

A Review on Efficacy of Spices and Herbs as per *Ayurveda* and their Role as a Potent Antioxidant and Antimicrobial Agents

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Abstract

Bioactive compounds from spices and herbs play an important role to immunize our body system. From ancient time they are used as *Ayurvedic* medicine. This review mainly focuses on to the traditional medicinal uses of spices and herbs as per *Ayurveda* and their efficacy as a natural potent antioxidant and antimicrobial agents over synthetic one. The chemical component of essential oils were analysed by GC-MS and GC-FID techniques. Antioxidant activity was confirmed by different assays like DPPH assay, FRAP assay, ABTS assay, Hydroxy radical scavenging assay, NO scavenging assay etc. Quantitative estimation of phenol and flavonoid from different solvent extracts revealed the proportional relationship between concentration of polyphenols and antioxidant activity. Zone of inhibition (in mm), MIC and MBC were measured to assess the antimicrobial activity against different pathogens like *Escherichia coli*, *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Bacillus subtilis*, *Bacillus cereus*, *Pseudomonas aeruginosa*, *Streptococcus pyogenes* etc. Spices and herbs can be used as potent and safe *Ayurvedic* drug along with their use in cooking and seasoning different foods.

Keywords

Spices, Herbs, *Ayurvedic*, Phytochemicals, Antioxidant activity, Antimicrobial activity

How to Cite This Article

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Introduction

Since the beginning of human civilization, a number of Indian medicinal plants have been used in the traditional system of medicine (*Ayurveda*), aiming to maintain health and to cure diseases. The term nutraceuticals is a combination of two words nutrient and pharmaceutical. So, nutraceuticals can be defined as medicinal foods which have medicinal or health benefits along with nutritional values. Spices and herbs can be termed as nutraceuticals due to the presence of different bioactive components like essential oils, antioxidants and vitamins which are known to have wild biological activities to provide prevention against chronic diseases. These bioactive compounds are termed as phytochemicals or secondary metabolites for e.g. phenols, flavonoids, terpenoids, alkaloids etc.^{1,2} These are the reservoirs of potentially useful chemical compounds which could serve

as newer leads and clues for modern drug design.³ Presence of such bio nutrients makes spices and herbs as good antioxidant and antimicrobial agents.⁴ Now a day's these activities are widely studied in biological systems such as that of human. In general, the modes of action to perform such activities are disturbance of the cytoplasmic membrane, disrupting the proton motive force, electron flow, active transport, and coagulation of cell contents.⁵ The main challenge of pharmacology is to get detailed information of phytochemicals and their mode of action in alone or in combination. There are several endogenous and exogenous causes like metabolism, toxic chemicals from diverse environmental pollutants and ionizing radiation leads to the formation of reactive oxygen species (ROS). Free radicals such as singlet oxygen, super oxide, peroxy radicals, hydroxyl radicals and peroxynite are collectively known as ROS. Imbalance

between formation of ROS and their destruction leads to oxidative stress in human body system. This actually triggers the deactivation of many enzymes and cell damage by irreversible oxidation of DNA, proteins and lipids.^{6,7} Studies from various researcher showed that cellular reactive oxygen species may mediate the mitochondria-initiated apoptosis.⁸ Antioxidants protect cells against the damaging effects of reactive oxygen species. Free radicals follow chain reaction pathway and it continues its own until and unless we can scavenge these radicals from the system. Antioxidant blocks the chain reaction of free radical by supplying the hydrogen ion. So antioxidants mainly act as reducing agents. Compounds such as flavonoids and related compounds and amino acids function as both primary antioxidants and synergists Fig. 1.^{9,10} In market there are various synthetic antioxidants which are both hazardous to nature and human. Spices and herbs are the good precursor of these natural antioxidants. In general, these natural antioxidants are preferred by consumers because they are considered safe and these are widely used in our daily lives. Varieties of methods are used to find out the antioxidant properties of phytochemicals for e.g. DPPH assay, FRAP assay, ABTS assay, hydroxy radical scavenging assay, NO scavenging assay etc. The antioxidants have broad range of medicinal properties such as anti-allergic, antimicrobial, anticarcinogenic etc.^{11,12} Antibiotics play an important role to cure bacterial or fungal diseases by inhibiting their growth on human body. But for last 50 years abrupt use of antibiotics make them resistant to microbes. Thus increase in the Multiple Drug Resistant (MDR) strains of pathogens creates the most serious threats to the successful treatment of microbial diseases. To overcome this problem extensive researches are going on to find out effective naturally occurring antimicrobial agents from medicinal plants. Flavonoid compounds are good antioxidant and can also inhibit the growth of microbes.^{13,14} Spices and herbs like cinnamon, cloves, oregano, thyme etc. are the good source of flavonoids, phenolic acids and terpenes and can act as new antimicrobial compounds (Fig. 1). So, they are looked upon as a source of potential drugs with low side

effects. The essential oil from spices and herbs can inhibit the growth of pathogens like *Listeria monocytogenes*, *Salmonella typhi*, *E.coli* and *Bacillus cereus* in food as well as preserve them for long time.^{15,16} History of *Ayurveda* and local usages of herbal plants shows that plant products are useful in prevention and treatment of a verse variety of diseases. The main aim of *Ayurveda* is to prevent illness, and encourage healthy body along with happy mind. The object of this review is to summarize the most important and relevant research works on antioxidant and antimicrobial capacities on selected spices and herbs by different research groups and also its significance in *Ayurveda* so that readers or researchers can get an idea of how *Ayurvedic* medicine will be a better remedy over synthetic drugs.

Biodata and Traditional Medicinal Use of Spices and Herbs

Spices and herbs are widely used in our daily life for its aroma, taste and medicinal values. In *Ayurveda* they are widely used for their *Rasa* (Taste), *Guna* (Qualities), *Virya* (Potency), *Vipaka* (Post-digestion effect), *Karma* (Pharmacological activity) and *Prabhava* (Thereapeutics). The biological actions of different *Guna* (*Guru*, *Laghu*, *Shita*, *Ushana*, *Snigdha*, *Manda*, *Sthira*, *Picchil*, *Vishada*, *Shlakshna*, *Sthula* and *Sandra*) are as tonic, digestive, cooling, appetizer, laxative, constipation, bone mineralization, wound healing and nutritive. Various *Rasa* (*Madhura*, *Amla*, *Lavana*, *Katu*, *Tikta* and *Kashaya*) have different biological actions like promoting strength, prevent intensification of *vata* and *pitta*, clean channel, improve digestion, cure *pittaja* and *raktaja* disorder etc. Just like *Rasa* and *Guna*, *Vipaka* (*Madhur Vipaka*, *Amla Vipaka*, *Katu Vipaka*) has various biological roles like increases *Kapha*, *Vata*, *Pitta* and helps to excrete of urine and feces smoothly. *Virya* (*Shita Virya*, *Ushna Virya*, *Snigdha Virya*, *Ruksha Virya*, *Guru Virya*, *Laghu Virya*, *Mrudu Virya*, *Tikshna Virya*) has different biological actions like promoting strength, cure dysentery, heal wound (*Uparopan*), filling cavities (*Pooran*), improve digestion etc¹⁷. With increasing demand of processed food

due to change in our lifestyle, the usage of spices also grew up. Indian people love to eat spicy foods. India is the largest producer and exporter of spices in the world. As in the international market due to great demand of Indian spices, the economy of spice market of India rises very rapidly. Nowadays, the main health problems of mankind are diabetes, cardio-vascular diseases, arthritis and cancer. The active ingredients i.e. secondary metabolites for e.g. alkaloid, flavonoid, phenol, terpenoids, sterol, etc. of spices and herbs have the ability to prevent these health disorders. It was observed from different reports that plants rich in phenol, flavonoids, terpenoids, and tannins are used in phytotherapy.¹⁸ So, spices and herbs are getting huge importance as essential food component of our daily life due to its antioxidant, anti-diabetic, anti-carcinogenic, antimicrobial, anti-inflammatory effects etc. Following are the bio data of spices and herbs with following information- common name, scientific name, family, and their traditional uses in *Ayurveda*.

Yavani (Ajowin)

The scientific name of ajowin is *Trachyspermum ammi* L. and it belongs to Apiaceae family. It is seed like fruits having bitter taste with strong aroma. It was used as spice to cook foods for its strong aroma. *Rasa, Guna, Virya* and *Vipaka* for yavani are *Laghu, rukshan, tikshana, katu, tikta rasa Ushana* and *katu vipaka*¹⁹. In *Ayurveda* it is used to treat *gulma* and *pliha roga*. Ajowin was used from ancient time in different way in *Ayurveda* like with luke warm water, rock salt and asafoetida powder to get relief from different stomach related issues like indigestion, diarrhea, flatulence etc²⁰. According to Unani system of medicine it was used to enhance the body's resistance.^{21,22}

Hingu (Asafoetida)

The scientific name of asafoetida is *Ferula asafoetida* L. and it belongs to Apiaceae family. It is native to India. In Hindi it is known as hing. It is a milky juice resin extracted from the carrot shaped roots of *Ferula* plants. It emits pungent odour due to the presence of sulphur compounds.

The *Dravyaguna* for hingu is *laghu, snigdha, tikshan, katu rasa* and *Ushana, katu vipaka*. In *Ayurveda* it is used to treat *shula, murchha, gulama* and *anaha*.²³ Traditionally asafoetida has versatile role to treat different health related problems like whooping cough, bronchitis, asthma, ulcer, stomach ache, weak digestion flatulence, epilepsy, influenza etc.^{24,25,26,27}

Tejapatra (Bay Leaf)

The scientific name of bay leaf is *Laurus nobilis* L. and it belongs to Lauraceae family. It is not a commercial crop of India but due to its delicate aroma it was used in Indian cooking. The leaves are 2.5 to 7.5 cm long and 1.6 to 2.5 cm wide. Bay leaf is used for the treatment of digestive disorders like indigestion, flatulence etc.²⁸ Bay tea is used to solve different cold problems like colds, coughs and sore throat. Poultice of bay leaves is used to get relief from muscle pains. The essential oil components help to treat headache. The major functional properties are anti-microbial, anti-fungal, hypoglycaemic, anti-ulcerogenic etc.²⁷

Tulasi (Basil)

The scientific name of basil is *Ocimum basilicum* L. and it belongs to Lamiaceae family. Basil is known as Tulsi and it is cultivated all over the India but indigenous to Punjab and Himachal. It is a herb with height ranging from 30-90 cm.²⁷ Basil leaves have several oil glands with volatile oil. Daily intake of basil in diet improves glucose level and lipid profiles for diabetics.²⁹ It also helps to release stress and anxiety. Basil makes immune system stronger to fight against different health related issues like cold and cough, oral and skin health etc.³⁰

Ela (Cardamom)

The scientific name of cardamom is *Amomum subulatum* Roxb. and it belongs to Zingiberaceae family. Cardamom is a perennial herb and cultivated in the Sub-Himalayan region of North Eastern India. This plant grows in cold humid conditions under shade of trees. Cardamom is a fruit with round or oval shape.²⁷ The *Dravyaguna* for cardamom is *Laghu, ruksha, katu rasa* and *Sheeta &*

madhur vipaka. In *Ayurveda* it is used to treat *mutrakracha swasa, kasa, and kshaya*.³¹ In *Ayurvedic* composition *Ela* powder was taken with honey to get relief from sore throat. Paste of cardamom with cold water was given to stop vomiting.²⁰ It improves digestive system and increase appetite in people with anorexia.³² In *Ayurvedic* medicine system it is used to treat cold and cough, asthma, throat trouble, body pressure and cardiac health. Cardamom is mixed with neem and camphor to get relieves from sore throat.³³ In *Ayurveda* system it is used to control the disorder of excretory system. Essential oil of cardamom shows anti-inflammatory and antibacterial property.³⁴ So, in India, it was widely used to treat infections against teeth and gums and to relieve sore throats. Nasal preparation for cold is prepared by mixing cardamom with neem and camphor.

Lavanga (Clove)

The scientific name of clove is *Syzygium aromaticum* (L). and it belongs to *Myrtaceae* family. The plant is indigenous to Indonesia with height 10-12 mtrs long and clove is the flower bud with beautiful aroma. The aroma is due to the presence of essential oil in it. The mature bud is pink in colour.²⁷ The *Dravyaguna* for *lavanga* is *laghu*, *Snigdha*, *Tikta*, *katu rasa* and *Sheeta*, *katu vipaka*. It is used to treat *trishna*, *chardi*, *hikka*, *swasa* and *kasa*. In *Ayurveda*, Clove oil is used as analgesic to give relief from tooth pain and sore gums.^{35,36} When clove powder is used with lukewarm water, it gives relief from burning sensation, indigestion and vomiting.²⁰ Apart from analgesic property Cloves also has, anaesthetic action, antibacterial property, antioxidant property, antiparasitic action, antiseptic property, stimulant property etc.^{37,38}

Jiraka (Cumin)

The scientific name of cumin is *Cuminum cyminum* L. and it belongs to *Apiaceae* family. Cumin plant is a herb of 15 to 50 cm long. Cumin is a fruit with greyish brown colour and size varies between 3 to 6 mm. It has very strong aroma and bitter in taste.²⁷ The *Dravyaguna* for *jiraka* is *laghu*, *ruksha*, *Katu rasa* and *Ushna*, *katu vipaka*. In *Ayurveda* it is used to treat *atisaara*, *gulma* and

adhyamana. In *Ayurveda* cumin was used in various ways to treat some health issues. When cumin powder was taken with water or buttermilk it gives relief from stomach problem. Again daily intake of roasted cumin (half a teaspoon) increase memory power.²⁰ Presence of various bioactive components in cumin makes it useful in traditional medicinal use for e.g. as a stimulant, carminative, and astringent. Again the essential oil components of cumin show good anti-coagulant, anti-diabetic, antimicrobial, antiseptic and antioxidant properties.³⁹ Hot water extract of cumin seed is effective against dysentery.

Dhanyaka (Coriander)

The scientific name of coriander is *Coriandrum sativum* L. and it belongs to *Apiaceae* family. The plant is commercially produced in India. It is a small, bushy herb of 25 to 50 cm in height. Fruit is globular with single seed of pale brown colour. The whole plant as well as fruit has pleasant fragrance.²⁷ It has quiet used as traditional medicinal agent in *Ayurveda* system. The *Dravyaguna* for *dhanyaka* is *laghu*, *snigdha*, *kashaya*, *tikta*, *madhur*, *katurasa* and *Ushana*, *madhura vipaka*. In *Ayurveda* it is used to treat *antardaaha* and *ajirnaatisara*.⁴⁰ In *Ayurveda* composition decoction of *dhanyaka* and dry ginger powder is applied to treat digestive problems. Juice of coriander leaves mixed with honey to treat skin diseases.²⁰ Main use of coriander is to cure digestive disorder, excretory disorder and respiratory problems.⁴¹ In Iranian folk medicine it is used as sleeping agent to control the anxiety. In Morocco it is recommended for multi-health related issues for example skin problem, cold and cough problems, indigestion, urinary tract infection, allergies, hay fever and amebic dysentery.^{42,43}

Alakavhaya (Curry leaf)

The scientific name of curry leaf is *Murraya koenigii* (L) Sprengel and belongs to *Rutaceae* family. Curry leaf tree is found in all over the India. The tree is five meter in height and its leaves are used as spices. The volatile oils

of the leaves are the main source of its aroma.²⁷ Curry leaf is widely used in *Ayurveda* to control diabetic issues, indigestion, depression and fungal problems.^{44,45,46} Coconut oil extract of curry leaves is very useful to maintain normal hair colour and its growth.

***Madhurika* (Fennel)**

The scientific name of fennel is *Foeniculum vulgare* Mill. and it belongs to Apiaceae family. The plant is 1.5 to 1.8 mtr high. The ripe fruit is slightly curved and greenish yellow. This plant is native to Europe and Asia Minor. The production of fruit (seed) is good in cold weather so it was largely cultivated in Northern India. The dried fruit and seed are used in cooking due to its pleasant aroma and taste.²⁷ The *Dravyaguna* for *madhurika* is *laghu snigdha*, *Madhura*, *katu*, *tikta rasa* and *Sheeta*, *madhur vipaka*. It is used to treat *Kshatshirna*, *swasa*, *kasa ajeerna*, *adhyamaan* and *udarshool*.⁴⁷ In *Ayurvedic* preparation decoction of fennel improves constipation, fennel powder mixed with ghee cure asthma and cough. Hot water extract of fennel is used to relieve from flatulence. It improves eyesight and milk supply in lactating mother by increasing the growth of breast tissues.⁴⁸

***Methika* (Fenugreek)**

The scientific name of fenugreek is *Trigonella foenum-graecum* L. Mill. and it belongs to Fabaceae family. It is an herb of 30-60 cm long fenugreek seeds are 3 mm long with yellowish brown colour and it is the ripe fruit of the herb. Its origin is South Eastern Europe and West Asia, now cultivated in India. In Bengali it is known as *methe*. The suitable weather for its cultivation is cold condition and prefers clayey loam. Dried leaves and seeds has strong beautiful aroma but bitter in taste.²⁷ The *Dravyaguna* for *methika* is *Laghu*, *snigdha*, *katu rasa* and *Ushana*, *katu vipaka*. In *Ayurveda* it is used to treat *jwara*, *agnimandhya*.⁴⁹ Fenugreek traditionally used to cope with various health problems like indigestion, diabetic problem, hypertension, high triglyceride, high cholesterol, lungs problem, sore throats problem, arthritis, skin rash,

loss of appetite, menopausal problems etc.^{50,51} As per *Ayurveda*, consumption of one teaspoon fenugreek powder daily with lukewarm water in empty stomach is useful to control blood sugar.²⁰

Polyherbal formulation and its significance

Polyherbal formulation means herb-herb combination of two or more herbs in a prescribed ratio which depends on physiological status of body. In *Ayurvedic* drug formulation the concept of polyherbalism was used to attain better therapeutic effect. The idea of polyherbal formulation was reported in *Sarangdhar Samhita*. In herbal medication pounded herb was used to achieve better bioavailability *in vivo* as pulverized form has the greater surface area for interaction. For this reason spices are used in cooking or as herbal medicine in powder form to get best from it. In polyherbal combination it was assumed that secondary metabolites of herbs mixture have synergistic effect for better pharmacology and less toxic effect on patients but scientifically it has not been explored. These combinations can act on multiple targets on same time for faster recovery from diseases.⁵² Due to the synergistic effects poly herbal formulations (PHFs) gives better treatment over single herb. Again patients are benefitted by eliminating the requirement of various single herb formulations for different health issues. Various literatures reported the use of spices and herbs in combination to provide better therapeutic values. Such as combination of ginger with black pepper and long pepper increase the mucous reducing effects; some digestive problems can be cured by use the combination of cumin. Enhancement in immunity by use of guduchi and turmeric combination.^{53,54} These polyherbal combinations have lots of pharmacological activities like anti-inflammatory activity, antidiabetic activity, antioxidant activity, anti-depressant activity, anti-ulcer activity etc. Varieties of PHFs use spices and herbs along with other medicinal plants to attain different pharmacological activities for e.g. the antioxidant activity showed by the product NR-ANX-C with PHFs *W. somnifera*, *O. sanctum*, *C. sinensis*;⁵⁵ Trikatu megaext

with PHFs *Piper nigrum*, *Piper longum*, *Zingiber officinale*;⁵⁶ Hingwashtak churna with PHFs *Piper nigrum*, *Piper longum*, *Zingiber officinale*, *Nigella sativa*, *Cuminum cyminum*, *Trachyspermum ammi*, *Ferula foetida*, rock salt etc.⁵⁷ So in polyherbal formulation natural combination of active principle may be useful to deal with different diseases suitably due to presence of various active agents in sufficient amount. Despite the benefits of PHFs there are some important areas where to be more focused such as more clinical trials, toxicological studies, mode of action of secondary metabolites etc. Although standardization of clinical reproducibility of *Ayurvedic* PHFs is not easy to achieve as the nature and composition of bioactive chemicals vary with location, climatic condition, way of harvesting and their collection procedure.⁵⁸

Antioxidant and Antimicrobial Activity Assay

Medicinal properties of spices and herbs are due to its ability to scavenge reactive oxygen species (ROS), reactive nitrogen species (RNS) etc. and also having the potential to stop the growth of various harmful microorganisms. Due to the presence of polyphenolic compounds they are natural precursor of antioxidant and antimicrobial agents.⁵⁹ To find the antioxidant property different assays like DPPH assay, FRAP assay, ABTS assay, hydroxy radical scavenging assay, NO scavenging assay etc. were carried out by various group of researchers. In DPPH radical scavenging assay the antioxidant power of the plant extract was monitored spectrophotometrically at 517 nm.⁶⁰ Trolox equivalent antioxidant capacity (TEAC) assay or ABTS assay is one of the antioxidant assay by which one can measure the antioxidant capacity of plant extract in terms of ABTS radical cation (ABTS⁺) scavenging power of the extract spectrophotometrically at 734 nm. Here green-blue ABTS⁺ (2,2-azinobis-(3-ethylbenzothiazoline-6-sulfonate) was generated by reaction between ABTS salt and potassium persulfate. Antioxidant capacity is expressed as Trolox-equivalent antioxidant capacity (TEAC/mg).⁶¹ NO scavenging antioxidant power is

measured by Griess reagent (1% sulfanilamide, 2% phosphoric acid and 0.1% N-(1-naphthyl) ethylenediamine dihydrochloride) spectrophotometrically at 546 nm.⁶² In this assay generation of nitric oxide (NO) from sodium nitropruside [Na₂Fe(CN)₅NO] is hindered by antioxidant so can't form complex with Griess reagent. As a result there is decrease in absorbance. Antioxidant property is also measured in terms of iron reducing power method which was described by.⁶³ In this assay sample is mixed with potassium ferricyanide and reduction of ferric (Fe³⁺) to ferrous (Fe²⁺) is measured spectrophotometrically at 700 nm. Another well known iron reducing assay is FRAP (Ferric Reducing Antioxidant Power) assay. Here at low pH reduction of FRAP reagent (300 mM acetate buffer, pH = 3.6, 10 mM TPTZ (tripyrindyl-striazine) in 40 mM HCl and 20 mM FeCl₃.6H₂O in the ratio of 10:1:1) by antioxidant is measured at 593 nm.⁶⁴ β-Carotene-linoleic acid assay method is also used to determine the antioxidant power of extracts. Antioxidant can prevent the bleaching of β-Carotene by linoleic acid free radical. This destruction was monitored by measuring the absorbance at 470 nm.⁶⁵ Antimicrobial activities of spice and herbs extracts are measured by some standard methods like agar well diffusion method, agar disc diffusion method, broth micro-dilution method etc. Presence of antimicrobial activity was confirmed by measuring different parameters like diameter of inhibition zone, MIC (minimal inhibitory concentration) and MBC/ MFC (minimum bacterial or fungal concentration). Tested microorganisms are gram positive bacteria, gram negative bacteria and fungi. Followings are the name of pathogens of interest: *Escherichia coli*, *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Bacillus subtilis*, *Bacillus cereus*, *Pseudomonas aeruginosa*, *Klebsiella pneumonia*, *Candida albicans*, *Erwinia Carotovora*, *Proteus vulgaris*, *Eterobacter cloacae*, *Shigella sp.*, *Streptococcus pyogenes*, *Salmonella enteric*, *Enterococcus faecalis*, *Listeria monocytogenes*, *Aspergillus niger*, *Trichophyton rubrum*, *S. typhi*, *A. flavus* etc (Table 1). Inhibition zone is measured by agar diffusion method.⁶⁶ MIC actually measures the least concentration of the extract which can completely inhibit the growth of pathogens. It is

determined by micro-well dilution method.⁶⁷ MBC is defined as-the lowest concentration of extract required to kill the pathogens for a fixed period of time.⁶⁸

Literature Review on Antioxidant and Antimicrobial Properties of Spices and Herbs

Spices and herbs are potent agents to show antioxidant and antimicrobial properties. These properties are due to the presence of various bioactive ingredients such as 'Nigellone' in black cumin, 'Linalool' in coriander, 'Cuminaldehyde' in cumin, 'Piperine' in black pepper, 'Cinnamaldehyde' in cinnamon, 'Eugenol' in cloves etc. Presence of various secondary metabolites makes spices and herbs useful to immunize our body system. Lots of researches were done to ascertain antioxidant and antimicrobial properties of different spices and herbs. Sahukari et al., 2020 reported antioxidant and antibacterial properties of *Trachyspermum ammi* L. seeds. Quantitative estimations of phenol and flavonoids were done by spectrophotometric method and results showed that the different solvent extracts (methanol, ethanol, acetone, chloroform, hexane and distilled water) had high concentration of these two phytochemicals. Among these solvents phenol and flavonoid contents in acetone extract was maximum. Amount of phenol and flavonoid was 800.65µg/mg and 453.93µg/mg respectively. Essential oil of ajwain seeds contain Thymol as the major constituent followed by γ-terpinene and p-cymene. Antioxidant properties were confirmed by DPPH, lipid peroxidation, reducing capacity and total antioxidant activity assays. All the above said assays show highest antioxidant values for acetone extract as the phenolic and flavonoid content is high in this extract. The values for DPPH, lipid peroxidation, reducing capacity and total antioxidant activity assays for acetone extract were 98.00±1.9; 99.90±2.1; 76.48±3.1; 59.31±1.8 respectively. Antibacterial activity was performed by agar well-diffusion method. Methanol extract showed maximum inhibition against *E. coli* and zone of inhibition was 5 mm whereas chloroform extract showed maximum inhibition against *Pseudomonas* and *S. aureus* bacteria.

The zone of inhibition for both the bacteria was 6 mm.⁶⁹

Antioxidant and antimicrobial properties from the essential oil of *Ferula assa-foetida* oleo-gum-resins was reported by Kavoori and Rowshan, 2012. Essential oil component was isolated by hydro-distillation method and analysed by Gas Chromatography (GC). The essential oil compounds had high level of acyclic sulphur containing compounds and bicyclic monoterpenes. Total phenolic and flavonoid content was measured spectrophotometrically and the value for phenol was 90.14 ± 3.5, 82.8 ± 4.2 and 55.56 ± 5.6 mg gallic acid equivalents per gram of essential oils and flavonoid was 35.75 ± 2.5, 27.35 ± 1.63 and 21.48 ± 1.33 mg quercetin equivalents per gram of essential oils. Antioxidant assay was measured in terms of mg ascorbic acid equivalents per gram of essential oils and the value was 18.16 ± 1.2, 14.14 ± 2.2, 10.8 ± 2.5 (mg AAE/g) respectively. Apart from that different radical scavenging assays like NO scavenging, H₂O₂ scavenging, TBARS scavenging assays were performed to find the inhibitory concentration (IC₅₀) for these assays. Experiments showed the IC₅₀ values of 0.012–0.035, 0.025–0.047 and 0.035–0.066 mg/ml of essential oil at different time interval respectively. The essential oil from oleo-gum-resin was tested for antimicrobial activity against different gram-positive and gram-negative bacteria like *S. typhi*, *E. coli*, *S. aureus*, *B. subtilis*, *A. niger* and *C. albicans*. Minimal inhibitory concentration (MIC) values were 0.028–0.111, 0.027–0.107 and 0.018–0.058 mg/ml of essential oil respectively.⁷⁰

In this study in-vitro antimicrobial and antioxidant activities of different extracts of Bay leaves was performed by Algabri et al., 2018. Three different solvent extracts of n-hexane, dichloromethane and methanol were prepared by Soxhlet apparatus and studied for antioxidant and antimicrobial activities. Antioxidant activity was confirmed by thin layer chromatography (TLC) based qualitative DPPH assay. In this assay appearance of intense yellow colour against purple background ascertained the antioxidant activity. The yellow colour

was prominent for methanolic extract. Different solvent extracts were tested for antimicrobial activity against the two Gram-negative bacteria *Pseudomonas aeruginosa* (ATCC 29138) and *Escherichia coli* (ATCC 25922), one Gram- positive bacteria *Staphylococcus aureus* (ATCC 29213) and yeast *Candida albicans* (ATCC 10231) in agar medium. There is no zone of inhibition of n-hexane extract. But methanol extract had zone of inhibition 18 ± 0.8 mm against *Staphylococcus aureus* only whereas dichloromethane extract had zone of inhibition 13 ± 0.5 and 14 ± 0.6 respectively against *Staphylococcus aureus* and *Escherichia coli*.⁷¹

Stanojevic et al., 2017 reported the antioxidant and antimicrobial property of essential oil obtained from *Ocimum basilicum* L. Essential oil was isolated by hydrodistillation process and the composition was analysed by gas chromatography-flame-ionization detector (GC-FID) process. The major compounds of essential oils were oxygen-containing monoterpenes, sesquiterpene hydrocarbons, oxygen-containing sesquiterpenes and monoterpene hydrocarbons. DPPH assay was performed to find out the antioxidant activity of the extract. The EC_{50} value was gradually increasing with increasing concentration of basil essential oil and incubation time. It was highest after 90 mins of incubation. The antimicrobial activity of basil was tested against different gram positive, gram negative bacteria and fungus *C. albicans* only. The inhibition zone for basil essential oil on *Providencia stuartii*, Coagulase-positive *Staphylococcus* and *Streptococcus* group D was more over selected antibiotics like Ciprofloxacin and Gentamicin. Again basil oil showed higher antimicrobial activity on *C. albicans* in compare to metronidazol.⁷² Use of cardamom (*Amomum subulatum* Roxb.) as antioxidant and antimicrobial agent was studied by group of researchers from Nepal. Subba et al., 2017 performed DPPH assay and agar well diffusion method to confirm its antioxidant and antimicrobial activities. Antimicrobial activity was tested against two gram-positive bacteria - *Bacillus pumilus*, *Staphylococcus aureus* and two gram-negative bacteria - *Escherichia coli*, *Salmonella enteric*.

The IC_{50} value of DPPH assay was 7.7 ± 2.0 $\mu\text{g/mL}$, and 7.01 ± 2.0 $\mu\text{g/mL}$ respectively. The mean zone of inhibitions against *Bacillus pumilus*, *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella enteric* were 11.5 ± 0.15 mm, 10.4 ± 0.35 mm, 13.3 ± 0.20 mm and 10.3 ± 0.25 mm respectively.⁷³

Potent antioxidant and antimicrobial activity of the Indian clove *Syzygium aromaticum* L. was reported by Wankhede on 2015. To show antioxidant activity he quantitatively measured that antioxidants present in clove and the amounts were 6600 μg of ascorbic acid, 1.96 μg of lycopene, 80 μg of anthocyanin and 0.900 mg of chlorophyll in per ml of clove bud extract. Antimicrobial activities were tested against different human pathogenic bacteria like *Staphylococcus aureus*, *Salmonella typhi*, *Klebsiella pneumoniae*, *Proteus vulgar*, and *Shigella flexneri* along with fungus *Candida albicans*. They reported that both the aqueous, Petroleum ether, methanol and ethanol extract showed highest zone of inhibition against *Aspergillus niger* and the zone of inhibition was 16 mm, 17 mm, 14 mm and 17 mm respectively.⁷⁴

Essential oil from *Cuminum cyminum* was investigated for antioxidant and antibacterial activities by Patil et al., 2016. The chemical composition of essential oil was determined by gas chromatography-mass spectrometry (GC-MS). GC-MS analysis showed that the concentrations of cuminaldehyde and caryophyllal were quite high compare to other components like terpinen-4-ol, α -thujene, α -pinene etc. The antioxidant efficacy was measured in terms of DPPH assay and showed less antioxidant power compare to standard ascorbic acid. The antimicrobial assay was performed by using disc diffusion method against *Streptococcus mutans*, *Streptococcus pyogenes*, *Proteus vulgaris*, *Escherichia coli*, *Klebsiella pneumonia*, *Salmonella typhi*, *Salmonella paratyphi A*, *Enterobacter aerogenes*, *Pseudomonas aeruginosa*. Among all of these pathogens zone of inhibition was highest for *Salmonella typhi* with 60 mm diameter. They reported that the presence of γ -terpinene and p-cymene are the key components to show antibacterial activity.⁷⁵

Jeya et al., 2019 reported antioxidant and antimicrobial properties of *Coriandrum sativum* L. seed essential oil. The essential oil was extracted by hydro distillation method and dried with anhydrous sodium sulphate. Antioxidant activity was assessed by DPPH assay method. They reported ($66.48 \pm 0.80\%$) inhibition of DPPH at a concentration of 500 $\mu\text{g/ml}$ and concluded this high activity due to presence of linalool in essential oil. Antimicrobial activity of *Coriandrum sativum* seed essential oil was evaluated against *E. coli*, *Enterobacter aerogenes*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and *Candida albicans*. As per their experiment minimum inhibitory concentration (MIC) value of *Coriandrum sativum* L. essential oil was highest for *Pseudomonas aeruginosa* and then followed the descending order for the *Escherichia coli*, *Enterobacter aerogenes*, *Klebsiella pneumonia* and *Candida albicans*.⁷⁶

In this study antioxidant and antibacterial activities were determined by using different extracts of *Murraya koenigii* (L.) leaves. DPPH scavenging assay showed highest IC_{50} value for ethyl alcohol extract followed by chloroform and hexane. The IC_{50} values were 30 $\mu\text{g/ml}$, 27 $\mu\text{g/ml}$ and 22 $\mu\text{g/ml}$. The zone of inhibitions measured to report antibacterial activity against *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae*, *Salmonella paratyphi* and *Pseudomonas aeruginosa* were quite impressive. As per their report hexane and chloroform extracts showed antibacterial activity against three bacterial strains; *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa* whereas chloroform extract was active against all the bacterial strain. Among this ethanol extract showed highest zone of inhibition 16.33 ± 0.57 mm against *Staphylococcus aureus*.⁷⁷

Roby et al., 2013 reported antioxidant and antimicrobial properties from essential oil and various solvent extracts of fennel (*Foeniculum vulgare* L.). GC-MS analysis revealed the presence of different monoterpenoids, trans-anethole, estragole, fenchone and limonene. Antioxidant activity was measured by free radical scavenging capacity of the extracts against DPPH radical. The IC_{50} values of extracts were ranging from 0.0022 to 0.0041 and highest for ethanol and methanol extracts. Essential oils and

different extracts of fennel can inhibit the growth of different pathogens like *E. coli*, *S. typhi*, *B. cereus*, *S. aureus*, *A. flavus* and *C. albicans*. Zone of inhibition increased with increasing concentration of different solvent extracts.⁷⁸

Tejaswini et al., 2012 and Premanath et al., 2011 reported antioxidant and antimicrobial activities from the seeds and leaves of *Trigonella foenum-graecum* L. Mill. Different solvent extracts of seeds were examined to determine total antioxidant activity, catalase, peroxidase, ascorbate oxidase, total phenolic compounds and antimicrobial activity. Investigation of antimicrobial activity was done by agar well diffusion method for the following pathogens *Escherichia coli* (NCIM 2067), *Bacillus subtilis* (NCIM 2063), *Klebsiella pneumonia* (NCIM 2957), *Proteus vulgaris* (NCIM 2027), *Staphylococcus aureus* (NCIM 5021) and fungi- *Aspergillus niger* (NCIM 1054), *Trichophyton rubrum* (MTCC 1123). The antioxidant activities for water and ethyl acetate extracts were 1.812 and 0.544 $\mu\text{g/gm}$ of α -tocopherol equivalent. The antioxidant activity of water extract was high due to its high phenolic content (0.855 mg of gallic acid equivalent/g) compare to ethyl acetate extract (0.041 mg of gallic acid equivalent/g). They reported that ethyl acetate fraction had significant zone of inhibition against *Escherichia coli*, *Klebsiella pneumonia*, *Staphylococcus aureus*, *Aspergillus niger* *Trichophyton rubrum*.⁷⁹

This section describes the methods (*in vitro*) to find out the antioxidant and antimicrobial properties of spices and herbs. But on pharmaceutical perspectives the main issues are their mode of application, dosage and bioavailability. To overcome these issues thorough scientific researches are necessary. Bioavailability is the primary concern to use spices and herb as herbal medicine for human health care. The bioavailability of turmeric, cinnamon, clove etc. was already reported by different group of researchers.^{80,81} Therefore these studies will help to formulate natural remedies without side effects over synthetic drugs. Also herbal remedies of antioxidant and antimicrobial agents will meet up the increasing requirement of growing population along with low cost of procurement. Tapsell

et al. 2006 reported that herb can boost immunity to battle against oxidative stress and various diseases if consumed in appropriate way.⁸²

Conclusion

Antioxidants are essential components of our daily life to protect our cells from reactive oxygen species. This reactive oxygen species are generated in our body due to pollution, stress and food habit. Reactive oxygen species actually damage our body cell. On the other hand antimicrobial agents help mankind to get rid of various diseases from bacterial and fungal infections. Synthetic antioxidant, antibacterial or antifungal drug can cure these problems but they have various hazardous side effects in our body system. Natural products are good remedy to solve these problems. In this review various traditional medicinal uses of eleven (11) spices and herbs along with their antioxidant and antimicrobial studies have been reviewed. It was noticed from the works of various group of researchers that spices and herbs can be used as potent antioxidant and antimicrobial agents and can be used as *Ayurvedic* medicine. Chemical analysis and quantitative estimation of phytochemicals confirmed that phenol, flavonoid compounds were involved in this protective mechanism. Antioxidant and antimicrobial studies by various methods (*in vitro*) revealed that the efficacy of extracts or essential oil from spices and herbs is better or similar compare to synthetic agents. So, spices and herbs can strong our immunity system to fight against reactive oxygen species, reactive nitrogen species and microorganisms. Therefore these can be used in our daily life in cooking and as *Ayurvedic* medicinal supplements. More rigorous clinical trials are required to proof their effectiveness over human so that it can be utilised more effectively for human health care. In the year 2010, Department of Ayurveda, Unani, Siddha, and Homeopathy (AYUSH) introduced a new rule regarding documentation of efficacy for licensing of a patent *Ayurvedic* medicine. From the year 2015 Central Drugs Standards Control Organization (CDSCO) regulates the requirements of scientific data based on purity, toxicity, efficacy of phytopharmaceuticals to permit it use as an herbal drug in markets just like synthetic agents. So various solvent

extracts and essential oils of spices and herbs can be the new antimicrobial or antioxidant agents in our pharmaceutical industry and also can be used as potent *Ayurvedic* medicine after proper clinical trials and permission from authorize organization.

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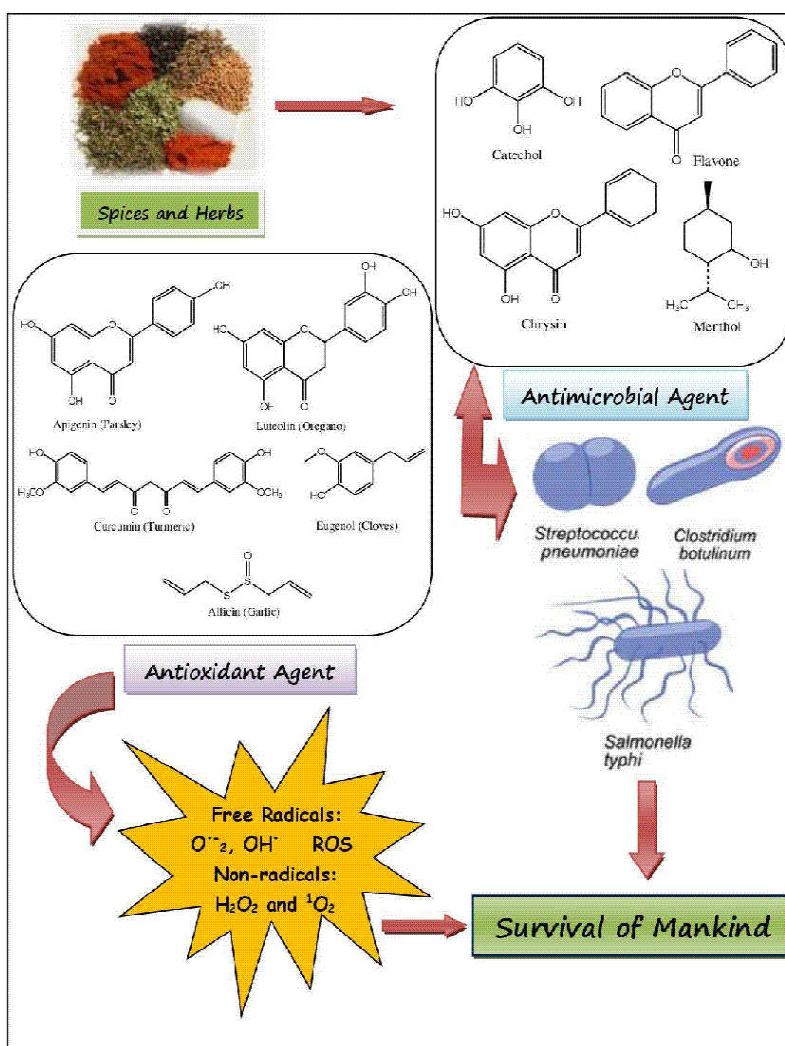


Fig. 1: Antioxidant and antimicrobial properties of spices and herbs