Chapter-V
Discussion

Plants and plant based medicaments are the basis of many of the modern pharmaceuticals used for various ailments (Abraham, 1981). The medicinal value of plant lies in some chemical substances that produce a definite physiological action on the human body. Knowledge of the chemical constituents of plants is desirable not only for the discovery of therapeutic agents but also be valuable in discovering the actual value of folklore remedies (Mojab et al., 2003). The members of Curcuma species are economically used as spices, dyes, food, perfumes, cosmetics, tonics, starch and as tropical greenhouse ornaments. They are mostly aromatic and have medicinal properties. Based on their medicinal properties and uses as dyes, the present investigations were done on the analysis of bioactive compounds, antioxidant properties and characterisation of the main colouring substances present in them such as curcuminoids and essential oils.

In the present investigation Curcuma species contain significant amount of bioactive compounds which are responsible for their medicinal uses. The results suggested that there is striking correlation between phenolic compounds like total phenols, flavonoids, curcuminoids and anti-oxidant properties. Nutritional constituents like carbohydrate, protein are significantly high in these Curcuma species which signifies their used in the form of spices. However, these species also contain anti-nutritional compounds such as
terpenoids, alkaloids, phytates and phytosterols. These anti-nutritional compounds in another view are currently used as drug or dietary supplements to cure or prevent various diseases (Raskin et al., 2002). Some of these compounds in particular seem to be efficient in preventing and inhibiting various types of cancers (Watson et al., 2001; Reddy et al., 2003).

The fibre content in *Curcuma* species ranged from 2.77% to 10.63% dry weight. The highest fibre content is in *C. zedoaria* and the lowest is in *C. caesia*. The ash content in *Curcuma* species ranged from 1.27% dry weight to 11.23% dry weight. Ash content indicates the presence of minerals and unwanted earthy matter. The range of ash content is in accordance to the report of Singh et al., (2003) who reported the ash content of *C. longa* as 4.5%. The highest content is in *C. amada* and the lowest content is in *C. caesia*. Singh et al.,(2003) reported the moisture content of *C. longa* as 11±2% which is in agreement with our present finding that the moisture content in *C. longa* is 12.25% dry weight. Moisture content ranged from 12.01% dry weight to 19.05% dry weight. Crude protein content is highest in *C. leucorrhiza* 31.97mg/g dry wt.

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 of or progression of human diseases (Parshad et al., 1998; Lee et al., 2000). In the present investigations the levels of total phenols ranges from 42mg/g dry weight to
220mg/g dry weight in the rhizomes of *Curcuma* species. The highest content is in *C. longa* (turmeric) which is widely used world-wide as medicine, condiment, dye and cosmetics (Jayaprakasha *et al.*, 2005). Bound phenol content is also comparatively high in *C. longa* comparing to the other species, 74mg/g dry weight. Polyphenols are reported to decrease the risk of heart diseases (Williams and Elliot, 1997). Epidemiological studies have also shown that consumption of food rich in phenols is in correlation with reducing heart diseases (Criqui and Ringel, 1997).

In the present investigation, flavonoid contents in *Curcuma* species ranges from 20.46mg/g to 132mg/g dry weight. Flavonoids exhibit inhibitory against multiple viruses. Numerous studies have documented the effectiveness of flavonoids such as glycyrrhizin (from licorice), Watanbe, (1996) and Chrysin (Critchfield *et al.*, 1996) against HIV. Trinidad *et al.*, (2012) reported that total phenols and flavonoids content in *C. longa* as 174mg/100g and 125mg/100g respectively. Nan Chen *et al.*, (2008) reported, total phenols content in *C. longa* as 21.4±1.7mg/g and in *C. zedoaria* 33.4± 5.7mg/g dry wt. This variation in flavonoids may be due to the differences in climate factors and the time of harvesting the rhizomes (Cheryl *et al.*, 2008).

In addition to total phenols and flavonoids,*Curcuma* species also contain other phenolic compounds such as tannins and anthocyanins. Tannins contents ranges from 12.7mg/g dry weight to 24.10mg/g dry weight. Anthocyanin content ranged from 8.00mg/g fresh weight to 156.32mg/g fresh weight. Anthocyanins are the most important group of water soluble pigment present in
plants (Clifford, 2000). They are responsible for the wide range of colours of plants including purple, violet, magenta, red, orange and yellow (Fennema, 1998). Anthocyanins content is found to be high in Curcuma species showing different colours in the rhizome (white, yellow, blue, orange). C. longa having yellowish orange colour rhizome is having the highest anthocyanins content (156.32mg/g fresh weight) followed by C. amada having light yellow rhizome (33.66mg/g fresh weight) and the lowest is in C. angustifolia (8.0mg/g fresh weight) having a straw (almost white) coloured rhizome. Trinidad et al., (2012) also reported the anthocyanins content of C. longa as 129mg/100g which is in lower values as compared to our present values. Phenolic compounds are known to possess antioxidant properties act as antioxidant by radical scavenging in which they break the free radical chain reaction through hydrogen atom donation (Kosem et al., 2007).

From the present finding all the rhizomes of Curcuma species had significant antioxidant properties, total phenols and flavonoid contents. The rhizome of C. longa which has the highest total phenol and flavonoid content is having the highest antioxidant properties. Miller (1996) stated that flavonoids and phenolic compounds widely distributed in plants have been reported to exert multiple biological effects, including antioxidants, free radical scavenging abilities, anti-inflammatory and anti-carcinogenic. Free radicals are fundamental to any biochemical process and represent an essential part of aerobic life and metabolism (Tiwari, 2001). The most 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 nuclei acids can trigger various chronic diseases such as coronary heart diseases, atherosclerosis, cancer, AIDS and aging (Finkel and Holbrook, 2002). In the treatment of these diseases antioxidant therapy has gained an immense importance. Antioxidants have been reported to prevent oxidative damage caused by free radicals and prevent the occurrence of diseases (Velavan et al., 2007). The used of Curcuma species in the treatments of various diseases such as bronchitis, asthma, inflammation, ulcer, anorexia, cough, diabetic wounds etc. may be due to the presence of high phenols and flavonoids which also have high antioxidant properties. Rice -Evans and Packer (1998) reported that the antioxidant activity of many compounds of botanical origin is proportional to the phenolic content. Veglioglu et al., (1998) suggested a causative relationship between total phenolic content and antioxidant activity. In the present study also there is a correlation between phenolic content and antioxidant activity. C. longa having the highest phenolic content (220mg/g dry weight) showed the highest antioxidant activity in concentration dependent manner and the % inhibition of DPPH radical is 81.60% which almost equal to authentic standard vitamin C and Quercetin having percent inhibitions of 84.00% and 97.35% respectively. The lowest percent inhibition is in C. leucorrhiza having 40.06% inhibition with a phenolic content of 42mg/g dry weight. Primary antioxidant properties are generally measured by DPPH assay (expressed as IC$_{50}$). The
DPPH assay measures the ability of the extracts to donate hydrogen atom to the DPPH radical resulting in bleaching of the DPPH solution. The greater the bleaching action, the higher the antioxidant activity AEAC (Ascorbic acid equivalent to capacity) and this is reflected in lower IC₅₀ value (Lim et al., 2006). The same action is found in Curcuma species C. longa having lowest IC₅₀ value (112µg/ml) from other samples has the highest percent inhibition.

Alkaloids function as plant stimulant or regulators like hormones and activities like growth metabolism and reproduction. Diterpenoid alkaloids are commonly found to have antimicrobial properties (Omulokoli et al., 1997). Solamargine, a glycol-alkaloid from the berries of Solanum khasianum and other alkaloids may be useful against HIV infection (McMohan et al., 1995 and Sethi, 1979) as well as intestinal infections associated with AIDS (McDevit et al., 1996). In the present investigation C. angustifoilia which is used in the treatments of gastrointestinal tracts, lungs or the excretory system is having the highest alkaloid content (162.08mg/g dry weight) which is also used in the treatments of leukodermia epilepsy, cancer and HIV/AIDS.

Tannins act as anti-nutritional factor because tannin combines with digestive enzymes thereby making them unavailable for digestion (Binita and Khetapaul, 1997). Tannin also form complexes with protein and reduces their digestable and palability (Eka, 1985; Sabahelkhiel et al., 2010). On the other hand, tannin has received a great deal of attention in recent years since it was suggested that the consumption of tannin containing beverages especially green teas and red wines can cure or prevent a variety of ailments (Serafiue et al.,
1994). Many human physiological activities such as stimulations of phagocytic cells, host mediated tumour activity and a wide range of anti-infective actions have been assigned to tannins. Tannin in plants inhibits insect growth (Schultz, 1988) and disrupted digestive events in ruminal animals (Bulter, 1998). In the present investigation tannins content ranged from 12.7mg/g dry weight to 24.10 mg/g dry weight. The highest content is with that of Curcuma amada.

Phytates content in the rhizomes of Curcuma species ranges from 0.42mg/g dry weight to 1.90mg/g dry weight. The highest content is with C.caesia and the lowest conten is C. aromatica. Phytates are inorganic acid found in plant materials (Heldt, 1997). It decreases calcium bioavailability and form calcium phytate complexes that inhibited the absorption of Fe, Zn (Plaami, 1997). Phytate is also associated with nutritional diseases such as rickets and osteomalacia in children and adult respectively (Agbaire, 2012). Inspite of the many adverse effects many beneficial effects have also been found in phytates. Phytates exert beneficial effects in the gastro-intestinal tract and other largest tissue through its chelating ability. Phytate as a calcium salt can protect against dietary Pb$^{2+}$ poisoning in experimental animal and human volunteers.

Hence, phytates have the ability to counteract acute oral Pb$^{2+}$ toxicity. Ononi et al., (2004) found that phytic acid at a level of 0.035% may protect against a fatty liver resulting from elevated hepatic lipogenesis. According to Potter (1995) phytates which is a compound of fibre can influence the aetiology of heart disease. Jariwalla et al., (1990) show that dietary phytates
supplementation resulted in the lowering of serum cholesterol and triglyceride levels. This effect accompanied the decrease in serum zinc level and Zn−Cu ratio. This is because coronary heart disease appears to be caused by an imbalance Zn−Cu metabolism. Trinidad et al., (2012) reported that C. longa content 11.4mg/100g of phytic acid which is higher than the present finding (C.longa 1.13 mg/g dry wt.).These differences may arise due to the differences at the time of harvesting the rhizomes and prevailing climatic factor (Cheryl et al., 2008).

Saponin is another naturally occurring oily glycosides present in wide variety of plants. They are dangerous when injected into the blood stream as it quickly haemolysed red blood corpuscles (Applebaum et al., 1969). According to Awe and Sodipo (2001), high saponin level has been associated with gastro-enteritis manifested by diarrhoea and dysentery. Saponin reduces the uptake of certain nutrients including glucose and cholesterol at the gut through intraluminal physiochemical interactions. Hence, it has been reported to have hypocholesterolemic effects (Basu et al., 2007) and thus they may aid in lowering the metabolic burden that would have been place on the liver. Saponins in foods have traditionally been considered as anti-nutritional factors (Thompson, 1993) and in some cases have limited their uses due to their bitter tastes (Rideout et al., 1988). However, food and non-food sources of saponin have come into renewed focus in recent years due to increasing evidences of their benefits such as cholesterol lowering and anticancer properties (Gurfinkel and Rao, 2003). Considering the harmful and beneficial effects we find it
important to analyse saponin content in the rhizomes of *Curcuma* species. From our finding the highest saponins content is in *C. longa* 56.16mg/g dry wt. and the lowest is in *C. amada* 9.15mg/g dry wt. Recent research has established saponin as the active components in many herbal medicines (Liu and Henkel, 2002) and the presence of saponin in *Curcuma* species indicated that saponin is one of the active component which placed *Curcuma* species among the herbal remedies.

From the present investigation, the rhizomes of *Curcuma* species content considerable amount of phytosterols which range from 13.39mg/g dry wt. to 49.14mg/g dry wt. Denke, 1995 reported that phytosterols have been shown to reduce dietary cholesterol absorption and hence total and low density lipoprotein (LDL) cholesterol concentration in man. Phytates also have diverse therapeutic effects such as anti-cancerous property. It also provides non-pharmacological approach to reduction of atherosclerosis in population.

The influence of healthy living and eating has been the impetus for scientific disciplines of functional foods and nutraceutical (Shi *et al.*, 2002). The rhizomes of *Curcuma* species having high phenolic and flavonoid content are also having high nutritional contents. Total soluble protein content, total soluble sugar and non-reducing sugar content are highest in *C. longa* (turmeric) which is used widely used as spices in cooking. Reducing sugar and total free amino acid contents ranges from 12.80mg/g to 88.43mg/g fresh weight and 0.10 mg/g to 5.66mg/g dry wt. respectively. The tubers of *C. angustifolia* are easily digestible and recommended for invalids and children (Sinha, 2001).
drink including *C. angustifolia* as an ingredient is also used as a replacement of breast milk or a nutritional supplement for babies a short while after weaning. This may be due to the high content of total soluble protein, reducing sugar and total free amino acids in this species.

Bhanuprakash and Suryanarayana (2005) reported that turmeric (*C. longa*) contain 6.3% protein, 70% carbohydrates. Consumption of turmeric 0.5 to 1.5g/day/person produce no toxic symptoms (Eigner and Scholz, 1999) but petroleum ether and aqueous extracts of turmeric rhizomes show 100% antifertility effect in rats when fed orally (Garg, 1974). Chemical constituents of plants may be therapeutically active or inactive. The ones which are inactive are called inert chemical constituents (Iyengar, 1995). The main active compounds of *Curcuma* species are curcuminoids and essential oils. Curcuminoids are the yellow colouring substance in *Curcuma* species composed of curcumin and two related demethoxy compounds demethoxycurcumin and bisdemethoxycurcumin. Curcuminoids exhibit free radical scavenging property (Song, 2001) and acts as inhibitors of human immune deficiency virus (HIV-1) integrase (Mazumdar *et al.*, 1995) and antioxidant activity (Jayaprakasha *et al.*, 2006). Hence, isolation and characterisation of curcuminoids, essential oils and terpenoids are essential.

Quantification of curcuminoids was carried out in the present study with all the rhizomes of *Curcuma* species following cold solvent extraction method given by Cheryl *et al.*, (2008). Among the *Curcuma* species analysed *C. longa* (turmeric) contains maximum amount of curcuminoids (38.71mg/g fresh
weight) and the lowest is in *C. leucorrhiza* (10.66 mg/g fresh weight). These findings are in agreement with WHO’s (1999), that dried turmeric should contain not less than 4.0% v/w of oil and 3.0% total curcuminoids. Cheryl *et al.*, (2008) reported that the highest yield of curcuminoid content as 47.7±6.4% from the freshly processed turmeric samples 55.5± 1.2% from the dried samples 44.4% after 10 months of storage and 40.4% after 14\textsuperscript{th} months of storage. The variation in the curcuminoids level may be due to the variation at the time of harvesting the rhizomes, mode of storage and difference in the mode of extraction (Cheryl *et al.*, 2008). The contents of curcuminoids in the rhizomes of *Curcuma* species is related with the anti-oxidant property.

*Curcuma longa* having the highest curcuminoids content is giving highest percent inhibition of DPPH radical that is 81.60% and the lowest is in *C. leucorrhiza* 40.06% with curcuminoids content of 12.66 mg/g fresh weight. There are reports on the antioxidant properties of curcuminoids (Pulla and Lokesh, 1994; Perchellet and Perchellet, 1989; Sreejayan and Rao, 1996; Subramaniam *et al.*, 1994) that protective effects of turmeric and curcumin were greater than those of vitamin A and E. The correlation coefficient between total phenols, flavonoids, curcuminoids and antioxidant properties suggested that 71% of antioxidant properties is contributed by total phenols contents, 77% contributed by flavonoids contents and 58% by curcuminoids contents in the rhizomes of seven *Curcuma* species.

In the present investigation characterisation of curcuminoids was carried out using Thin Layer Chromatography (TLC) analysis. The curcuminoids were
detected by the presence of three individual bands and identified by comparing with the standard curcumin giving Rf value of 0.60, 0.40 and 0.31 with that of curcumin, demethoxycurcumin and bisdemethoxycurcumin respectively using chloroform and methanol as the developing solvent. The first spot which separate as light spot is bisdemethoxycurcumin and the next is demethoxycurcumin and third spot which developed as a thick deep spot is curcumin showing the presence of curcumin in large amount comparing to the two demethoxycurcumin compounds. Similar to the present result, Asghari et al., (2009) and Paramasivam, et al., (2008) reported the presences of three individual bands in the rhizome of *C. longa* (turmeric) TLC analysis. However, there is no report available on the characterisation of curcuminoids in the rhizomes of other *Curcuma* species. The present research findings suggested that the other species of *Curcuma* can also be used as a source of curcuminoids and curcumin as the active components. 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) antitumor (Kawamori et al., 1999) antiplasmodic (Ittipanichpong et al., 2003) hepatoprotective (Park et al., 2000), anticarcinogenic (Kuo et al., 1996) and enhances intestinal ligase, sucrase and maltase activity (Platil and Srinivasan, 1996). These findings clearly related the medicinal and culinary uses of *Curcuma* species with the presence of active components.

Essential oils are highly concentrated natural plant extracts: a drop or two can produce significant results. In the past essential oils have been studied
most from the view point of the flavour and fragrance chemistry only for
flavouring foods, drinks, cosmetics and other goods (Sacchetti et al., 2005).
They are gaining interest increasingly because of their relatively safe status,
their wide acceptance by consumers and their exploitation for potential
multipurpose functional uses (Bounatirou et al., 2007). The essential oils of
*C. longa* shows anti-inflammatory (Chandra and Gupta, 1972), antibacterial
(Lutomski et al., 1974), antifungal activities (Banerjee and Nigam, 1978).
Keeping these important properties in view the present investigation has been
undertaken to characterise the essential oil components in the rhizomes of
*Curcuma* species. It was found that the important components present in the
rhizome of *C. longa* are ar-curcumin, at-turmerone, β-pinene, β-bisabolene,
terpinolene and borneol. Similarly Bruenton (1995) also reported the presence
of bisabolene, germacrones and ar-turmerone in *C. longa*. Behua and
Srivastava (2004) also reported that the essential oils from the leaves of *C.
longa* contain terpinolene and myrcene. Ar-turmerone, β-pinene, camphor and
1,8-cineole are present in the essential oil of *C. amada*. In the rhizomes of *C.
aesia*, the main essential oil components are camphor, camphene, linalool,
borneol, ocimene, zingiberone and longifolene are present. In *C. leucorrhiza* α-
ingiberene, ar-curcumin, camphor, sabinene, terpinolene, β-pinene,
longifolene-12 are present in the rhizome. The essential oils from the rhizomes
of *C. angustifolia* are zingiberol, camphor, β-pinene, mecloqualone, ar-
curcumin, borneol, trinolein, Isoprophyllinoleate, terpinolene and
phenanthrene, 2-nitro. In *C. aromatica*, camphor, p-cymene, ar-turmerone,
borneol, β-pinene, bisabolene, terpinolene are present as observed in the
present investigation. In *C. zedoaria*, the essential oil components are ar-turmerone, borneol, beta-pinene, bisabolene, terpinolene.

Hong *et al.*, (2002) reported that α-turmerone and ar-turmerone, a sesquiterpenoids isolated from the rhizome of *C. zedoaria* inhibited lipopolysaccharide (LPS) –induced prostaglandin E₂ production in culture mouse macrophage cell. Ramachandraich *et al.*, (2002) reported the presence of terpenes and terpenoids as the major constituents in the leaf oil of *C. longa*. In the present study terpenoid compositions of seven *Curcuma* species are reported by head-space GC-MS analysis in the fresh rhizomes. Head space GC-MS analysis of *C. longa* fresh rhizome showed the presence of 11 peaks eluted at the retention time (tR. 8.675 minute, tR. 10.618 minute, tR. 24.693 minute, tR. 27.235 minute, tR. 27.816 minute, tR. 31.487 minute, tR. 34.379 minute, tR. 34.579 minute, tR. 35.460 minute, tR. 35.773 minute and tR. 51.346 minute). The highest peak eluted at tR. 27.816 minute is represented by ar-turmerone and the lowest peak eluted at tR. 24.693 minute is phenanthrene, 2-nitro. The other components are di-epi-α-cedrene, fenretinide, β-gauine, γ-himachalene, noscapine, longifolene-12, β-phellandrene, ergost-8(14)-en-3-01.

In the present study, the highest peak present in *C. angustifolia* at the retention time (tR. 55.532 minute) is camphor and the next peak eluted at (tR. 55.920 minute) is camphene followed by β-pinene (tR. 55.730 minute). These three compounds are having the same mass spectra (MS) fragmented at m/z 93. The other compounds are borneol (tR. 54.090 minute) Neo-triangularine (tR. 5.531 minute), mecloqualone (tR. 8.609 minute) zolpidem (tR. 8.609 minute),
trilinolein (tR. 53.466 minute), isopropyl linoleate (tR. 31.538 minute), trans-α–bergamotene (tR. 6.801 minute), ar-turmerone (tR. 32.345 minute), phenanthrene, 2 - nitro (tR.26.177 minute), heliosupine (tR. 22.902 minute), β-phellandrene (tR. 11.129 minute), and the lowest peak is benzo (c) carbozole (tR. 8.462 minute).

In the rhizome of *C. Caesia* the four highest peaks are IR-alpha-pinene (tR. 57.083 minute), IS-α-pinene (tR. 54.810 minute), camphene (tR. 57.365 minute) and β-pinene (tR. 55.075 minute) having the same molecular formula and mass fragments m/z 93. The other components are camphor (tR. 53.395 minute), lenacil (tR. 56.702 minute), (-) caryophyllene-(II) (tR. 31.506 minute), longifolene -12 (tR. 52.553 minute), ar-turmerone (tR. 58.534 minute), santolina (tR. 8.689 minute), β-phellendrene, (tR. 13.228 minute), heliosupine (tR. 19.136 minute), trilinolein (tR. 13.899 minute), isopropyl linoleate (tR. 35.456 minute), diisooctyl adipate (tR. 41.288 minute).

In the present study, Head space GC-MS analysis of terpenoids in the fresh rhizome of *Curcuma aromatica* showed the presence of four peaks. The highest peak eluted at retention time (tR 5.614 minute) is represented by the compound camphor MS fragments at m/z 95, the next higher peak is β-pinene (tR. 6.875 minute), MS fragments at m/z 93 and eucalyptol (tR. 8.667 minute), the smallest peak is lenacil ((tR. 8.529 minute) MS fragment at 153m/z.

In the rhizome of *C. leucorrhiza* 14 peaks are eluted in the chromatogram. The highest peak is camphene (tR. 8.704 minute) followed by
β-pinene (tR. 6.900 minute) and the lowest peak is santalol (tR. 30.371 minute). The other compounds are camphor, ar-turmerone, pyridine, 3,4-diphenyl 1,4-dibromo-2-butanol, borneol, heliosupene, eucalyptol, trilinolein, isopropyl linoleate, zolpidem lenacil, santalol.

In *C. amada* four peaks are eluted at retention time (tR 31.424 minute), (tR. 7.199 minute), (tR. 31.024 minute) and (tR. 41.357 minute) the components are ar-turmerone representing the highest peak followed by zolpidem, santalol, camphene. Terpenoids composition in the fresh rhizome of *C. zedoria* are β-pinene (tR. 31.475 minute), borneol (tR. 6.082 minute), noscapine (tR. 11.174 minute), β-guaiene(tR. 5.614 minute), β-phellendrene (tR. 41.270 minute), ar-turmerone (tR. 6.882 minute) and lenacil (tR. 14.256 minute).

Gas chromatography-mass spectrometry (GC-MS) is chosen for determination of terpenoids in this study, largely due to the ability of GC-MS to identify the terpenoids through retention index matching and provide confirmation through comparison to library mass spectra.

Tsao *et al.*, (1995) reported that monoterpenes in general have been active as fumigants, repellents or insecticides toward stored grain insects. Rath *et al.*, (1998) documented that turmeric contains pungent, odoriferous oils and oleoresins; the rhizomes have been reported to possess many kinds of biological activities. The insect repellent components in turmeric are turmerones and ar-turmerone (Su *et al.*, 1982). Terpenes or terpenoids are active against bacteria (Ahmed *et al.*, 1993, Amaral *et al.*, 1998), viruses

Volatile terpenoids are abundant and diverse in plants and play a complex, vital role in relationship between plants and insects. Signals for sexual reproduction for defence against herbivores or to attract natural predators of herbivores are conveyed through volatile terpenoids (Harrewinjin *et al.*, 2001). Identifying these chemical signals and their function may suggest alternative methods to enhance resistance of plants to insect attacks.
Conclusion

*Curcuma* species are widely known for their broad range of pharmacological activities. Interestingly, in the present study the rhizome of these *Curcuma* species (*Curcuma longa*, *C. angustifolia*, *C. caesia*, *C. aromatica*, *C. leucorrhiza*, *C. amada* and *C. zedoaria*) show free radical scavenging activities. Therefore, these plants can be used as sources of health supplement for prevention of degenerative diseases. Moreover, these rhizomes are also found to have significant nutritive values. The results represented in this investigation also demonstrated that a considerable significant amount of bioactive compounds such as total phenols, bound phenols, flavonoids, tannins, phytosterols, phytates, saponins, alkaloids, essential oils and terpenoids are present in the rhizomes of *Curcuma* species which are related to their medicinal uses. These scientific findings will no doubt build leverage for pharmaceutical industries. Special attention should be paid to develop these rhizomes having more bioactive components for utilisation as food, condiments and health related applications.