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Turmeric: A Promising Spice for Phytochemical and Antimicrobial Activities

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Abstract: Meat and meat based products are becoming more prevalent all over the world. Fresh meat has an ideal configuration for the development of a huge variety of microorganisms that causes spoilage. Thus the application of any natural compound having pronounced antimicrobial activity may be beneficial for sustaining meat quality and prolonging its shelf- *life. Curcumalonga belongs to Zingiberaceae family.* The most imperative fraction of turmeric is named as curcuminoids. Among curcuminoids, Curcumin is mostly accountable for all biological activities of turmeric. Keeping in view the antimicrobial effect of turmeric, the present review will help the readers to understand antibacterial activity of different extracts of Turmeric (*Curcuma longa)* on meat samples and their antimicrobial potential on various pathogens.

Key words: Antimicrobial · Meat · Microorganisms · Turmeric · Curcumalonga

INTRODUCTION

Turmeric (*Curcuma longa* L.) is a therapeutic plant that belongs to family Zingiberaceae. It is moderately tall, perennial plant with underground rhizomes. Rhizomes are mostly ovate, pyriform, oblong and often short-branched [1]. It is widely consumed as a flavoring, preservative and coloring agent in South Asia, India and China. It is well notorious for its unique medicinal properties. It is cultivated in tropical regions like Pakistan, China, Peru and India [2]. *Curcuma longa* is considered as native to the India. It is grown commercially in many countries of south Asia, China and India. It is well known for culinary use as a key constituent of curry powder. It is an approved food additive In the United States. Turmeric is normally called haldi or haridra in India. It is also called as "Manjal" and its powder as Manjal Thool in Tamil language. It is also known as "Indian saffron", as it was broadly used as a substitute to the more costly saffron spice [3]. It is generally cultivated in the tropical regions like China, India and Pakistan. In the past people frequently use turmeric for treating diabetic wounds, cough, anorexia, biliary disorders and hepatic disorders.

Turmeric has healthy influence on digestive system and it also enhances the mucin secretion in the digestive tract. In classical literature several actions of turmeric have been specified like antibacterial, antithelmintic, anticancer, antiparasitic, antiseptic, anti-oxidative, anti-inflammatory, anti-rheumatic, anti-tumor, anti-phlegmatic, antiviral, astringent, aromatic, blood purifier, clear skin color, remove wound maggots, hepatoprotective, stop liver obstruction, heals wound, stimulant and sedative in the food industries, as a coloring agent as well as an additive to impart flavor in curries [4]. Turmeric is a prompt source of bioactive compounds like antioxidants, polyphenols and flavonoids, which may be the substitute of antibiotics used in food and food products. Turmerone, zingiberene, ar-turmerone and curlone are included in volatile constituents of turmeric while the nonvolatile constituents are curcuminoids [5].

The bioactive element of *Curcuma longa* is curcumin. The characteristic color of turmeric is because of curcuminoids, first time identified in 1842 by Vogal. Curcuminoids are the phenolic compounds that are predominantly present in turmeric. Curcuminoids mainly comprise of curcumin demethoxycurcumin and bisdemethoxycurcumin. Among Curcuminoids, Curcumin is the main element which is responsible for the biological functions of turmeric. Curcumin is an orange-yellow crystalline substance that is insoluble in water. It is thought to be the powerful bioactive portion of turmeric [6].

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In the 19th century the principle coloring agent of turmeric was isolated, named curcumin. It was first characterized in 1910 as low molecular weight molecule, having melting point 183 °C. It is the key component of turmeric, being accountable for its anti-inflammatory properties It is anti-carcinogenic, antidiabetic, anti-inflammatory, antioxidant, antiviral, anti-mutagenic, anti-venom, anticoagulant, antiprotozoal, antibacterial, antifungal, anti-ulcer and hypercholesteremic [2].

Turmeric; an Overview: Turmeric (*Curcuma longa*) is a perennial herb which belongs to family Zingiberaceae. It is Cultivated in tropical and subtropical area of the earth mostly in India, Pakistan and China. It is normally famous as Haldi in Pakistan and India. From prehistoric time it is mostly used as a house hold therapy to manage several physiological ailments. The particular aroma of turmeric rhizome is due to the aromatic volatile oil like turmerone (25%), curdione (11.58%) and ar-turmerone (8.5%) whereas phenolic compound like curcumin impart specific yellow color to the rhizomes of *Curcuma longa*. Numerous plant based antibiotics and bioactive compounds have been known in herbaceous tropical plants by the scientists that play an important role in physiological and biochemical metabolic reactions of animal and human body. In Pakistan the environment is appropriate for the growth of these herbaceous plants. Currently India is the biggest producer and consumer of turmeric. China comes at the second number as a producer of different spices including *Curcuma longa* and then followed by several other subcontinent countries. Other producers of turmeric in Asian countries include Pakistan, Srilanka, Bangladesh, Indonesia, Burma and Taiwan. India produces approx. 80% of the world turmeric and as well as export 60% of it all over the world. Some common names of turmeric in different countries: Pakistan (Haldi), japan (ukon), Arabic (Kurkum), China (Watgam) and Indonesia (Kunyit) [7].

Morphology of Plant: Turmeric plant possesses underground rhizomes like ginger plant. It is a perennial, leafy and erect herbaceous plant. Turmeric is usually grown as annual crop. It needs warm and slightly humid atmosphere. It requires temperature between 20-30 °C and also a significant amount of rainfall to bloom. It is 60-90 cm in height. The colors of flower are yellow, grouped together in a dense spike like structure and 10-15 cm in length. The blade of leaf is thin, ovate, sheath like long petiole and entire margined. The Leaves are oblong, broad and narrowed towards base. They are slight green, 35-40 cm long and 8-14 cm wide. The plant has no fruits above the ground. The rhizomes of turmeric possess finger like projections and segmented skin. The central rhizome is mostly thickened like a tuber and has numerous roots. The roots are terminates in many elliptical tubers. The turmeric rhizomes are branched and fleshy. The primary rhizome is ovate and mostly pear shaped, known as "bulb" and the secondary one are cylindrical [4]. The rhizomes color is yellow and a orange line is present inside the rhizomes. But externally rhizomes are brownish and scaly. The rhizomes are mostly 2.6-7 cm in length and 2-2.4 cm in width. It was used as household therapy for inflammation of wounds, digestive ailments, jaundice, dysentery, trauma and many other physiological threats in ancient times. The Indian people used to call turmeric as kitchen queen. The turmeric rhizomes are harvested, steamed, boiled and then dried into powder form. Turmeric has different aromatic odour. Large amount of turmeric is consumed in curries, soups and sauces [7].

Table 1: Scientific classification of (*Curcuma longa* L.)

Kingdom	Plantae
Subkingdom	Tracheobionts
Super division	Spermatophyta
Division	Mangoliophyta
Order	Zingiberales
Family	Zingiberaceae
Genus	Curcuma
Species	longa
Scientific name	*Curcuma longa*

History of Turmeric: Marco polo in 1280 named turmeric as an Indian saffron which is used as a colorant. In India, at the time of Lord Ram Chandra turmeric was used for face protection during sun worship. Turmeric has a history of 6000 years for its use in medicine. Turmeric is mostly cultivated in India, China, Thailand, Bangladesh, Malaysia and Indonesia. It is also cultivated in tropical areas of America and Africa. Turmeric has been proved helpful in number of health complications and in different pathological conditions [8].

Turmeric is considered as a medicinal plant widely used in Unani, Siddha and Ayurveda medicine as a home remedy for different diseases.Turmeric has been grown in Southeast Asia and India from thousands years. The turmeric plant was first familiarized to Africa and China in the 8th centuries. It is cultivated as home garden plant in

the tropical areas all over the world. In Ayurvedic and Chinese systems it has been widely used as a medicine for inflammatory diseases for many years [9]. Aryan culture gave *Curcuma longa* a dominant place in religious ceremonies. They believed that the golden yellow color of turmeric represents sunlight which possesses protective properties. Today turmeric also finds its importance in Hindu religious ceremonies. Conventionally, turmeric was used to dye cloths that have to be used in marriage rituals in Hindu culture. The faith was that it keeps the wearer safe from any harm or infection. In many Ayurvedic formulas turmeric is used as a basic ingredient. A paste of turmeric, salt and lime was applied to relieve inflammation and muscular sprain. Smoke formed by sprinkling turmeric above burned charcoal was consumed to release pain from stings of scorpion, to offer relief from indigestion and to combat hysteric fits. In the Unani culture of medicine, turmeric is widely used to cure dropsy, liver obstruction, ulcers, inflammation and jaundice. In the Himalayan, it is mostly used as skin tonic, to treat swelling, wounds, insect stings, whooping cough, internal injuries, inflammation, pimples and for external injuries [10].

It is taken as auspicious and also a sign of religious rituals. In recent eras, traditional medicine consumes turmeric for biliary disorders, anorexia, cough, hepatic disorders, diabetic wounds, sinusitis and rheumatism. Several curcuminoids and sesquiterpenes have been separated from turmeric, ascribing a wide range of biological properties like antioxidant, wound healing, anticancer, antibacterial activity and anti-inflammatory [11].

Phytochemistry of Turmeric: Turmeric contains fat (5.1%), protein (6.3%), carbohydrates (69.4%), minerals (3.5%) and moisture (13.1%). Essential oil obtained through steam distillation of turmeric rhizomes possesses sabinene (0.6%), borneol (0.5%), *a*-phellandrene (1%), cineol (1%), sesquiterpines (53%), zingiberene (25%) and curcumin (diferuloylmethane) (3–4%). Turmeric comprises volatile as well as nonvolatile compounds. Volatile compounds are turmerone, zingiberene, curlone and ar-turmerone. The nonvolatile components include the curcuminoids [12].

Turmeric is an oleoresin which is consists of a light volatile oil fraction and a heavy yellow–brown fraction. It comprises a large number of curcuminoids, sesquiterpenoids and monoterpenoids. The active components of turmeric include the flavonoid curcumin and different volatile oils like turmeron, gingibaron and atlanton [1].

Curcumin (diferuloylmethane) a phenolic diketone, is accountable for the bright yellow colour, of the turmeric and consist of curcumin I (94%), II (6%) and III (0.3%). Many other phenolic ketones like demethoxycurcumin and bis-demethoxycurcumin are also present in the the rhizomes of *Curcuma longa*. The essential oil of turmeric have been examined by liquid chromatography and reported to comprise of α-pinene, sabinene, myrcene, β-pinene, α-phellandrene, C_8-aldehyde, linalool, 1,8-cineole, p-cymene, geraniol methyl heptanone and caryophyllene [13].

The yellow colour compounds are three curcuminoids; curcumin (diferuloylmethane), bisdemethoxycurcumin and demethoxycurcumin [9]. Turmeric acts like a therapeutic agent against various chronic complications like diabetes, cancer, cardiovascular problems, inflammatory diseases and neurodegenerative problems such as Alzheimer's disease, epilepsy and Parkinson's disease [14]. Phenolic compounds are powerful antioxidants which defend the human body against free radicals. Turmericis considered to be abundant in phenolic components such as curcuminoids that grab the antioxidant activity of turmeric. Curcuminoids avert the development of free radicals.Amongcurcuminoids, Curcumin has demonstrated great antioxidant and immunosuppressive activity in animals [15].

Curcumin or diferuloylmethane (1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5- dione) and many other curcuminoids are considered as key phytochemicals of turmeric. Curcumin is the vital fraction of turmeric that is responsible for its all biological activities. Melting point of the curcumin ($C_2H_2OO_6$) is 184 °C. It is easily soluble in acetone, ketone, chloroform and ethanol, but not soluble in water [16]. Curcumin was isolated in 1815. Its actual chemical configuration was determined in 1973 by Whiting and Roughley. Curcumin forms reddish-brown salts with alkali. In the curcumin molecule, the central chain is unsaturated, aliphatic and the aryl group may be substituted or not [12].

Curcumin is lost owing to heat processing up to an extent of 28–54%, while maximum loss happened from pressure cooking. It was observed that with tamarind, the curcumin loss was only 13–30%. Curcumin I was considered to have minimum stability, while curcumin III was proved to be the most stable among all curcuminoids [17].

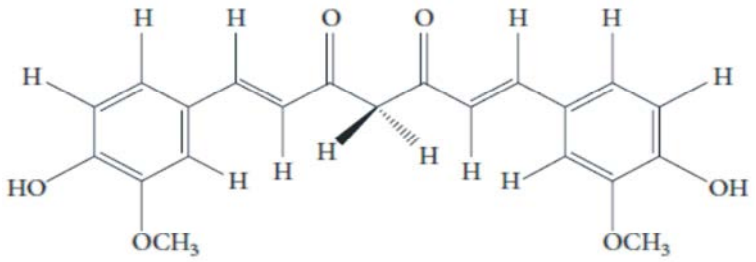

Fig. 1: Chemical structure of curcumin

Curcumin is a powerful antioxidant and it is supposed to be the most soothing and bioactive part of the turmeric. It possesses antioxidant, anti-platelet, anti-inflammatory, antibacterial, anti-fungal and cholesterol lowering properties. It encloses a combination of potent antioxidant phytonutrients such as curcuminoids and it inhibits the cancer at different stages like initiation, progression and promotion [18]. It has proved as an effective anticarcinogenic compound. It has been proved that curcumin has the potential to decrease tumor development, carcinogenesis and angiogenesis. Curcumin shows its potential to suppress mitogen-induced proliferation of blood cell and various reactions of lymphocytes. It also prevents the stimulation of neutrophils and inhibits the mutagenesis of smooth muscle cells [19].

Recent studies showed that curcuminoids are effective in the treatment of various cancerous conditions, which is likely associated to the cytotoxicity of those substances that has been verified on cell cultures and tumor cells. In addition to these properties, curcumin showed a diversity of potentially therapeutic activities like antineoplastic, antiangiogenic, anti-apoptotic, cytotoxic, antithrombotic, immunomodulatory, wound healing, anti-stressor, anti- lithogenic and anti-diabetic actions [20]. The current research shows that curcumin have distinctive anti-mutagenic, antioxidant, anti-carcinogenic, anti-tumorigenic, anti-arthritic, hypocholesterolemia And anti-inflammatory properties. Curcuminoids are isolated by different analytical methods among them solvent extraction technique is the most important method. Curcuminoids are generally estimated by HPLC absorption and flourimetric methods. HPLC method is most appropriate for the estimation of individual curcuminoids [20].

Antioxidant Properties: Free radicals with unpaired electrons (hydroxyl, peroxyl, superoxide) are formed in the normal or pathological metabolisms. The compounds which can scavenge free radical compounds have the ability to treat many diseases and pathological cells. Antioxidant plays a significant role in protecting the human body cells from damage by many reactive oxygen species. The free radicals are considered as the key offenders in lipid peroxidation. Plants which contain biologically active compounds have been stated to have powerful antioxidant properties. In inflammatory diseases there is excessive production of oxygen,activation of phagocytes, hydroxide radicals and non-free radical species, which can be harmful for tissues due to direct powerful oxidizing action or indirect formation of OH and hydrogen peroxide radicals from O_2. It starts lipid peroxidation which results in destruction of the cell membrane. Tissue damage then aggravates inflammatory reaction by the production of various mediators and chemotactic factors [21].

Turmeric and its component show great antioxidant activity as compared to vitamins E and C. A study indicated that curcumin is considered eight times powerful as compared to vitamin E in inhibiting lipid peroxidation. Curcuminoids hinder the biosynthesis of leukotriene through lipoxygenase pathway and it also decreases the formation of prostaglandin. A case study of ischemia present in the feline heart showed that pretreatment with curcumin decreased the changes induced by ischemic heart [12]. The natural antioxidants protect the cells from the damage caused by the free radicals. Curcumin is well known to have therapeutic properties like free radical scavenging properties to obstruct clastogenesis in various mammalian cells. It has been reported that curcumin acts as pro-oxidant and it induced a major increase in the rate of chromosomal aberrations occurs in Chinese hamster ovary cells facilitated by the generation of hydroxyl radicals [22].

The pro-oxidant behavior of the curcumin might be associated to the special conjugated β-diketone configuration of it [23]. The aqueous extracts of fresh rhizomes exhibited greater antioxidant potential as

compared to dry rhizomes. There was considerable loss of antioxidant potential of turmeric rhizomes when they are turned into dry powder. The antimicrobial and antioxidant properties of *Curcuma longa* were studied by using sensitive microbiological and chemical assays. The antioxidant activities were studied by using β-carotene-linoleate and phosphomolydenum methods. The phosphomolybdenum test showed antioxidant capacity of 53 mmol α-tocopherol/g and the β-carotene-linoleate exhibited significant antioxidant activity of (92.3%). Curcumin can be extracted from turmeric oleoresin with hexane to obtain turmeric oil that can be fractionated by silica gel column chromatography in order to get three fractions of turmeric oil comprising turmerone (15.09%), aromatic turmerone (31.33%) and curlone (9.8%), while fraction III possesses aromatic turmerone (44.6%), turmerone (10.9%) and curlone (19.23%) as main compounds. Similarly, oxygenated compounds were found to be supplemented with fraction III. Turmeric oil and various fractions of it were verified for their antioxidant potential by β-carotene–lineolate model and phosphomolybdenum technique. Faction III exhibited maximum antioxidant activity. Turmeric oil and all the fractions exhibited a noticeable anti-mutagenicity by the Ames test, however fraction III was found to be the most effective as compared to all other fractions. The antioxidant effects of turmeric oil may give an explanation for its anti-mutagenic action [20].

Anti-Diabetic Effects: Diabetes mellitus has becomes a severe metabolic disorder worldwide. It occurs mainly due to deficiency of pancreatic hormone (insulin). The diabetes mellitus causes various severe complications including vascular dysfunctions. It is world widely accepted that imbalance of antioxidant potential in body and generation of free radicals is related to the oxidative stress within the body [24]. Diabetes is perceived as global health disorder all over the world. Between Type I and II diabetes, the second one is spreading immensely among the human beings. Recently turmeric has been consumed in many herbal preparations to reduce the risk of diabetes. Diabetic rats induced with alloxan, when compared to non-diabetic rats, weight increase in diabetic rats was normalized by administration of the aqueous extract of curcumin. Usage of curcumin and turmeric in diabetic rats drastically lowers the level of glucose-6-phosphatase, increases the action of liver. It also elevates the serum hexokinase and lactate dehydrogenase level in blood which shows a reduction in cellular outflow of alkaline phosphatase lactate dehydrogenase and acid phosphatase into the blood of diabetic animals. Curcumin seemed to be more active in reducing diabetes mellitus as compared to turmeric [25].

Turmeric possesses wide ranging vigorous effects of on human health. Turmeric oleoresin is generally consumed to color and flavor food stuffs. Turmeric essential oil and curcuminoids both are present in turmeric oleoresins and both of them showed hypoglycemic effects in diabetic animals. Turmeric oleoresin showed vibrant effects on hepatic gene expressions in obese diabetic rat KK-Ay, with DNA microarray analysis and evaluate the real-time PCR [26].

Several studies had showed that diabetes mellitus is generally associated with high production of free radicals and reduction in in antioxidant properties in the cells of the body. Due to which balance is disturbed in the body cells in free radicals production. It will lead to oxidative mutilation of cell components like proteins, lipids and nucleic acid [27]. Various spices play an important role in controlling diabetes mellitus and in reducing its complications. Turmeric and curcumin lower blood glucose level in case of alloxan-induced diabetes in rats. It also reduces complications due to advanced glycation products in diabetes [28].

Curcumin also showed potent hypocholesteremia effects in rats. Curcumin significantly lowers the concentration of low density lipoprotein in plasma and total cholesterol concentration in liver. It increases the level of a-tocopherol in rat plasma. Ether extract of *Curcuma longa* and curcumin (50%) exhibited hypolipemic action in case of rats and lower fatty acids, triglycerides and cholesterol in toxicity induced by alcohol [12].

Anti-Inflamatory Properties: Several frequently used plant produces, including curcumin, have potent antiinflammatory properties. Through *in vitro* studies, it has been recognized that water-soluble extracts of turmeric were considered as not cytotoxic and they did not show any biological activity. While organic extracts of *Curcuma longa* were cytotoxic merely at concentrations of about 50 ìg/ml. Organic extracts of turmericwere able of obstructing tumor necrosis factor (TNF) lipopolysaccharide (LPS)-induced factor and prostaglandin E2 (PGE2). Purified curcumin proved more effective as compared to bis-demethoxycurcumin [29].

Turmeric shows high anti-inflammatory properties as it encompasses many natural cyclooxygenase inhibitors. Turmeric extracts, turmeric oil and curcuminoids had been found effective against arthritis due to their high anti-

inflammatory properties. Arora *et al*. [30] studied the anti-inflammatory of turmeric rhizomes in animals by using various extracts of petroleum ether. They observed that the extracts retard the growth of granuloma and no toxicity was observed. The anti-inflammatory activity of turmeric is due to its capacity to decrease histamine levels, however it increase production of cortisone by the adrenal glands. It helps both gall bladder and liver functions. It has been revealed to be useful in the treatment of rheumatoid arthritis, arthritis, osteoarthritis, trauma, stiffness and injuries under normal activity and as well as in hyperactivity [31]. The ethanolic extract of curcumin, feruloyl-(4-hydroxycinnamoyl)- methane] and sodium curcuminate and their different derivatives, showed high anti-inflammatory activities against carrageenin-induced rats paw oedema [32].

In the developing countries, the turmeric is extensively used in traditional medicines especially due to its great immune-modulatory properties. Dendritic cells are mostly antigen presenting cells which are specialized to start and regulate immunity system. The capability of dendritic cells to start immunity is associated to their stimulation status. The hydroethanolic extract (HEE) of turmeric hinders the stimulation of human dendritic cells in answer to the inflammatory cytokines. The treatment of dendritic cells with HEE obstructs the capability of dendritic cells to stimulate mixed-lymphocyte reaction. More significantly, lipophilic fractions of turmeric do not synergize with hydroethanolic fraction for inhibiting dendritic cells maturation. Culturing of dendritic cells with HEE leads to the fractional abrogation of the all effects of HEE on dendritic cells. These studies describe a mechanism of the antiinflammatory action of turmeric. But, they recommend that these turmeric extracts may contain constituents with some antagonistic effect on human dendritic cells [29].

Anticancerous Effects: Cancer is the main leading cause of the death in many developing countries. Several epodemiological studies had shown that the incidence of cancer is less in the people who depend more on the vegetables and fruits. This outcome is owed to bioactive composites that are present in plant foods recognized as flavonoids. While Immnse body evidences has revealed chemo-preventive potency of flavoniods [33].

Oxidative stress in the body cause harm to DNA which leads to the genetic mutation. The mutation deviate normal cell division cycle and as a outcome unwanted cell aggregates forms that are known as tumor. Flavoniods prevent genetic mutation of DNA from oxidative stress via scavenging free radicals that are produced in the vicinity of DNA which cooperate with carcinoma formed by detoxification process [34].

It has been shown that curcumin, the key bioactive components of turmeric possesses dose dependent chemo-preventive and physiological effects in several tumor bioassay systems which comprise oral, esophahus, stomach, duodenal and colon carcinogensis. According to the research, curcumin has potency to diminish the poliferation of tumor cells, that is produced artificially by 7, 12 dimethyl benz anthracene and benz pyrene [35]. Curcumin has strong anticarcinogenic activities.Induction of apoptosis is important in curcumin's anticarcinogenic effect. Curcumin obstructs cell-cycle progression, which is helpful in inhibiting the growth of cancerous cell in rats aortic muscle cells [36].

Curcumin cause apoptosis and cause disturbances cell-cycle, both of them are involved in inhibiting the growth of cancerous cell [2]. Curcumin has shown the chemopreventive effects in the cell cultures, human investigations and animal models. Curcumin has anti-cancer potency through its consequence on a number of biological pathways which are involved in oncogene expression, mutagenesis, apoptosis, cell cycle regulation, metastasis and tumorigenesis. It has shown antiproliferative influence in multiple malignancies. Curcumin is a inhibitor of transcription factor-NF-B and downstream genes product including Bcl-2, COX-2, c-myc, Cyclin D1, NOS, interleukins, MMP-9 and TNF-a. In addition, it also affects a various receptors of growth factor and molecules of cell adhesion that are involved in the growth, metastasis and angiogenesis of tumor [37].

Curcumin declares its anti-tumor effect in cancerous cells by changing deregulated cell cycles through cyclin-dependent, p53-dependent and p53-independent paths. Such effects of curcumin on important signals transduction pathways of the cell cycle and efficiency in the animal model methods have qualified curcumin as a manifold edged weapon in contending the cancer [38].

Effects on Cardiovascular System: Cardiovascular disorders are comparatively increasing in young population all over the world. Animal studies demonstrate that curcumin decreases triglycerides and cholesterol level in blood stream which is a major reason for cardiovascular disease. Turmeric shows various shielding effects on cardiovascular system like decreasing triglyceride and cholesterol level, lowering liability of low density lipoprotein to lipid peroxidation and preventing platelet aggregation. Even low dose of turmeric showed

these effects. In an experiment of 18 atherosclerotic rabbits, fed with low dose of turmeric extracts (1.7-3.3 mg/kg daily per body weight) showed reduced susceptibility of lipid peroxidation and also lowers blood cholesterol level. The higher doses did not lowers lipid peroxidation of low density lipoproteins, but it decreases the triglyceride and cholesterol level, although at a slighter less degree as compared to lower dose. Turmeric effects on serum cholesterol levels might be due to higher transformation of cholesterol into bile acids in liver and reduced cholesterol uptake in the large intestine. Obstruction of platelet aggregation by turmeric constituents is believed to be by inhibition of thromboxane and potentiation of prostacyclin production [13].

Curcumin extracted from turmeric rhizomes, showed antiangiogenic properties in a human angiogenic assay. Being a liposoluble component, curcumin can be easily extracted with organic solvents such as ethanol or hexane) from turmeric rhizomes. Curcumin has poor water solubility properties, which possibly restraining its use as medicine use in humans when taken orally or inoculated in serum. Curcumin reduces the severity of different pathological changes occurring in body and it also prevents myocardial infarction. Curcumin increases Ca^{2+} transport and their slippage from sarcoplasmic reticulum of cardiac muscles, so raising the probability of different pharmacological interventions in order to precise the defective homeostasis of Ca^{2+} in the cardiac muscles. Curcumin showed substantial hypocholesteremic effects in various hypercholesteremic rats [39].

Antimicrobial Activity of Turmeric: Chandarana *et al*. [40] stated that turmeric is active against *B. subtilus*, *S. aureus* and *E. coli* due to the phenolic compounds present in turmeric like curcuminoids. The essential oil, alkaloid, curcumins, turmerol and veleric acid are accountable for antimicrobial activity of turmeric.

Mode of Antimicrobial Action: Odhav *et al*. [41] proposed that the mechanism behind the antimicrobial action of different spices include the hydrogen bonding and hydrophobic interaction of various phenolic compounds to the membrane proteins, which cause cell membrane disturbance, disruption of cell wall and damage of electron transport chain. The antibacterial potential of aqueous extracts is possibly due to the anionic constituents like nitrate, chlorides, sulphates and thiocyanate in addition to several other compounds that are present naturally in plants. The ethanolic extracts exhibited better effects as compared to the aqueous extracts as organic solvent dissolves organic compounds quickly resulting in release of larger amount of vigorous antimicrobial constituents. The thick structural components of gram-positive bacteria in this case can be accountable for the more interaction between curcumin, active components and the structural lipoproteins. The increased collaboration may outcomes in the inhibition of the gram-positive bacteria [42].

According to Moreno *et al.* [43] the antimicrobial action of various phenolic complexes was associated to inactivation of different cellular enzymes which relied on the penetration rate of the substances into the cell and changes in the permeability of membrane. A change in the cell membrane permeability is the main factor in antimicrobial action of a particular compound. Phenolic compounds may completely disrupt the cellular membranes, affect the cellular integrity and cause ultimate cell death.

Anti-Protozoal Activity: The first study to relate the action of curcumin and some other semi-synthetic derivatives present in the previous literature against the activity of tripanosomatids was observed in promastigotes and amastigotes form of *Leishmania amazonensis*. The authors obsereved that curcumin in experiments showed tremendous activity with a LD_{50} = 25 ìM or 9.5 mg/mL and the other semi-synthetic derivatives like methylcurcumin showed its best activity with LD_{50}< 6ìg/mL and LD_{90} = 36 ìM against the promastigotes forms. This derivative was verified in mice and showed a good antiviral activity with 66.5% of the inhibition of lesion size present on footpad of the animals, when matched with the groups injected only with the parasites [22]. The authors revealed another interesting point that there was no inflammatory action in those areas where drug was injected, possibly because of the reason that curcuminoids are effective inhibitors of inflammation.

Antifungal Activity: Turmeric oil proved effective activity against seven different fungi which are responsible for spoilage of stored agriculture commodities. More than 70% growth inhibition was found in *Aspergillus parasiticus, Fusarium moniliforme, Penicillium digitatum* and *Aspergillus flavus* [20]. Chloroform and ether extracts of turmeric have proved antibacterial, antifungal, antiviral and anti-protozoan. In one screening test for antibiotics, turmeric exhibited broad-spectrum antimicrobial activity. Turmeric oil and its ether extracts were effective against *Bacillus coagulans*, *Bacillus subtilis*, *Bacillus cereus*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Escherichia coli* [40].

Due to traditional use of turmeric powder in food products, several researches have done to study the antifungal aspects of turmeric and curcumin. The study of adding turmeric in the plant tissue culture exhibited that turmeric at the concentration of 0.8 to 1.0 g/L had substantial inhibitory action against different fungal contaminations. Regarding the antifungal activities of *Curcuma longa* the most noteworthy effect was recorded against *Paracoccidioides brasiliensis* and *Aspergillus parasiticus,* species, although curcumin shown fungicide effect against several fungi. The methanolic extract of *Curcuma longa* revealed antifungal activity against *Candida albicans* and *Cryptococcus neoformans* with MIC values of 126 and 258 ??g/mL, respectively [44].

In a study hexane extract of turmeric at 1000 mg/L showed antifungal avtivity against *Phytophthora infestans*, *Erysiphe graminis* and *Rhizoctonia solani*. It was observed that ethyl acetate extract of turmeric reveal inhibitory action against *P. infestans*, *R. solani*, *Botrytis cinerea* and *Puccinia recondite* at the concentration of 1000 mg/L. While Curcumin exhibit the antifungal action against *Pu. recondita*, *P. infestans* and *R. solani* at the concentration of 500 mg/L [45]. The turmeric essential oil exhibits toxicity to seven pathogenic fungi which are involved in spoilage of stored agricultural produces. *Aspergillus flavus*, *Colletotrichum gloeosporioides*, *C. musae* and *Fusarium semitectum* were sensitive with the inhibition of growth. Only one antifungal band produced in the bio-autography of the oil which was showing only 40% of the oil. In the reverse phase HPLC, the fractionation of band yielded two peaks which were in the percentage of 42.1% and 57.9%. Nuclear magnetic resonance spectra and MS had identified that ar-turmerone was present in the larger peak. In the smaller peak two components were identified as ar-turmerone and a-turmerone. Therefore, ar-turmerone made 87% of the fungitoxic element to the oil. The purified ar-turmerone exhibited antifungal activity alike the crude oil [46].

The antifungal potency of numerous herbal and chemical compounds was tested on *Aspergillus parasiticus.* The study showed that all the nominated herbal and chemical compounds retarded the fungal growth by decreasing fungal spore count and also reduced the aflatoxin production. Among all the herbal compounds verified, clove oil showed best results, followed by the turmeric, onion and garlic; but in the chemical compounds, sodium propionate, ammonia, propionic acid and benzoic acid showed the best antifungal activity, followed by citric acid and urea [47]. Turmeric oil was verified for its antifungal properties against *Aspergillus parasiticus, Fusarium moniliforme, Penicillium digitatum* and *Aspergillus flavus*[20]. Curcumin with fluconazole or amphotericin B showed better fungicidal effect for the treatment of different fungal infections like in candidemia and candidiasis [6].

Antiviral Effect: There is a need to find some novel effective antiviral compounds due to emergence of antiviral resistant drugs and very high cost of certain antiviral therapies. Moreover, the prevailing antiviral remedies are not satisfactory and well tolerated. Therefore, the increasing necessity for antiviral elements will be extra highlighted. Different plants as a prompt source of numerous phytochemicals with unique biological activities like high antiviral activities stay as an interest of scientists [48].

Curcumin has been revealed to possess high antiviral activities. It inhibits the activities of Epstein-Barr virus in Raji DR-LUC cells. Epstein-Barr virus inducers like 12-0-tetradecanoylphorbol-13-acetate, transforming growth factor-beta and sodium butyrate raise the level of BZLF1 in cells at 12-48 h of treatment, which is efficiently obstructed by curcumin. Most significantly, curcumin also demonstrates anti-HIV activity by constraining the HIV-1 integrase which is needed for replication of virus. It also obstructs HIV gene expressions induced by UV light. Consequently curcumin and its different analogues may possibly be used as a novel drug therapy against HIV [12].

Antibacterial Property: Bacterial infections are considered as important infectious diseases. Therefore extensive researches of about 50 years have been isolated various innovative antimicrobial medicines to combat different bacterial infections. Regardless of progress in the development of antibacterial substances, there is a special need to find innovative antibacterial substances due to the emergence of different multidrug resistant bacteria [44].

Curcumin extracts have been proved very effective for retarding the growth of pathogenic bacterial strains. Turmeric was investigated for its antimicrobial and antioxidant properties by using sensitive microbiological and chemical assays. The mechanism behind the antimicrobial action of different spices involves the hydrogen bonding of various phenolic compounds to the membrane proteins, membrane damage, disruption of the electron transport chain and cell wall distraction. Odhav *et al*. [41] various studies showed that turmeric and curcumin can be tolerated at a high dosage without any risk of toxicity. Both of them can be used as a modern medicine for the cure of several food borne diseases. The

antioxidant activities were study by using β-carotene-linoleate and phosphomolydenum methods. The phosphomolybdenum shows antioxidant activity of 52 mmol α-tocopherol/g. For the β –carotene linoleate antioxidant activity of turmeric extract was 92.3%. Turmeric extracts also showed significant antimicrobial activity measured by MIC assay. Growth of both gram-negative and gram positive bacteria were retarded by using concentrations of 20 to 90 µg/mL of turmeric extracts [49]. The antibacterial effect of turmeric, cinnamon and garlic was investigated by Mukhtar and Ghori [50].

Turmeric extracts and essential oil of turmeric obstruct the growth of various pathogenic bacteria, fungi and parasites. In a study of chicks infested with *caecal parasite* and with *Eimera maxima* revealed that diets with 1% turmeric demonstrated a decrease in intestinal lesion marks and improved net weight gain [51]. In a study, antibacterial activity of ethanol and hexane extracts of turmeric and curcuminoids (isolated from ethyl acetate extract of *Curcuma longa*) was observed against 24 strains of pathogenic bacteria that were isolated from chicken and shrimp. Ethanolic extract exhibited the highest antibacterial activity with the MIC of 3.91 to 130 ppt. The methanol and hexane extracts of *C. longa* showed antimicrobial activity against 13 different bacterial strains, namely *V. alginolyticus*, *V. parahaemolyticus*, *V. harveyi*, *V. vulnificus*, *V. cholerae*, *B. cereus*, *Aeromonas hydrophila*, *Bacillus subtilis*, *Streptococcus agalactiae*, *Staph. intermedius*, *Staph. aureus*, *Edwardsiella tarda* and *Staph. epidermidis.* Though, curcuminoids demonstrated inhibitory actions against 8 strains of bacteria namely, *Str. agalactiae*, *Staph. epidermidis*, *Staph. Intermedius*, *Staph. aureus*, *B. subtilis*,, *A. hydrophila*, *Ed. Tarda* and *B. cereus.* Hexane extracts and curcuminoids displayed the MIC values of 120 to 1000 ppt and 3.90 to 500 ppt, individually [52].Turmeric oil a byproduct of curcumin was also found active against *B. coagulans*, *Staph. aureus, B. subtilis, P. aeruginosa* and *E. coli*[44]. In a study, it was revealed that the addition of 0.3% of curcumin extract in the cheese triggered the decrease in bacterial counts of *Pseudomonas aeruginosa,E. coli* O_{157}:H_7 and *Salmonella typhimurium*. Furthermore, it has reduced the *B. cereus, Listeria monocytogenes* and *Staph. aureus* contamination even after 14 days of storage period [53].

In a study, dried rhizome of turmeric and Oleo resins of *Boswellia serrata* were evaluated for their antimicrobial activities against gram negative (*Escherichia coli* and *Salmonella typhi*) and gram positive (*Staphylococcus aureus*, *Bacillus subtilis*) microorganisms. Both of the extracts showed considerable antimicrobial activities. The zones of inhibition for *Curcuma longa* were 13±0.16 mm for *S.typhi*, 12±0.22 mm for *E.coli* and 11±0.24 mm for *S. aureus*[37]. Turmeric essential oil when combined with the ascorbic acid, it showed substantial antibacterial activity against *Salmonella typhimurium* and *Listeria monocytogenes*. The highest antibacterial activity of turmeric oil was 15.0±1.40 mm against *Salmonella typhimurium* and was 13.8±0.59 mm against *Listeria monocytogenes*

In an *in vitro* study, the antimicrobial activity of *Curcuma longa* against various bacterial strains was checked by using agar well diffusion method. The natural dye exhibited antibacterial action against all the bacterial strains. Natural dye turmeric exhibited best inhibitory action against *Vibrio cholera* and *E.coli* with a zone of inhibition of 11mm to 15mm, 8mm to 15mm respectively [54].

CONCLUSIONS

It was concluded that *Curcuma longa* is highly considered as a universal panacea in herbal medicine with varied pharmacological and antimicrobial activities. The overall assessment concludes that turmeric possesses strong antibacterial, anti thelmintic, anticancer, antiparasitic, antiseptic, anti-oxidative, anti-inflammatory, anti-rheumatic, anti-tumor, anti-phlegmatic,antiviral properties. It is expected that *Curcuma longa* may find use as a novel herbal drug in the upcoming future to combat several diseases, including carcinogenesis, inflammatory disorders and oxidative stress-induced pathogenesis. Additional evaluations need to be done on *Curcuma longa* in order to explore to its other countless medicinal uses.

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