. Cell Biol.* 1997, *29*, 1297–1301. [Google Scholar] [CrossRef]
2. Naczk, M.; Shahidi, F. Phenolics in cereals, fruits and vegetables: Occurrence, extraction and analysis. *J. Pharm. Biomed. Anal.* 2006, *41*, 1523–1542. [Google Scholar] [CrossRef] [PubMed]
3. Suffredini, I.B.; Sader, H.S.; Gonçalves, A.G.; Reis, A.O.; Gales, A.C.; Varella, A.D.; Younes, R.N. Screening of antibacterial extracts from plants native to the brazilian amazon rain forest and atlantic forest. *Braz. J. Med. Biol. Res.* 2004, *37*, 379–384. [Google Scholar] [CrossRef] [PubMed]
4. Boots, A.W.; Haenen, G.R.; Bast, A. Health effects of quercetin: From antioxidant to nutraceutical. *Eur. J. Pharmacol.* 2008, *585*, 325–337. [Google Scholar] [CrossRef] [PubMed]
5. Valko, M.; Rhodes, C.J.; Moncol, J.; Izakovic, M.; Mazur, M. Free radicals, metals and antioxidants in oxidative stress-induced cancer. *Chem. Biol. Interact.* 2006, *160*, 1–40. [Google Scholar] [CrossRef] [PubMed]
6. Ames, B.N.; Shigenaga, M.K.; Hagen, T.M. Oxidants, antioxidants, and the degenerative diseases of aging. *Proc. Natl. Acad. Sci. USA* 1993, *90*, 7915–7922. [Google Scholar] [CrossRef] [PubMed]
7. Duthie, S.J.; Ma, A.; Ross, M.A.; Collins, A.R. Antioxidant supplementation decreases oxidative DNA damage in human lymphocytes. *Cancer Res.* 1996, *56*, 1291–1295. [Google Scholar] [PubMed]
8. Vivekananthan, D.P.; Penn, M.S.; Sapp, S.K.; Hsu, A.; Topol, E.J. Use of antioxidant vitamins for the prevention of cardiovascular disease: Meta-analysis of randomised trials. *Lancet* 2003, *361*, 2017–2023. [Google Scholar] [CrossRef]
9. Wong, P.Y.Y.; Kitts, D.D. Studies on the dual antioxidant and antibacterial properties of parsley (petroselinum crispum) and cilantro (coriandrum sativum) extracts. *Food Chem.* 2006, *97*, 505–515. [Google Scholar] [CrossRef]
10. Ruan, Z.P.; Zhang, L.L.; Lin, Y.M. Evaluation of the antioxidant activity of syzygium cumini leaves. *Molecules* 2008, *13*, 2545–2556. [Google Scholar] [CrossRef] [PubMed]
11. Koffi, E.; Sea, T.; Dodehe, Y.; Soro, S. Effect of solvent type on extraction of polyphenols from twenty three ivorian plants. *J. Anim. Plant Sci.* 2010, *5*, 550–558. [Google Scholar]
12. Anokwuru, C.P.; Anyasor, G.N.; Ajibaye, O.; Fakoya, O.; Okebugwu, P. Effect of extraction solvents on phenolic, flavonoid and antioxidant activities of three nigerian medicinal plants. *Nat. Sci.* 2011, *9*, 53–61. [Google Scholar]
13. Ballard, T.S.; Mallikarjunan, P.; Zhou, K.; O'Keefe, S. Microwave-assisted extraction of phenolic antioxidant compounds from peanut skins. *Food Chem.* 2010, *120*, 1185–1192. [Google Scholar] [CrossRef]
14. Kingston, H.M.; Jessie, L.B. *Introduction to Microwave Sample Preparation*; American Chemical Society: Washington, DC, USA, 1998. [Google Scholar]
15. Suzara, S.; Costa, D.A.; Gariepyb, Y.; Rochaa, S.C.S.; Raghavanb, V. Spilanthol extraction using microwave: Calibration curve for gas chromatography. *Chem. Eng. Trans.* 2013, *32*, 1783–1788. [Google Scholar]
16. Li, H.; Deng, Z.; Wu, T.; Liu, R.; Loewen, S.; Tsao, R. Microwave-assisted extraction of phenolics with maximal antioxidant activities in tomatoes. *Food Chem.* 2012, *130*, 928–936. [Google Scholar] [CrossRef]
17. Tsubaki, S.; Sakamoto, M.; Azuma, J. Microwave-assisted extraction of phenolic compounds from tea residues under autohydrolytic conditions. *Food Chem.* 2000, *123*, 1255–1258. [Google Scholar] [CrossRef]
18. Christophoridou, S.; Dais, P.; Tseng, L.H.; Spraul, M. Separation and identification of phenolic compounds in olive oil by coupling high-performance liquid chromatography with postcolumn solid-phase extraction to nuclear magnetic resonance spectroscopy (lc-spe-nmr). *J. Agric. Food Chem.* 2005, *53*, 4667–4679. [Google Scholar] [CrossRef] [PubMed]
19. Williams, O.J.; Raghavan, G.S.V.; Orsat, V.; Dai, J. Microwave-assisted extraction of capsaicinoids from capsicum fruit. *J. Food Biochem.* 2004, *28*, 113–122. [Google Scholar] [CrossRef]
20. Garcia-Salas, P.; Morales-Soto, A.; Segura-Carretero, A.; Fernandez-Gutierrez, A. Phenolic-compound-extraction systems for fruit and vegetable samples. *Molecules* 2010, *15*, 8813–8826. [Google Scholar] [CrossRef] [PubMed]
21. Corrales, M.; Toepfl, S.; Butz, P.; Knorr, D.; Tauscher, B. Extraction of anthocyanins from grape by-products assisted by ultrasonics, high hydrostatic pressure or pulsed electric fields: A comparison. *Innov. Food Sci. Emerg.*

Technol. 2008, *9*, 85–91. [Google Scholar] [CrossRef]
22. Tabaraki, R.; Nateghi, A. Optimization of ultrasonic-assisted extraction of natural antioxidants from rice bran using response surface methodology. *Ultrason. Sonochem.* 2011, *18*, 1279–1286. [Google Scholar] [CrossRef] [PubMed]
23. Albu, S.; Joyce, E.; Paniwnyk, L.; Lorimer, J.P.; Mason, T.J. Potential for the use of ultrasound in the extraction of antioxidants from rosmarinus officinalis for the food and pharmaceutical industry. *Ultrason. Sonochem.* 2004, *11*, 261–265. [Google Scholar] [CrossRef] [PubMed]
24. Cho, W.I.; Choi, J.B.; Lee, K.; Chung, M.S.; Pyun, Y.R. Antimicrobial activity of torilin isolated from torilis japonica fruit against bacillus subtilis. *J. Food Sci.* 2008, *73*, 37–46. [Google Scholar] [CrossRef] [PubMed]
25. Barbero, G.F.; Liazid, A.; Palma, M.; Barroso, C.G. Ultrasound-assisted extraction of capsaicinoids from peppers. *Talanta* 2008, *75*, 1332–1337. [Google Scholar] [CrossRef] [PubMed]
26. Luque-García, J.L.; Luque de Castro, M.D. Ultrasound: A powerful tool for leaching. *TrAC Trends Anal. Chem.* 2003, *22*, 41–47. [Google Scholar] [CrossRef]
27. Mulinacci, N.; Prucher, D.; Peruzzi, M.; Romani, A.; Pinelli, P.; Giaccherini, C.; Vincieri, F.F. Commercial and laboratory extracts from artichoke leaves: Estimation of caffeoyl esters and flavonoidic compounds content. *J. Pharm. Biomed. Anal.* 2004, *34*, 349–357. [Google Scholar] [CrossRef]
28. Altemimi, A.W.; Watson, D.G.; Kinsel, M.; Lightfoot, D.A. Simultaneous extraction, optimization, and analysis of flavonoids and polyphenols from peach and pumpkin extracts using a tlc-densitometric method. *Chem. Cent. J.* 2015, *9*, 1–15. [Google Scholar] [CrossRef] [PubMed]
29. Altemimi, A.; Lightfoot, D.A.; Kinsel, M.; Watson, D.G. Employing response surface methodology for the optimization of ultrasound assisted extraction of lutein and β-carotene from spinach. *Molecules* 2015, *20*, 6611–6625. [Google Scholar] [CrossRef] [PubMed]
30. Sarajlija, H.; Čkelj, N.; Novotni, D.; Mršić, G.; Ćurić, M.; Brncic, M.; Curic, D. Preparation of flaxseed for lignan determination by gas chromatography-mass spectrometry method. *Czech J. Food Sci.* 2012, *30*, 45–52. [Google Scholar]
31. Popova, I.E.; Hall, C.; Kubátová, A. Determination of lignans in flaxseed using liquid chromatography with time-of-flight mass spectrometry. *J. Chromatogr. A* 2009, *1216*, 217–229. [Google Scholar] [CrossRef] [PubMed]
32. Zhang, Z.; Pang, X.; Xuewu, D.; Ji, Z.; Jiang, Y. Role of peroxidase in anthocyanin degradation in litchi fruit pericarp. *Food Chem.* 2005, *90*, 47–52. [Google Scholar] [CrossRef]
33. Kemp, W. Energy and electromagnetic spectrum. In *Organic Spectroscopy*; Kemp, W., Ed.; Macmillan Press: London, UK, 1991; pp. 1–7. [Google Scholar]
34. Kemp, W. Infrared spectroscopy. In *Organic Spectroscopy*; Macmillan Press Ltd.: London, UK, 1991; pp. 19–56. [Google Scholar]
35. Urbano, M.; Luque de Castro, M.D.; Pérez, P.M.; García-Olmo, J.; Gómez-Nieto, M.A. Ultraviolet–visible spectroscopy and pattern recognition methods for differentiation and classification of wines. *Food Chem.* 2006, *97*, 166–175. [Google Scholar] [CrossRef]
36. Cherkaoui, A.; Hibbs, J.; Emonet, S.; Tangomo, M.; Girard, M.; Francois, P.; Schrenzel, J. Comparison of two matrix-assisted laser desorption ionization-time of flight mass spectrometry methods with conventional phenotypic identification for routine identification of bacteria to the species level. *J. Clin. Microbiol.* 2010, *48*, 1169–1175. [Google Scholar] [CrossRef] [PubMed]
37. Beckey, H.D. *1–Theory of Field Ionization (FI) and Field Emission (FE)*; Pergamon: Bergama, Turkey, 1971. [Google Scholar]
38. Beckey, H.D. *2–Field Ionization Sources*; Pergamon: Bergama, Turkey, 1971. [Google Scholar]
39. Beckey, H.D. *3–Application of the FI Mass Spectrometer to Physico-Chemical Problems*; Pergamon: Bergama, Turkey, 1971. [Google Scholar]
40. Beckey, H.D. *4–Qualitative Analyses with the Fi Mass Spectrometer*; Pergamon: Bergama, Turkey, 1971. [Google Scholar]
41. Kemp, W. Nuclear magnetic resonance spectroscopy. In *Organic Spectroscopy*; Kemp, W., Ed.; Macmillan Press: London, UK, 1991; pp. 101–240. [Google Scholar]
42. Halliwell, B.; Murcia, M.A.; Chirico, S.; Aruoma, O.I. Free radicals and antioxidants in food and in vivo: What they do and how they work. *Crit. Rev. Food Sci. Nutr.* 1995, *35*, 7–20. [Google Scholar] [CrossRef] [PubMed]
43. Clemente, T.E.; Cahoon, E.B. Soybean oil: Genetic approaches for modification of functionality and total content. *Plant Physiol.* 2009, *151*, 1030–1040. [Google Scholar] [CrossRef] [PubMed]
44. Lakhssassi, N.; Zhou, Z.; Liu, S.; Colantonio, V.; AbuGhazaleh, A.; Meksem, K. Characterization of the fad2 gene family in soybean reveals the limitations of gel-based tilling in genes with high copy number. *Front. Plant Sci.* 2017, *8*, 324. [Google Scholar] [CrossRef] [PubMed]
45. Mensink, R.P.; Katan, M.B. Effect of dietary trans fatty acids on high-density and low-density lipoprotein cholesterol levels in healthy subjects. *N.*

Engl. J. Med. 1990, *323*, 439–445. [Google Scholar] [CrossRef] [PubMed]
46. Kris-Etherton, P.M.; Yu, S.; Etherton, T.D.; Morgan, R.; Moriarty, K.; Shaffer, D. Fatty acids and progression of coronary artery disease. *Am. J. Clin. Nutr.* 1997, *65*, 1088–1090. [Google Scholar] [PubMed]
47. Kris-Etherton, P.M.; Yu, S. Individual fatty acid effects on plasma lipids and lipoproteins: Human studies. *Am. J. Clin. Nutr.* 1997, *65*, 1628–1644. [Google Scholar]
48. Byfield, G.E.; Xue, H.; Upchurch, R.G. Two genes from soybean encoding soluble δ9 stearoyl-acp desaturases. *Crop Sci.* 2006, *46*, 840–846. [Google Scholar] [CrossRef]
49. Lakhssassi, N.; Colantonio, V.; Flowers, N.D.; Zhou, Z.; Henry, J.S.; Liu, S.; Meksem, K. Stearoyl-acyl carrier protein desaturase mutations uncover an impact of stearic acid in leaf and nodule structure. *Plant Physiol.* 2017, *174*, 1531–1543. [Google Scholar] [CrossRef] [PubMed]
50. St Angelo, A.J. Lipid oxidation on foods. *Crit. Rev. Food Sci. Nutr.* 1996, *36*, 175–224. [Google Scholar] [CrossRef] [PubMed]
51. Javanmardi, J.; Stushnoff, C.; Locke, E.; Vivanco, J.M. Antioxidant activity and total phenolic content of iranian ocimum accessions. *Food Chem.* 2003, *83*, 547–550. [Google Scholar] [CrossRef]
52. Negi, P.S.; Chauhan, A.S.; Sadia, G.A.; Rohinishree, Y.S.; Ramteke, R.S. Antioxidant and antibacterial activities of various seabuckthorn (hippophae rhamnoides l.) seed extracts. *Food Chem.* 2005, *92*, 119–124. [Google Scholar] [CrossRef]
53. Baharlouei, A.; Sharifi-Sirchi, G.R.; Bonjar, G.H.S. Identification of an antifungal chitinase from a potential biocontrol agent, streptomyces plicatus strain 101, and its new antagonistic spectrum of activity. *Philipp. Agric. Sci.* 2010, *93*, 439–445. [Google Scholar]
54. Baharlouei, A.; Sharifi-Sirchi, G.R.; Bonjar, G.H.S. Biological control of sclerotinia sclerotiorum (oilseed rape isolate) by an effective antagonist streptomyces. *Afr. J. Biotechnol.* 2011, *10*, 5785–5794. [Google Scholar]
55. Ruberto, G.; Baratta, M.T.; Deans, S.G.; Dorman, H.J.D. Antioxidant and antimicrobial activity of foeniculum vulgare and crithmum maritimum essential oils. *Planta Medica* 2000, *66*, 687–693. [Google Scholar] [CrossRef] [PubMed]
56. Butterfield, N.J. Implications for the evolution of sex, multicellularity, and the mesoproterozoic/neoproterozoic radiation of eukaryotes. *Paleobiology* 2000, *26*, 386–404. [Google Scholar] [CrossRef]
57. Ashawat, M.S.; Shailendra, S.; Swarnlata, S. In vitro antioxidant activity of ethanolic extracts of centella asiatica, punica granatum, glycyrrhiza glabra and areca catechu. *Res. J. Med. Plants* 2007, *1*, 13–16. [Google Scholar]
58. Londonkar, R.; Kamble, A. Evaluation of free radical scavenging activity of pandanus odoratissimus. *Int. J. Pharmacol.* 2009, *5*, 377–380. [Google Scholar] [CrossRef]
59. Zahin, M.; Aqil, F.; Ahmad, I. The in vitro antioxidant activity and total phenolic content of four indian medicinal plants. *J. Appl. Biol. Sci.* 2007, *1*, 87–90. [Google Scholar]
60. Block, G.; Patterson, B.; Subar, A. Fruit, vegetables, and cancer prevention: A review of the epidemiological evidence. *Nutr. Cancer* 1992, *18*, 1–29. [Google Scholar] [CrossRef] [PubMed]
61. Pratt, D.E.; Watts, B.M. The antioxidant activity of vegetable extracts i. Flavone aglyconesa. *J. Food Sci.* 1964, *29*, 27–33. [Google Scholar] [CrossRef]
62. Plumb, G.W.; García-Conesa, M.T.; Kroon, P.A.; Rhodes, M.; Ridley, S.; Williamson, G. Metabolism of chlorogenic acid by human plasma, liver, intestine and gut microflora. *J. Sci. Food Agric.* 1999, *79*, 390–392. [Google Scholar] [CrossRef]
63. Frankel, E.N.M.; Meyer, A. Antioxidants in grapes and grape juices and their potential health effects. *Pharm. Biol.* 1998, *36*, 1–7. [Google Scholar] [CrossRef]
64. Wangensteen, H.; Miron, A.; Alamgir, M.; Rajia, S.; Samuelsen, A.B.; Malterud, K.E. Antioxidant and 15-lipoxygenase inhibitory activity of rotenoids, isoflavones and phenolic glycosides from sarcolobus globosus. *Fitoterapia* 2006, *77*, 290–295. [Google Scholar] [CrossRef] [PubMed]
65. Monagas, M.; Gómez-Cordovés, C.; Bartolomeä, B.; Laureano, O.; Ricardo da Silva, J.M. Monomeric, oligomeric, and polymeric flavan-3-ol composition of wines and grapes from vitis vinifera l. Cv. Graciano, tempranillo, and cabernet sauvignon. *J. Agric. Food Chem.* 2003, *51*, 6475–6481. [Google Scholar] [CrossRef] [PubMed]
66. Khan, S.A.; Beekwilder, J.; Schaart, J.G.; Mumm, R.; Soriano, J.M.; Jacobsen, E.; Schouten, H.J. Differences in acidity of apples are probably mainly caused by a malic acid transporter gene on lg16. *Tree Genet. Genomes* 2013, *9*, 475–487. [Google Scholar] [CrossRef]
67. Jugde, H.; Nguy, D.; Moller, I.; Cooney, J.M.; Atkinson, R.G. Isolation and characterization of a novel glycosyltransferase that converts phloretin to phlorizin, a potent antioxidant in apple. *FEBS J.* 2008, *275*, 3804–3814. [Google Scholar] [CrossRef] [PubMed]
68. Huang, Y.F.; Doligez, A.; Fournier-Level, A.; Le Cunff, L.; Bertrand, Y.; Canaguier, A.; Morel, C.; Miralles, V.; Veran, F.; Souquet, J.M.; Dissecting genetic architecture of grape proanthocyanidin composition through quantitative trait locus mapping. *BMC Plant Biol.* 2012, *12*, 30. [Google Scholar] [CrossRef] [PubMed][Green Version]

69. Takos, A.M.; Ubi, B.E.; Robinson, S.P.; Walker, A.R. Condensed tannin biosynthesis genes are regulated separately from other flavonoid biosynthesis genes in apple fruit skin. *Plant Sci.* 2006, *170*, 487–499. [Google Scholar] [CrossRef]
70. Soong, Y.Y.; Barlow, P.J. Antioxidant activity and phenolic content of selected fruit seeds. *Food Chem.* 2004, *88*, 411–417. [Google Scholar] [CrossRef]
71. Abdille, M.H.; Singh, R.P.; Jayaprakasha, G.K.; Jena, B.S. Antioxidant activity of the extracts from dillenia indica fruits. *Food Chem.* 2005, *90*, 891–896. [Google Scholar] [CrossRef]
72. Juntachote, T.; Berghofer, E. Antioxidative properties and stability of ethanolic extracts of holy basil and galangal. *Food Chem.* 2005, *92*, 193–202. [Google Scholar] [CrossRef]
73. Liyana-Pathirana, C.M.; Shahidi, F.; Alasalvar, C. Antioxidant activity of cherry laurel fruit (laurocerasus officinalis roem.) and its concentrated juice. *Food Chem.* 2006, *99*, 121–128. [Google Scholar] [CrossRef]
74. Orhan, I.; Kartal, M.; Naz, Q.; Ejaz, A.; Yilmaz, G.; Kan, Y.; Konuklugil, B.; Şener, B.; Iqbal Choudhary, M. Antioxidant and anticholinesterase evaluation of selected turkish salvia species. *Food Chem.* 2007, *103*, 1247–1254. [Google Scholar] [CrossRef]
75. Rathee, J.S.; Hassarajani, S.A.; Chattopadhyay, S. Antioxidant activity of mammea longifolia bud extracts. *Food Chem.* 2006, *99*, 436–443. [Google Scholar] [CrossRef]
76. Baskar, R.; Rajeswari, V.; Kumar, T.S. In vitro antioxidant studies in leaves of annona species. *Indian J. Exp. Biol.* 2007, *45*, 480–485. [Google Scholar] [PubMed]
77. Lu, Y.; Yeap, F.L. Antioxidant activities of polyphenols from sage (salvia officinalis). *Food Chem.* 2001, *75*, 197–202. [Google Scholar] [CrossRef]
78. Zhao, G.R.; Xiang, Z.J.; Ye, T.X.; Yuan, Y.J.; Guo, Z.X. Antioxidant activities of salvia miltiorrhiza and panax notoginseng. *Food Chem.* 2006, *99*, 767–774. [Google Scholar] [CrossRef]
79. Singh, R.P.; Chidambara Murthy, K.N.; Jayaprakasha, G.K. Studies on the antioxidant activity of pomegranate (punica granatum) peel and seed extracts using in vitro models. *J. Agric. Food Chem.* 2002, *50*, 81–86. [Google Scholar] [CrossRef] [PubMed]
80. Ćetković, G.S.; Djilas, S.M.; Čanadanović-Brunet, J.M.; Tumbas, V.T. Antioxidant properties of marigold extracts. *Food Res. Int.* 2004, *37*, 643–650. [Google Scholar] [CrossRef]
81. Siddhuraju, P.; Manian, S. The antioxidant activity and free radical-scavenging capacity of dietary phenolic extracts from horse gram (macrotyloma uniflorum (lam.) verdc.) seeds. *Food Chem.* 2007, *105*, 950–958. [Google Scholar] [CrossRef]
82. Samak, G.; Shenoy, R.P.; Manjunatha, S.M.; Vinayak, K.S. Superoxide and hydroxyl radical scavenging actions of botanical extracts of wagatea spicata. *Food Chem.* 2009, *115*, 631–634. [Google Scholar] [CrossRef]
83. Barla, A.; Öztürk, M.; Kültür, Ş.; Öksüz, S. Screening of antioxidant activity of three euphorbia species from turkey. *Fitoterapia* 2007, *78*, 423–425. [Google Scholar] [CrossRef] [PubMed]
84. Pinelo, M.; Rubilar, M.; Sineiro, J.; Núñez, M.J. Extraction of antioxidant phenolics from almond hulls (prunus amygdalus) and pine sawdust (pinus pinaster). *Food Chem.* 2004, *85*, 267–273. [Google Scholar] [CrossRef]
85. Ibrahim, N.A.; El-Seedi, H.R.; Mohammed, M.M. Phytochemical investigation and hepatoprotective activity of cupressus sempervirens l. Leaves growing in egypt. *Nat. Prod. Res.* 2007, *21*, 857–866. [Google Scholar] [CrossRef] [PubMed]
86. Kaur, R.; Thind, T.S.; Singh, B.; Arora, S. Inhibition of lipid peroxidation by extracts/subfractions of chickrassy (chukrasia tabularis a. Juss.). *Die Naturwissenschaften* 2009, *96*, 129–133. [Google Scholar] [CrossRef] [PubMed]
87. Singh, G.; Marimuthu, P.; de Heluani, C.S.; Catalan, C. Chemical constituents and antimicrobial and antioxidant potentials of essential oil and acetone extract of nigella sativa seeds. *J. Sci. Food Agric.* 2005, *85*, 2297–2306. [Google Scholar] [CrossRef]
88. Tiwari, O.P.; Tripathi, Y.B. Antioxidant properties of different fractions of vitex negundo linn. *Food Chem.* 2007, *100*, 1170–1176. [Google Scholar] [CrossRef]
89. Zin, Z.M.; Abdul-Hamid, A.; Osman, A. Antioxidative activity of extracts from mengkudu (*Morinda citrifolia* L.) root, fruit and leaf. *Food Chem.* 2002, *78*, 227–231. [Google Scholar] [CrossRef]
90. Oktay, M.; Gülçin, İ.; Küfrevioğlu, Ö.İ. Determination of in vitro antioxidant activity of fennel (foeniculum vulgare) seed extracts. *LWT Food Sci. Technol.* 2003, *36*, 263–271. [Google Scholar] [CrossRef]
91. Parejo, I.; Viladomat, F.; Bastida, J.; Rosas-Romero, A.; Saavedra, G.; Murcia, M.A.; Jimenez, A.M.; Codina, C. Investigation of bolivian plant extracts for their radical scavenging activity and antioxidant activity. *Life Sci.* 2003, *73*, 1667–1681. [Google Scholar] [CrossRef]
92. Harish, R.; Shivanandappa, T. Antioxidant activity and hepatoprotective potential of phyllanthus niruri. *Food Chem.* 2006, *95*, 180–185. [Google Scholar] [CrossRef]
93. Ajila, C.M.; Naidu, K.A.; Bhat, S.G.; Rao, U.J.S.P. Bioactive compounds and antioxidant potential of

mango peel extract. *Food Chem.* 2007, *105*, 982–988. [Google Scholar] [CrossRef]
94. Chen, H.Y.; Yen, G.C. Antioxidant activity and free radical-scavenging capacity of extracts from guava (psidium guajava l.) leaves. *Food Chem.* 2007, *101*, 686–694. [Google Scholar] [CrossRef]
95. Dastmalchi, K.; Damien Dorman, H.J.; Koşar, M.; Hiltunen, R. Chemical composition and in vitro antioxidant evaluation of a water-soluble moldavian balm (dracocephalum moldavica l.) extract. *LWT Food Sci. Technol.* 2007, *40*, 239–248. [Google Scholar] [CrossRef]
96. Arabshahi-Delouee, S.; Urooj, A. Antioxidant properties of various solvent extracts of mulberry (morus indica l.) leaves. *Food Chem.* 2007, *102*, 1233–1240. [Google Scholar] [CrossRef]
97. Ayaz, F.A.; Ayaz, S.; Alpay-Karaoglu, S.; Gruz, J.; Valentová, K.; Ulrichová, J.; Strnad, M. Phenolic acid contents of kale (*Brassica oleraceae* L. Var. Acephala dc.) extracts and their antioxidant and antibacterial activities. *Food Chem.* 1976, *7*, 3. [Google Scholar] [CrossRef]
98. Kaviarasan, S.; Naik, G.H.; Gangabhagirathi, R.; Anuradha, C.V.; Priyadarsini, K.I. In vitro studies on antiradical and antioxidant activities of fenugreek (trigonella foenum graecum) seeds. *Food Chem.* 2007, *103*, 31–37. [Google Scholar] [CrossRef]
99. Pandey, N.; Tripathi, Y.B. Antioxidant activity of tuberosin isolated from pueraria tuberose linn. *J. Inflamm.* 2010, *7*, 47. [Google Scholar] [CrossRef] [PubMed]
100. Yang, D.; Wang, Q.; Ke, L.; Jiang, J.; Ying, T. Antioxidant activities of various extracts of lotus (nelumbo nuficera gaertn) rhizome. *Asia Pac. J. Clin. Nutr.* 2007, *16*, 158–163. [Google Scholar] [PubMed]
101. Meot-Duros, L.; Magne, C. Antioxidant activity and phenol content of crithmum maritimum l. Leaves. *Plant Physiol. Biochem.* 2009, *47*, 37–41. [Google Scholar] [CrossRef] [PubMed]
102. Sakat, S.; Juvekar, R.A.; Gambhire, M.N.; Juvekar, M.; Wankhede, S. In vitro antioxidant and anti-inflammatory activity of methanol extract of oxalis corniculata linn. *Int. J. Pharm. Pharm. Sci.* 2010, *2*, 146–155. [Google Scholar]
103. Jain, S.; Jain, A.; Jain, N.; Jain, D.K.; Balekar, N. Phytochemical investigation and evaluation of in vitro free radical scavenging activity of tabernaemontana divaricata linn. *Nat. Prod. Res.* 2010, *24*, 300–304. [Google Scholar] [CrossRef] [PubMed]
104. Laitonjam, W.S.; Kongbrailatpam, B.D. Studies on the chemical constituents and antioxidant activities of extracts from the roots of smilax lanceaefolia roxb. *Nat. Prod. Res.* 2010, *24*, 1168–1176. [Google Scholar] [CrossRef] [PubMed]
105. Inbaraj, B.S.; Chien, J.T.; Chen, B.H. Improved high performance liquid chromatographic method for determination of carotenoids in the microalga chlorella pyrenoidosa. *J. Chromatogr. A* 2006, *1102*, 193–199. [Google Scholar] [CrossRef] [PubMed]
106. Gandul-Rojas, B.; Cepero, M.R.; Minguez-Mosquera, M.I. Chlorophyll and carotenoid patterns in olive fruits, olea europaea cv. Arbequina. *J. Agric. Food Chem.* 1999, *47*, 2207–2212. [Google Scholar] [CrossRef] [PubMed]
107. Ren, D.; Zhang, S. Separation and identification of the yellow carotenoids in *Potamogeton crispus* L. *Food Chem.* 2008, *106*, 410–414. [Google Scholar] [CrossRef]
108. Alves-Rodrigues, A.; Shao, A. The science behind lutein. *Toxicol. Lett.* 2004, *150*, 57–83. [Google Scholar] [CrossRef] [PubMed]
109. Altemimi, A.; Lakhssassi, N.; Abu-Ghazaleh, A.; Lightfoot, D.A. Evaluation of the antimicrobial activities of ultrasonicated spinach leaf extracts using rapd markers and electron microscopy. *Arch. Microbiol.* 2017, 1–13. [Google Scholar] [CrossRef] [PubMed]
110. Konczak, I.; Zhang, W. Anthocyanins—More than nature's colours. *J. Biomed. Biotechnol.* 2004, *2004*, 239–240. [Google Scholar] [CrossRef] [PubMed]
111. Vermerris, W.; Nicholson, R. *Phenolic Compound Biochemistry Book*; Springer: Dordrecht, The Netherland, 2006. [Google Scholar]
112. Hursting, S.D.; Slaga, T.J.; Fischer, S.M.; DiGiovanni, J.; Phang, J.M. Mechanism-based cancer prevention approaches: Targets, examples, and the use of transgenic mice. *J. Natl. Cancer Inst.* 1999, *91*, 215–225. [Google Scholar] [CrossRef] [PubMed]
113. Cai, Y.; Luo, Q.; Sun, M.; Corke, H. Antioxidant activity and phenolic compounds of 112 traditional chinese medicinal plants associated with anticancer. *Life Sci.* 2004, *74*, 2157–2184. [Google Scholar] [CrossRef] [PubMed]
114. Palanisamy, U.; Cheng, H.M.; Masilamani, T.; Subramaniam, T.; Ling, L.T.; Radhakrishnan, A.K. Rind of the rambutan, nephelium lappaceum, a potential source of natural antioxidants. *Food Chem.* 2008, *109*, 54–63. [Google Scholar] [CrossRef] [PubMed]
115. Nassr-allah, A.A.; Aboul-enein, K.M.; Lightfoot, D.A.; Cocchetto, A.; El-shemy, H.A. Anti-cancer and anti-oxidant activity of some egyptian medicinal plants. *J. Med. Plants Res.* 2009, *3*, 799–808. [Google Scholar]
116. El-Shemy, H.A.; Aboul-Enein, K.M.; Lightfoot, D.A. Predicting in silico which mixtures of the natural products of plants might most effectively kill human leukemia cells? *Evid.-Based Complement. Altern. Med.* 2013, *2013*, 801501. [Google Scholar] [CrossRef] [PubMed]
117. El-Shemy, H.A.; Aboul-Enein, A.M.; Aboul-Enein, K.M.; Fujita, K. Willow leaves' extracts contain anti-tumor agents effective against three cell

types. *PLoS ONE* 2007, *2*, e178. [Google Scholar] [CrossRef] [PubMed]
118. Altemimi, A.B. A study of the protective properties of iraqi olive leaves against oxidation and pathogenic bacteria in food applications. *Antioxidants* 2017, *6*, 34. [Google Scholar] [CrossRef] [PubMed]
119. Gil, M.I.; Tomas-Barberan, F.A.; Hess-Pierce, B.; Kader, A.A. Antioxidant capacities, phenolic compounds, carotenoids, and vitamin c contents of nectarine, peach, and plum cultivars from california. *J. Agric. Food Chem.* 2002, *50*, 4976–4982. [Google Scholar] [CrossRef] [PubMed]
120. Shariff, N.; Sudarshana, M.S.; Umesha, S.; Hariprasad, P. Antimicrobial activity of rauvolfia tetraphylla and physalis minima leaf and callus extracts. *Afr. J. Biotechnol.* 2006, *5*, 946–950. [Google Scholar]
121. Devi, P.U.; Murugan, S.; Suja, S.; Selvi, S.; Chinnaswamy, P.; Vijayanand, E. Antibacterial, in vitro lipid per oxidation and phytochemical observation on achyranthes bidentata blume. *Pak. J. Nutr.* 2007, *6*, 447–451. [Google Scholar] [CrossRef]
122. Dabur, R.; Gupta, A.; Mandal, T.K.; Singh, D.D.; Bajpai, V.; Gurav, A.M.; Lavekar, G.S. Antimicrobial activity of some indian medicinal plants. *Afr. J. Tradit. Complement. Altern. Med.* 2007, *4*, 313–318. [Google Scholar] [CrossRef] [PubMed]
123. Ramkumar, K.M.; Rajaguru, P.; Latha, M.; Ananthan, R. Ethanol extract of gymnema montanum leaves reduces glycoprotein components in experimental diabetes. *Nutr. Res.* 2007, *27*, 97–103. [Google Scholar] [CrossRef]
124. Zakaria, Z.; Sreenivasan, S.; Mohamad, M. Antimicrobial activity of piper ribesoides root extract against staphylococcus aureus. *J. Appl. Biol. Sci.* 2007, *1*, 87–90. [Google Scholar]
125. Ghosh, S.; Subudhi, E.; Nayak, S. Antimicrobial assay of stevia rebaudiana bertoni leaf extracts against 10 pathogens. *Int. J. Integr. Biol.* 2008, *2*, 1–5. [Google Scholar]
126. Mahesh, B.; Satish, S. Antimicrobial activity of some important medicinal plant against plant and human pathogens. *World J. Agric. Sci.* 2008, *4*, 839–843. [Google Scholar]
127. Ehsan, B.R. Antimicrobial activity of the ethanolic extract of bryonopsis laciniosa leaf, stem, fruit and seed. *Afr. J. Biotechnol.* 2009, *8*, 565–3567. [Google Scholar]
128. Khond, M.; Bhosale, J.D.; Tasleem, A.; Mandal, T.; Padhi, M.M.; Dabur, R. Screening of some selected medicinal plants extracts for in-vitro antimicrobial activity. *Middle-East J. Sci. Res.* 2009, *4*, 271–278. [Google Scholar]
129. Pavithra, P.S.; Sreevidya, N.; Verma, R.S. Antibacterial and antioxidant activity of methanol extract of evolvulus nummularius. *Indian J. Pharmacol.* 2009, *41*, 233–236. [Google Scholar] [PubMed]
130. Patra, A.; Jha, S.; Murthy, P.N.; Vaibhav, A.D.; Chattopadhyay, P.; Panigrahi, G.; Roy, D. Anti-inflammatory and antipyretic activities of hygrophila spinosa t. Anders leaves (acanthaceae). *Trop. J. Pharm. Res.* 2009, *8*, 133–137. [Google Scholar] [CrossRef]
131. Akroum, S. Antimicrobial activity of some alimentary and medicinal plants. *Afr. J. Microbiol. Res.* 2012, *6*, 1860–1864. [Google Scholar]
132. Bajpai, V.K.; Rahman, A.; Shukla, S.; Mehta, A.; Shukla, S.; Arafat, S.M.Y.; Rahman, M.M.; Ferdousi, Z. Antibacterial activity of leaf extracts of pongamia pinnata from india. *Pharm. Biol.* 2009, *47*, 1162–1167. [Google Scholar] [CrossRef]
133. Bansal, S. Anti-bacterial efficacy of some plants used in folkaric medicines in arid zone. *J. Pharm. Res.* 2010, *3*, 2640–2642. [Google Scholar]
134. Vinothkumar, P.S.K.; Ahmed, P.; Sivamani, K.; Senthilkumar, B. Evaluation of antibacterial activities of andrographis paniculata leaf extract against gram positive and gram negative species by in vitro methods. *J. Pharm. Res.* 2010, *3*, 1513–1515. [Google Scholar]
135. Kumar, K.H.; Hullatti, K.K.; Sharanappa, P.; Sharma, P. Computative antimicrobial activity and tlcbioautographic analysis of root and aerial parts of andrographis serpyllifolia. *Int. J. Pharm. Pharm. Sci.* 2010, *2*, 52–54. [Google Scholar]
136. Jamuna, B.A.; Rai, V.R.; Samaga, P.V. Evaluation of the antimicrobial activity of three medicinal plants of south india. *Malays. J. Microbiol.* 2011, *7*, 14–18. [Google Scholar] [CrossRef]
137. Khanahmadi, M.; Rezazadeh, S.; Taran, M. In vitro antimicrobial and antioxidant properties of smyrnum cordifolium Boiss. (*Umbelliferae*) extract. *Asian J. Plant Sci.* 2010, *9*, 99–103. [Google Scholar]
138. Koperuncholan, M.; Kumar, P.S.; Sathiyanarayanan, G.; Vivek, G. Phytochemical screening and antimicrobial studies of some ethnomedicinal plants in south-eastern slope of western ghats. *Int. J. Med. Res.* 2010, *1*, 48–58. [Google Scholar]
139. Niranjan, M.H.; Kavitha, H.U.; Sreedharamurthy, S.; Sudarshana, M.S. Antibacterial activity of schrebera swietenioides roxb. Against some human pathogenic bacteria. *J. Pharm. Res.* 2010, *3*, 1779–1781. [Google Scholar]
140. Naveen, S.M.T. Evaluation of antibacterial activity of flower extracts of cassia auriculata. *Ethnobot. Leafl.* 2010, *14*, 8–20. [Google Scholar]