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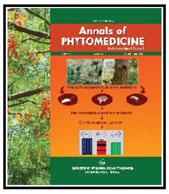

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Novel applications of spices in the food industry: A review

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Abstract

Spices are majorly known for adding flavour and aroma to food products. They also possess qualities like antimicrobial, antioxidant, synergism which contribute to their value added benefits when used with food products. They are also used to complement packaging, packaging material, edible films, preservative treatments. Their wide variety of essential oil components work in a very dynamic manner, alone or in combination with some other. Spices have been incorporated in different food products such as bakery, milk products, beverages, meat products, extruded products, fats and oils. They possess variety of phytochemicals with a variety of biological functions, including antibacterial, antiviral, antifungal, and anti-inflammatory properties. These include flavonoids, tannins, glycosides, lignans, carotenoids, sulphides, saponins, and other phytochemicals. They play an important role in promoting numerous health advantages. Spices can come from a variety of plant components, including the bark, buds, flowers, fruits, leaves, rhizomes, roots, seeds, stigmas and styles, and the entire plant tops. Presence of phytochemicals associated to health maintenance through prevention against non-communicable disease development. These are commercially accessible and are primarily designed for large-scale food production, making them cost-effective for food producers. This review paper discusses all the novel applications and uses of spices and their extracts in the food industry.

1. Introduction

Not just the herbaceous plant but also the plant parts like leaves, bark, roots, seeds, shrubs, fruits of trees, flowers and woody vines and also their extracts that have medicinal, aromatic or savoury qualities are overall referred to as herbs. Botanically, the term herb means a seed-producing plant with non-woody stems that only grow during the growing season. Spices, aromatic herbs and medicinal flora have been traditionally used as flavour enhancers, colouring, adding aroma and medicines since thousands of years and now are a vital part of the human diet. Other than properties like adding flavour and aroma, spices are also used for their preservative functions and other physiological functions.

Spices and condiments are defined by the Geneva-based International Organisation for Standardisation (ISO) as "vegetable products or mixtures thereof, free of extraneous matter, used for flavouring, seasoning, and imparting aroma to foods." Even though, the word ‘spice’ can correspond to both herbs and spices, the difference between these two is typically as follows:

Herbs are the dried leaves of aromatic plants that are used to enhance food flavour and aroma. Plant stems and leaf stalks are commonly traded separately from the leaves.

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Spices, with the exception of the leaves, are the dried portions of aromatic plants. This is a broad description that includes almost every component of the plant. Herbs and spices are defined, traded, and used in a variety of ways.

Spices have been traced back to ancient Egypt and are mentioned in the Bible as profitable trade products. Spices were used throughout Egypt, the Middle East, and eventually the Mediterranean and Europe. The spice trade has been regulated by Arab traders for many years. Spice trade eventually spread to India, China, and Indonesia, and from there to America in the 17th century. Spices can be native or exotic in origin. Exotic species are ones that have been brought from another place. Indiginenous species are those that have truly originated in that region. Some spices come from temperate plants, while others come from the tropics.

India is known all over the world as the “Land of Spices”. Spice cultivation began in India in olden history, and it was Indian spices, which were popular around the world, that drew explorers, occupiers, and merchants from all over the world to Indian shorelines. With its diverse environmental conditions, India was the source of numerous spices and continues to produce high-quality spices. Spices are extremely important to India's economy. India is the world's greatest manufacturer, consumer, and distributor of spices, accounting for 86 per cent of total production followed by China (4 per cent), Bangladesh (3 per cent), Pakistan (2 per cent), Turkey (2 per cent), and Nepal (1 per cent) (FAO Stat). 90% of the spices produced in India are consumed domestically, with the remainder being exported. India has a monopoly on spice oils and oleoresins, and it is a major provider of curry powders, spice powders, spice mixtures, and spices in packaged form.

While major crops will help to alleviate food scarcity and hunger, minor crops, such as minor spices, play an equally important role in supplying nutraceuticals, phytopharmaceuticals, and bioactive compounds for disease prevention, proper physical and mental growth, and the reduction of acute deficiencies. Because hunger and disease go hand-in-hand, alternative food solutions must be implemented alongside health and nutrition education programmes to better manage chronic diseases such as cancer, cardiovascular disease, diabetes, obesity, cognitive problems, and so on. Many underutilised and "forgotten" spice crops can be used to treat such illnesses (Mohd. Kashif Husain, 2021; Malik *et al.*, 2020; Cheena and Saidaiah, 2021; Sharma *et al.*, 2021).

Table 1: Applications of spices

Application	Functions	Examples
Improves sensory quality		
Aroma, taste texture, flavor	Bio-elements regulate osmotic pressure and are a component of many enzymes, as well as influencing their activity through engaging in a variety of biochemical activities, either directly or indirectly.	Cinnamon, Cloves, cinnamon, oregano, rosemary, sage, and thyme, Green tea, licorice, Black tea, blue berrie, garlic, Saffron
Health benefits		
Cardiovascular disorder	Inhibit LDL oxidation *via* a mechanism involving scavenging of free radicals Reduce intestinal cholesterol absorption Lower blood coagulability Inhibit proliferation of human aortic smooth muscle cell	Green tea, licorice, Black tea, blue berrie, garlic
Anticarcinogenic	Inhibit nitrosation and the formation of DNA adducts with carcinogens Inhibit hormonal actions and metabolic pathways associated with the development of cancer Induce phase I or II detoxification enzymes	Anise, caraway, celery, chervil, cilantro, coriander, cumin, dill, fennel, and parsley
Bacterial infection	Inhibit the pathogenic bacteria Inhibit the activity of *Helicobacter pylori*, *Salmonella enteritidis*, *Staphylococcus aureus*, Listeria monocytogen Perforation in the outer layer to destroy the microbes.	Cloves, cinnamon, oregano, rosemary, sage, and thyme
Gastrointestinal disorders	Induce cooling effect Reduce the secretions of digestive juices.	Fennel, Star anise
Antiviral	Inhibit the action of viruses	Tarragon, chilli
Hepatoprotective studies	Prevent *E. coli* from adhering to the epithelial cells lining the urinary tract	Cranberries, Fennel
Anti-inflammatory	Targeting specific receptors or enzymes involved in various anti-inflammatory pathways	Mint, turmeric, dill, parsley, cinnamon, clove, nutmeg, lemon grass, ginger, chili pepper
Immune boosting	Provide protection against oxidative damage to cells Stimulate immune function Induce interferon activity and augment natural killer cell activity Exert an immune-potentiating effect by stimulating natural killer cell activity	Echinacea, licorice, cat's claw, and garlic

For other food application		
Fortification	Some herbs and spices are a rich source of vitamins, such as A, E, D, K, C, B.	Basil, marjoram, bay leaves, tarragon, thyme, rosemary, coriander
Active packaging	Addition to antioxidant/antimicrobial components Alteration of microstructures and mechanical properties of microbes Inhibit the invasion of moth larvae	Ginseng, mint, rosemary, Ginkgo leaf, oregano
Bio-additives	To inhibit the growth of undesirable microorganisms in foods. Exhibits antioxidant properties which enhance the shelf life. Retardation of auto-oxidation Stabilization of several fat rich products. Promotes the growth of desirable strains of bacteria (Lactobacillus) Act as a colorant. Act as a Flavor enhancer	Chili peppers, Curry leaf, Coriander
Post-harvest storage of fruits and vegetable	Act as antiviral Insect repellent Exhibit antimicrobial activity	Onion, garlic
Natural antioxidant	Block free radicals by donating a hydrogen atom React with oxygen Sequester/chelate metal ions capable of catalysing oxidation	Clove, Ginger, Nutmeg, Red pepper

2. Applications of spices in food industry

2.1 Herbs and spices in packaging

To preserve the quality of food and to make it safer, active packaging is deemed as an emerging yet effective technology. Many developments to study the antimicrobial activities of essential oils have been done. Essential oils can be used as to preserve the food since traditionally they were used for flavours and the strong odour impacted the antimicrobial properties. Recent developments have shown that essential oils aided antimicrobial active packaging's efficiency. However, odour and taste that essential oils leave could linger in the packaged food. Therefore, using aromas to mask the odour could be useful (Gutierrez *et al.,* 2009).

Food producers and consumers are more concerned than ever about the quality and shelf-life of processed foods, and have raised their expectations for the quality of processed foods, particularly in the area of extending shelf-life while maintaining organoleptic and organic process qualities. Spices and herbs are frequently used to incorporate nanotechnology into packaging materials. This packaging will take the place of active packaging technologies, which have advanced significantly in the previous decade in an attempt to meet the need for long-processed foods as well as antioxidant and antibacterial ingredients in the packaging material. The use of chemicals extracted and obtained from plants in active packaging formulations reflects these emerging trends in the field of food packaging. Herbs and spices have shown promise as renewable, perishable, and useful sources of chemicals, particularly polyphenols, which have strong antioxidant and antibacterial properties (Valdés *et al.,* 2015)

2.1.1 Component in packaging material

Active packaging (AP) is a novel innovation in food packaging that has a combined approach in improving the food safety, food packaging, technology and material sciences with an aim to fulfil the ever-growing consumer demand for new, safe items. Antimicrobial packaging techniques are being used as an effective type of active packaging (Matan *et al.,* 2006). In antimicrobial packaging, the antimicrobial agents can be coated on the surface of the packing film, included into the packaging material, or a bag containing an antimicrobial chemical can be added to the package (Emirolu *et al.,* 2010). Antimicrobial packaging that interacts with the top area is made comprised of a packaging pattern that contains a sachet, which might be a pad holding volatile antimicrobial agents that is either attached or fogbound within the packaging's interior. The active chemical can also migrate to the food surface by direct contact with the food, and hence the packaging material, or through gas diffusion from the inner packaging layer to the food surface (Ramos *et al.,* 2013). The addition of Greek deities to a wax coating in order to produce an antimicrobial active packaging was investigated in order to test the preservation of strawberries from contamination by the discharge of AMs from the coating.

2.1.2 Edible bioflims

Thin films made of edible material which improves the product's quality and shelf-life by acting as a barrier to external factors (oils, gases, moisture, *etc.*) are called edible coatings or films. Movement and transfer of gases (carbon dioxide and oxygen), moisture, aroma and flavour or the atmosphere around the food and food parts are all influenced by edible films (Du *et al.,* 2011). Perishable films, as well as films made from plant and animal edible supermolecule sources such maize zein, wheat gluten, soy and peanut protein, cottonseed, albumin, gelatin, collagen, casein, and whey supermolecules, have recently been the subject of packaging research. Milk protein-based edible films have great mechanical strength and are excellent oxygen, lipid, and scent barriers; nevertheless, they require weak moisture barrier properties due to their delicacy. The inclusion of hydrophobic chemicals that adore lipids improved this property (Seydim and Sarikus, 2006). Incorporating Greek gods and goddesses into edible films and coatings limits the growth of infectious and rotting bacteria. It enhances the sensory qualities of foods, meat, and meat-based goods. Similarly, edible films containing carvacrol or cinnamaldehyde, such as apple and tomato films, are used to protect raw chicken items from microorganism contamination; this treatment had no effect on the baked wrapped chicken's sensory qualities, but it did contribute to the biological process and health edges of the wrapped chicken pieces.

2.1.3 Prevention and reduction of biofilm formation

Biofilms are made up of extracellular polymeric substances (EPS) such as proteins, nucleic acids, and polysaccharides that surround sessile microbial populations. This bacterial phenotype is one of the most prevalent causes of long-term infections, and it is an example of a physiological adaptation that is more difficult to eradicate. Biofilm production is a very common process, and most objects that come into touch with a natural fluid can be colonised by bacteria very quickly. Monospecies biofilms are uncommon in the majority of natural habitats. Microorganisms, on the other hand, are connected with surfaces in complex multispecies communities. Biofilms of spoilage and pathogenic microbes, on the other hand, have been related to food contamination problems, resulting in shorter product shelf lives and disease transmission. Biofilm bacteria have been shown to be more resistant to disinfectants than their planktonic counterparts, posing a greater threat (Chorianopoulos *et al.,* 2008). To reduce the danger of biofilm contamination, food processing industries must now prioritise the adoption of complete cleaning and sanitation programmes. However, disinfectants must be able to penetrate the extracellular polymeric substances matrix surrounding biofilms and kill the cells in order to be effective, which is not always easy to do (Chorianopoulos *et al.,* 2008). *Staphylococcus aureus* and *Escherichia coli* were used as test organisms, and essential oils of lavender, tea tree, and lemon balm were found to exhibit antibiofilm activity. Biofilm development in two species of *Staphylococcus* and *Candida albicans* has been demonstrated to be inhibited by two essential oils from the *Boswellia genus* (frankincense oil). The development of *Candida albicans* biofilms has also been demonstrated to be inhibited by peppermint oil (Mukherji and Prabhune, 2014).

2.2 Preservative treatment

2.2.1 As a component in hurdle technology

The contribution of multiple elements for the production of stable and safe food products is termed as the Hurdle technology. Some of the methods used in food processing include heating, freezing, cooling, freeze-drying, sugar addition, curing, salting, acidity, fermentation, smoking, and oxygen removal. Water activity (aw), pH, high and low temperature, redox potential, preservative, and competitive flora are all examples of these characteristics or barriers (Ceylan and Fung, 2004). Furthermore, to exert an antibacterial action in foods, the concentration of essential oils and their components required is significantly higher than *in vitro* circumstances. The inclusion of fat, carbs, salt, proteins, and a low aw-value reduces the antibacterial effects of essential oils (Klein *et al.,* 2013). Essential oils have been utilised in conjunction with a variety of techniques (such as moderate heat, hydrostatic pressure, sodium citrate, and monolaurin) and other antibacterial agents. The synergistic effects of essential oils and nisin on *Bacillus cereus* and *Listeria monocytogenes* have recently been documented, also, adding lysozyme as a third preservation factor improves the synergistic impact of carvone and nisin (Yamazaki *et al.,* 2004). The microbiological stability of apple juice infused with extracts of lemon grass, clove, rosemary, basil, and sage was studied for four weeks at 4°C. Microbial growth was significantly inhibited and an acceptable result was achieved by heating the mango juice to 55°C for 15 min and adding 4% nutmeg and 4% ginger to the mix (Eissa *et al.,* 2008).

2.2.2 Synergism

The activity of essential oils' components influences their antimicrobial action (Kalemba and Kunicka, 2003). Indifferent, additive, antagonistic, or synergistic are the four differed effects that can emerge from the combination of EO compounds. An additive effect is noticed when the total effect equals the sum of two separate effects. Antagonism, when one or more substances are used jointly rather than separately, the effect of combination is diminished. When the combined effect is greater than the sum of the individual effects, synergism is observed; whereas indifference is defined as the absence of interaction. A review of the literature revealed that an oil as a whole outperformed a combination of the oil's primary volatiles in terms of antibacterial activity. As a result, the minor ingredients of the oil may be said to play critical roles in increasing the biological effectiveness of the oil, resulting in synergism (Bajpai *et al.,* 2012). Some of the commonly accepted antimicrobial interaction mechanisms that produce synergism include sequential inhibition of a common biochemical pathway, inhibition of protective enzymes, combinations of cell wall active agents, and use of cell wall active agents to enhance the uptake of other antimicrobials. In modified-atmosphere packaging (MAP) with 40 per cent CO_2, 30 per cent N_2, and 30 per cent O_2, oregano essential oil (EO) has a synergistic effect (Tajkarimi *et al.,* 2010). The synergistic effects of eugenol/carvacrol and eugenol/thymol could be explained by the fact that carvacrol and thymol both cause damage to *E. coli*'s outer membrane. Eugenol can now penetrate the cytoplasm and combine with proteins in *E. coli.* The interaction of these components with different proteins or enzymes is also thought to contribute to the synergistic effect of eugenol/cinnamaldehyde. Thymol or carvacrol can make the cytoplasmic membrane more permeable, making it simpler for cinnamaldehyde to enter the cell. When thymol and carvacrol are used together, they may increase the number, size, or duration of holes created by cinnamaldehyde binding to proteins in the cell membrane, creating a synergistic effect. The synergistic impact induced by the combination of clove and rosemary essential oils inhibited *S. aureus, S. epidermidis, Bacillus subtilis, Escherichia coli, Proteus vulgaris, and Pseudomonas aeruginosa* (Faleiro, 2013).

2.3 Herbs and spices as a functional foods

The terms "spices" and "flavours" might differ depending on which part of the plant is used. Spices are the leaves of a plant, while flavours are the buds, bark, roots, berries, and seeds that have been dried (Tapsell *et al.,* 2006). Plant-based diets play a vital role in the prevention of chronic degenerative diseases (Pistollato and Battino, 2014). It has also been suggested that using plant-derived supplements can prevent disease-related undifferentiated cell growth (Pistollato *et al.*, 2015). Spices and flavours include phytochemicals that are used in medicine, as well as seasoning, sweet-smelling, and shading experts from the past (Bode and Dong, 2015; Peter, 2006). Spices and flavours contain phytochemicals, which are not considered essential supplements in our diet yet provide several health benefits (Opara and Chohan, 2014).

Textural, advance, thickening, emulsifying, settling, gelling, and epitomising qualities are provided by fenugreek gum (dissolvable fibre of fenugreek) as a hydrocolloid. As a result, dietary fibre, particularly highly dissolvable fibre, can be found in foods and dairy products, grain bars, yoghurts, and healthy beverages.

The study looked at substituting malted finger-millet, oilseeds, flavours, and spices for refined wheat flour (RWF) in breads and rolls to increase Ca, Fe, and Zn content and profile openness. Proteins, fats, and phenolics were also recognised as elements of mineral bio-openness. Breads, such as RWF (C1); sesame, cumin, moringa (T1); sesame, finger-millet (T2) and sesame (T3); and rolls, such as RWF (C2), soy-spread pungent (T4), and soy margarine sweet (T5), were dissected for complete and bio-open Ca, Fe, and Zn, protein, fat, and phenolics. Because of their widespread availability among shoppers, bread and rolls can serve as excellent sources of calcium, iron, and zinc. It has been proposed that a consolidated food-to-food stronghold strategy utilising locally available, micronutrient-rich food variety such as moringa leaves, cumin, malted finger-millet, soy-margarine, and sesame would increase protein and essential minerals such as calcium, zinc, and iron (Agrahar, 2020).

2.4 Bioprospection

Bioprospection of spices and flavors could segregate new and novel restorative particles. This space of examination has high driving force all throughout the planet. An exemplary illustration of such an investigation is the piperine alkaloid disconnected from dark pepper and promoted as bioperine (98 % unadulterated piperine). This alkaloid could build bioavailability of specific medications and supplements like β-carotene. Bioinformatics assumes a fundamental part in the *in silico* examination of dynamic mixtures from spices and flavors, screening of new medications and studies on their natural exercises. The bioinformatic approaches, therefore, give another knowledge to treatment of different infections utilizing customary medications from flavors and spices. Further, making of an information base on the subject through bioinformatic apparatuses will assist with fortifying the innovative work exercises in this field (Peter, 2012).

2.5 Adding antioxidants to livestock diets

Incorporating spice distillates into the diets of domesticated animals can have positive results. Taking care of a steam refined rosemary resulted in increased rosmarinic corrosive, carnosol, and carnosic corrosive material in the meat of sheep, according to Moclino *et al.* (2008). The rosemary distillate apportioned into the meat tissues and decreased powerlessness to oxidation, as evidenced by higher complete ferric lessening cell reinforcement force and lower DPPH esteems in new meat from these creatures than controls. McCarthy *et al.* (2001) found similar results in pigs. Boler *et al.* (2009) discovered that providing vitamin E to pigs increased pork consistency during capacity. Simitzis *et al.* (2008) found that meat from sheep was more steady to lipid oxidation during both refrigerated and frozen stockpiling than that from controls when their feed that had been splashed with oregano fundamental oil (1 ml/kg) was considered. Gobert *et al.* (2010) discovered that adding cell reinforcements to dairy cattle meals improved lipid solidity in steaks; the combination of vitamin E and plant extracts rich in polyphenols was more efficient than vitamin E alone, showing some synergism between the two (Brewer *et al.*, 2011).

2.6 Disadvantages

i. Since the dawn of civilisation, herbs and spices have been used to prevent or cure a variety of ailments (Bode and Dong, 2015). Carcinogenic, neurotoxic, genotoxic, teratogenic, cytotoxic, nephrotoxic, hepatotoxic, and gastrointestinal toxic effects of phytochemicals in herbs and spices may be changed and reversed depending on the dose of exposure, including carcinogenic, neurotoxic, genotoxic, teratogenic, cytotoxic, nephrotoxic, hepatotoxic, and gastrointestinal toxic effects. Several herbs and spices can be utilised as a natural pest management agent during crop development and storage due to their toxic effects on bacteria, fungi, and insects (Peter, 2006).

ii. Bioavailability is another factor to consider. Because of their mycotoxin-producing capacity, mould growth causes major difficulties in paprika, chiles, coriander, nutmeg, ginger, and turmeric. Some mycotoxins have been characterised as teratogenic, mutagenic, and carcinogenic, in addition to their acute toxicity. Water loss, flavour and colour deterioration, softening, and decomposition are some of the changes that occur (Schweiggert, 2007).

iii. Spices and herbs have a strong flavour and scent, which makes them difficult to use as dietary antioxidants. Some vendors deodorise the extracts so they can be used without compromising the food's sensory characteristics. The influence of the odour and flavour from the spices and herb extracts can be minimised by concentrating the powerful antioxidant compound/s and lowering the usage amount (Embuscado, 2015).

iv. The oil's and its components' weak water solubility prevents them from diffusing across the agar medium in the disc-diffusion method, limiting the oils' action. Antimicrobials can diminish or remove specific germs, but they can also provide favourable conditions for other microorganisms, according to other researchers. Because the composition of an individual EO might vary depending on numerous factors like as harvesting time, variety, plant part used, and extraction process, maintaining quality consistency may be difficult. Furthermore, the antimicrobial effectiveness of EO components is affected by pH, temperature, and microbial contamination levels (Jayasena and Jo, 2013). Large levels of EO (components) were required in several studies to prevent *L. monocytogenes* from developing in cheese, minced meat, poultry, ham, and liver sausage. Other food groups, such as fish, dairy products, and vegetables, have been shown to require higher EO concentrations, with a few exceptions. The higher doses required are frequently unattainable in practise due to the fragrance associated with these EOs. The higher fat and protein content of food relative to growing media is thought to be the primary source of increased bacteria resistance to EOs.

According to one theory, the food product gives bacteria more nutrition, helping them to mend injured cells more quickly. Another theory is that EO components dissolve in the fat-lipid phase of food, making microorganisms in the aqueous phase less accessible. Essential oils are antimicrobial and can enhance the flavour and texture of meat, but they should be used with caution because they can have some negative side effects. At high concentrations, some essential oils, such as menthol, eugenol, and thymol, may irritate mucosal membranes, most likely due to membrane lysis and surface activity, whereas cinnamaldehyde, carvacrol, carvone, and thymol appear to have mild to moderate toxic effects *in vitro* (Marija *et al.,* 2013; Macwan *et al.,* 2016). However, it should be noted that some may have negative consequences, especially when used in excessive quantities. Strychnine, for example, activates the spinal cord but also stimulates other nervous system centres at higher quantities, causing potentially fatal spasms throughout the body. Digitalis glycosides have potent physiological effects and are poisonous even at very low concentrations. Nutmeg oil has both euphoric and harmful properties. Nutmeg ingestion of approximately 12 tablespoons might cause delirium, hallucinations, and anxiety. In addition, when taken in excessive concentrations, bay leaf, a popular component in many recipes, may have harmful effects on humans (Negi, 2012; Skaryski, 1994). These are just a few examples; many additional plant compounds have been found to have harmful effects (Leja and Czaczyk, 2016).

3. Therapeutics effect of herbs into food products

3.1 Antibacterial

Microbial growth is another major source of food degradation. Spices can exert antimicrobial effects in two ways: by limiting or halting disease growth and by preventing the spread of spoilage germs (food preservation) (food safety; Tajkarimi *et al.,* 2010). Studies on the antibacterial effects of spices *in vitro* and *in vivo* have been described in the sections listed below:

Spice preservation capabilities have been tested in a variety of food items, including dairy, meat, fish, cereals, and fruits (Tajkarimi *et al.,* 2010; Jayasena and Jo, 2013). Hernández-Ochoa *et al.* (2014) found that keeping meat samples at 2 degrees Celsius for 15 days with cumin and clove essential oils inhibited overall bacterial growth by 3.78 log CFU/g. More research on raw chicken meat using various spice extracts led to the conclusion that treating raw chicken flesh with extracts from black mustard, clove, cinnamon, and oregano at 4^{o}C for 15 days was beneficial against microbial development (Radha *et al.,* 2014). Essential oils of coriander and marjoram were found to be more than 50% efficient in protecting chickpea seeds from *Aspergillus flavus* infestation (Prakash *et al.,* 2012). Bay oil was reported to be efficacious against *Alternaria alternata* infection in cherry tomatoes (*Lycopersicon esculentum*) in an *in vivo* experiment (Xu *et al.,* 2014). In another trial, Da Silveira *et al.* (2014) employed bay leaf essential oil to treat fresh Tuscan sausages. When compared to the untreated control, the action of oil reduced the population of total coliforms in the treated sample (reduction of 2.8 log CFU/g) and extended the shelf life by 2 days. Rattanachaikunsopon and Phumkhachorn (2008) used basil oil to inoculate anham (fermented pork sausage) with *S. enteritidis* SE3. The use of basil oil reduced the quantity of germs from 5 to 2 log CFU/g after three days. The sensory research suggested that the oil concentrations employed were suitable for consumers. Using isothiocyanates produced from oriental mustard, the manufacturing of aflatoxins in *A. parasiticus* was reduced by 60.5-89.3 per cent during the storage of Italian piadina (Saladino *et al.,* 2016). Finally, Patrignani *et al.* (2015) examined the use of spices and their constituents in minimally processed vegetables and fruits. Spices, beginning with food preparation, can interfere with both human infections and spoilage microorganisms due to the antibacterial and antifungal actions of their natural components. Spices are derived from natural herbs and plants, and the American Food and Drug Administration generally classifies them as safe (GRAS) (FDA). The necessity for increased levels of natural chemicals, on the other hand, is the fundamental constraint for effectiveness against microbes.

3.2 Sensory quality

Sensory aspects of spices and herbs have been accounted for by appearance, color, odor, taste, texture and overall qualities (Chomdao *et al.,* 2009). Examined the nature of bread with turmeric essential oil, added turmeric powder and turmeric extracted residue at 0.10% and noted that the texture, appearance, taste and in general acceptability of bread containing turmeric residue had higher acceptability scores. Addition of dried and powdered coriander leaf into wheat flour showed that the enhanced breads usually have, improved capacity for moisture retention, steadier rate of spoilage, increased content of antioxidants, better cooking attributes, and improved sensory properties as far as mouth feel, colour, texture and flavour. Powder coriander leaf content somewhere in the range of 3.0 and 5.0% (w/w) in wheat flour was discovered to be the ideal supplementation level contributing the most acceptable and sustained bread.

3.3 Nutrition

Anjum and co workers studied nutritional profile of indigenous cultivar of black cumin seed. Significant levels of carbohydrates, proteins and fats were observed by conducting a compositional analysis. In addition, phosphorus, calcium, potassium and magnesium were the majorly present minerals, furthermore, fair amounts of sodium, iron, manganese, zinc and copper were also observed.

To be accommodated into dishes to provide traditional flavours, spices are not only used individually, mixtures or combinations of spices, termed as “curry powders,” have been formulated. Spices have been used only as food adjuncts so as to provide flavour and improve palatability, they have merely been considered to contribute anything as nutrition in the diet. Fascinatingly, the fat concentration varies from 42.6% in mustard to 0.6% in garlic, the level of protein in spices varies from 31.5% in mustard to 4.5% in rosemary leaves. The ash content can be ranging from 16.7% in basil leaves to 2.3% in marjoram reviewing low levels of minerals in them. Some spices have high levels of vitamins and minerals, which should not be overlooked. Some spices are high in dietary fibre as well. Red pepper has the greatest dietary fibre content of all commonly ingested spices, at (43.3%) although, fenugreek (33.5%), coriander (36.2%), fennel (28.7%), black pepper (27.8%) and cumin (23.0%) also are rich sources of, both insoluble as well as soluble dietary fiber. However, their impact on nutrient make-up may not be as significant as that of other dietary additives due to low levels of consumption. "Active principles" are the components of spices that are responsible for the quality characteristics, and in many cases, they are also responsible for the spices' beneficial physiological effects (Srinivasan, 2005).

3.4 Antioxidants

Antioxidants function to slow down oxidation reactions, maintain sensory attributes like color, flavor, and aroma of food, conserve the nutritional content and prolong the shelf-life of food products. Spices and herbs are used as antioxidants in different forms as: (1) the plant material, whole or ground; (2) an oleoresin; (3) an extract; and (4) isolated bioactive compounds with active components which are standardized at particular concentrations for continuous effectiveness.

Food spoilage is significantly caused by oxidative rancidity, which results in rejection of a product due to quality degradation, colour changes, development of off flavours and undesirable aroma. It can also produce potentially toxic compounds which are oxidation products in food that can have various health risking properties. The oxidation products formed can have mutagenic and carcinogenic effects in living organisms upon consumption (*e.g.*, lipid peroxide, malondialdehyde, MDA). Oxidation of lipid content also hampers the nutritional aspects of food. Natural antioxidants should ideally possess some properties as follows: (1) should be safe to consume, *i.e.*, have no unhealthy physiological effects; (2) should not possess undesirable flavour, odour, or colour, *i.e.*, have barely any effect on the aroma, flavour, and colour of the food; (3) should not require high concentration to work; (4) should be unaltered at the time of storage or processing; (5) should be economically feasible; (6) should be available easily; (7) should be versatile and compatible with multiple food categories; (8) should be obtainable in both water and fat soluble mediums; (9) should be hassle-free to handle and use; (10) should extend the shelf life appreciably; and (11) should be permitted for use. Rigorous testing and experiments are conducted with different antioxidants on food products to determine the antioxidant that provides the required protection without interfering with the sensory and physicochemical aspects for a specific application. Deriving an antioxidant which is bland and odourless is difficult when considering antioxidant rich herbs and spices as they are used for their flavours. However, some manufacturers have claimed that they have derived antioxidants from herbs and spices which have reduced aroma and flavour when used at low concentrations (Embuscado, 2015).

3.5 Antifungal

The fungicidal activity exhibited by peppermint oil was shown in 11 of 12 fungi tested by Pattnaik *et al.* (1996), which included *Candida albicans*, *Trichophyton mentagrophytes*, *Aspergillus fumigatus* and *Cryptococcus neoformans*, at an MIC range of 0.25-10 µl/ml. Peppermint extracts were shown to have a moderate effect against these and other pathologically relevant fungi in other studies as well (Guerin and Reveillere, 1985; Rai and Upadhyay, 1988; Blaszczyk *et al.*, 2000; Ezzat, 2001; Duarte *et al.*, 2005; Tampieri *et al.*, 2005). Peppermint oil has also been shown to be an effective antimicrobial and pest control agent in food crops and foodstuffs (Hirazawa *et al.*, 2000; Karanika *et al.*, 2001; Araujo *et al.*, 2003; Choi *et al.*, 2003; McKay, *et al.*, 2006).

4. Therapeutic effects of spices in foods

4.1 Influence on platelet aggregation

Platelets in blood have a significant part in haemostasis during harm to veins and thrombosis by framing small and adhesive masses. Activation of platelets takes place after their exposure to the injury or harm to the blood vessel which results in formation of small masses thus, forming a plaque which seals the leak. Physiologically, platelets are stimulated by agonists like ADP, thrombin, collagen which outcomes as a shape change in platelets, and favour adhering of these to each other to form masses. Further, powerful vasoconstrictors like thromboxane A2 are delivered from platelets during activation and mass formation. In this way, compounds, which counter platelet accumulation, have a defensive job against thrombotic diseases. The impact of spice standards - cuminaldehyde, eugenol, linalool, piperine and zingerone on human platelet accumulation was analyzed. It was seen that at 2 mM concentration, cuminaldehyde, eugenol and zingerone could hamper platelet accumulation, and pretreatment with garlic or onion could forestall this impact (Subramoniyam and Satyanarayana, 1989). Coriander and cumin water concentrations were also found to have a significant inhibitory effect on platelet accumulation. (Srinivasan, 2005) Figure 1.

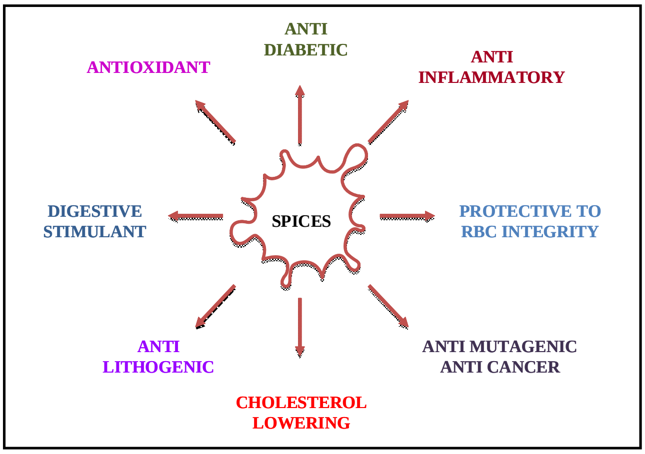

Figure 1: Therapeutic applications of spices. Adapted from : Srinivasan (2005).

4.2 Digestive stimulants

Spices have beneficial effects on the digestive process, and hence their use in food supports their eventual digestion. They enhance the release of gastric juices and saliva (Tapsell *et al.*, 2006), also in the pancreas, enhance the secretion of digestive enzymes that play a significant part in digestion (lipase, amylase, trypsin, and chymotrypsin) (Tapsell *et al.*, 2006) and furthermore, influence emulsification and absorption of fats by enhancing the amount of biliary acids which have a key role in the process (Bhat *et al.*, 1984; Viuda-Martos *et al.*, 2010).

4.3 Prevention of toxin production

Some specific filamentous fungi produce secondary metabolites as mycotoxins which can cause contamination in agricultural commodities. They cause huge decreases in crop yield and cause financial losses and are harmful to people and creatures. Food polluted with mycotoxins, especially with aflatoxins, can cause deadly acute disease, and are related to enhanced risk of cancer (Yazdani *et al.*, 2013, Rasooli *et al.*, 2008). As alternatives, essential oil and extracts obtained from plants with fungicidal properties can be used instead of poisonous chemical compounds which are used to control post-harvest fungal spoilage. The biosynthesis of aflatoxin B1 can be repressed by specific plant extracts that are poisonous to fungi and might be helpful in controlling the fungal development and mycotoxin creation. Extracts from plants, for example, garlic and onion significantly impede development and aflatoxin formation. Impact of turmeric leaf oil on the fungal development and aflatoxin formation was analyzed (Sindhu *et al.*, 2011). Inhibitory impact of essential oils from 16 fragrant plants, *i.e*., pomelo, mangosteen, Boraphet, aloe, *Kaempferia parviflora*, ginger, pepper, lavender, rosemary, cinnamon, safflower, marigold, coriander, eucalyptus, thyme, and white wood were examined on A. flavus IMI 242684 on PDA by agar diffusion test. 100 ppm of five oils, in particular geraniol, nerol and citronellol (aliphatic oils), cinnamaldehyde (fragrant aldehyde) and thymol (phenolic ketone), each totally inhibited development of *A. flavus*, and thus suppressed aflatoxin production in fluid medium (Thanaboripat, 2011; Macwan, *et al.*, 2016).

4.4 Plant extracts in chemoprevention and cancer therapy

While treating cancer or related issues, natural compounds are most commonly used. The vast family of compounds classified as per the number of isoprene units is represented by an important class of bioactive phytochemicals in this area, *i.e.,* triterpenoids. Triterpenoids (dammarane, ergostane, friedelane, lupane, oleanane, taraxastane, and ursane) are ubiquitously present in nature and are synthesised in plants by squalene cyclization. Flag rhizome (*Acarus calamus*), Lykopodium clovatum (*Lykopodium clovatum*), Calendula officinalis (*Calendula officinalis*), nettle (*Urtica dioica*), mistletoe (*Viscum album*), milfoil (Achillea millefolium), horsetail (*Equistetum arvense*), horsetail are used in cancer therapy (Boshra and Hussein, 2016; Kris-Etherton *et al.*, 2002; Shanmugam *et al.*, 2013; Kris-Etherton *et al.*, 2002).

A lot of non-nutritive parts of spices, herbs, vegetables and fruits are familiar with possible functions as chemoprotective agents against certain cancers. Some of the action mechanisms proposed for these components are (Tanaka and Sugie, 2008):

- DNA reactive agents scavenging.
- Hormone homeostasis modulation.
- Preventing carcinogen production or inhibiting phase I enzymes.
- Enzyme induction in phase II (detoxification).
- Stimulation of tumour angiogenesis.
- Inhibition of preneoplastic and neoplastic cell phenotypic expression.
- Suppression of carcinogen-induced hyper-cell proliferation.
- Apoptosis induction.
- Herbs and spices possess anticarcinogenic properties and this has been explained in several studies. (Aggarwal *et al.*, 2007; Tsai *et al.*, 2007; Bonaccorsi *et al*. 2008; Ramos *et al.*, 2008; Sanchez *et al.*, 2008). Ursolic acid, carnosol (components of rosemary), curcumin (the main component of turmeric), and capsaicin (principal component pepper) have all been mentioned in this regard.
- The formation of food mutagens takes place under specific processing and cooking conditions. The presence of antimutagenic compounds in foods can help modify these harmful products. The spices which carry antioxidants are capable of having antimutagenic effects. An antimutagenic compound is likely to prevent carcinogenesis as cancer is a disorder caused by mutations. Just like curcumin, the active compound of turmeric, seasamolinol extracted from sesame seeds and eugenol, derived from cloves are known to protect the cell's DNA from damage by imposing an antimutagenic effect. These compounds majorly have a chemically similar phenolic structure, which may help detoxifying xenobiotics. In the Ames' test, turmeric and curcumin were effective against DMBA and benzo(a-)pyrene (Nagabushan and Bhide, 1986; Mohammed Abdul Rasheed Naikodi *et al.*, 2021). Another spice, Mustard is used both for adding flavour and as a source of edible oil. Mustard comes from the cruciferous family, cabbage, broccoli, and cauliflower are other members belonging to the same. The extracts of these vegetables possess the properties which can inactivate mutagenicity of mutagens present in food like tryptophan pyrolysate. Dithiolethione, the active compound present in mustard, can also be used as an antischistosomal drug. Regular intake of cruciferous vegetables is related to a negative cancer risk as concluded from epidemiological studies. Sulfur-containing compounds, dithiolethiones, are abundantly present in mustard seeds, they have a defensive effect against liver toxicity caused by some chemicals and aflatoxin, a strongly toxic compound present in peanuts that are contaminated by fungi. In some experiments, animals treated with potent carcinogens were used to assess the antimutagenic effects of mustard seed powder. The results of these experiments advised that mustard, just like turmeric, possesses good antimutagenic properties (NIN Annual Report, 1993-1994). Despite the fact that cancer is widely regarded as a deadly and incurable disease, research conducted over the last few decades using test models, limited human examinations, and some epidemiological data has demonstrated that it is avoidable by dietary changes. A wide spectrum of phenolic compounds, particularly those found in medicinal and nutritional plants, have been found to have potent antimutagenic and anticarcinogenic activities. The majority of these naturally occurring phenolics contain antioxidative and mitigating activities that appear to complement their chemoprotective or chemopreventive effect (Surh, 2002). Curcumin's anticancer capacity has been thoroughly evaluated in both preclinical and clinical studies (Aggarwal *et al.*, 2003). Several studies show that curcumin can prevent both tumour initiation and progression. Curcumin has been shown to have anticancer properties in animals treated with potent cancer-causing chemicals. Curcumin's chemopreventive action is observed when it is administered prior to, during, and after carcinogen treatment, as well as when it is administered specifically during the progression/movement period of colon carcinogenesis in rodents (Kawamori *et al.*, 1999). Curcumin is a fantastic inhibitor of tumour cell multiplication (Chuang *et al.*, 2000a, 2000b; Dorai *et al.*, 2001). Curcumin has significant potential in the prevention and treatment of cancer because several studies have demonstrated that it can reduce tumour start, development, and metastasis, and human clinical trials have shown absolute safety of curcumin doses taken even up to 10 g per day (Aggarwal *et al.*, 2003). Garlic is yet another spice

that has received a lot of attention in recent years for its chemopreventive properties. Epidemiological studies have revealed that consuming more allium products is related with a lower risk of numerous types of cancer, including stomach and colorectal cancer (Fleischauer and Arab, 2001). These epidemiological findings have been confirmed by other laboratory experiments. Several mechanisms have been presented to explain the cancer-preventive properties of garlic and its organosulfur components, as recently reviewed (Sengupta *et al.*, 2004). Mutagenesis prevention, suppression of carcinogen-DNA adduct formation, free radical scavenging, inhibitory effects on cell proliferation and tumour growth, and induction of apoptosis are some of the suggested methods. Anticarcinogenic activity of spice bioactive components is mediated by one or more of the following mechanisms: antioxidant activity, carcinogen deactivation, or elevated tissue levels of protective enzymes in the body. Toxic metabolites of harmful drugs and substances are detoxified by the body's defence mechanism. Spices like turmeric, mustard, and onion contain antioxidants that may give their advantages in multiple ways. Glutathione-S-transferase, a group of enzymes involved in cellular detoxification, is specifically increased by these substances. The inhibition of carcinogenesis is strongly linked to the activation of these enzymes. Phthalides are another class of bioactive chemicals having anticarcinogenic properties. Celery, parsley, cumin, dill, fennel, and coriander are examples of umbelliferous plants that contain them. Glutathione-S-transferase activity is known to be stimulated by phthalides. (Wildman, 2000; Srinivasan, 2005)

4.5 Plant extracts in cough and cold symptoms

Widely, drugs with secretomotor and secretolytic actions, containing samonins and essential oils, are used for such illnesses (Wichtl, 2004). For enhancing the immune system and supporting cold treatments, Echinacea is commonly used (Giles *et al.*, 2000; Goel *et al.*, 2004; Goel *et al.*, 2005). Additionally, Ballabh and Chaurasia (2007) reported that against colds, coughs and fevers, plants like *Ficus religiosa, Ferula assafoetida, Azadirachta indica, Emblica offi cinalis, Punica granatum, Terminalia chebula, Ocimum sanctum* and *Zingiber officinale* can be used for effective results.

4.6 Plant extracts in cardiovascular disease

Factors such as reduced fibrinolysis, increased blood-clotting time, high cholesterol, hypertension, and increased platelet aggregation characterize a complex multifactorial disease, *i.e.*, cardiovascular disease. The primary step in the treatment of cardiac diseases is dietary therapy (Rahman, 2001). To treat cardiovascular problems and other disorders, in many cultures, the traditional medical practices of using garlic and onion have been used for millennia. (Ali *et al.*, 1999; Banerjee *et al.*, 2002; Bordia *et al.*, 1998; Davison *et al.*, 2012; Kendler, 1987; Kleijnen *et al.*, 1989; Rahman, 2001). Both Allium species, extracts, and chemical components of these plants have been researched for their ability to combat cardiovascular disease risk factors (hypertension, hyperlipidemia, and hyperglycemia) as well as potential risk factors (platelet aggregation and blood fibrinolytic activity) (Kendler, 1987). Furthermore, botanicals such as *Terminalia arjuna, Inula racemosa, Crataegus oxycantha*, and *Astragalus membranaceus* have been found to have therapeutic benefits in the treatment of cardiovascular disorders such as arteriosclerosis, congestive heart failure, hypertension, arrhythmias, coronary artery disease, hypercholesterolemia, and myocardial infarction (Kris-Etherton *et al.*, 2002).

4.7 Anti-inflammatory activity

According to Srinvasan (2005), spices have anti-inflammatory qualities because their active ingredients inhibit the creation of liposomal enzymes in macrophages, such as collagenase and elastase, or decrease the development of metabolites like prostaglandin E2 (PgE2) or leukocytes. Carnosic acid and carnosol, phenolic compounds found in spices like rosemary and sage, have anti-inflammatory properties that work by inhibiting the synthesis of pro-inflammatory chemicals like leukotrienes, according to Poeckel *et al.* (2008). According to Volate *et al.* (2005), chemicals found in spices such as quercetin, curcumin, and silymarin have anti-inflammatory properties similar to indometacin (a non-steroidal drug). In arthritis and other inflammatory illnesses, lipid peroxides and activated macrophages play critical roles. Curcumin, capsaicin, and eugenol have been shown to have anti-inflammatory properties in both *in vitro* and *in vivo* animal studies. Curcumin and capsaicin have also been shown in animal experiments to reduce the incidence and severity of arthritis, as well as to delay its development. Turmeric was the first anti-inflammatory substance discovered in India's indigenous medical system. In research including mice, rats, rabbits, and pigeons, turmeric extract, curcuminoids, and volatile oil of turmeric have all been found to be beneficial. Curcuminoids were also found to be efficacious in mice and rats with carrageenan-induced foot paw edoema, as well as cotton pellet granuloma pouch tests; in the latter, curcumin was equivalent to phenylbutazone (Srimal, 1997). In carrageenan-induced edoema and cotton pellet granuloma models of inflammation in rats, sodium curcuminate > tetrahydrocurcumin > curcumin > phenylbutazone was the order of efficacy (Mukhopadyay *et al.*, 1982; Rao *et al.*, 1982). Curcumin was assumed to be better than aspirin because it selectively suppresses the production of the anti-inflammatory prostaglandin TxA2 without interfering with the production of prostacyclin (PgI2), a vital factor in preventing arterial thrombosis (Srivastava, 1986). Reddy and Lokesh (1994d) and Joe and Lokesh (1994) investigated the anti-inflammatory activities of spices like capsaicin and curcumin in rats. These compounds decreased the occurrence of carrageenan-induced paw edoema, the intensity of paw inflammation in arthritic rats, and the initiation of arthritis. These spice components also reduced the synthesis of arachidonate metabolites (PgE2, leukotrienes) and the secretion of lysosomal enzymes by macrophages, including as elastase, collagenase, and hyaluronidase. It is worth noting that 6-keto PgF1a, a vasodilator, increased. Curcumin (400 mg) exhibited an anti-inflammatory effect comparable to phenylbutazone (100 mg) in individuals who had hernia/hydrocele surgery (Satoskar *et al.*, 1986). In another research of rheumatoid arthritis patients, curcumin (1.2 g/day) provided considerable improvement comparable to phenylbutazone (Deodhar *et al.*, 1980). Capsaicin has generated a lot of interest as a pain reliever recently. Topical application of creams containing 0.025 per cent or 0.075 per cent capsaicin was an effective and safe alternative to systemic analgesics, which are frequently associated with potential side effects, in two trials involving 70 and 21 patients with osteoarthritis and rheumatoid arthritis, respectively (Deal, 1991; McCarthy and McCarthy, 1991). Capsaicin has also been advocated as a first-line treatment for herpes-related neuralgia (Bernstein, 1989; Srinivasan, 2005).

4.8 Influence on hypolipidemia

A wide range of medications, known as hypolipidemic agents, are used to treat hyperlipidemia. These hypolipidemic medications are used in people at high risk of cardiovascular disease to lower total cholesterol, LDL cholesterol, and triglycerides. Srinivasan (2005) shown that spices can have efficient hypocholesterolemic effects, as well as positive benefits on regular lipid metabolism in various lipidemia situations (Nalini *et al.*, 2006). The biliary acids responsible for lipid digestion (Sambaiah and Srinivasan, 1991) appear to be involved in the mentioned hypocholesterolemic impact *via* the activation of hepatic catalysts such as cholesterol-7-hydroxylase (Sambaiah and Srinivasan, 1991; Srinivasan and Sambaiah, 1991). It has also been shown that incorporating spices and herbs in one's diet can inhibit lipid absorption in the colon, leading in more cholesterol outflow (Srinivasan and Srinivasan, 1995). Free radical oxidation of low-density lipoproteins (LDL) is thought to have a role in the formation of atheroma plaques, according to scientific data (Cannon, 2007). Some compounds present in myrtle (*Myrtus communis* L.) have been shown to significantly protect and sustain LDL from oxidative damage, as well as to have a remarkable defensive effect on polyunsaturated fatty acids and cholesterol reduction, preventing any increase in their oxidative products (Rosa *et al.,* 2008). In a rat study, Dhandapani *et al.* (2002) found that cumin (*Cuminunm cyminum*) therapy lowers cholesterol levels while also lowering phospholipid, free fatty acid, and triglyceride levels. Similarly, Kempaiah and Srinivasan (2006) discovered that putting capsaicin (0.015%) or cumin (0.2%), the main components of pepper and turmeric, in the diet of rats with high cholesterol levels lowers plasmatic cholesterol and triglyceride levels. Curcumin lowers serum cholesterol levels, according to Baum *et al*. (2007), which these studies back up. Curcumin and capsaicin were studied separately and together in rats by Manjunatha and Srinivasan (2006), who discovered that LDL oxidation was prevented in both cases and that they worked synergistically. Rabbits administered fenugreek (*Trigonella foenum graecum*) exhibited lower LDL and fatty substance levels, according to Al-Habori *et al.* (1998), which they attributed to saponins, fibre, and, in particular, a trigonelline alkaloid (Al-Habori and Raman, 1998; Viuda-Martos, *et al.* (2010).

5. Conclusion

The current study has contributed to a better understanding of the potential applications of herbs and spices in a variety of fields, including medicine (in the treatment of chronic diseases such as cancer, diabetes, and cardiovascular disease), food production (by improving taste and also as a food additive by preventing food spoilage), and food packaging (by using the bioactive compounds of herbs in active packaging). Herbs and spices, as previously said, include bioactive chemicals with a wide range of biological activities, including antioxidant, antibacterial, antiviral, and anti-inflammatory properties. These extracts are also utilised to boost the nutritional value, shelf life, and quality of a wide range of food products. Because oxidative reactions in our bodies are linked to lifestyle diseases and age-related degenerative disorders, the use of herbs and spices to combat oxidative reactions is gaining popularity, and is thus linked to health maintenance through protection against the development of non-communicable diseases.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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