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Structure: Activity and Emerging Applications of Spices and Herbs

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Abstract

Herbs and spices are plant parts (herbs from leaves and spices from other parts) that are conventionally used in their fresh or dried state for flavouring, natural condiments, preservatives and for medicinal purposes. Worldwide, most spices are classified on the basis of taste, season of growth, economic importance, growth habit and plant part used. Black pepper, chilies, small cardamom, ginger and turmeric are some of the widely used spices while common herbs include thyme, basil and bay leaves. These herbs are basically classified according to usage, active constituents and period of life. Secondary metabolites such as Eugenol, thymol, limonene, cuminaldehyde, curcumin, piperine, quercetin, luteolin in these plant parts have been found to be responsible for anticancer, antimicrobial, antiviral, antidiabetic, antioxidant, anti-inflammatory and hypocholesterolemic effects. Their application in water fortification, milk and cheese processing, production of beauty products and pesticides among others could not be underestimated. Finally, adulteration, toxicity and allergic reactions are some of the identified limitations and challenges often encountered in the use of herbs and spices.

Keywords: herbs, spices, water fortification, emerging applications, food preservation

1. Introduction

Herbs, spices and derived extracts have been used since ancient times to improve sensory characteristics of food, as preservatives as well as their nutritional and health properties [1]. Herb is derived from the Latin word '*herba*', meaning grass, green stalks or blades which refers to the leafy part of a plant used either in its fresh or dried state, altering the taste of the food with the aim of flavour enhancement. On the other hand, any other part of a plant; seed, bark, root, fruit, or flower, often used in the dried state is called a spice. Common examples of spices are cloves bud, turmeric rhizome, cinnamon bark, garlic bulb, ginger rhizome, peppercorn berries and cumin seeds (**Figure 1**) [2]. Each can be differentiated by their growing condition, taste, and part used [3]. Technically, herbs are usually grown in temperate or cooler climate, while spices are grown in the tropics [4]. Some plants can be

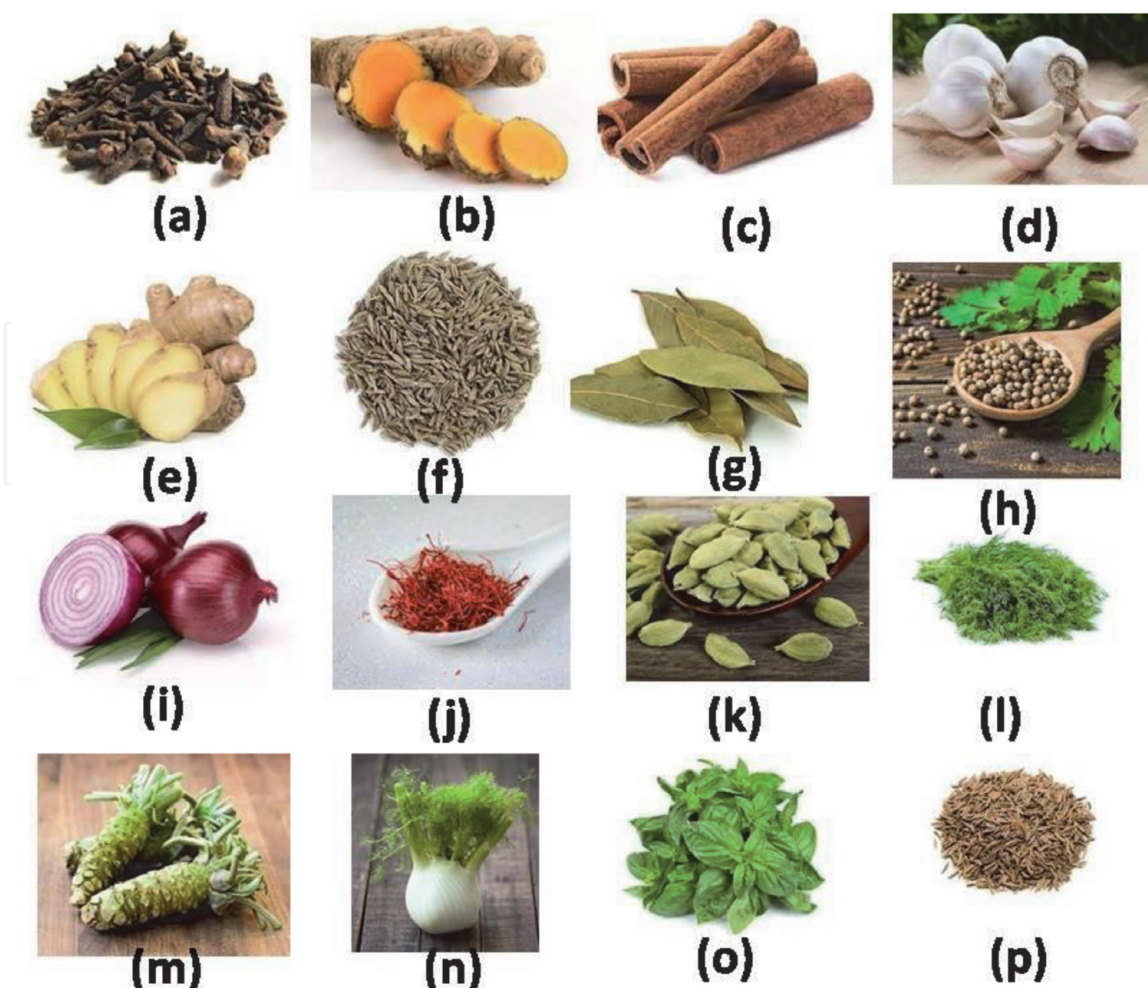


Figure 1.

Some common spices in use; (a) clove (b) turmeric (c) cinnamon (d) garlic (e) ginger (f) cumin (g) bay leaf (h) coriander (i) onion (j) saffron (k) cardamom (l) dill (m) wasabi (n) fennel (o) basil (p) caraway.

both herb and spice. For example, Coriander leaves and seeds are used for the production of both herb and spice, respectively [5]. For many centuries, herbs and spices have been used generally and basically in enhancing organoleptic properties of food like taste and flavour. However, newer applications have been reported in recent times. They have gained importance as potential sources of natural food preservatives due to the growing interest in the development of safe and effective natural preservatives which has been better alternatives to chemical additives [6, 7].

Furthermore, various compounds derived from herbs and spices have been reported for medicinal activities such as antimicrobial, antiviral, anti-inflammatory and antioxidant [8, 9]. Certain herbs and spices that have been reported for cancer prevention, cholesterol lowering effects and overall protection of human health [10]. In folk medicine, turmeric is used for gynaecological problems, stomach diseases, liver diseases, infectious diseases, and blood diseases and has been suggested for the treatment of proinflammatory diseases, cancer, diabetes, obesity, and atherosclerosis [11]. Turmeric, native to India and Southeast Asia, is commonly used as food colouring in Asian dishes, such as curries.

Herbs and spices have also been used in water enrichment. Herbs have been used in the production of functional beverages which are useful in boosting immune system, increase vitality, body weight control and fighting degenerative diseases. They are also used in the production of flavoured or enhanced water which also offer nutritional benefits [12]. More advanced application of herbs and spices is in dairy products, cosmetics and production of insecticides [13–15]. Herbal products

have been researched and tested in skin care and reported for mildness, efficacy, biodegradability, low toxicity, cleansing ability, emulsification, moisturising, skin appearance, feel, fragrance, and lubrication [16, 17]. Clove buds' oils possess insecticidal properties [5]. To this end, the chapter therefore covers the recent application of herbs and spices as important natural products, in addition to information on the different types, classification, bioactivities and bioactive compositions, as well as the current limitations in optimization and disadvantages in the use of herbs and spices. A total of 102 articles were reviewed in the study, which deal directly with the subject having removed articles out of the scope of study. Articles used for the development covers the year 1990 to 2021.

2. Economic benefits of herbs and species

The use of herbs and spices were report as far back as 2000 to 1500 B.Cs in India and Egypt respectively which was later introduced to other countries of the world due to globalisation [18]. Economically, the main spice in the international trade is pepper and its price determine the value of spices in general. In 2012, the annual global trade in spices was 6–7 lakh tonnes valued at US\$3–3.5 billion [19]. The European Union has the largest imports of spices in value terms, worth US\$2.2 billion and consisting 44% retail sales to consumers, 41% sales to the food manufacturing sector and 15% to the catering sector. In South Africa, the annual spice trade is worth US\$94 million with the potential of increase as consumers desire better taste in food [19].

3. Classification and examples of herbs and spices

The classifications of herbs and spices as described in literature Chhetri et al., 2019; [3, 20–24] are presented in **Tables 1–3**. **Table 1** shows the class, sub classes, super orders, orders and families of some spices. Spices can be conventionally classified on the basis of taste as hot, mild or aromatic. Spices can also be classified based on season of growth which can be annual, biennial or perennial, on the basis of growth habit which can be shrubs, trees, climbers or rhizomes or on the basis of plant part used (**Table 2**). Additionally, spices can be classified on the basis of their economic importance as either major spices or minor spices. Major spices are black pepper, chilies, small cardamom, ginger and turmeric. All other spices asides these are considered as minor spices [3, 22, 23].

Herbs are basically classified according to usage, active constituents and period of life (**Table 3**). When classified according to usage, herbs can be medicinal, culinary, aromatic and ornamental. Medicinal herbs as the name implies have therapeutic properties and are used in the treatment of illnesses. Culinary herbs are used majorly in cooking because of their strong flavours. Ornamental herbs are used for decoration owing to their bright colours [24]. When classified on the basis of active ingredient, herbs can be classified as aromatic (volatile oils), astringents (tannins), bitter (phenolics, saponins and alkaloids), mucilaginous (polysaccharides) and nutritive (food). Aromatics herbs have pleasant odours and are used medicinally as well as in flavouring. They are subdivided into stimulant herbs, used to increase energy and activity of the body. Astringent herbs help to tighten, contract or tone living tissues and this helps to halt discharges. Bitter herbs can be further divided into laxative bitter herbs, diuretic herbs or saponin-containing herbs. Mucilaginous herbs help to eliminate toxins from the intestinal systems and function as antibiotic, antacid, demulcent, emollient and detoxifier in nature [21].

Class	Subclass	Super order	Order	Family	Examples		
Angiospermae	Dicotyledoneae	Sympetalae	Campalunatae	Solariaceae	Chilli, paprika, red pepper		
				Pedahaceae	sesame		
				Compositae	Camomile, chicory, tarragon		
			Archichlamydaee	Piperales	Piperaceae	Cubeba, long pepper, pepper	
			Ranales	Myristicaceae	Mace, nutmeg		
				Lauraceae	Bay leaf, cassia, cinnamon		
				Magnoliaceae	Star-anise		
			Rhoeadales	Cruciferae	Mustard, wasabi		
			Myrtiflorae	Myrtaceae	allspice, clove		
			Umbelliflorae	Umbelliferae	Anise, caraway, celery, chervil, coriander, cumin, dill, fennel, parsley		
			Monocotyle-doneae		Liliiflorae	Liliaceae	Garlic, onion
						Irdaceae	Saffron
					Scitamineae	Zingiberaceae	Cardamom, ginger, turmeric
					Orchidales	Orchidaceae	Vanilla

Table 1.
Taxonomic classification of spices [21].

Category	Classes	Examples
Degree of taste	Hot spices	Capsicum (chillies), Cayenne pepper, black and white peppers, ginger, mustard
	Mild spices	Paprika, coriander
	Aromatic spices	Allspice (pimento), cardamom, cassia, cinnamon, clove, cumin, dill, fennel, fenugreek, mace and nutmeg
	Aromatic vegetables	Onion, garlic, shallot, celery
Growth habit	Shrubs	Rosemary, chillies, pomegranate
	Trees	Nutmeg, clove, cinnamon, tamarind, garcinia, Japanese pepper
	Climbers	Black pepper, tailed pepper, vanilla
	Rhizomes	Cardamom, ginger, turmeric, mango ginger, galangal, asafoetida
Season of growth	Annual	Coriander, cumin, fennel, fenugreek, ajowan, black cumin, aniseed, mustard, chilli
	Biennial	Onion, parsley
	Perennial	Cardamom, turmeric, ginger, black pepper, saffron, clove, nutmeg, asafoetida, cinnamon

Category	Classes	Examples
Part usage	Bark	Cinnamon, cassia, tejpat
	Rhizome	Ginger, turmeric, sweet flag, greater galangal
	Fruit	Pepper, cardamom, chilli, coriander, cumin, fennel, celery, aniseed, ajowan, caraway, dill, pepper long, star anise, allspice, tamarind
	Seed	Cardamom, fenugreek, mustard, pomegranate, nutmeg, poppy seed
	Rind	Kokam, camboge
	Bulb	Garlic
	Stem	Celery, lovage
	Pod	Vanilla
	Stigma	Saffron
	Root	Horse radish, angelica, lovage
	Flower bud	Caper
	Unopened flower bud	Clove
	Berry	Juniper berry
	Aril	Mace

Table 2.
Classification of spices based on taste, growth condition and plant part usage [3, 21–24].

Criteria	Class	Examples
Industrial Usage	Medicinal	Echinaceae, feverfew
	culinary	Basil, parsley, mint
	Ornamental	Lavender, chives
Seasonal Usage	Annual	Anise, basil, borage, calendula, chamomile, dill dukat, marjoram, parsley, shiso, saffron
	Biennial	Prime rose, caraway seeds, mullein, viper’s bugloss
	Perennial	Alfalfa, aloe vera, arimony, asafetida, bee balm, bay leaves, thyme, dill, fennel, Echinacea, lavender, lemon balm, pepper mint, spear mint, mitsuba, oregano, rose mary, sage, salad burnet, yarrow, water cress.
Active ingredient	Aromatic	<i>Stimulant:</i> Fennel, ginger, garlic, lemon grass <i>Nervine:</i> Ginger, catnip
	Astringent	Pepper mint, raspberry
	Bitter	<i>Laxative:</i> Aloe, cascara, licorice, pumpkin, senna, yellow dock, yucca, barberry, gentian, safflower, golden seal <i>Diuretic:</i> Asparagus, Blessed thistle, burdock, butcher’s broom, buchu, corn silk, dandelion, parsley <i>Saponin-containing:</i> Alfalfa, yucca, ginseng, gotu kola, schizandra
	Mucilaginous	Aloe, burdock, dandelion, glucomannan, Irish moss
	Nutritive	Apple, roseships, orange, wheat germ, spirulina, red clover, cauliflower, cabbage, broccoli, accerola, asparagus, oatstraw, carrot

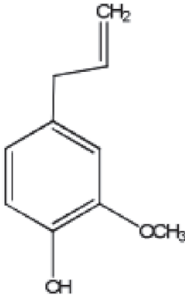
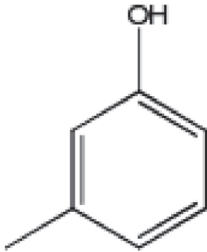
Table 3.
Usage, seasonal and nutritional classification of herbs [3, 22–24].

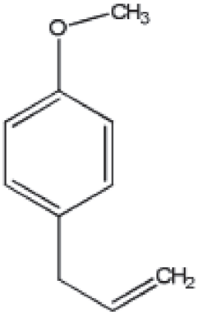
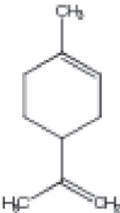
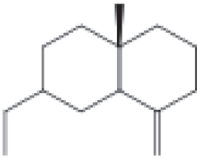
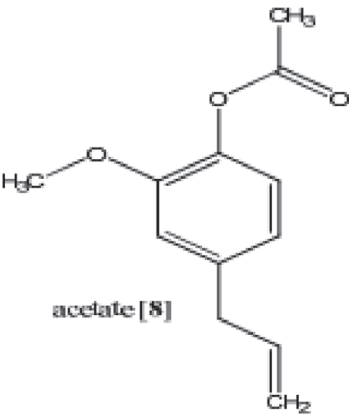
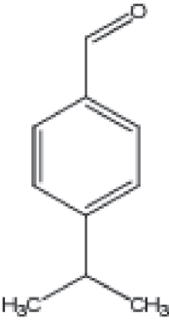
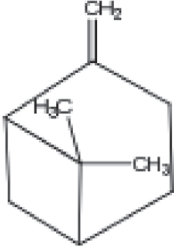
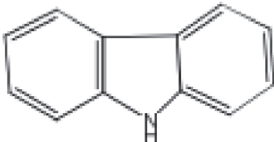
4. Bioactive compounds in herbs and spices

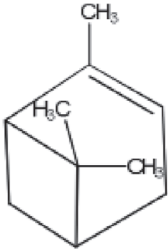
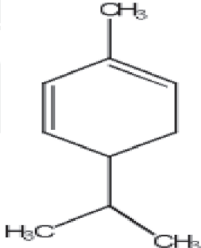
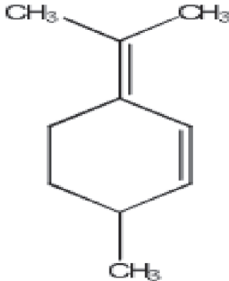
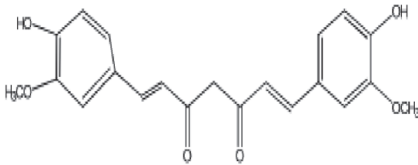
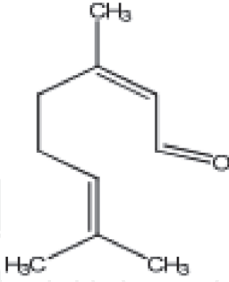
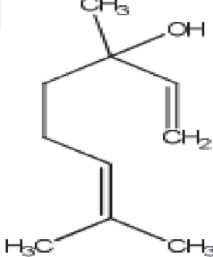
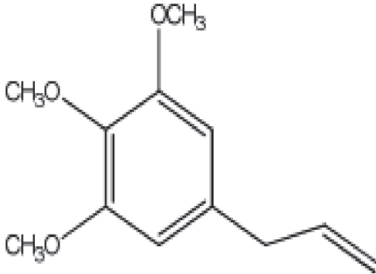
Bioactive compounds are produced as secondary metabolites in plants other than the primary biosynthetic compounds such as amino acids, proteins, carbohydrates, and lipids. The types of bioactive components that can be found in herbs include glycosides (e.g., saponins and anthraquinone glycosides), resins and phenol compounds (e.g., flavonoids, tannins and quinones). Some of these compounds are listed in **Table 4** and their structures in **Table 5**. The post-harvesting process of medicinal herbs is crucial in industrial production which affects the quantity and quality of the bioactive components [28].

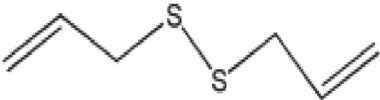
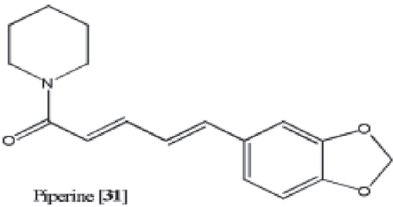
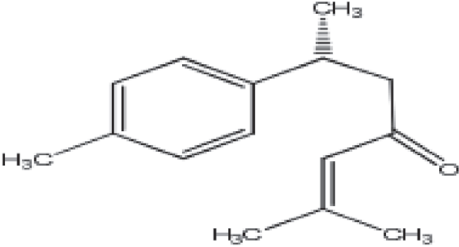
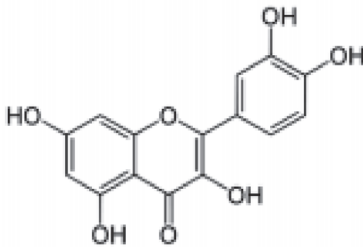
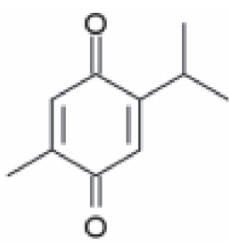
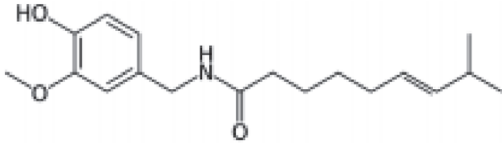
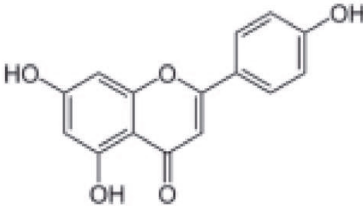
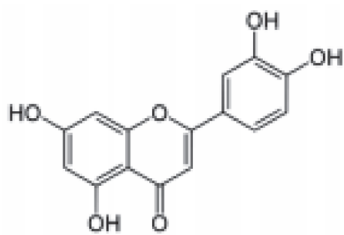
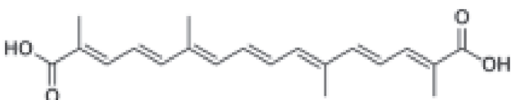
Name	Bioactive compounds
Turmeric herb	Primarily monoterpenes and phenolic compounds
Coriander (Spice)	Alcoholic monoterpene
Chilli (Spice)	Capsaicin
Cinnamon (spice)	Eugenol
Clove (herb)	Eugenol
Curry Leaf	Oxalic acid, resin, carbazole alkaloids and volatile oils
Fennel (herb)	Trans-anethole, p-coumaric acid and rosmarinic acid
Garlic (herb/spice)	Allicin, alliin, diallyl sulfide, diallyl disulfide, diallyl trisulfide, ajoene, and S-allyl-cysteine
Ginger (herb)	Phenolic and terpene compounds
Musterd (spice)	Methallyl cyanide
Pepper (spice)	Ascorbic acid, carotenoids, and other antioxidants

Table 4.
Bioactive compounds in herbs and spices (source: [5, 25–27]).

Herbs/Spices	Compound name	Structure
Basil	Eugenol	
	Thymol	

Herbs/Spices	Compound name	Structure
	Estragole	
Celery leaves	Limonene	
	b-selinene	
Clove oil	Eugenyl acetate	
Cumin	Cuminaldehyde	
	b-pinene	
Curry leaf	Carbazole	

Herbs/Spices	Compound name	Structure
	α -pinene	
	d-terpenene	
	b-phellandrene	
Ginger	Curcumin	
	Citral	
Nutmeg	Linalool	
	Elemicin	

Herbs/Spices	Compound name	Structure
	a-sulphinyl-disulphide	
Black pepper	Piperine	 Piperine [31]
Star anise	Turnerone	
Onion	Quercetin	
Fennelflower	Thymoquinone	
Red pepper	Capsaicin	
Parsley	Apigenin	
Oregano	Luteolin	
Saffron	Crocetin	

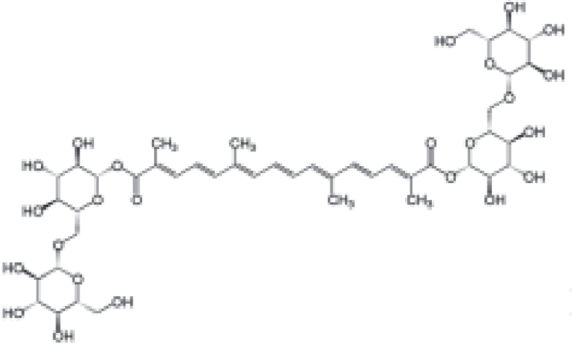
Herbs/Spices	Compound name	Structure
	Crocin	

Table 5.
Structures of bioactive compounds in herbs and spices (source: [5, 27]).

5. Innovative functionality and medical application of herbs and spices

5.1 Antibacterial and antifungal activities

Phytochemicals such as phenolics, carotenoids and organosulphur compounds present in herbs and spices function for antimicrobial activity. Clove, oregano, thyme, cinnamon, cumin, rosemary, garlic, ginger, basil, fennel, coriander and galangal have been reported for antibacterial and antifungal activity [29]. Antimicrobial activity of clove bud oils possesses antibacterial and antifungal properties owing to the high level of eugenol present in the essential oil [30]. Curry leaves also exert antifungal activity [31]. Coriander and cinnamon were also reported for antifungal activity against *Aspergillus parasiticus*, *Cladosporium cladosporoides*, *Eurotium herboriorum*, *Penicillium chrysogenum* and *Aspergillus carbonarius* [32]. Galangal is a food additive used in Thailand and some other Asian countries and has been reported for antibacterial activity against *Staphylococcus aureus* and *Listeria monocytogenes*. The synergistic effect of galangal, rosemary and lemon iron bark was also reported [29]. Extracts of roselle, clove and rosemary were reported for antibacterial activity against *Escherichia coli*, *Vibrio parahaemolyticus*, *Pseudomonas aeruginosa*, *Salmonella enteritidis*, *Bacillus cereus*, *Candida albicans* and *S. aureus* [33].

5.2 Antiviral activity

A number of herbs and spices have been reported for antiviral activity [34]. Antiviral activity of turmeric was observed and documented in different viruses such as hepatitis virus, corona virus, influenza, Human Immunodeficiency virus (HIV) and others [34, 35]. Turmeric targets different cellular pathways, which further inhibiting the growth, and replication of viruses and this makes it an ideal candidate as an anti-viral drug. Antiviral activity of curcumin was observed against different viruses including hepatitis viruses, SARS coronavirus, influenza viruses, human immunodeficiency virus (HIV), herpes simplex virus, dengue virus and chikungunya virus [36]. Utomo et al. [37] reported that curcumin binds and inhibits the target receptors including SARS-CoV-2 protease, spike glycoprotein-RBD, and PD-ACE2, which are involved in virus infection.

Garlic produces an enzyme called alliinase and this enzyme has antiviral activities. Antiviral activity of garlic extract has been studied against influenza virusA/H1N1 in cell culture and it was found that it inhibits the virus penetration and proliferation in cell culture [38]. In another study conducted by Shojai et al. [39], garlic extract showed inhibitory activity on infectious bronchitis virus in

chicken embryo. During the inception of COVID-19 pandemic, Ministry of AYUSH, India released an advisory of immunity and self-care of Ayurveda's spices [40]. This includes the use of spices such as turmeric, cumin, coriander, and garlic that are recommended in cooking. They have also advised taking herbal drinks, tea/decoction (kadha) made from basil, cinnamon, black pepper, ginger, and raisin once or twice in a day [40].

5.3 Anticancer activity

National Foundation for Cancer Research [41] mentions that herbs and spices are effective in the preventions and treatment of cancer. For decades, the National Cancer Institute and Memorial Sloan-Kettering Cancer Center in the United States have recognised the cancer preventive potential of herbs and spices from labiatae, zingiberaceae, and the unbelliferae family [10]. Some of the reported culinary herbs and spices for anticancer activities include basil, caraway, cardamom, clove, cumin, dill, garlic, ginger, rosemary, saffron and thyme [42]. Likewise, Wigutow [43] reported turmeric, ginger, cayenne pepper, saffron, oregano and garlic to be one of the good cancer fighters. Epidemiological studies suggest that a high intake of raw and cooked garlic may provide a protective effect against stomach and colorectal cancers [44]. A commonly available spice, Saffron (*Crocus sativus* L.), used as a food flavouring spice has also been thoroughly reported for its cancer preventive and tumoricidal properties [45]. Research over the last 50 years indicated that curcumin, a polyphenolic ingredient in turmeric, can prevent cancer, and can be used to treat cancer [46]. Flaxseeds also known as linseeds, usually sprinkled on cereals, salads and desserts as nutritional booster is also a good source of lignans known as "phytoestrogens", which are studied for chemo-preventive properties. Various studies have shown that garlic and organosulfur compounds, especially diallyl disulfide, can slow the development of cancers of the skin, oesophagus, stomach, colon, liver, lung and the mammary glands [47].

5.4 Antidiabetic activity

In all cases of diabetes, development of one or more complicated chronic diseases such as neuropathy, retinopathy, nephropathy and cardiomyopathy are common. Culinary herbs and spices have been found useful in the treatment of diabetes [48]. Curcumin, an active component of turmeric, was reported to ameliorate diabetic nephropathy in streptozotocin-induced diabetic rats [49]. Supplementation of turmeric in patients with overt type 2 diabetic nephropathy was also shown to attenuate proteinuria, IL-8 and can be administered as a safe adjuvant for these patients [50]. Cinnamon was also reported for its hypoglycaemic activity [51]. In addition, aniseed, bay leaf, cardamom, cinnamon, cumin, dill, ginger, hops, rosemary, saffron, sage have been examined in type 2 diabetes mellitus patients [52].

5.5 Antioxidant activity

Antioxidants can protect lipids and oils in food against oxidative degradation. When added to food, antioxidants control rancidity development, retard the formation of toxic oxidation products, maintain nutritional quality, and extend the shelf-life of products [27]. Natural antioxidants contained in spices help to reduce oxidative stress. Bakheit and Foda [53] determined the antioxidant activity of individual spices like black pepper, black cumin, and clove using (DPPH) free radical scavenging assay. Rosemary is one of the most effective spices widely used in food processing. It is the only spice commercially available for use as an antioxidant in

Europe and around the world [54]. Garlic has also been reported for antioxidant activity [55]. It has been documented by Wootton-Beard and Ryan [56] that natural antioxidant compounds are much effective than the synthetic compounds with regards to toxicity and carcinogenicity. Antioxidants help to defend human bodies by deterring the formation of free radicals chain reaction. Moreover, antioxidant compounds are responsible for preventing diseases including cancer, cardiovascular disease, Alzheimer's disease, and muscular degeneration [56].

5.6 Hypcholesterolemic activity

Hypercholesterolemia, commonly known as high blood cholesterol, is a major risk factor for the development of atherosclerosis and occlusive vascular disorders [57]. Therapeutic lifestyles such as low saturated fat and cholesterol diet, weight management, and increased physical activity are vital for blood cholesterol regulation. Spices and herbs have also been reported for cholesterol-lowering activity [58]. Scientific evidence from several animal models revealed that curcumin from turmeric and capsaicin from red pepper are potent hypocholesterolaemic and hypolipidemic agents [59, 60]. Spices have been shown to possess good nutrient benefits with low calories, possess good inhibitory profiles on carbohydrate modulating enzymes, ACE and HMG-CoA reductase, which correlates to their total phenolic contents, phenolic profile and antioxidant properties. Ahmed et al. [61] reported that spices belonging to the Apiaceae family, for example, cumin, coriander, fennel and dill, are rich in monosaturated fatty acids and contain a good amount of polysaturated fatty acids and thus have great hypocholesterolemic effect.

5.7 Anti-inflammatory activity

Different studies have demonstrated an association between the typical Western diet rich in refined starches, sugars, saturated and transfatty acids but poor in fruit, vegetables, fibre, ω -omega-3 fatty acids and whole grains, which causes an increased tendency toward inflammatory disorders and related diseases, such as cardiovascular diseases, arthritis, or diabetes [62]. These signs can be prevented by eating or cooking food with herbs and spices that have medicinal properties to combat inflammation. Prevention is better than cure and healthy eating should be promoted to prevent inflammatory symptoms [63]. That is why turmeric is traditionally used in India in the treatment of rheumatic disorder because of its anti-inflammatory properties [64]. Ginger also has anti-inflammatory effect and has been researched to be effective in ameliorating arthritis pain [65]. Other herbs and spices reported for anti-inflammatory potential are cinnamon, garlic, black pepper and clove [63]. Herbs and spices have also been reported as anti-inflammatory food supplements against COVID-19 as excellent sources of vitamin C, for example, thyme, coriander, turmeric and cardamom [66].

6. Recent application of herbs and spices

6.1 Flavouring

Although herbs and spices are low-cost commodities, they have been valued as gold or jewels for many centuries being utilised as food additives all over the world. Herbs and spices are basically used in enhancing the flavour of food [13]. The addition of herbs and spices to vegetables, salad and fruits can help to improve the

taste. Herbs and spices can be used as substitute for the less desirable taste promoters such as salt, sugar and fat. They generally add to appearance and smell of food [5]. African dishes such as jollof rice, soups and snacks as well as some drinks are flavoured using herbs and/or spices such as onion, chilli, turmeric, ginger, clove and tamarind [67]. Herbs such as basil, celery leaf, cumin, garlic also are important in African traditional snacks [5].

6.2 Preservatives

Green preservatives are becoming increasingly popular with new techniques of applications being developed [68]. Herbs and spices have been used to fortify foods throughout history not only as flavours but also as preservatives. Though used to enhance the organoleptic properties of food, they are also used in controlling natural spoilage by decreasing or eliminating foodborne pathogens thus increasing the shelf life [69]. Phenolic compounds present in herbs and spices are a major constituent responsible for their antimicrobial activity thus leading to preservation [1]. Chives, garlic, celery seed, tarragon, dill, black cumin, cinnamon, turmeric, cumin all have compounds functioning as preservatives in them [70]. Gallic acid, rutin and caffeic acid in black mustard, alicin and diallylsulfides in chives, garlic and eugenol in cinnamon prevent the growth of *E. coli* [71–73]. Capsicum in chilli pepper inhibits the growth of *Salmonella typhimurium* [74]. The antimicrobial efficacy of hydrosols of thyme, bay leaf, rosemary, sage and black cumin against *S. typhimurium* and *E. coli* has been reported [75]. Rosemary integration to rice cakes effectively inhibited *Bacillus cereus* and *S. aureus* [76]. The preserving function of herbs and spices can be linked to their antioxidant and antimicrobial activities [70, 77].

6.3 Dairy products

Antimicrobial properties of herbs and spices can be successfully used to control the growth of spoilage and pathogenic bacteria in dairy products. Phenolic compounds such as tea catechins, oleuropein, ferulic acid, ellagic acid and coumaric acid have been found to prevent the growth of some pathogenic bacteria (*S. aureus*, *S. enteritidis* and *L. monocytogenes*) and fungi [78]. Bakrm and Salihin [79] reported that addition of *Cinnamomum verum* and *Allium sativum* water extract in goat, cow and camel milk had no important effect on the acidification through fermentation. However, the presence of these two herbs in milk improved the proteolytic activity of the used cultures with the highest proteolytic activity gotten in cow milk yoghurt. Herbs and spices are also added to cheeses to impart unique flavours. These cheeses are regularly considered as specialty cheeses. Most spices impart specific flavours to cheeses, and some may affect the microbiological quality. Hamid and Abdelrahman [80] investigated the effect of adding 0.02% Cinnamon, Cardamom and Fenugreek powder to goat's milk curd after coagulation on the quality of the obtained white soft cheese. The additions of these spices enhanced the flavour and odour of goat's milk cheese. Herbs and spices also improved biological value and prolonged the shelf life of cottage cheese [80]. Black pepper, black cumin, and clove were also used to produce novel Mudaffara cheese [53]. Herbs and spices fortify dairy product acting as natural antioxidant, bio-preservative, improvement of sensory qualities while also functioning for nutritional and medicinal purposes [13]. Herbs-fortified dairy products are a good source of antioxidant [81].

6.4 Essential in water and drink fortification

The production of flavoured and fortified water is another area in which herbs and spices have found application [82]. Besides the regular function of water for distribution of nutrient and maintenance of electrolyte balance, functional water (flavoured and fortified) has added medicinal functions of preventing illness and diseases. Herbs alongside vitamins, minerals, and amino acids are the main components of these beverages [12]. Beet root, ginger, and red ginseng have been used in fortification of quite a number of beverages and drinks [83, 84].

6.5 Herbal cosmetics

Exposure of human skin to sunlight and other atmospheric conditions causes production of reactive oxygen species, which can react with DNA, proteins, and fatty acids, causing oxidative damage and impairment of antioxidant system. Beauty products made from herbs are tested and preferred for low toxicity, mildness, moisturising, and cleaning activities. Herbal cosmetics have recently gained ground and natural ingredients such as herbs and spices have been incorporated into skin care formulation either directly or their essential oils [15]. Botanical extracts are multifunctional in nature because they possess various properties like photoprotection, antiaging, moisturising, antioxidant, astringent, anti-irritant, and antimicrobial activity, which are correlated with each other [85]. Turmeric is effective for the treatment as well as prevention of psoriasis and other skin conditions such as acne, eczema, sun damage, wounds and premature ageing since it inhibits the activity of phosphorylase kinase [86]. Garlic possess anti-inflammatory effect which reduces the inflammation of acne. Garlic oils are also useful in controlling sores, pimples and acne [87]. Eugenol present in clove is useful in keeping the skin dirt-free also reduces redness and inflammation of acne. Ginger possesses cleansing and antiseptic compounds in it and thus keep the skin smooth and without blemish and is used in many cosmetics for skin health [15].

6.6 Pest control

A number of herbs and spices have been reported for insecticidal potential and essential oil from Cinnamon is an example of such. Extracted oil from stem bark, leaves and fruits of *Cinnamomum camphora* were found to possess great fumigant toxicity against *Tribolium castaneum* and *Lasioderma serricone* [14]. Black pepper has also been reported for pest control. Scott et al. [88] reports that black pepper offers a unique biopesticide material that can be used in controlling small-scale insect outbreaks and also reduce the likelihood of development of resistance. Basil, sage and lemon thyme have all been researched for insecticidal activity [89].

7. Current challenges in the use of herbs and spices

Although several herbs and spices have been reported for great medicinal and flavouring benefits, there are a number of challenges confronting their use. The current challenges in the use of herbs and spices include toxicity, allergy as well as quality and adulteration.

7.1 Adulteration

The detection of adulteration in herbs and spices is important for value assessment in order to mitigate the health problems caused by undeclared constituents [90]. Adulteration can be direct and intentional which involves the practice of partially or fully substituted constituents with inferior ones. Adulteration can also be unintentional resulting mainly from the absence of a proper evaluation method and/or clerical errors [91]. Reported adulteration of herbs and spices include the addition of dried pawpaw seeds with black pepper, red beet pulp and tomato waste to pepper powder, exhausted clove added to good ones, grass seeds added to cumin seeds, exhausted ginger added to good ginger, capsicum added to ginger powder, wild *Curcuma* spp. added to turmeric powder and lots more [92].

Techniques have been developed to counter alteration including physical methods such as macroscopic and microscopic analysis [93] or analytical methods including chromatographic techniques, electrophoresis, spectroscopy, chemometrics and hyphenated techniques [94, 95]. Biotechnological [96] and hybridization methods, polymerase chain reaction, immunological and biosensors assays can all be used in adulterant detection [92].

7.2 Toxicity and allergy

Quite a number of studies have revealed the cytotoxicity, carcinogenicity, neurotoxicity, genotoxicity and teratogenicity of phytochemicals derived from herbs and spices [97]. Capsaicin has been reported to cause neural and retinal degeneration [98] and increase blood ATL level [99] in experimental animals. Chilli peppers was reported to cause hypertensive crisis in a 19 years old male [100]. Singh et al. [101] reported the cytotoxic effect of cinnamon extract on human and mouse cell lines. Eugenol at 0.06% concentration was also reported to have toxic effect on human skin cells [102]. Although herbs and spices have been reported for several health benefits, their use also has side effects just as possible in other medicinal plants [103]. Therefore, it is paramount that attention is paid to their dosage. Generally, herbs and spices should be consumed with the knowledge of their existing side effects [104]. As stated by Stiller [105], people's allergic reactions to spices and herbs can be either Type IV or Type I reactions. Occupational contact dermatitis is the most experienced Type IV allergy while rhinitis, bronchial asthma, gastrointestinal symptoms, oral allergy syndrome and anaphylactic shock are the Type I allergies most experienced.

8. Conclusion

Herbs and spices are products obtained from plants which have been used traditionally for their flavour enhancement properties and have also been scientifically proven to possess medicinal properties. Bioactive compounds present in these plants are responsible for their health benefits when they function for anti-oxidant, anti-inflammatory, anticancer, antimicrobial and antiviral activities. Besides the general use of herbs and spices in flavouring dishes, they have also found application in enrichment of water, other drinks and dairy products. They have been used for preservation of food, production of skin care product and pesticides. It was also established that bioactive compounds such as eugenol, curcumin and essential oils of a variety of herbs and spices are of great important, however, there is a need for more in-vivo studies for better evaluation and toxicological properties of herbs and spices.

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