Chapter-II
Review of Literature

2.1 *Curcuma* species

India has rich history of using many plants for medicinal purposes. Among them *Curcuma species*, specially *Curcuma longa* L. has long been used in Ayurveda, Unani and Siddha medicine for various diseases (Chattopadhyay *et al.*, 2004). *Curcuma* species are perennial rhizomatous herbs belonging to the family Zingiberaceae. It comprises about 70 species of rhizomatous herbs distributed mostly in Southeast Asia as wild and cultivated plants (Sastri, 1950). Many species belonging to this family are used solely for the purpose of indigenous medicines or as vegetables, dyes, condiments and as ornamentals (Shishodia, *et al.*, 2005). *Curcuma* species have a great importance for its medicinal value.

The rhizomes of the *Curcuma* species are rhizomatous with tuberous rootstock bearing sessile and long stipulate accessory tubers at the end of long fleshy rootstock, leaves large elliptical or oblong, flower in dense compound spikes in a crown, crowned by a coma of coloured spikes and enlarged bracts, peduncle clothed with a depressed ovate membranous bracts, floral bracts adnate in their lower part and enclosing several flowers opening in succession, calyx short, cylindrical, minutely toothed, corolla tube short, funnel shaped, lobes 3, ovate or oblong, the upper longer and concave, stamen one perfect, filament short, anther uncrested with contiguous cells spurred at the base,
lateral staminodes oblong, petalloid connate with the filament, lip orbicular with deflexed tip, ovary 3-celled with many ovules in each cell, style filiform, stigma bilobed, lobes ciliate, fruit globous, membranous 3-valued capsule, seeds ovoid or oblong usually arillate.

2.2 Habitat

The genus *Curcuma* can be grown in diverse tropical conditions from sea level to a height of 1500m on the hilly slopes, in the temperature range of 20 to 30°C. A rainfall of 150cm or more or an equivalent amount of irrigation is essential for optimum growth and development of *Curcuma* species. The ideal soil requirements are the loose, friable, loamy or alluvial suitable for irrigation that should have efficient drainage capacity (Babu, 1977).

2.3 Distribution

*Curcuma* species were known to be originated in India and now is cultivated in tropical and subtropical parts of the world (McCaleb et al., 2000). India has a rich diversity of Zingiberaceous flora, representing 18 genera and 120 species (Sirigugsa, 1998). The biological wealth in the North-eastern Himalayan region, including Manipur which happens to be one of the mega-biodiversity hotspots, also has several wild and domesticated species of medicinal Zingiberales. The North-East India contributes 19 genera and 88 species (Prakash and Mehrotra, 1996). About 50 species of *Curcuma* from Indo-Malaysia and China have been reported and among them 18 species are found in India (Deb, 1983).
2.4 Taxonomical Hierarchy

- **Kingdom**: Plantae
- **Subkingdom**: Viridaeplantae
- **Phylum**: Tracheophyta
- **Subphylum**: Euphyllophytina
- **Class**: Magnoliopsida
- **“monocotyledons”**
- **“commelinids”**
- **Order**: Zingiberales
- **Family**: Zingiberaceae
- **Subfamily**: Zingiberoideae
- **Tribe**: Hedychieae
- **Genus**: Curcuma

2.5 *Curcuma* in Manipur.

Many species of *Curcuma* plants belonging to the family Zingiberaceae play a major role in the socio economic and culture of Manipur. Ethnobotanically, turmeric still occupies an important position as almost every food item preparation contains turmeric. The villagers of Manipur prefer fresh rhizome extracts to processed dried powder for preparation of their dishes. In religious ceremonies use of turmeric tubers in fresh and dried form is well known in the Meetei community of Manipur. In the indigenous system of medicine, turmeric enjoys the reputation as a stomachic, blood purifier, useful in common cold, leprosy, intermittent fevers, dropsy, purulent ophthalmia, indolent ulcers, pyogenic infection (Khana, 1999) wound healing and inflammation.
2.6 Medicinal application of Curcuma species

2.6.1 Curcuma longa Linn.

Curcuma longa generally known as turmeric have been in use from the Vedic ages (Ammon and Wahl, 1991; Jain and De Phillips, 1991) and is ascribed for its wound healing (Gujral et al., 1953), anti-inflammatory (Vegnanarayan et al., 1976), antitumour (Chen et al., 1996; Deeb et al., 2003) aromatic, stimulant and carminative properties in native medicine. Turmeric mixed with slaked lime is known as household remedy for the treatment of sprain and swelling caused by injury (Chopra et al., 1958). It is used as an external applicant in bruises, leech bites and is said to be anti-helmintic and anti/protozoan (Bhavani and Sreenivasa, 1979). A decoction of the rhizomes is applied to relieve cataract and purulent opthalmia. Powdered rhizome is used to treat wounds, bruises, inflamed joints and sprains (Surh, 2002) in Nepal. In current traditional Indian medicine, it is used for the treatment of biliary disorders, anorexia, cough, diabetic wounds, hepatic disorders, rheumatism and sinusitis (Jain and Dephillip, 1991). The powder, when applied as capsules to patients with respiratory disease, gives relief from symptoms like cough and sputum. It also showed significant improvement in treating definite rheumatoid arthritis stiffness and joint swelling after two weeks of therapy with oral doses of 120 mg/day (Sinha et al., 1974). Application of the powder in combination with other plant products is also reported for purification of blood and for menstrual and abdominal problems (Srimal, and Dhawan, 1985).
Turmeric powder has beneficial effect on the stomach. It increases mucin secretion in rabbits and may thus act as gastro-protectant against irritants (Azuine and Bhide, 1994). However, controversy exists regarding its antiulcer activity. *Curcuma longa* is used in traditional medicine of China to treat diseases which are associated with abdominal pains, icterus. Turmeric roots are known to be antiseptic and aromatic. Its paste is used in cleaning and disinfecting the skin and skin ulcers without drying out its natural oils (Chopra *et al*., 1958).

### 2.6.2 *Curcuma angustifolia* Roxb. (East-Indian Arrowroot)

In Manipur, the flower of *Curcuma angustifolia* locally known as Yaipan is taken as vegetable items. Most importantly, the west has begun to notice its potential as a source of nutrition and as a non-irritating diet for patients suffering from specific chronic ailments, recovering from fever, or experiencing irritations of the gastro intestinal tract, the lungs or the excretory system. This species of *Curcuma* is great value especially as a source of starch for Indian foods and medicines. The rhizomes are typically grounded into flour which can be mixed together with milk or water to form nutritious meals (Ravindran *et al*., 2007). A drink including *Curcuma angustifolia* as an ingredients is also used as a replacement of breast-milk or as a nutritional supplement for babies a short while after weaning. Essential oils from *Curcuma angustifolia* have been extracted and are used in antifungal medications. Compounds in the leaves and rhizomes of this plant have also shown to have potential as anti-bacterial agents (Doble *et al*., 2012).
Rhizome paste of *Curcuma angustifolia* are applied in leprosy, leucoderma, burning sensation, decoction is given in asthma, jaundice, dyspepsia, kidney stone and anaemia (Prakash & Mehrotra, 1996). Juice is rubbed on swelling and paste is applied to hasten the joining of fractures, cooling, demulcent and nutritious. It is an excellent medicine in the form of Kangi for dysentery, dysuria, and gonorrhea (Sudhir Kumar, 2002). Tubers are easily digestible and recommended for invalids and children (Sinha, 2001).

2.6.3 *Curcuma caesia* Roxb.

The rhizomes of *Curcuma caesia* Roxb. have a high economical importance because of its putative medicinal properties. The rhizomes of the plant are aromatic in nature. The inner part of the rhizome is bluish-black in colour and emits a characteristic sweet smell, due to presence of essential oil (Pandey AK and Chowdhary, 2003). In Manipur, traditionally, the rhizomes of *Curcuma caesia* Roxb. are used in treating leucoderma, asthma, tumours, piles, bronchitis etc. The paste is applied on bruises, contusions and rheumatic pains (Sarangthem and Haokip, 2010). The rhizomes are used in the treatment of muscle relaxant activity (Arulmozhi *et al.*, 2006), haemorrhoids, leprosy, asthma, cancer, epilepsy, fever, wound, vomiting, menstrual disorder, anthelmentic, aphrodisiac, inflammation, gonorrheal discharges, etc. (Sasikumar, 2005). In Arunachal Pradesh, Adi tribes use decoction of fresh rhizome as anti-diarrhoeic. The Khamti tribe of Lohit district applied the paste of fresh rhizome in case of snake and scorpion bite (Tag *et al.*, 2007; Kagyung *et al.*, 2010). In north-east India, the powder of rhizome is used by the tribal
women as a face pack during their engagement and marriage. Fresh rhizomes are crushed and applied as a paste on forehead to relief from migraine, body sprains, bruises and in treating rheumatic arthritis (Trivedi, 2003). A small globule of grounded fresh rhizome pieces of *Curcuma caesia* made paste with honey is used as tonsil remedy by the Meiteis in Manipur. The Garo tribe also used the rhizome *Curcuma caesia* during inflammation of tonsils (Mia et al., 2009). Dried rhizomes and leaves of *curcuma caesia* Roxb. are used in piles, leprosy, asthma, cancer, wounds, impotency, fertility, tooth ache, vomiting, and allergies (Amalraj et al., 1989; Syamkumar and Sasikumar, 2007; Israr et al., 2012). Rhizome with other ingredients is given in weakness after childbirth. Juice is rubbed on the body of the patient suffering from Jaundice and the rhizome also is taken as condiments in North-eastern India (Prakash and Mehrotra, 1996).

### 2.6.4 *Curcuma aromatica* Salisb.

The rhizomes of *Curcuma aromatica* have been used medicinally in China, Japan and Southeast Asia (Vo Van Chi, 1997). In India, it is known as wild turmeric and used as an antidote to snake bite astringent and on bruises, and sprains (Jain et al., 1991). Rhizome paste as well as powder are used externally in leucoderma, scabies and small pox, and are considered useful in blood diseases and intestinal worm. Juice given orally is a strong remedy against rheumatism and juices mixed with gingers are administered for smooth delivery in North Eastern India (Prakash and Mehrotra, 1996). In Meghalaya, the Khasi and Garo tribes make the rhizome paste with water to fill intestinal
worm. Wild turmeric is recognized to play a role in preventing and curing cancer in Chinese medicine. *Curcuma aromatica* contains aromatic volatile oils that help to remove excessive lipids from the blood, reduce aggregation of platelets (sticking of the blood cells to form masses) and reduce inflammation.

2.6.5 *Curcuma leucorrhiza* Roxb.

The rhizome of *Curcuma leucorrhiza* is used in Singbhum, Bihar for enlarged liver, spleen and ulcer in stomach (Pal and Srivastava, 1976). Rhizomes yield a form of arrow root (CSIR, 1986).

2.6.6 *Curcuma amada* Roxb.

*Curcuma amada* commonly known as mango ginger are used as stimulant expectorant, diuretic, carminative and stomachic. Rhizome paste is used as plaster in sprains and bone fractures (Sinha, 2001). Rhizome paste mixed with hot water is applied in inflammation, itching and skin diseases and given as decoction in bronchitis, asthma, constipation and gastric troubles (Prakash and Mehrotra, 1996). Rootstock is reported to be edible in Midnapore in Bengal (Maji and Sikdar, 1982). The rhizome that smells of a fresh mango is used in making pickles and as a flavouring species in Asian cooking (Prakash and Mehrotra, 1996). In hypertriglycyricemic rats, the drug caused significant decreases in total lipids and serum triglycerides (Srinivasan and Chandrasekhara, 1992). Etherial extract lowered blood cholesterol in rabbits (Pachauri and Mukherjee, 1970). It also showed antifungal activity (Ghosh et al., 1980).
2.6.7 *Curcuma zedoaria Rosc.*

The rhizomes of *Curcuma zedoaria* Rosc. are stimulant, carminative and stomachic. The paste of the rhizome are also applied to bruises and pains, used as decoction along with pepper, cinnamon and honey (Sinha, 2001). A natural sesquiterpenoids isolated from *Curcuma zedoaria* had an effect on prostaglandin E\textsubscript{2} and nitric oxide production (Hong *et al.*, 2002).

2.7 Pharmacological action of the bioactive components of *Curcuma* species

2.7.1 Phenolic compounds

Phenolic compounds are one of the most major groups of bioactive secondary metabolites such compound bear at least one hydroxyl group or functional derivatives of it attached to one aromatic ring system.

Over the past few years, investigations for phenolic compounds in medicinal herbs have gained importance due to their high antioxidative activity (Zhu *et al.*, 2004). A large number of reports have demonstrated that these compounds are of great value in preventing the onset and or progression of many human diseases (Parshad *et al.*, 1998, Lee *et al.*, 2000). Polyphenols have many favourable effects on human health, like inhibiting the oxidation of low-density protein there by decrease the risk of heart disease (Williams and Elliot, 1997).

These phenolic compounds have anti-inflammatory and anti-carcinogenic properties (Carrol *et al.*, 1999; Maeda Yamamoto *et al.*, 1999). Flavonoids and many other phenolic compounds of plant origin have been
reported as scavenger of reactive oxygen species (ROS) and are viewed as promising therapeutic drugs for free radical pathologies (Parshad et al., 1998; Lee et al., 2000).

The site(s) and number of hydroxyl groups on the phenol groups are thought to be related to their relative toxicity to micro-organism with evidence that increased hydroxylation results in increased toxicity (Ghoshal et al., 1996). In addition some authors have found that more highly oxidized phenols are more inhibitory (Scalbert, 1991; Urs and Dunleavy, 1975). The mechanisms thought to be responsible for phenolic toxicity to micro-organisms include enzyme inhibition by oxidized compounds possibly through reaction with sulfhydryl groups or through more non-specific interactions with the proteins (Mason and Wasserman, 1987).

Epidemiological studies have shown that consumption of food rich in phenols is in correlation with reduced incidence of heart disease (Criqui and Ringel, 1994) phenols retard the progression of arteriosclerosis by acting as antioxidants protecting the low-density lipoproteins and inhibits oxidation in in-vitro test systems (Frankel et al., 1995). Phenolic compounds that are widespread in the plant kingdom and show a wide variety of biological activities; anti-tumour, anti-HIV, immunosuppressive, Lipolipidemic, antifungal, phyto-estrogenic and anti-asthmatic activities (MacRae et al., 1989; Massanet et al., 1989, Ward, 1999) phenolic compounds are known to possesses anti-oxidant properties (Krishnaswamy and Raghuramulu, 1998) phenolic compounds can also act as antioxidants by radical scavenging, in
which they break the free radical chain reaction through hydrogen atom donation (Kosem et al., 2007).

Flavonoids are one of the largest classes of plant phenolic based on degree of oxidation of three Carbon Bridge; flavonoids are categorized into the followings flavones, flavonols, Isoflavones, anthocyanidins.

Flavonoids compounds exhibit inhibitory affects against multiple viruses. Numerous studies have documented the effectiveness of flavonoids such as Swertfrancheside (Pengsuparp, et al., 1995), glycyrrhizin (from licorie) (Watanbe, et al., 1996) and Chrysins (Crifthied et al., 1996) against HIV. A study had found that flavone derivatives are inhibitory to respiratory syncytial virus (RSV) (Barnard et al., 1993; Kaul et al., 1985). Compounds belonging to the terpenoids, alkaloids and flavonoids are currently used as drugs or as dietary supplement to cure, to prevent various diseases (Raskin et al., 2002) and in particular some of the compounds seems to be efficient in preventing and inhibiting various types of cancer (Watson et al., 2001; Reddy et al., 2003).

Flavonoids found in fruits, vegetables and plant-derived beverages have diverse pharmacological action as in central and peripheral nervous system (Bastianetto et al., 2000; Jiang and Dusting, 2003) atleast some of which appear to be related to their activities as free-radical scavengers and as antioxidants.
Recent advances on the neuropharmacology of flavonoids suggest that they have potential for the management of various neurological and psychiatric conditions (Youdim and Joseph, 2001). Flavonoids have been referred to as “nature’s biological response modifier because of strong experimental evidence of their inherent ability to modify the body’s reaction to allergens, viruses and carcinogens. They show anti-allergic, anti-inflammatory, anti-microbial and anti-cancer activity (Cushnie and Lamb, 2005).

Tannins are formed by condensation of flavone derivatives which have been transported to woody tissue of plants or are formed by polymerization of quinone units (Geissman, 1963). Tannin containing beverages, especially green teas and red wine can cure or prevent a variety of illness (Serafiui et al., 1994).

Many human activities such as stimulation of phagocytic cells, host-medicated tumor activity, and a wide range of anti-infective action have been assigned to tannins (Haslam, 1996). One of the molecular actions of tannin is to complex with proteins through so-called non-specific forces such as hydrogen bonding and hydrophobic effects, as well as by covalent bonds formation (Haslam, 1996; Stern et al., 1996). There is an evidence for direct in activation of micro-organism as low tannin concentrations modify the morphology of germ tubes of Crinipellis peroniceora (Brownlee et al., 1990). Tannin in plants inhibits insect growth (Schultz, 1988) and disrupt digestive events in ruminal animals (Butler, 1988; Scalbert, 1991), reviewed the antimicrobial properties of tannin. Condensed tannins have been determined to bud cells walls of ruminal bacteria, preventing growth and protease activity (Jones et al., 1994).
2.7.2 Curcuminoids

The coloured substances in the rhizomes of *Curcuma* species are curcumin and two related demethoxy compounds, demethoxy curcumin and bis-demethoxy curcumin (Vopel *et al.*, 1990). Curcumin is the main active compound, possessing anti-inflammatory, hepatoprotective, anti-microbial, wound healing, anticancer, anti-tumor and anti-viral properties (Toonnesen, 1986). Dietary curcumin significantly reduced the incidence and the multiplicity of colonic tumours as well as activities of cyclo-oxygenase and lipo-oxygenase in colonic mucosa (Rao *et al.*, 1995).

Curcumin has a wide spectrum of therapeutic effects such as anti-inflammatory (Arora *et al.*, 1971) antibacterial (Negi *et al.*, 1999) antiviral (Bourne *et al.*, 1999) antifungal (Apisariyakul *et al.*, 1995) anti-tumour (Kawamori *et al.*, 1999) anti-plasmodic (Itthipanichpong *et al.*, 2003) and hepatoprotective (Park *et al.*, 2000). Curcuminoids exhibit free radical scavenging property (Song, 2001) and (Ramsewak *et al.*, 2000) and act as inhibitors of human immune deficiency virus 1(HIV-1) (Mazumdar *et al.*, 1995) and antioxidant activity (Jayaprakasha *et al.*, 2006). Curcumin protects isoproterenol induced myocardial infarction in rats (Nirmala and Puvanakrishnan, 1996). Curcumin and an ether extract of *C. longa* have hypolipemic action in rats (Rao *et al.*, 1970) and lower cholesterol, fatty acids and triglycerides in alcohol-induced toxicity (Rukkumani *et al.*, 2003) Curcumin is also reported to have antibacterial (Bhavani and Screenivasa, 1979) and anti-HIV (Mazumdar *et al.*, 1995). Curcumin shows antioxidant
activity (Pulla and Lokesh, 1994). It also shows antitumour (Surh et al., 2001) and anticarcinogenic (Kuo et al., 1996) Curcumin enhances intestinal lipase, sucrose and maltase activity (Platel and Srinivasan, 1996) demonstrated curcumin potential utility in anti-immune deficiency syndrome (AIDS).

Many biological activities of curcumin are attributing to its antioxidant properties (Perchellet and Perchellet 1989). Curcumin is also shown to be effective against Alzheimer’s disease in animal model (Yang et al., 2005), curcumin prevents adriamycin neprotoxicity in rats (Narayanan et al., 2000) curcumin a major phenolic antioxidant and anti-inflammatory agent in turmeric has been demonstrated to be effective inhibitor of tumour production (Tanaka et al., 1994, Stoner and Mukhtar, 1995). Plant phenols curcumin (diferuloylmethane) from Curcuma longa, esculetin. (6, 7-dihydroxy coumarin) from Artemisia scoperia inhibited antiproliferative effect in cultural vascular smooth muscle cells (Huang et al., 1992). Curcumin from Curcuma longa (Turmeric) are potent antioxidants (Sreejayan and Rao, 1996) and possess a number of therapeudic properties (Srimal, 1997). Curcumin significantly reduced the possibility of gallstone formation (Panjehshahin et al., 2003).

2.7.3 Alkaloids

The functions of alkaloids in plants are uncertain and they are regarded as by-products of plants metabolism. They may act as reservoir of protein synthesis. Alkaloids are also believed to act as protective substances against the animal or insect attack. They may function as plant stimulant or regulators like hormones and repulate activities like growth metabolism and reproduction.
Alkaloids functions are detoxicating agents by methylating, condensing and cycling compounds.

The first medicinally useful example of an alkaloid was morphine, isolated in 1805 from opium poppy *Papaver somniferum* (Fessenden and Fessenden, 1982). Diterpenoid alkaloids are commonly found to have antimicrobial properties (Omulokoli *et al.*, 1997). Solamargine, glycol-alkaloid from the berries of *Solanum khasianum* and other alkaloids may be useful against HIV infection (McMahon *et al.*, 1995 and Sethi 1979) as well as intestinal infections, associated with AIDS (McDevitt *et al.*, 1996). Alkaloids have been found to have micro-biocidal effects (including against *Giardia* and *Entamoeba* Species). (Ghoshal *et al.*, 1996), the major antidiarrheal effect is probably due to the effect of transit time in the small intestine. The mechanism of action of highly aromatic planar quaternary alkaloid such as berberine and hormone is attributed to their ability to intercalate with DNA (Phillipson *et al.*, 1987).

### 2.7.4 Anti-oxidant compounds

Antioxidant compounds have protective effects in adianycin cardiotoxicity (Ciaccio *et al.*, 1993; Nowak *et al.*, 1995). Majority of the diseases are mainly linked to oxidative stress due to free radicals (Guttrridge, 1995). Free radicals are fundamental to any biochemical process and represent an essential part of aerobic life and metabolism (Tiwari, 2001). The most common reactive oxygen species (ROS) include superoxide anion (O$_2^-$) hydrogen peroxide (H$_2$O$_2$), peroxyl (ROO$^-$) and hydroxyl (OH$^-$) radicals. The
oxidative damage caused by these ROS to lipids, proteins and nucleic acids can trigger various chronic diseases such as coronary heart diseases, atherosclerosis, cancer, AIDS and ageing (Finkel and Holbrook 2002). Treatment of these diseases, antioxidants have been reported to prevent oxidation damage caused by free radicals ROS and prevent the occurrence of diseases (Velavan et al., 2007).

Antioxidants can interfere with the production of free radicals and also with the oxidation process by reacting with free radicals, chelatings, catalysing metals and also by acting as oxygen scavengers (Buyukokuroglu et al., 2001). The medicinal properties of plants have been investigated in the current scientific development throughout the world due to their potent antioxidants activities, no side effects and economic viability (Auudy et al., 2003). Flavonoids and phenolic compounds, widely distributed in plants have been reported to exert multiple biological effects, including antioxidant, free radical scavenging abilities, anti-inflammatory, anti-carcinogenic (Miller, 1996).

Reactive oxygen species such as superoxide anions hydroxyl radical and hydrogen peroxide have been suggested to contribute to the genesis of atherosclerosis, diabetes, ischaemic heart diseases, heart failure and hypertension (Griendling and Alexander, 1997; Nakazono et al., 1991) and thus prevention of oxidative stress-induced damage is an area of interest. Hypertensive patients show increased level of plasma superoxide, hydrogen peroxide and lipid peroxide and reduced plasma levels of the antioxidant vit. C. (Lacy et al., 1998; Kumar and Das, 1993). Several epidemiological studies
have shown a significant inverse association between dietary flavonoids (mainly quercetin) and long term mortality from coronary heart disease (Hertog et al., 1997; Knekt et al., 1996; Rimm et al., 1996). A very wide range of biological actions of flavonoids, including antioxidants antiaggregant (Gryglewski et al., 1987) and vasodilator effects these protective effects of quercetin in cardiovascular diseases.

2.8 Biological activities of essential oils

Essential oils have been studied most from the viewpoint of the flavor and fragrance chemistry only for flavouring foods, drinks and other goods (Sacchetti et al., 2005). However essential oils and their components are gaining increasing interest because of their relatively safe status, their wide acceptance by consumers, and their exploitation for potential multipurpose functional uses (Bounatirou et al., 2007).

Essential oils are highly enriched in compounds based on isoprene structure called terpenes. They occur as monoterpenes, diterpenes, triterpenes, tetraterpenes and sesquiterpenes when terpenes are modified chemically such as by oxidation or rearrangement of the carbon skeleton, the resulting compounds are generally referred to as terpenoids. Terpenes and terpenoids are the primary constituents of the essential oils of many types of plants and flowers. Essential oils are used widely as natural flavour additives for foods, as fragrances in perfumery, and in traditional and alternative medicines such as aromatherapy.
Terpenes or terpenoid are active against bacteria (Ahmed et al., 1993; Amaral et al., 1998), viruses (Fujioka and Kashiwada, 1994), fungi (Ayafor et al., 1994) and protozoa (Ghoshal et al., 1996). In 1977, it was reported that 60% of essential oil derivatives examined to date were inhibitory to fungi while 30 inhibited bacteria (Chaurasia and Vyas, 1977).

2.8.1 Essential oil from Curcuma species

The essential oil fractions from C. longa rhizomes of various habitats exhibits fungistatic activity particularly against aspergillus niger in vitro and Physalospora bucumanesis, Cerotocystis paradoxa, Sclerotium rolfii, Curvularia lunata, Helminthosporium sacchari, (Rao and Joseph, 1971).

The volatile oil of C. longa shows anti-inflammatory (Chandra and Gupta, 1972) antibacterial (Lutomski et al., 1974) and antifungal activities (Banerjee and Nizam, 1978). Essential oils containing monoterpenes, sesquiterpenes (bisabolanes and germacranes), arabinogalactous and ar-turmerone are present in C. longa (Bruenton, 1995).

Behua and Srivastava (2004) isolated the presence of terpinolene, myrcene from the leaves of C. longa and 1,8-cineole and camphor from C. caesia. Alpha-turmerone and ar-turmerone, sesquiterpenoids isolated from the rhizomes of Curcuma zedoaria inhibited lipopolysaccharide (LPS) induced prostaglandin E2 production in culture mouse macrophage cell (Hong et al., 2002).
The essential oils obtained by hydrodistillation of the fresh leaves of *Curcuma longa* contains mainly of monoterpenoids, monoterpenes, hydrocarbons and oxygenated sesquiterpenes. GC analysis of turmeric (*C. longa*) leaf oil from various sources showed major constituent as terpenes and terpenoids (Ramachandraiah *et al.*, 2002).