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Nutritional Composition, Bioavailability, Medicinal Functions and Uses of Turmeric: A Review

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Abstract

In recent years, studies have placed a greater emphasis on the scientific evaluation of historical plant-based medications, as well as the examination of various plant parts for medicinal and pharmacological significance. In light of cultural histories and ancient medicine from previous decades, which have continued to promote the healing benefits of plants and their extracts, the medicinal values of plants cannot be overstated. Nutraceuticals are the use of therapeutic properties of plants or plant parts to prevent and control illness. The Zingiberaceae family includes *Curcuma longa* (Turmeric), which is one of the most innovative nutraceuticals. It is widely grown and consumed in India and Asian countries as a shelf-life enhancer and preservative, aromatic, and coloring ingredient. It possesses anti-glycemic, antioxidant, anti-inflammatory, anti-carcinogenic, and anti-viral properties, among other health advantages. For millennia, *Curcuma longa* has been regarded safe to use as a spice and seasoning.

Keywords: Turmeric, *Curcuma longa*, plant-based medications, Nutraceutical, anti-glycemia, antioxidant, anti-inflammatory, anti-cancer, anti-viral.

1.0 INTRODUCTION

In recent era, a new diet pattern and health template has emerged, emphasizing the positive features of eating habits (Das, Bhaumik, Raychaudhuri, & Chakraborty, 2012). Increased health concerns throughout the world have led to the usage of nutraceuticals, which is Primarily, the use of nutrients and dietary components (or a portion of diet) for pharmacological or clinical purposes, such as sickness mitigation and management (Vidyasagar & Shivakumar, 2021). Most phytochemicals such as flavonoids, present in a functional and whole food, usually are employed as nutraceuticals (Panche, Diwan & Chandra, 2016).

External and Environmental conditions, sedentary lifestyle choices, and unhealthy dietary pattern and feeding disorders, cause the majority of chronic diseases, and certain foods can help prevent them (Berz, 2012). According to Abdel-Salam (2010) and Shiel (2018), many crops have become more important in human diets as functional foods, in addition to its nutritional content, some of the foods have a positive influence on an individual's wellbeing, physical ability, or cognitive state because of their phytochemical composition; they can prevent or delay the onset of various chronic diseases. According to Ezeugo (2017), vegetables and fruits including watermelon, beetroot, tomatoes, broccoli, turmeric, ginger, garlic, and onions have additional health advantages, making them "super foods."

Turmeric, botanically known as *Curcuma* is the root of the Zingiberaceae family's flowering perennial shrub that is extensively cultivated and widely consumed across India and other Asian countries as a spice, seasoning, pigment and shelf-life enhancer ingredient (Nisar *et al.*, 2015). It is known as ata ile

pupa (Yoruba) and gangamau (Hausa) in Nigerian language (Nwaekpe, Anyaegbunam, Okoye & Asumugha, 2015; Oja, 2021). Most times it requires temperatures between 20 - 30 °C, and a good amount of annual rainfall to survive (Oparah, Adamu & Giwa, 2014).

According to Oza (2017), turmeric is use in giving colours to food products such as yogurt, and several food items in the form of yellow-orange dye - E100. She also said that it is a home remedy as well as traditional Ayurvedic therapy for coughs, colds, and several other communicable and non-communicable diseases. It's a superficially rooted flowery crop with thick and bulbous rhizomes whose potential has yet to be exploited in Nigeria because farmers lack understanding of the methods required for its production (proper farming technology), leading in low yields (Nwaekpe, Anyaegbunam, Okoye, & Asumugha, 2015).

According to Nair (2013), when reading Hindu Mythology text, the most essential spice that one encounters is Indian saffron, presently known as turmeric which has been in use since 4000 BC according to Nair. Saffron (Turmeric) utilization was thought to have primarily begun in the South-East Asian region, according to Lal (2012). He claims that it has been used as therapeutic medicines, aesthetic aids, culinary seasoning, and colouring material in India for at least 6000 years, according to documented data. It was referenced in India's Artharveda and was also featured in Ayurveda, an ancient Indian traditional system of medicine, as well as Sanskrit, Indian historic language used to describe the immortal Vedas (old Hindu teachings) around 1700 and 800 BC, during the medieval era.

In the global market, there are two major sorts of turmeric: 'Madras' and 'Alleppey,' both named after Indian producing regions. Apart from curcuma longa, there are about 30 other species in the turmeric genus (Nwaekpe *et al.*, 2015). The turmeric known as Alleppey, has a yellow soft tissue inside and is basically imported into United States, where it is well-known and use as a food condiment and additive. Alleppey turmeric contains about 3 to 5 percent volatile oil and 4 to 7 percent curcumin content, whereas Madras type, consist of about 2 percent volatile oils and 2 percent curcumin content only (Lal, 2012).

Pictorial Representation of Turmeric

Fig 1: Turmeric root (https://journal.rishi-tea.com)

Fig 2: Turmeric rhizome (Miami, 2021)

Fig 3: Turmeric leaf (NCCIH, 2020)

Fig 4: Turmeric powder (Watson, 2017)

2.1 Nutritive Components of Turmeric

Turmeric's nutritive components, according to Ikpeama, Onwuka, and Nwankwo (2014), do far beyond merely averting deficiency disorders; it also has a superior dietary property that is useful. One of the superior dietary property and bioactive components of Turmeric called curcumin also contains vitamins or vitamin precursors that generate ascorbic acid, beta-carotene, polyphenols, fatty acids, and essential oils, according to the researchers. The rhizomes of turmeric have also been shown to have five novel polysaccharides: ukonans, stigmasterole, β-sitosterole, cholesterol, and 2-hydroxymethyl anthraquinone

(Kapoor 1990; Kirtikar & Basu 1993; Prasad & Aggarwal, 2011). Nutrient and proximate analysis showed that 100 g of turmeric according to Balakrishnan (2007) consist of the following as shown in the table below;

Table 1: proximate analysis of turmeric per 100g

Nutrients	Composition
Energy	390 kcal
Total fat (g) Saturated fat (g) Cholesterol (mg)	10 3 0
Protein (g)	8
Total carbohydrate (g) Sugar (g)	69.9 3
Calcium (g)	0.2
Phosphorous (g)	0.26
Sodium (mg)	10
Potassium (mg)	2500
Iron (mg)	47.5
Thiamine (mg)	0.9
Riboflavin (mg)	0.19
Niacin (mg)	4.8
Ascorbic acid (mg)	50
Fiber (g)	21

(Source: Balakrishnan, 2007)

Due to its appreciable amount of iron, calcium, riboflavin, potassium and niacin content, Turmeric constant ingestion can help sustain strong bone and haemoglobin formation, muscle contraction and relaxation, blood clotting and blood pressure modulation (Ikpeama, Onwuka, & Nwankwo, 2014). Turmeric also contains a lot of omega-3 and -linolenic acids (Goud, Polasa, & Krishnaswamy 1993; Prasad & Aggarwal, 2011). Turmeric's fiber content aids in the cleansing and detoxification of the digestive tract by eliminating potential cancer-causing agents from the body and preventing the uptake of excessive cholesterol (Ikpeama, Onwuka, & Nwankwo, 2014).

2.2 Turmeric and Its Phytocomponents

Studies have proven Turmeric to contain curcuminoids (consisting of curcumin), turmerin, and good oils, (Sharma, Steward, & Gescher, 2007). Curcumin accounts up to 2%–5% of turmeric, according to Meng, Li, and Cao (2013). Curcumin with the chemical formular as [1.7-bis-(4-hydroxy-3-methoxyphenyl)-1, 6- heptadiene-3, 5-dione], is the spice turmeric's most physiologically active ingredient, constituting 2–8% of most turmeric formulations (Sharma *et al.*, 2007). Apart from curcumin, Curcuminoid comprises of other components such as diferuloylmethane, demethoxycurcumin, and bismethoxycurcumin (Ikpeama *et al.*, 2014).

Nasri *et al.*, (2014) reported that the essential oil (5.8%) produced from turmeric by steam distillation contains borneol (0.5%), sabinene (0.6%), a-phellandrene (1%), cineol (1%), zingiberene (25%), sesquiterpenes (53%). Curcumin (3–4%) causes the yellow color observed in turmeric and is made up of curcumin I (94%), curcumin II (6%), and curcumin III (0.3%). Turmeric has also yielded demethoxy and bisdemethoxy compounds of curcumin.

Yadav and Tarun (2017) listed the phytoconstituents of turmeric as follow:

i. 1,8-cineole, 2-bornanol, 2-hydroxy-methyl-anthraquinone,4-hydroxybisabola-2
ii. 10-diene-9-one; 4-methoxy-5-hydroxybiosabola; 4-hydroxy-cinnamoyl-(Feruloyl)-methane, Alpha-atlantone, Alpha-pinene, Alphaterpineol, Ar-turmerone, Arabinose
iii. Ascorbic-acid, Ash, Azulene, Beta-carotene, Beta-pinene, Beta-sesquiphellandrene, Bis-(Para-hydroxy-cinnamoyl)-methane,
iv. Bis-desmethoxycurcumin, Bisabolene, Bixin, Borneol, Boron, Caffeic-acid, Calcium, Caprylic-acid, Caryophyllene, Chromium, Cineole, Cinnamic-acid, Cobalt, Copper, Cuminyl-alcohol, Curcumene, Curcumenol, Curcumin, Curdione,
v. Eugenol, Epiprocurcumenol; Eucalyptol;Eugenol; Feruloyl-p-coumaroyl-methane, Gamma-atlantone, Germacrone, Germacrone-13-al; Guaiacol, Isoborneol, L-alpha-curcumene
vi. Acidic polysaccharides: utonan A、B、C、D.
vii. L-beta-curcumene, Limonene, Manganese, Monodesmethoxycurcumin, Niacin, Nickel, norbixin; O-coumaric-acid, P-coumaric-acid, Pcymene, P-methoxycinnamic-acid.
viii. 4.2 percent of essential oil.
ix. Others include fatty acids, cholesterol and metallic elements (Cu, Zn, Fe, Ca, Mg, Na, K).

2.3 Bioavailability of Turmeric

Curcumin has a low oral bioavailability and a suboptimal pharmacokinetic and pharmacodynamic profile, according to extensive research by Sanidad, Sukamtoh, Xioa, McClements and Zhang (2019). Numerous animal studies demonstrate that 90% of the amount of curcumin ingested orally is eliminated in the excrement (faeces) as posited by Metzler, Pfeiffer, Schulz, and Dempe (2013).

Low solubility in aqueous gastrointestinal fluids, minimal chemical stability at physiological pH, low absorption in the gastrointestinal tract (GIT), and quick metabolism in the GIT and liver all contribute to curcumin's low bioavailability (Sanidad *et al.*, 2019).

Curcumin's limited assimilation and retention is one cause for its low bioavailability. Curcumin is absorbed mostly through the small intestine in the GIT (Heger, van-Golen, Broekgaarden, & Michel, 2014). Curcumin, on the other hand, is a lipophilic phenolic molecule, making it difficult to take curcumin orally and have it absorbed by the cells of the small intestine epithelium (Prasad *et al.,* 2011; Sanidad *et al.,* 2019). Its hydrophobic characteristic would compel it to be flushed back into the lumen through the efflux system even if it was absorbed into the epithelium (Heger, van-Golen, Broekgaarden, & Michel, 2014).

Shusuke and Ajay (2017) reported that curcumin's poor bioavailability is mostly due to three factors: low aqueous solubility, poor absorption, and substantial metabolic conversion. Though curcumin's low solubility in water is due to its polarity and slow dissolving rate, its lipophilic nature is a crucial component in its malabsorption. Because most food components are absorbed along the digestive tract and do not reach the colon, large intestine curcumin concentration can be greatly enhanced through consumption for gastrointestinal illnesses remedy (Bischoff *et al.,* 2014; Konig *et al.,* 2016).

Certain tactics are now being investigated to improve curcumin bioavailability, such as modifying the route and medium of curcumin delivery, blocking metabolic processes through concurrent administration of other dietary compounds or drugs, and structural alterations (Meng *et al.,* 2013).

Jovicic, Jozinovic, Grcevic, Aleksovska, and Subaric (2017) reported that recent research has revealed that oral administration of curcumin in the form of nanoparticles boosts the usage of curcumin 5-6 times in correlation to the standardized extract because it dissolves better in the gastrointestinal tract due to increased water solubility. Nanoparticles are also non-toxic, biodegradable, do not cause allergic reactions in humans, and can be tailored to release over time (Jovicic, *et al.,* 2017; Rahimi, Nedaeinia, Sepehri, Nikdoust, & Kazemi, 2016).

Curcumin co-ingestion with lipids can assist enhance curcumin solubility and bio-accessibility by encapsulating curcumin in mixed micelles generated by lipid hydrolysis in the GIT (Sanidad *et al.,* 2019; Porat & Dahan, 2018). This combination not only protects curcumin from destruction, but it also improves its absorption into the GIT epithelial lining. The solubility of nutraceuticals in mixed micelles is determined by the length of the fatty acid chains and the degree of saturation. Curcumin solubility and bio-accessibility have been found to be improved using medium-chain triglycerides (MCT) and long-chain triglycerides (LCT) (Prasad *et al.,* 2011; Hu, Liu, Zhang & Zeng, 2017). Combining curcumin with piperine, liposomal, and phospholipid compounds boosts bioavailability (Jovicic *et al.,* 2017; Kharat & McClements, 2019).

2.4 Turmeric uses and applications

Turmeric has both industrial and domestic importance. Turmeric is commonly used in its native nations for a range of purposes, including as a culinary condiment, a dietary colourant, and a Hindu herbal remedy for treating a variety of ailments (Yadav & Tarun, 2017). In India, the application of its paste is a significant cultural event and also serve as a raw resource in most of the cosmetic industry. (Sabale, Modi & Sabale, 2013; Kiso *et al.,* 1983; Yadav & Tarun, 2017).

2.4.1 Turmeric as Spice and Culinary Condiment

Turmeric consists of aromatic compounds and essential oils, and as a result, it lends a distinct flavour and scent to cuisine as well as forming the most significant constituent of Curry powders and spices (Jovicic *et al.,* 2017; Sabale, Modi & Sabale, 2013). Powdered root of turmeric also serves as dietary preservatives and colourant because of its aromatic characteristics (Damalas, 2011). Food industries use turmeric mostly as colouring agent in amounts ranging from 5-500 mg/kg, depending on the product output and type (Jovicic *et al.,* 2017).

Mustards, canned chicken stock and broth, and pickles all include curcumin from turmeric as a colourant (Govindarajan, 1980; Nair, 2013), in the same note, Canned beverages, cakes and other baked goods, milk and milk product, soups and sauces, dry seasonings, and compressed tablets, has turmeric coded as a food additive "E 100" (Nair, 2013; FAO, 2004).

2.4.2 Turmeric as a Dye

Turmeric has a distinctive colour property and appearance. The pulverized and powdery root of turmeric has been used widely in Asian fabric colouring and dyeing, as stated by Nair (2013). Turmeric was widely used in India to dye woollen textiles, silk, and cotton materials in an acid solution to give them a yellow hue (Sabale, Modi & Sabale, 2013). Currently, it is still in use in dyeing cotton materials. Its application has extended to pharmaceutical, confectionery/sweetened products, rice milling, and food sectors as a colouring agent (Ammon & Wahl, 1991; Nwadiokwu, Ezeanyanaso, & Akinboade, 2019).

Oparah, Adamu and Giwa (2014) carried out a study focused on the dyeing of leather with aqueous extracts of curcumin (turmeric), using post-mordanting method of dyeing and concluded that the most significant outcome of the work, was obtaining the dry powdered extract of the curcumin dye as well as the good shades from different mordants. They stated that the dyes had moderate to good rub and light fastness properties on the leathers.

2.4.3 Turmeric in Cosmetics

Curcumin from turmeric is an active ingredient in skin care and cosmetic industries as a natural colorant (Nair, 2013). It is commonly used together with milk internally and lotion topically as a skin beautifier in Indian tribes, races, creeds, and beliefs. Turmeric extract is administered to the bride and groom's skin prior to wedding ceremony in various parts of India, Bangladesh, and Pakistan, with the belief that it will make the skin glow and keep harmful microorganisms at bay (Sabale, Modi & Sabale, 2013). It's presently used in the creation of a number of sunscreens and production of turmeric-based facial creams by a number of global corporations and international companies (Prasad & Aggarwaal, 2011).

Turmeric and turmeric preparations such as kumkum and parani are used by Hindu women in their baths as an affordable and natural beauty enhancer. During a bath, rubbing turmeric paste on the face and limbs has been reported to cleanse the skin and enhance the face. Its antibacterial and therapeutic powers are thought to be a preventive and healing remedy for the awful adolescent illness of pimples (Sabale, Modi & Sabale, 2013). It is also proven to inhibit unwanted hair from growing on female skin and limit growth of feminine facial hair (Ratanshi, 2017; Sa & Das, 2008; Sabale, Modi & Sabale, 2013).

Curcumin is universally acknowledged and used for its therapeutic properties in a variety of ways around the world as follows;

Table 2: Uses of turmeric in different countries

Countries	Turmeric Uses
Japan	Beverages and tea
Thailand	Skincare and beauty products
China	Food additives and colourant
Korea	Alcoholic beverages and drinks
Malaysia	Disinfectant and antiseptic
Pakistan	Anti-inflammatory agent
United state	Preservatives, stabilizing and colouring agent for mustard sauce, cheese, butter and chips including capsules

(Source: Gupta, Patchva, & Aggarwal, 2013).

Women in Northern India are prescribed a tonic of fresh turmeric paste, dried ginger powder, and honey in a glass of milk to drink twice a day after childbirth, which is supposed to revive the mother's postpartum state (Nair, 2013; Krishnaswamy. 2008).

2.5 Pharmacological and Medicinal Properties of Turmeric

Modern medications, according to Meng *et al.*, (2013), have therapeutic effects when used correctly. However, these therapies can be costly and time-consuming, and they may cause a variety of side effects. The current healthcare system still faces a problem in managing chronic disease without adverse reactions. Patients are increasingly looking for natural solutions with medicinal properties but no adverse effects. This has sparked a surge of interest among scientists to test as many food components and native medicinal plants as possible for their ability to treat chronic disease and its repercussions (Sabale, Modi & Sabale, 2013).

According to Santoshkumar, *et al.*, 2013, turmeric has a wide range of therapeutic characteristics, including anti-inflammatory, anti-fungal, anti-mutagenic, anti-carcinogenic, anti-coagulant, anti-hepatotoxic, fertility, anti-protozoa, and anti-viral, anti-fibrotic, anti-venom, antiulcer, anti-hypertensive, and anti-diabetic properties. They went on to say that turmeric has lately been studied for its protective effect on Alzheimer's disease, rheumatoid arthritis, multiple sclerosis, irritable bowel syndrome, cataracts, and HIV/AIDS (Araujo & Leon, 2001).

Curcumin is a biologically active substance found in turmeric that combats inflammatory response at the molecular level and is the main active ingredient, according to Vyas (2015). It is a powerful anti-bacterial, anti-septic, anti-spasmodic, antifungal, anti-inflammatory, anti-allergic, anti-oxidant, anti-mutagenic, anti-carcinogenic, astringent, carminative, digestive, diuretic, stimulant, and healing agent (vulnerary). Curcumin also aids in weight loss and the prevention of obesity-related disorders. The presence of immune cells called macrophages in fat regions throughout the body contributes to the inflammation linked with obesity (Vyas, 2015; Sabale, Modi & Sabale, 2013). Flavonoids in turmeric have a variety of physiological functions, one of which is their propensity to scavenge biological and reactive anion radicals, making them health-promising (Ikpeama *et al.*, 2014).

2.6 Health Benefits of Turmeric (Curcumin)

2.6.1 Anti-Diabetic Property

Research from Auburn University was reported in Biochemistry and Biophysical Research Communications in 2009, and it looked at how supplementation with turmeric can effectively reverse

diabetes. Curcumin in turmeric is 400 times more efficient than Metformin (a common diabetic treatment) in stimulating AMPK, which promotes insulin sensitivity and can help alleviate Type 2 Diabetes, according to the study (American Cancer Society, 2016). According to Singletary (2010), curcumin has been shown in rats to boost plasma insulin levels, block diabetic cataracts, counteract dyslipidemia and renal impairment, and ameliorate diabetes-associated neuropathic pain, in addition to lowering blood glucose levels.

Curcumin, according to Vyas (2015), protects persons with prediabetes from developing type 2 diabetes. This was demonstrated in a Thai study published in the journal Diabetes Care, in which researchers discovered that people with prediabetes who took curcumin supplements were less prone to developing type 2 diabetes than those who did not; this is because turmeric reduces insulin resistance and inhibits type-2 diabetes. Clinical evidence suggests that turmeric may be more beneficial at preventing microvascular injury in diabetics than it is at managing overall blood glucose levels (Nair, 2013).

2.6.2 Anti-oxidant Property of Turmeric

Curcumin can prevent the body against oxidative stress of reactive oxygen species (ROS) and other free radicals, which can destroy DNA and cause mutations, increasing the chance of cancer development (Sanidad *et al.,* 2019). Curcumin in turmeric, according to Jayaprakasha, Jaganmohan, & Sakariah (2006), has considerable antioxidant capabilities as a dietary additive. They also stated that in the existence of curcumin, linoleic acid oxidation is very inefficient and that the antioxidant potential is about 80% when used as a food supplement.

Curcumin has the potential to donate electron that neutralizes free radicals by forming stable product, according to Jovicic *et al.,* (2017), interrupting a chain reaction of forming reactive oxygen species free radicals in a live body. Curcumins have a better potential to capture hydrogen peroxide than industrial or commercial antioxidants such as BHA, BHT and vitamin E at the same concentration - 20 mM (Ak & Gülcin, 2008).

2.6.3 Anti-inflammatory property

Curcumin's capacity to decrease inflammation is undoubtedly its most potent feature. Several animal investigations have demonstrated that a dosage of 100-200 mg per kilogram of body weight has powerful anti-inflammatory effect (Kohli & Ali, 2005; Jovicic *et al.,* 2017). According to the American Cancer Society (2016), curcumin is one of the most efficient anti-inflammatory substances in the world, according to a study published in the journal Oncogene. According to Anthwal *et al.,* (2014), curcumin suppresses the activation of particular proteins - cytokines that emerge in the processes and activities of inflammation, such as interleukins, chemokines, TNF-α, through the regulatory impact on NF-κB (cellular factor kappa B), and even directly binding and chelating TNF-α. Curcumin decreases the inflammation associated with colitis by dramatically lowering the activity of TNF-α and myeloperoxidase (Jovicic *et al.,* 2017).

Chuengsamarn, Rattanamongkolgul, Phonrat, Tungtrongchitr, and Jirawatnotai (2014) investigated the effects of curcumin medication on type 2 diabetes patients' atherosclerosis (an inflammation-related cardiovascular ailment). 240 individuals were given 1.5 g of curcumin each day for 9 months. Curcumin-treated patients had a lower pulse wave velocity (PWV), a recognized measure and accepted marker of atherosclerosis, at the end of the treatment period. Curcumin-treated patients also exhibited lower levels of insulin resistance, triglycerides, uric acid, and visceral and total body fat, all of which are atherosclerosis independent predictors.

2.6.5 Anti-Cancer Property

Curcumin inhibits proliferation, cell migration, and invasion of human tumor and cancer cell lines through several mechanisms, including the anti-inflammatory mechanisms mentioned above as well as:

1. Increasing the amount of tumor inhibitory/suppressor proteins (Chen *et al.,* 2016; Sanidad *et al.,* 2019);
2. Blocking proliferation by arresting cell cycle and apoptosis, cell migration, and invasion (Mudduluru *et al.,* 2011; Sanidad *et al.,* 2019); and
3. Suppression of lymphangiogenesis and angiogenesis which contribute to cancer and tumor development and spread (Wang *et al.,* 2019; Sanidad *et al.,* 2019).

From multiple studies, Prasad and Aggarwal (2011) concluded that turmeric inhibited the development of skin cancer, breast cancer, oral cancer, and stomach cancer in diverse animals. It inhibits carcinogenesis by suppressing mutation, detoxifying carcinogens, reducing cell proliferation, and causing apoptosis in tumor cells, according to the researchers. Curcumin has been shown to have anticancer properties in animal models having different cancers such as pancreatic, colon, and breast cancer (Sanidad *et al.,* 2019).

Curcumin in turmeric, according to Li *et al.,* (2015), inhibits the proliferation of androgen-independent prostate cancer cells by inhibiting p65 via ERK1/2 and SAPK/JNK, followed by a reduction in MUC1-C protein production (MUC1-C is a protein that has a significantly increased expression in prostate tumors). To summarize, Turmeric is an excellent natural cancer treatment that is highly useful in the

treatment of breast cancer, colon cancer, and skin cancer (Jovicic *et al.*, 2017).

2.6.6 Anti-Depressant

Although few clinical trials have been completed, scores of research trials have shown that turmeric is very beneficial in treating depressive symptoms in experimental animals' models, according to the American Cancer Society (2016).

According to Prasad and Aggarwal (2011), turmeric can help with depression. They hypothesized that its ethanolic extract significantly reduced serotonin, 5-hydroxyindoleacetic acid, noradrenaline, and dopamine concentrations, as well as serotonin turnover, as a result of swim stress. In a study published by Yu, Kong, and Chen (2002), found that giving mice aqueous extracts of turmeric (140–560 mg/kg for 14 days) lowered immobility in the tail suspension and forced swimming tests. Turmeric's impacts were shown to be more effective than those of the antidepressant fluoxetine at 560-mg/kg. The extracts strongly suppressed brain monoamine oxidase-A function at low doses, and at a high dose, it affected brain MAO-B activity. In animal brains, fluoxetine only had a slight tendency to reduce MAO-A and -B function when compared to turmeric action. These findings show that turmeric has antidepressant properties in vivo. However, because curcumin is not water soluble, the chemical accountable for this activity in aqueous preparations of turmeric remains unknown.

2.6.7 Arthritis Management and Pain-Relieving Benefits

Curcumin is well-known for its anti-inflammatory and pain-relieving properties (Prasad & Aggarwal, 2011). A study comparing the benefits of curcumin in turmeric to arthritis drugs (diclofenac sodium) that put people at risk of having leaky gut and cardiovascular problems found that the curcumin group had the greatest percent of improvement in overall scores (Disease Activity Score), and these scores were considerably better than the patients in the diclofenac sodium group (American Cancer Society, 2016). Curcumin has been shown in clinical trials to relieve arthritic symptoms, according to Singletary (2010). Curcumin was given to mice (eg, 4 mg/kg per day, intraperitoneally) in preclinical animal model of arthritis, and it lowered tissue inflammation as well as the secretion of inflammation-related cytokines and other inflammatory mediators. Curcumin can be used to treat burns instead of traditional drugs, according to the US Army Institute of Surgical Research, because of its anti-inflammatory properties (American Cancer Society, 2016).

Turmeric's anti-arthritic actions, according to Prasad and Aggarwal (2011), include the suppression of acute joint pain, inflammation and periarticular joint deterioration. Turmeric extract reduced local NF-κB activation and consequent expression of NF-κB-regulated genes that mediate inflammatory response and joint destruction, such as COX-2, chemokines, and the receptor activator of NF-κB ligands.

2.6.7 Gastrointestinal Treatments, Anti-Mutagenic and Antimicrobial Effect

Many patients were able to quit taking their prescription corticosteroids after taking curcumin, according to a comprehensive examination of all trials testing curcumin's capacity to control irritable bowel illness (inflammatory bowel disease, Crohn's disease, and ulcerative Colitis) (American Cancer Society, 2016). In the gut, curcumin is quite effective at suppressing Helicobacter pylori. Curcumin also repairs damaged walls of the stomach induced by Helicobacter pylori, according to histological study (Jovicic *et al.*, 2017). Curcumin has antibacterial effects that are considerable. Curcumin prevents the production of pneumonia in rats resulting from Staphylococcus aureus through binding to alpha-hemolysin, a toxin released by S. aureus according to Wang *et al.*, (2016). Experiments on gram positive (B. cereus and S. aureus) and gram negative (E. coli and Y. enterocolitica) bacteria revealed that curcumin beta-glycoside at concentrations of 0.2-0.7 M, have a 100 percent protective effects on the tested gram-positive bacteria and Y. enterocolitica, while they have a significantly reduced impact on t. enterocolitica (Jovicic *et al.*, 2017).

2.6.8 Cardioprotective Property

Numerous animal model findings suggest that curcumin delivery (70-100 μmol/kg, intravenously) shields the heart against harm during myocardial ischemia and reperfusion (I/R) and cardiopulmonary bypass, as posited by Srivastava and Mehta (2009). Curcumin protected the myocardium from ischemia injury in particular by inhibiting mechanism and pathways that produce free radicals of reactive oxygen species and lipid peroxidation and up-regulating other free radical detoxification mechanisms (Singletary, 2010).

Curcumin may protect the heart by slowing the progression of atherosclerosis. It can do so by preventing low-density lipoprotein oxidation, limiting vascular smooth muscle cell proliferation, minimizing thrombosis, lowering aortic fatty streak deposition, and inhibiting homocysteine-induced endothelial dysfunction, among other things (Srivastava & Mehta, 2009; Aggarwal & Harikumar, 2009).

According to Prasad and Aggarwal (2011), turmeric has shown to be efficacious in curing gingivitis, multiple sclerosis, pruritus (itching skin), atherosclerosis, Hepatitis, Genital Herpes, heartburn (dyspepsia), stomach ache and ulcers, intestinal gas, stomach bloating, kidney infection (Lupus nephritis), stomach ulcers, external ulcers, menstrual cramp,

fibromyalgia, leukaemia, lung problem, eye defect, sore throat, jaundice, gallbladder disorder and gallstones, liver disease, leprosy, amenorrhea, oedema, headache, anaemia, bursitis, chicken bronchitis, common cold and so on.

It's also an effective insect repellant and wound healing for bruises, pain, sprains, ringworms, leeches' bite, and scorpion's sting (Vyas, 2015; Prasad & Aggarwal, 2011; Nair, 2013). In India, buttermilk cooked with powdered turmeric is a common cure for diarrhoea. This formula is antibacterial, anti-diarrheal, and aid digestion (Nair, 2013). The overall beneficial effects of turmeric, according to Yadav and Tarun 2017, include: promoting a stable mood; facilitating tissue repair and wound healing; assisting in blood sugar balance; soothing irritated tissue, enabling cholesterol optimization; for managing chronic and acute allergies, useful in acne treatment and skin problems; beneficial to asthmatic patient and serve as immunomodulator.

2.7 Effect of Curcumin on Glycemia in Animal Model of Diabetes

Curcumin's potential to regulate sugar levels in various animal models has been the focus of many studies. Rodents (mice and rats) are perhaps the most commonly utilized animals in studies of curcumin's efficacy, according to Dong-wei, Min, Si-Hua, and Jun-Li (2013). Curcumin's influence on glycemic control was investigated using a variety of diabetic rat models.

Pari and Murugan (2007) reported that orally administered doses of curcumin to alloxan-induced diabetes rats, streptozotocin- (STZ-) induced rats, and STZ-nicotinamide-induced rat models, prevented body loss of weight, decreased blood sugar level, haemoglobin, and glycosylated haemoglobin (HbA1C), and enhanced insulin sensitivity. The doses include 80mg/kg body weight (BW) for 21 days and 45 days, 60mg/kg BW for 14 days, by Peeyush, *et al.,* (2009); 90mg/kg BW for 15 days by Xavier *et al.,* (2012); 150mg/kg BW for 49 days and 300mg/kg BW for 56 days by Patumraj *et al.,* (2006); 100mg/kg BW for 4 weeks by Soetikno, Sari, & Veeraveedu, (2011); 100mg/kg BW for 7 weeks by Jain *et al.,* (2009) and 100mg/kg BW for 8 weeks by Soetikno, Watanabe and Sari (2011) were all found to be good alternative for blood sugar control and management.

In high fat diet (HFD) induced insulin resistance and type 2 diabetes models in rats, El-Moselhy, Taye, Sharkawi, El-Sisi, and Ahmed (2011) discovered that oral dosing of curcumin (80mg/kg BW) for 15 and 60 days had an anti-hyperglycemic impact and increased insulin sensitivity. In another study conducted by Chougala, Bhaskar, Rajan, and Salimath (2012), dietary curcumin (0.5 percent in the food) was found to be helpful in reducing fasting blood glucose, urine sugar, and urine volume in STZ-induced diabetic rats.

Dietary curcumin (3%) for 6 weeks enhanced glycaemic status including blood glucose, glucose tolerance, HbA1c and insulin action/sensitivity in diet-induced obese mice (Weisberg, Leibel & Tortoriello, 2008). El-Azab, Attia, and El-Mowafy (2011) found that giving STZ-induced Swiss diabetic mice intraperitoneal curcumin (10mM; 100L/mouse) for 28 days effectively restored hyperglycemia, glucose intolerance, and hypoinsulinemia. In high fat diet derived obesity and insulin resistance mice, oral treatment of curcumin (50mg/kg BW) for 15 days improved glucose intolerance (He *et al.,* 2012).

Alloxan monohydrate was used to produce diabetes mellitus in albino rats at a dose of 120mg/kg intraperitoneally in a study by Santoshkumar *et al.,* (2013), and the anti-diabetic effect of ethanol extract of turmeric was investigated using the research design below;

Group I: normal control, given normal saline (10ml/kg/day);
Group II: diabetic control, given normal saline (10ml/kg/day);
Group III: euglycemic rats, given turmeric extract (300mg/kg/day);
Group IV: Diabetic rats, given turmeric extract (300mg/kg/day);
Group V: Diabetic control, given turmeric extract (500mg/kg/day);
Group VI: Diabetic rats, given Pioglitazone (6mg/kg/day).

The research lasted for 28days and all the medicines were administered orally once per day during the trial, and blood glucose levels were measured at 1, 3, 5, 7 hrs (acute study) and 7, 14, 21, 28 days (chronic study).

On the 7th, 14th, 21st, and 28th days, the extract of turmeric produced significant ($p < 005$) decreases in blood glucose levels in diabetic rats, but there was no substantial decrease in blood glucose levels after 1hr, 3hrs, 5hrs, and 7hrs following a single dosage of turmeric extract administration. This means that turmeric extract lowered blood glucose levels in all groups after a single dose, but the decrease was not significant statistically, indicating that it takes longer time for the effects to manifest.

Santoshkumar, *et al.,* (2013) found that turmeric extract at a dose of 300mg/kg had no significant effect on blood glucose levels in euglycemic rats (Group III), implying that it has no effect on blood glucose levels in healthy rats. However, the same dose drastically decreased blood glucose levels in diabetic rats from the 7th day upwards. However, 500mg/kg has

a more effective action, with a statistically significant decrease in blood glucose levels. In all the acute and chronic studies, pioglitazone, a common anti-diabetic medicine, significantly lowered blood glucose levels too.

2.8 Safe Level of Turmeric

For ages, turmeric has been regarded safe for usage as a spice, according to Oza (2017). Humans consuming substantial (8 g/day) dosage of curcumin, a key constituent of turmeric, have shown little or no harm. Human investigations, according to Singletary (2010), show that doses as high as 8 g curcumin per day are generally accepted, while a dose of 12 g/d has been shown to have no negative effects. Curcumin's weak water solubility and quick breakdown in the gut, which reduce its bioavailability, may be part of the reason for its low toxicity (Anand, Kunnumakkara, Newman and Aggarwal in Singletary, 2010).

The U.S Food and Drug Administration (FDA) have approved turmeric as a healthy substance and safe spice, even in high dosages, according to Oza (2017). He also stated that no evidence on the negative impacts of turmeric in the general population has been collected as of yet.

Curcuminoids have been accepted by the US Food and Drug Administration (FDA) as "Generally Recognized As Safe" (GRAS), and animal model and human trials have shown great tolerability, safe and healthy profiles, even at dose levels between 4000 and 8000 mg/day (Basnet & Skalko-Basnet, 2011) and doses up to 12,000 mg/day of 95 percent concentration of curcuminoids (curcumin, bisdemethoxycurcumin, and demethoxycurcumin) (Gupta, Patchva, and Aggarwal, 2013).

2.9 CONCLUSIONS

Curcumin, the most biologically active constituent of curcuma longa, aids in blood glucose regulation, heart disease prevention, cancer prevention, and Alzheimer's disease prevention. It would, without a doubt, provide evident benefits in terms of longevity. However, because curcumin in curcuma longa (Turmeric) has a low oral bioavailability due to its lipophylic and hydrophobic characteristics, it is advisable that one take it with piperine (component of black pepper) to gain the full health and pharmacological benefits of turmeric.

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