Research Article

Analysis of Curcumin Content of Turmeric Samples from Various States of India

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ABSTRACT

Turmeric samples were collected from various states of India and analysed for its curcumin content. The results of the study disclose turmeric samples from Odisha and Andra Pradesh to have comparatively higher percentage of curcumin than the other samples. The quality of curcumin and hence the activity of turmeric depends on the quantity of curcumin in it. The findings reveal the curcumin content to depend on geographical variation which influences the soil, environment, climatic conditions etc.

Keywords: Turmeric, Curcumin, spectrophotometric, geographical distribution.

INTRODUCTION

Turmeric is widely used popular Indian medicinal plant which belongs to the family of Zingiberaceae. Turmeric (*Curcuma longa* L.) rhizome is the commonly used additive which gives flavour, colour and add spices to food preparation in south east Asian countries is the turmeric. It is a traditional medicine used in Ayurvedha, Unani and Siddha medicine for various diseases (**Selvi *et al*., 2015**). Turmeric and its active component curcumin have received considerable attention due to their many recognized biological activities. Turmeric is used in India in herbal remedies leading to a high consumption rate of curcumin in this region. Turmeric is known for its antidiabetic, antiseptic, antibacterial, anti-asthmatic, antiulcer drug, insect repellant and wound healing properties (**Ammon and Wahl, 1991**). It is also used as a ceremonial dye during functions (**Wilson, 2005**). Indian turmeric is preferred due to its high Curcumin content as compared to other countries. However, the raw materials if not standardized and uniform may result in lesser active compounds than required for the said activity. A study conducted to reveal the genetic diversity and variation in active compounds and the bioactivity of turmeric collected from different parts of Thailand revealed variation in curcuminoid content of 67 samples of *Curcuma longa* L. with samples from the central region having highest total curcuminoids (**Thaikert and Paisooksantivatana, 2009**).

Phytonutrients play an crucial role in many of the chronic diseases due to their pharmacological and biological properties (**Rajalakshmi and Narasimhan, 1996**). Curcumin, derived from the rhizome of *Curcuma longa* is a linear diarylheptanoid possessing excellent medicinal properties (**Manju *et al*., 2008**). It is a small molecular weight polyphenolic compound (1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadien-3,5-dione) lipophilic in nature. It is one of the primary ingredients in turmeric and curry powders (**Tayyem *et al*., 2006**). Generally, the commercially produced curcumin is a mixture of curcumin, demethoxy curcurnin and bis-demethoxy curcumin with curcumin as the main constituent.

Synthetically prepared curcumin and natural curcumin are reported to be equal in their activity. (**Ruby *et al*., 1995**). Curcumin is a free radical scavenger with rich antioxidant activity, binds metals, particularly iron and copper, and can function as an iron chelator. It is remarkably non-toxic and exhibits limited bioavailability.

Curcumin exhibits great promise as a therapeutic agent and is currently in human clinical trials for a variety of conditions, including cancer, myelodysplastic syndromes, colon cancer, psoriasis and Alzheimers disease

(**Hatcher *et al*., 2008**). It is reported to exhibit several pharmacological, microbial and other medicinal properties (**Nagabhushan *et al*., 1981; Kelloff *et al*., 2000, Elizabeth and Rao 1990, Ruby *et al*., 1998, Allen *et al*., 1998, Donatus *et al*., 1990, Srivastava *et al*., 1986; Ramirez-Tortosa *et al*., 1999, Tayyem *et al*., 2006, Lekshmi *et al*., 2013, Bhutani *et al.,* 2009, Jang *et al.,* 2008**). The antidiabetic effect of 3.0% curcumin and its effects on diabetes-induced ROS generation and lipid peroxidation in type- 1 *Diabetes mellitus* is reported (**Abdel-Aziz *et al*., 2012).**

In order to achieve the beneficial health effects of curcumin, however, high consumption of curcumin is necessary, although the required dose may vary depending on disease conditions. Nearly 1.5 to 4 g/day of curcumin are required for the effective treatment of cancer like lung and pancreatic cancers. Less than 0.5 g of curcumin is effective in treating some inflammatory conditions. No toxicity has been observed during the long history of high curcumin intake in the diet and also at high doses (4-8 g/day). Oral intake of (8 g) curcumin daily for several months is well-tolerated in treated patients (**Youngjoo, 2014**). Spent turmeric, the left over residue of curcumin extracted turmeric has beneficial effects on various diabetic parameters and also ameliorated intestinal disaccharidase activities (**Kumar *et al*., 2000; Zhang *et al*., 2006**).

All the aforesaid activities of turmeric depend on the amount of curcumin. The amount of curcumin in turn depends on various factors. The curcumin content varies from fresh to stored rhizomes (**Ganapati *et al*., 2011**). It has been observed that the chemical composition of most of the herbs changes with geographical region which may be due to climatic conditions and biochemical variations (**Pawar, 2014**). Previous reports have indicated that the curcumin content varies between the different lines of this species. These results suggest that the difference of curcumin content among the various lines of *C. longa* was caused by hybridization and introgression with other Curcuma species (**Hayakawa *et al*., 2011**).

The performance of 21 varieties of turmeric for curcumin content studied at Konkan region revealed Salem to be the best variety with significantly higher curcumin content (4.87%) . The phenotypic and genotypic coefficient of variation, heritability and genetic advance on mean basis were appreciably high for yield and curcumin content (**Sinkar, 2005**). In the analysis of curcumin by thin layer chromatographic method the content of curcumin was found to vary significantly in different geographical regions. The highest concentration of curcumin in turmeric was found to be in Erode and Surat respectively inferring the superior quality of turmeric in Erode (TamilNadu) (**Ashraf *et al*., 2012**).

Among the turmeric cultivars of different growing regions in Meghalaya, Lakadong turmeric is reported to have the highest curcumin content (6.8%-7.3%) in a study conducted by **Kanjilal *et al.,*** (**2002**) and **Chandra *et al.,*** (**2005**). The variations m *Curcuma longa* cultivars namely Rashmi, Krishna, Roma, CL-315, CEL-6, CL-70, CL-13 and CL-16 collected from various locations in India revealed Rashmi to have highest curcumin content (**Dixit *et al.,* 2002**). The quality of turmeric also depends on different sprouting stages (**Shanmugam and Bhavani 2014**). **Muthuswamy and Shah** (**1982**) have reported Salem turmeric to show 4.75% curcumin content compared to 3.9% of Erode.

Muralidharan and Ramankutty (**1976**) have reported Alleppy turmeric among the selected 20 clones of turmeric *(Curcuma spp.)* in Wynad, Kerala for the highest curcumin content (6.2%). **Mathai** (**1976**) reported the 2.5% to 8.1 % variability in curcumin in freshly harvested mature rhizomes of 38 varieties representing *C. longa* and *C. aromatica.* **Kotoky *et al.,*** (**1999**) reported Tamenglong turmeric to have the highest curcumin content (7.3%) among the 7 *Curcuma longa* cultivars grown in Manipur. **Garg *et al.,*** (**1999**) reported the variation in the rhizome essential oil and curcumin contents and oil quality in the land races of turmeric of North Indian plains for twenty-seven accessions of *C. longa.* Curcumin content was found to vary from 0.61% to 1.45%. **Satish *et al.,*** (**1997**) investigated the growth and yield of twelve C. *dornestica* C. *longa* cultivars in the southern dry region of Karnataka. The highest curcumin content (8.08%) was observed in rhizomes of PCT-8. **Rakhunde *et al.,*** (**1998**) estimated the curcumin and essential oil contents of some commonly grown turmeric *(Curcuma longa* L.) cultivars of Maharashtra and found that the curcumin contents in mother rhizomes of all cultivars were comparatively higher than those in the fingers, except in the case of cv. Rajapuri. Mother rhizomes of Mydukur and fingers of Salem exhibited the highest curcumin content.

Cooray *et al.,* (**1988**) studied the effects of maturity on rhizome yield on the content and composition of essential oils and curcumins.

Contents of curcumin, demethoxycurcumin and bis-demethoxycurcumin monitored by TLC coupled initially with UV spectrophotometry and UV densitometry showed difference in content of mother and finger rhizomes; the ratio hardly changed with maturity. Maximum curcumin per bush was reached after about 9 months and declined thereafter. **Nadgauda and Mascarenhas** (**1986**) determined the curcumin concentration in the swollen rhizome-like portions of the base of *in vitro* grown shoots of plantlets (cultivars Tekurpeta and Duggirala) derived from callus was positively correlated (r = 0.87) with curcumin concentration in rhizomes of callus-derived plantlets grown to maturity in the field.

There are reports on several methods of isolation of curcumins from the rhizomes of *C. longa* like solvent extraction of the rhizome (**Verghese, 1993**), thin layer chromatography based on the absorption maxima of the compounds at 428, 423 and 418 nm (**Chempakam *et al.,* 2000**), High performance liquid chromatographic separation of curcumin (**He *et al.,* 1998; Gupta *et al.,* 1999**) and spectrophotometric method (**Taylor and McDowell, 1992**). Most of them are spectrophotometric methods (**BP, 1973; Ministry of Public Health, 1990; ASTA Method, 1985**).

Jayaprakash *et al.,* (**2002**) developed an improved HPLC method for the determination of curcumin, demethoxycurcumin, and bisdemethoxycurcumin. Four different commercially available varieties of turmeric, namely, Salem, Erode, Balasore and local market samples, analyzed to detect the percentage of curcumin, demethoxycurcumin, and bisdemethoxycurcumin revealed 1.06 +/- 0.061 to 5.65 +/- 0.040, 0.83 +/- 0.047 to 3.36 +/- 0.040 and 0.42 +/- 0.036 to 2.16 +/- 0.06, respectively, in four different samples.

Kita *et al.,* (**2002**) developed a method of micellar electrokinetic chromatography (MEKC) for the analysis of curcuminoids in turmeric samples. The authors have reported ethanol to be the best solvent for curcuminoid extraction and separation by HPLC. The detection limits for curcuminoids by HPLC and MEKC were 0.02 and 0.1 J.Lg/ml, respectively. **Lechtenberg *et al.,*** (**2004**) developed a method for quantitative determination of curcuminoids in *Curcuma* rhizomes and rapid differentiation of *Curcuma domestica* Val. and *Curcuma xanthorrhiza Roxb.* by capillary electrophoresis. The three major curcuminoids *viz*., curcumin, demethoxycurcurnin and bis-demethoxycurcumin from *Curcuma domestica* Val. (*Curcuma longa* L.) and *Curcuma xanthorrhiza* Roxb. (Zingiberaceae) were fully separated and quantified in less than 5 min using a capillary zone electrophoresis method with standard fused-silica capillaries and photodiode array detection.

All the aforesaid literature reports portray the need for superior quality of medicinal plants for high metabolic content and yield. In this context, it was felt pertinent to analyze the variation in the curcumin content of samples of turmeric collected from various states of India.

METHODS AND MATERIALS

The turmeric samples were collected from Kerala (KT), Karnataka (KAH), Maharashtra (MU), Manipur (MA), Tamil Nadu (TA), Uttar Pradesh (UP), Kolkata (KOL), Andhra Pradesh (AN) and Odhisa (OT). The rhizome was collected from different areas in a state and pooled together to get a representative sample of one state. Standard Curcumin sample was purchased and used as such without purification.

Preparation of solution

About 1g of the sample was refluxed with 75ml acetone for 1 hour after which it was filtered and made up to 200ml. From this further 1ml was taken and made up to 100ml in a standard flask. The flasks were wrapped with dark coloured paper and dark conditions maintained since curcumin is light sensitive. The UV spectral reading for this solution was recorded under 420nm. A UV spectrum was recorded for standard curcumin. The obtained absorption of samples was compared with the standard value and percentage curcumin in samples calculated using the formula:

Curcumin (%) = [Ds*As/100*Ws*1650] *100

where, Ds - dilution volume of the sample (ie., 200*100 = 20000ml)

Ws - weight of the sample taken in grams

As - absorbance of the sample

1650 - standard value calculated by experts

RESULT AND DISCUSSION

The samples collected in triplicate from 9 states were analyzed for its curcumin content by UV-Visible spectrophotometry. The UV-Visible spectra recorded for all the samples were compared with that of UV spectrum of standard curcumin (**Figure 1**). The absorption band at 420nm is characteristic of curcumin.

The UV visible spectrum gives a relation between the absorbance and wavelength of the sample taken. It was observed from the results (**Figures 2, 3 and 4**) that curcumin extracted from turmeric samples from Uttar Pradesh and Tamil Nadu was similar and Andhra Pradesh and Odisha were similar (**Figure 1**). Curcumin in turmeric samples from Kerala, Karnataka, Maharashtra and Manipur were found to vary. The percentage of curcumin calculated for various samples is tabulated (**Table 1**).

The results reveal highest curcumin content of turmeric samples from Odisha and Andhra Pradesh. All samples showed the same observation. The quality of turmeric is related to its phytochemical composition and hence its activity. The curcumin percentage present in turmeric can be correlated to the inhibitory potential over Glucosidase, Antiglycation effects, Antioxidant activity, Radical scavenging capacity, Cellular oxidative stress reduction potential, Inhibition of human LDL oxidation etc.

The curcumin content of turmeric varies from sample to sample and the quality also with various other factors like seasonal, variation in soil, geographic variation etc. It is well-known that geographic indicators in protection of intellectual property rights play an important role in research. Turmeric of Assam which is also known as Lakadong and Megha Turmeric-1, is known for its superior quality. The Lakadong turmeric mostly produced in Jaintia hills is reported best quality turmeric, the reason owing to its high curcumin content (**Jha and Deka, 2012**).

The present study also reveals that geographical variation apart from other factors like soil, climate, method of cultivation, rainfall, etc. drastically affects the curcumin content in turmeric samples and that UV method offers a facile method of estimation of curcumin content compared to expensive chromatographic methods.

Table 1: Percentage of curcumin extracted from turmeric samples from different states

S. No	Name of states	Labelled as	% of curcumin
1.	Uttar Pradesh	UP	0.6888
2.	Tamil Nadu	TA	0.6888
3.	Kolkata	KOL	2.1670
4.	Andhra Pradesh	AN	2.3536
5.	Odisha	OT	2.3536
6.	Kerala	KT	0.1212
7.	Karnataka	KAH	2.0422
8.	Maharashtra	MU	2.0823
9.	Manipur	MA	2.0422

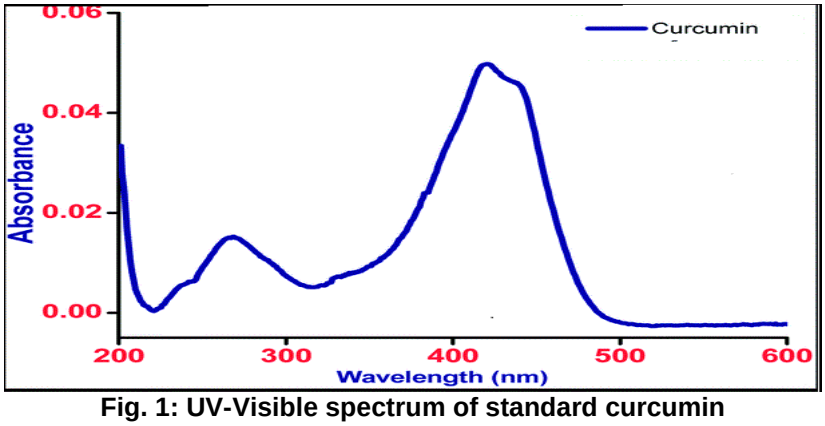

Fig. 1: UV-Visible spectrum of standard curcumin

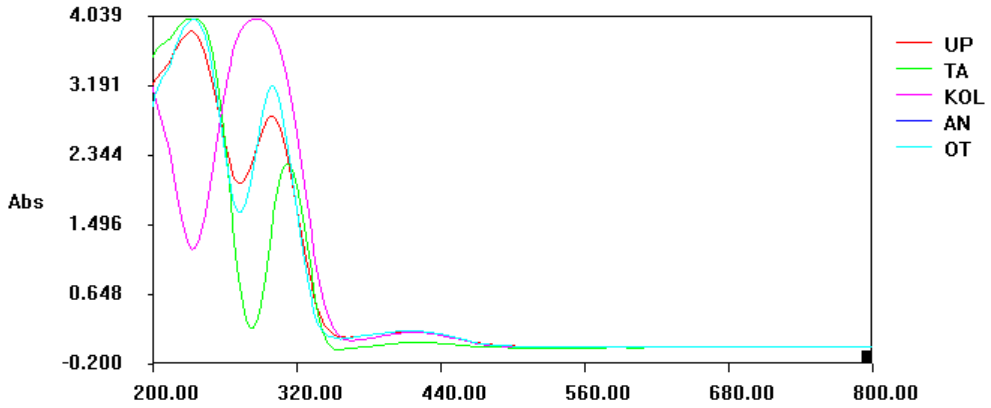

Fig. 2: Comparison of UV-Visible spectra of curcumin extracted from turmeric samples from 5 different states (UP, TA, KOL, AN and OT)

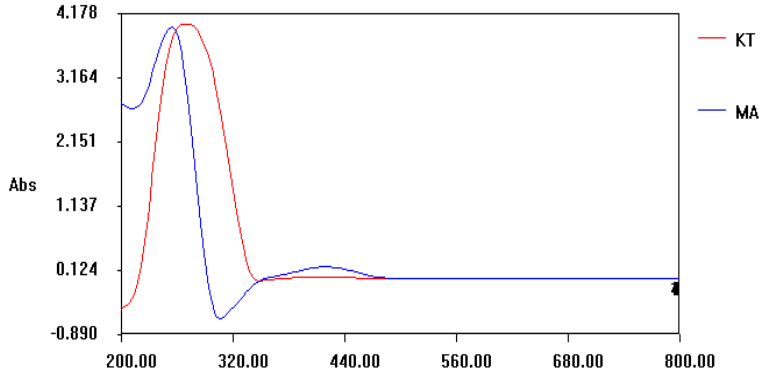

Fig. 3: Comparison of UV-Visible spectra of curcumin extracted from turmeric samples from Kerala and Manipur states

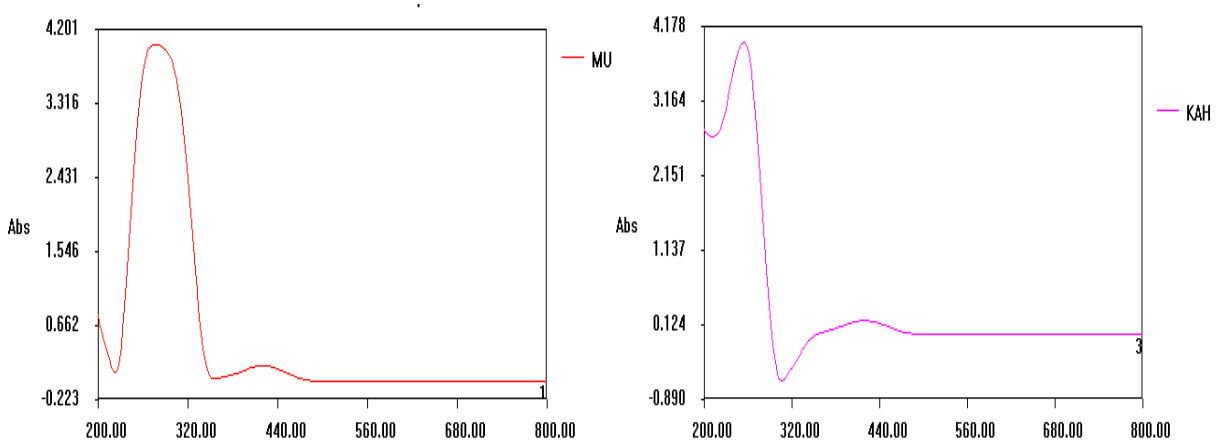

Fig. 4: UV-Visible spectra of curcumin extracted from turmeric samples from Maharashtra and Karnataka states

CONCLUSION

Curcumin, the main bioactive component of turmeric has been shown to have a wide spectrum of biological actions *viz.* anti-inflammatory, antioxidant, anticarcinogenic, antidiabetic and antimicrobial activities. The quantity and quality of curcumin vary due to the changes in ecological factors in different states. Hence, in order to increase the quality of turmeric, it is essential to domesticate and systematically cultivate these plants on a large scale. The curcumin percentage present in turmeric can be correlated to the inhibitory potential of many diseases and further analysis can be carried out to find the need for planting turmeric with higher quality of curcumin, which possesses tremendous medicinal properties.

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REFERENCES

1. Selvi N.M.K., Sridhar M.G., Swaminathan R.P., Sripradha R. (2015) Efficacy of turmeric as adjuvant therapy in type 2 Diabetic patients. Indian J Clin Biochem, 30(2): 180-186.
2. Ammon H.T.P., Wahl M.A. (1991) Pharmacology of *Curcuma longa*. Planta Med, 57: 1-7.
3. Wilson B., Abraham G., Manju V.S., Mathew M., Vimala, B., Sundaresan, S., Nambisan, B. (2005) Antimicrobial activity of *Curcuma zedoaria* and *Curcuma malabarica tubers*. J. Ethnopharmacol. 99: 147–151.
4. Thaikert R., Paisooksantivatana Y. (2009) Variation of total curcuminoids content, antioxidant activity and genetic diversity in turmeric (*Curcuma longa* L.) collections, Kasetsart, J. (Nat. Sci.) 43: 507-518.
5. Rajalakshmi D., Narasimhan S. (1996) Food antioxidants: sources and methods of evaluation. In: Madhavi DL, Deshpande SS, Salunkhe DK (eds) Food antioxidants: technological, toxicological, and health perspectives, Marcel Dekker, Inc.: New York, pp. 65-157.
6. Manju M., Sherin T.G., Rajasekharan K.N. (2009) Curcumin analogue inhibit slipidper oxidation in a freshwater teleost, Anabas testudineus (Bloch)—an *in vitro* and *in vivo* study. Fish Physiol Biochem, 35: 413–420.
7. Tayyem R.F., Heath D.D., Al-Delaimy W.K., Rock, C.L. (2006) Curcumin Content of Turmeric and Curry Powders. Nutr Cancer, 55(2): 126–131.
8. Ruby J.A., Kuttan G., Dinesh Babu K.V., Rajasekharan K.N., Kuttan R., (1995) Anti-tumour and free radical scavenging activity of synthetic curcuminoids. Int J Pharm, 131: 1–7.
9. Hatcher H., Planalp R., Cho J., Tortia F.M., Torti S.V., (2008) Curcumin: From ancient medicine to current clinical trials. Cell. Mol. Life Sci, 65: 1631-1652.
10. Nagabhushan M., Amonker A.J., Bhide S., (1981) *In vitro* antimutagenicity of curcumin against environmental mutagens. Food Chem Toxicol, 25: 545–547.
11. Kelloff G.J, Crowell J.A., Steele V.E., Lubet R.A., Malone W.A., Boone C.W. (2000) Progress in cancer chemoprevention : development of diet-derived chemopreventive agents. *J Nutr*, 130: 467–471.
12. Elizabeth K., Rao M.N.A. (1990) Oxygen radical scavenging activity of curcumin”*, Int J Pharm,* 58: 237–240.
13. Allen P.C., Danforth H.D., Augustine P.C. (1998) Dietary modulation of avian coccidiosis. Int J Parasitol, 28: 1131–1140.
14. Donatus I.A., Sardjoko J., Vermeulen N.P.E. (1990) Cytotoxic and cytoprotective activities of curcumin: effects on paracetamol-induced cytotoxicity, lipid peroxidation and glutathione depletion in rat hepatocytes. Biochem Pharmacol, 39: 1869–1875.
15. Srivastava R., Puri V., Srimal R.C., Dhawan B.N. (1986) Effect of curcumin on platelet aggregation and vascular prostacyclin synthesis. Arzneim Forsch, 36: 715–717.
16. Ramirez-Tortosa M.C., Mesa M.D., Aguilera M.C., Quiles J.L., Baro´ L., Ramirez-Tortosa C.L. (1999) Oral administration of a turmeric extract inhibits LDL oxidation and has hypocholesterolemic effects in rabbits

with experimental atherosclerosis. Atherosclerosis, 147: 371–378
17. Lekshmi P.C., Arimboor R., Nisha V.M., Nirmala M.A., Raghu. K.G. (2013) *In vitro* antidiabetic and inhibitory potential of turmeric (*Curcuma longa L*) rhizome against cellular and LDL oxidation and angiotensin converting enzyme. J Food Sci Technol, 51(12): 3910-3917.
18. Bhutani M.K., Bishnoi, M., Kulkarni S.K. (2009) Anti-depressant like effect of curcumin and its combination with piperine in unpredictable chronic stress-induced behavioural, biochemical and neurochemical changes. *Pharma Biochem Behav,* 92: 39-43.
19. Jang E., Choi M., Jung U.J., Kim M., Kim H., Jeon S., Shin S., Seong C., Lee M. (2008) Beneficial effects of curcumin on hyperlipidemia and insulin resistance in high-fat-fed hamsters. Metabolism, 57: 1576-1583.
20. Abdel-Aziz M.T., El-Asmar M., El-Ibrashy I.N., Ameen M.R., Al- Malki A.L., Wassef, Hanan M.A., Fouad H., Ahmed H.H., Taha F.M. (2012) Effect of novel water soluble curcumin derivative on experimental type- 1 diabetes mellitus (short term study). Diabetol Metab Syndr, 2: 1-10.
21. Youngjoo K. (2014) Estimation of curcumin intake in Korea based on the Korea National Health and Nutrition Examination Survey (2008-2012). Nutr Res Pract, 8(5): 589–594.
22. Kumar G.S., Salimath P.V. (2014) Effect of spent turmeric on kidney glycoconjugates in streptozotocin-induced diabetic rats. Journal of Diabetes & Metabolic Disorders, doi:10.1186/2251-6581-13-78.
23. Zhang M., Deng C.S., Zheng J.J., Xia, J. (2006) Curcumin regulated shift from Th1 to Th2 in trinitrobenzene sulphonic acid-induced chronic colitis. Acta Pharmacol Sin, 27(8): 1071-7.
24. Ganapati K.S., Sangle S.B., Kope K.I., Chaudhari R.D., Yewale P.N. (2011) Comparative studies on curcumin content in fresh and stored samples of turmeric rhizones, Int Res J Pharma, 2(4): 127-129.
25. Pawar H., Karde M., Mundle N., Jadhav P., Mehra K. (2014) Phytochemical evaluation and curcumin content determination of turmeric rhizomes collected from Bhandara District of Maharashtra (India). Med chem, 4: 588-591.
26. Sinkar P.V., Haldankar' P.M. Khandekar R.G., Ranpise S.A., Joshi G.D., Mahale B.B., (2005) Preliminary evaluation of turmeric (*Curcuma longa*) varieties at Konkan region of Maharashtra. J Spices Aromatic Crops, 14: 28-33.
27. Hayakawa H., Minaniya Y., Ito K., Yamamoto Y., Fukuda T. (2011) Difference of curcumin content in *Curcuma longa* L. (Zingiberaceae) caused by hybridization with other curcuma species. Am J Plant Sci, 2(2): 111-119.
28. Ashraf K., Mujeeb M., Altaf A., Amir M., Mallick M.N., Sharma D. (2012) Validated HPTLC analysis method for quantification of variability in content of curcumin in *Curcuma longa* L (turmeric) collected from different geographical region of India. Asian Pacific J Trop Biomed, S584-S588.
29. Kanjilal P.B., Kotoky R., Singh, R.S. (2002) Morphological and chemical parameter of certain cultivars of chilli, ginger and turmeric grown in Meghalaya. Adv in Plant Sci, 15(1): 225-229.
30. Chandra R., Yadav D.S., Rai N., Sarma P. (2005) Megha Turmeric 1: a new turmeric for Meghalaya. Indian Horticult, 50(2): 18.
31. Dixit D., Srivastava N.K., Sharma S., Dixit D. (2002) Boron deficiency induced changes in translocation of 14C02-photosynthate into primary metabolite in relation to essential oil and curcumin accumulation in turmeric (*Curcuma longa* L.). Photosynthetica, 40: 109-113.
32. Shanmugam S., Bhavani P. (2014) Studies on the comparison of phytochemical constituents and antimicrobial activity of *Curcuma longa* varieties, Int.J.Curr. Microbiol. App. Sci, 3(9): 573-581.
33. Muthuswamy S., Shah H.A. (1982) Comparative quality evaluation of Salem and Erode turmeric types. Indian Cocoa Arecanut and Spices Journal, 5: 77.
34. Muralidharan A., Ramankutty, H.N. (2013) Performance of some selected clones of turmeric (*Curcuma spp*.) in Wynad, Kerala. Int. Res J Pharm. App Sci, 3(6): 75-79.

35. Mathai C.K. (1976) Variability in Turmeric (Curcuma species) germplasm for essential oil and curcumin. Qualitas-Plantarum, 25: 227-230.
36. Nadgauda R.S., Mascarenhas A.F. (1986) A method for screening high curcumin containing turmeric (*Curcuma longa* L.) cultivars in-vitro. J Plant Physiol, 124: 359-364.
37. Cooray N.F., Jansz E.R., Ranatunga J., Wimalasena S. (1988) Effect of maturity on some chemical constituents of turmeric (*Curcuma longa* L.). J National Science Council SriLanka, 1: 39-51.
38. Verghese J. (1993) Isolation of curcumin from *Curcuma longa* L. rhizome. Flavour and Frag J, 8: 315-319.
39. Satish H., Venkatesha J., Chandrappa H. (1997) Performance of certain promising cultivars of turmeric (*Curcuma Domestica* Val.) under Southern Dry Region of Karnataka. Indian Cocoa, Arecanut and Spices Journal, 21: 11-13.
40. Rakhunde S.D., Munjal S.V., Patil S.R. Curcumin and essential oil contents of some commonly grown turmeric (*Curcuma longa* L.) cultivars in Maharashtra. J Food Sci Technol, 35: 352-354.
41. He X.G., Lin L.Z., Lian L.Z., Lindenmaier M. (1998) Liquid Chromatography Electrospray Mass Spectrometric Analysis of curcuminoids and sesquiterpenoids in turmeric (*Curcuma longa*). J Chromatography, 818: 127-132.
42. Garg S.N., Bansal R.P., Gupta M.M., Kumar S. (1999) Variation in the rhizome essential oil and curcumin contents and oil quality tn the land races of turmeric *Curcuma longa* of North Indian Plains. Flavour Frag J, 14: 315-318.
43. Gupta A.P., Gupta M.M., Sushil K., Kumar S. (1999) Simultaneous determination of curcuminoids in curcuma samples using High Performance Thin Layer Chromatography. J LiquidChromatography Related Technol, 22: 1561-1569.
44. Chempakam B., Leela N.K., John S.P. (2000) Distribution of curcuminoids during rhizome development in turmeric (*Curcuma longa* L.). Spices and aromatic plants:-challenges and opportunities in the new century, 293-296.
45. Kumar V.K., Vadiraj B.A., Sivadasan C.R., Potty S.N. (2000) Post harvest management of turmeric for higher recovery of curcumin. Spices and aromatic plants:- challenges and opportunities in the new century, 281-283.
46. Jayaprakasha G.K., Rao J.M., Sakariah K.K. (2002) Improved HPLC method for the determination of curcumin, demethoxycurcumin and bisdemethoxycurcumin. J Agric Food Chem, 13: 3668-72.
47. Kita T., Sakurai A., Kamata Y., Sawada H. (2002) Development of pigment cells and induction of curcuminoid synthesis by liquid culture of cell clumps of turmeric (*Curcuma longa*). Japanese J Trop Agric, 46: 198-201.
48. Lechtenberg M., Quandt B., Nahrstedt A. (2004) Quantitative determination of curcuminoids in curcuma rhizomes and rapid differentiation of *Curcuma domestica* Val. and *Curcuma xanthorrhiza* roxb. by capillary electrophoresis. Phytochem, 15: 152-8.
49. British Pharmacopoeia A19 - The medicine commission. London: Her Majesty's Stationary Office, 1973.
50. Ministry of Public Health. Manual of Medicinal Plant for Primary Health Care. Bangkok: Text and Journal Corporation, 1990.
51. ASTA Method. Official analytical methods of the American Spice Trade Association, 3rd ed. Englewood Cliffs, NJ: American Spice Trade Association, 1985.
52. Jha A.K., Deka B.C. (2012) Present status and prospects of ginger and turmeric in NE States, http://www.kiran.nic.in/pdf/publications/ Ginger_and_Turmeric.pdf.