

Mini Review

Analysis of curcuminoids in food and pharmaceutical products

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Abstract: Curcuminoids refer to three main chemical substances, namely curcumin, demethoxycurcumin, and *bis*-demethoxycurcumin. These are used as natural coloring agents in some food products and have been reported to exhibit several biological activities in animal and human clinical studies. Due to its beneficial effects to human health, several analytical methods have been continuously proposed and developed by scientist to analyze them in plant sources, food, and in pharmaceutical products. This article highlights the application of several instrumental techniques for analysis of curcuminoids.

Keywords: Analysis, curcuminoids, food, pharmaceutical, instrumental techniques

Introduction

Turmeric isolated from the plant of *Curcuma longa* L is the main sources of curcuminoids, a yellow in color, having the specific flavor attributed from its volatile compounds, and has been used as spice for early time of human civilization. It also correlated with several biological activities (Nagarajan *et al.*, 2010). *C. longa* is belonging to Zingiberaceae family and widely cultivated in the regions of tropical and subtropical, especially in India, Southeast Asia, and China. India is the main country exporting the turmeric and its production is approximately 80%. Today, the species cultivation has also widely distributed to some African countries (Parthasarathy *et al.*, 2008).

Because of its specific flavor and yellow color, the introduction of turmeric keeps the nutritional value and freshness of food items. As a food additive, turmeric can improve the deliciousness, aesthetic appeal, and shelf life of delicate food products (Joe *et al.*, 2005). Besides, the powder of turmeric is expansively used as preservative and coloring agents. It has been used as traditional medicine in order to prevent several diseases (Chattopadhyay *et al.*, 2004)

Numerous biological activities have been reported in turmeric and its related plant sources such as antioxidant (Kalpravidh *et al.*, 2010), anti-inflammatory (Skrzypezac-Jankun *et al.*, 2000), anti-atherogenic (Rami' rez-Bosca' *et al.*, 2000), anti-psoriatic (Heng *et al.*, 2000), anti-diabetic (Arun and Nalini, 2002), immunostimulatory (Antony *et al.*, 1999), antibacterial (Singh *et al.*, 2002), and anticancer effects as reviewed by Aggarwal *et al.* (2003). This also contributes to the incorporation of the healing process of dermal wound (Gopinath *et al.*, 2004) and the prevention of Alzheimer's disease

(Lim *et al.*, 2001). However, Mancuso and Barone (2009) made the criticism in relation to the use of curcuminoids in clinical practice due to its poor bioavailability.

The main components of commercial turmeric are curcuminoids which refer to group of phenolic substances present in turmeric powder, namely curcumin, molecular weight (MW of 368) which is accounting for 60–80%, demethoxycurcumin (MW of 338) accounting for 15–30%, and *bis*-demethoxycurcumin (MW of 308) with level of 2–6% (Wichitnithad *et al.*, 2009). The chemical structures of these curcuminoids are depicted in Figure 1. The contents of curcuminoids were used as one of the parameters in quality control of *C. longa* and other drugs derived from plant-based *Curcuma* (Cheng *et al.*, 2010).

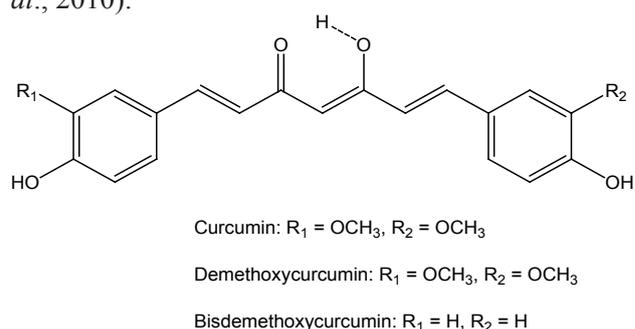


Figure 1. The chemical structures of curcumin, demethoxycurcumin, and *bis*-demethoxycurcumin

Most of the critical review is devoted to the biological activities *in vivo* and *in vitro* (Joe *et al.*, 2004) as well as to the pharmacological effects of curcuminoids and related plant sources in animal and human body (Miquel *et al.*, 2002; Jain *et al.*, 2007) rather than exploring the analytical methods for determination of curcuminoids. In this review, we highlight the application of several instrumental

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techniques for the quantitative analysis of curcuminoids either in raw materials or in food and pharmaceutical products.

Analytical methods for analysis of curcuminoids

Qualitative and quantitative analyses of curcuminoids in turmeric samples are very important in order to determine the quality of the raw materials or its finished products (Jiang *et al.*, 2009). Food industry and regulatory authorities require reliable validated techniques for determination of curcuminoids for the scope of the various range of food products stated in the European Color Directive (Scotter, 2009). For instance, curcumin is allowed to be used in smoked fish with maximum limit of 100 mg/kg. Some types of food such as jellies, sausages, and dried potato products are allowable to contain curcumin; therefore, its analysis is not a critical issue. In addition, sauces and seasonings are allowable to restrain curcumin up to levels of 500 ppm. From the point of regulatory compliance, it is necessary to determine the level contents of curcumin in certain foods.

Numerous analytical methods have been reported by some researchers for quantitative analysis of curcuminoids. Some of the methods are based-spectrophotometric techniques, expressed as the total color content of the sample. However, using this technique it is not possible to separate and to quantify the curcuminoids individually (Jayaprakasha *et al.*, 2002). For this reason, chromatographic-based techniques and electrophoresis are among the methods of choice for determination of curcuminoids attributed to their separation capacities.

Spectroscopic techniques

UV-Vis spectrophotometry

The official standard method for determination of curcuminoids or Curcuma-based products is UV-Vis spectrophotometry which is relied on the direct measurements of sample in certain solvents. In some organic solvents, curcuminoids show the intensive absorption intensity at wavelength of 420 – 430 nm. However, it should be taken into account that the presence of other species having the chromophoric groups absorbing at this wavelength will influence the accuracy of the results (Jayaprakasha *et al.*, 2005). The quantification of curcuminoid using UV-Vis spectrometry technique was usually expressed as the total curcuminoids content. Pothitirat and Gritsanapan (2006) determined the curcuminoids contents in *C. longa* obtained from 13 regions in Thailand, measured at 420 nm. Calibration curve was

made by weighing 2.00 mg curcumin (cat # C-1386, purity 60–70%), added with MeOH and adjusted to a final concentration of 0.8, 1.6, 2.0, 2.4 and 3.2 mg/ml. For sample preparation, the powder was added with tetrahydrofuran and diluted with MeOH.

Some researches also used the parameter of extinction coefficient $E_{1\text{ cm}}^{1\%}$ as the basis of their analysis. The Joint Expert Committee on Food Additives (2001) has specified that curcumin determined using visible spectroscopy in ethanol at λ 425 nm should have $E_{1\text{ cm}}^{1\%}$ of 1607. For this reason, some industries accepted this $E_{1\text{ cm}}^{1\%}$ (1607) as the reference value for three curcuminoids jointly. However, some values for different maximum wavelengths (λ_{max}) may be also established in literature. The European Commission (EC) has specified to use λ 426 nm, whereas other regulatory authorities stated λ_{max} between 424 and 430 nm. This difference comes from the proportion of each curcuminoids in the mixture, because each exhibits different maximum wavelength. It has been reported that curcumin (C) in ethanol has λ_{max} of 430 nm, meanwhile demethoxycurcumin (DMC) and bis-demethoxycurcumin (BDMC) exhibits λ_{max} of 423 and 418 nm, respectively. Consequently, this distribution affects the mean of λ_{max} in the mixture (Scotter, 2009).

Infrared spectroscopy

Infrared (IR) spectroscopy, especially in combination with chemometrics technique, has been widely used for determination of analytes of interest in food, agricultural, and pharmaceutical products (Roggo *et al.*, 2007). The method allows rapid and sensitive, ease in sample preparation, and non destructive technique meaning that the used samples can be used for further analysis. In addition, IR spectroscopy can be exploited for determination of components of interest simultaneously (Rohman *et al.*, 2010).

Tanaka *et al.* (2008) had investigated the possibility of near infrared (NIR) spectroscopy to quantify the contents of curcuminoids (C, DMC, and BDMC) in turmeric. Using the processing combination of second derivatives and standard normal variate, partial least square calibration using spectral regions of 1500-2500 nm and 1850-2040 nm was used for quantification of individual and total curcuminoids. The results showed that the optimized method offers good prediction model with standard error of prediction of 0.117, 0.061, 0.070, and 0.174 %, respectively for C, DMC, BDMC, and total curcuminoids.

Flow injection analysis (FIA)

FIA system with on-line detections using ultraviolet (UV) at 250 nm and fluorometric (FL) using λ_{ex} of 397 nm and λ_{em} 508 nm is developed for analysis of curcuminoids in *C. longa* (Inoue *et al.*, 2001). FIA was conducted at ambient temperature using various organic solvents, either alone or in combination with water as carrier solution delivered at flow rate of 1.0 ml/min. The detection limit obtained using FL (2.0 ng/ml) was better than that using UV (30.0 ng/ml). The r values obtained was higher than 0.99. The authors reported that the developed method could be applicable for a regular analysis of curcuminoids at an approximately estimation using curcumin standard.

A simple analysis procedure using FIA was also proposed by Thongchai *et al* (2009) for the quantification of curcuminoids in turmeric extracts, based on the development of a colored complex between curcuminoids and 4-aminoantipyrine, in the presence of the oxidizing agents such as potassium hexacyanoferrate (III) in base environment. Using the optimum parameters, the total contents of curcuminoids could be assessed within a working concentration range of 5 – 50 ppm. The sensitivity expressed with detection and quantification limits were 0.6 and 1.8 ppm, respectively. The precision using parameter of standard deviation for reproducibility reported was < 2.0 % with the percentage of recovery between 94.3–108.0 %.

Chromatographic-based methods

Chromatography-based methods are emerging analytical technique in chemical analyses which are appropriate for qualitative and quantitative determination of a large number of samples. Besides, these techniques also offer the separation capacities of analytes of interest into its component and make simultaneous analysis of a considerable number of samples (Cserhati *et al.*, 2005).

Due to its advantageous properties, namely low cost in operation, ease in sample preparation, and the availability of several detection systems, thin-layer chromatography (TLC) was regularly used for the identification, separation, quantification or semi-quantitative purposes of natural pigments, including curcuminoids (Forgacs and Cserhati, 2002). However, high-performance liquid chromatography (HPLC) is a method of choice for curcuminoids attributed to the high precision and accuracy offered and low detection limit achieved. Furthermore, in order to improve the separation power, multi-development in TLC and

gradient elution in HPLC are the preferred methods for analysis of samples. Capillary electrophoresis was currently developed as an optional technique for the analysis of curcuminoids (Sun *et al.*, 2005).

Thin layer chromatography (TLC)

Anderson *et al.* (2000) have isolated curcuminoids using preparative silica plates from ground turmeric. The extraction of turmeric was successfully done using dichloromethane with the aid of magnetic stirrer and heat at reflux for 60 min. The extract was filtered and concentrated in water bath at 50 °C, and the residue obtained was further redissolved in hexane. Plates were developed three times using dichloromethane–MeOH (99: 1 v/v). The R_F value obtained for curcumin was 0.52.

The ability of two-dimensional TLC for analysis of three curcuminoids in the rhizomes of *C. phaeocaulis*, *C. kwangsiensis*, *C. wenyujin* and *C. longa* has been investigated by Zhang *et al.* (2008). The chromatographic separation was achieved on silica gel 60F254 plate using eluent mixture of $CHCl_3$ –MeOH–formic acid (20:1:0.2, v/v/v) and petroleum ether–ethyl acetate (9:1,v/v) for twice development. The chromatogram spots were colorized using 1% vanillin–in sulfuric acid. The presence of curcuminoids in these plants was semi-quantified densitometrically at λ scan and λ reference of 518 and 800 nm, respectively. The authors stated that the developed TLC method can be used as a technique for quality control of Curcuma rhizomes. Table 1 compiled some of the published research related to the use of TLC and its high performance (HPTLC) for analysis of curcuminoids.

High performance liquid chromatography (HPLC) and related techniques

Because of to their low volatility and thermally labile properties, curcuminoids are not popular enough to be determined using gas chromatography and related techniques. Therefore, several methods including HPLC and its coupling with mass spectrometry (LC/MS), and capillary electrophoresis (CE) have been developed for determination of curcuminoids in foods or in pharmaceutical products (Jiang *et al.*, 2006). HPLC is the most reported methods for analysis of curcuminoids due to its versatility and ease in use. In most cases, HPLC methods using detector of UV/VIS spectrophotometer or photodiode-array detector (PDA) at λ around 260 or 450 nm were used, since these techniques necessitate simple instrumentation and are sufficiently enough to determine curcuminoids in some products (Jadhav *et al.*, 2007).

Table 1. Application of TLC and HPTLC for analysis of curcuminoids

Matrix sample	Stationary phase	Mobile phase	Densitometric scanning	Sample preparation	Reference
<i>C. longa</i>	silica gel 60 F254	CHCl ₃ -hexane-MeOH(1:1:0.1, v/v/v)	Camag TLC scanner II using absorbance mode at 254 nm.	The powder was soaked in 50 mL of MeOH, redissolved in 2.0 mL MeOH.	Phattanawasin <i>et al.</i> (2009)
Turmeric	silica gel HPTLC plate (60GF 254, 20 x 10 cm).	CHCl ₃ : MeOH, 24: 1, v/v).	camag UV chamber at absorbance mode (425 nm)	Sample was extracted separately in MeOH for 30 min by ultrasonication, filtered, concentrated, and -dissolved in MeOH	Paramasivam <i>et al.</i> (2009)
Turmeric rhizomes	nanosilica gel 60 F 254 plate	chloroform and ethyl acetate (19:1 v/v)	sprayed with ammonium molybdate/H ₂ SO ₄ and scanned at UV 254 nm, 366 nm	Cold and hot Solvent Extractions using EtOH	Green <i>et al.</i> (2008)
Turmeric powder and <i>C. longa</i>	Kieselgel 60 F 254	toluene:CH ₃ COOH (4:1, v/v) for curcuminoid separation and <i>n</i> -hexane:EtOAc:CH ₃ COOH (80:25:5, v/v/v) for quantification	Scanned at 425 nm	<i>C. longa</i> extract sample solution was prepared by dissolving in MeOH Turmeric samples were extracted using MeOH at 40°C in an ultrasound bath for 40 min.	Pozharitskaya <i>et al.</i> (2008)
<i>C. longa</i> rhizomes	HPTLC LiChrosphere Si 60F254	CHCl ₃ : MeOH (49: 1 v/v)	Wavelength 366 nm; Scanning speed: 2.0 cm/s	Samples were extracted with acetone, filtered and concentrated under vacuo, and dissolved in MeOH	Pathania <i>et al.</i> (2006)
Bulk and pharmaceutical products	silica gel aluminium plate 60F-254	CHCl ₃ : MeOH (9.25:0.75 v/v)	Absorbance at 430 nm	the tablets were powdered and and extracted using MeOH	Ansari <i>et al.</i> (2005)

Bos *et al.* (2007) have used HPLC using PDA detector at 425 nm to analyze curcuminoids in some *Curcuma* genus which are indigenous to Indonesia, namely *C. mangga* Val & v. Zijp, *C. heyneana* Val. & v. Zijp, *C. aeruginosa* Roxb. and *C. soloensis* Val. The separation was achieved using Zorbax Eclipse XDB-C18 (250 × 4.6 mm i.d.; 5 μm) with mobile phase consisted of a mixture of MeOH-H₂O (containing 0.1% trifluoroacetic acid)-acetonitrile (39.5:350:468, v/v/v). The developed method gives the accuracy of 100.4 ± 0.922 % (C), 99.8 ± 0.806 % (DMC), and 99.9 ± 0.574% (BDMC), with limit of detection of 0.044 μg for C, 0.048 μg for DMC and 0.058 μg for BDMC. Some other works were compiled in Table 2.

Recent work related to application of HPLC for determination of curcuminoids in commercial food samples in Korea such as curry, mustard, candy, pickle, and snack foods was carried out by Lee *et al.* (2011). The column of X Terra MS C18 (250 mm x 4.6 mm; 5 μm) was used for separation. The mobile phase was composed of 2% CH₃COOH in water (A) and 2 % CH₃COOH in ACN (B). The gradient elution was: 10% B (0–3 min), 20% B (8 min), 25% B (13 min), 35% B (18 min) and subsequently held for 10 min before coming back to the initial conditions. The

analytes were detected using PDA at 420 nm.

Because of the intrinsic fluorescence nature of curcuminoids, spectro-fluorescence detector can be used to detect the presence of curcuminoids. The sensitivity of this detector is about 10 times over UV-Vis spectroscopy. Zhang *et al.* (2009) has developed HPLC with fluorescence to determine curcuminoids in some *Curcuma* genus using 2,5-xyleneol as standard internal. The λ_{max} for 2,5-xyleneol is 287 nm (excitation) and 303 nm (emission), meanwhile for curcuminoids the λ_{max} used are 426 nm (excitation) and 539 nm (emission). The separation of curcuminoids substances was achieved within 30 min using Cadenza CD-C18 column (250 x 4.6 mm; i.d., 3 mm) using a mobile phase of mixture of 0.1 M of acetate buffer (pH 4.0)-ACN (57:43, v/v) as. The reported retention times of I.S., BDMC, DMC and C were 11, 19, 22 and 25 min, respectively.

Besides for quantitative analysis, HPLC involving high speed countercurrent chromatography (CCC) using a simple two-phase solvent systems composed of *n*-hexane/CHCl₃/MeOH/H₂O (2/4/3/1, v/v) (Inoue *et al.*, 2008) and pH-zone refining CCC (Patel *et al.* 2000) using methyl-tert-butyl ether/ACN/H₂O (4:1:5) was also used for the preparative separation and purification of curcuminoids into the individual

Table 2. Some of reported works related to the use of HPLC and related techniques for determination of curcuminoids

Matrix sample	Column	Mobile phase	Detector	Sample preparation	Reference
<i>C. longa</i>	Kromasil C ₁₈ (250 mm×4.6 mm, 5 μm)	CH ₃ COOH-MeOH (15:85 v/v)	UV 420 nm	Rhizome of powder <i>C. longa</i> was extracted by ultrasonication at ambient temperature. After cooling, MeOH was added sample was sonicated with ACN	Cheng <i>et al.</i> (2010)
Turmeric extract	Alltect Alltima C ₁₈ column (150 x 4.6 mm i.d.; μm)	ACN- CH ₃ COOH 2% in H ₂ O (4:6 v/v)	UV 425 nm	-	Wichitnithad <i>et al.</i> (2009)
Turmeric powder	welchroll-C ₁₈ column (4.6 mmx250 mm, 5 μm),	CH ₃ COOH 2% in H ₂ O-ACN (1:1)	UV 260 nm	-	Zhang Y-H <i>et al.</i> (2009)
<i>C. longa</i>	Kromasil C18 column (125 mm × 4.6 mm, 5 μm)	0.15 M SDS and 12.5% (v/v) propanol buffered using 0.01 M NaH ₂ PO ₄ at pH 7.0	UV 210 nm	at the samples were prepared with 0.05 M SDS-pH 7 at ratio of 1:10	Chin-Chen <i>et al.</i> (2009)
curcumin removed turmeric oleoresin	Exil-Amino column (5 μm, 4.6 × 150 mm)	2-propanol:water (19:1, v/v)	UV 425 nm	Curcumin-enriched powder from samples was dissolved with acetone and impregnated on silica gel, loaded onto a glasscolumn packed with silica gel. the column was eluted with CHCl ₃ and fractions were collected and grouped according to their TLC profile and evaporated.	Naidu <i>et al.</i> (2009).
Curcumin and its degradation products	Hi-Q-Sil C18 (250 mm x 4.6 mm, 10 μm)	ACN- acetate buffer pH 3.0; (3: 2, v/v)	UV 425 nm for curcumin and at 280 for its degradation products	Dissolved in MeOH	Dandekar and Patravale (2009)
<i>C. zedoaria</i>	BDS Hypersil C ₁₈	glacial acetic acid 1% in H ₂ O-ACN (1:1)	UV 425 nm	-	Paramapojn and Gritsanapan (2008).
Rupikang cataplasma	ODS-BP column(250 mm×4.6 mm,5 μm)	MeOH-H ₂ O-CH ₃ COOH (70:26.5:3.5) methanol, isopropyl alcohol,	UV 420 nm	extracted using ultrasound in MeOH	Chen <i>et al.</i> (2008)
Turmeric rhizomes	RP C18 250 × 4 mm i.d	water. and acetic acid in the proportions 20:4:27:48:5 v/v	UV 420 nm	Cold and hot Solvent Extractions using EtOH	Green <i>et al.</i> (2008)
Commercial curcumin	Vydac RP-18 (250 mm · 4.6 mm,5 μm)	ACN-0.1% trifluoro-acetic acid (1:1)	UV 420 nm	powder was extracted using hexane, evaporated, redissolved with MeOH	Jadhav <i>et al.</i> (2007)
Turmeric powder	Discovery1 HS C18 (150 mm x 3 mm, 2.1μm)	(A) buffer (5mM ammonium formate, 0.1% formic acid, in ddH2O) and (B) ACN; gradient (in buffer A): 0–2 min, 5% B; 2–57min, 5–100% B; 57–60 min, 100% B; 60–65min, 100–5% B; 65–75min, 5% B	MS	Samples were extracted using MeOH	Jiang <i>et al.</i> (2006)
<i>C. longa</i>	Kromasil™ C ₁₈	ACN and H ₃ PO ₄ in H ₂ O (pH = 2.5)	UV 420 nm	-	Liu <i>et al.</i> (2005)

Matrix sample	Column	Mobile phase	Detector	Sample preparation	Reference
Tablet, tea, and candy	PEGASIL ODS (2 x 150 mm, 5 µm)	CH ₃ COOH 0.01% in H ₂ O (A) and ACN (B). 0 min at 45% B, 0–15 min with a linear increase from 45 to 95% B, and at last hold at 95% B.	MS	The samples were extracted using MeOH methanol and ultrasonicated for 10 min	Inoue <i>et al.</i> (2003)
Commercial turmeric varieties of <i>C. longa</i>	Bondapack C18 (300 x 4.6 mm i.d.; µm)	MeOH (A), CH ₃ COOH 2% in H ₂ O (B), and ACN (C). 45 to 65% C in B (0-15 min). The gradient then went from 65 to 45% C in B for 15-20 min, with a constant of 5% A.	UV 425 nm	Turmeric powder samples were extracted using hexane by Soxhlet, re-extracted using MeOH.	Jayaprakasha <i>et al.</i> (2002)
<i>C. longa</i>	Phenomenex Luna C18 (150 mm x 4.6mm, 5 mm)	CH ₃ COOH 0.25% in H ₂ O (A)-ACN(B). Gradient elution and was as follows: 40-60% B in 10 min, held for 10min, changed to the initial in the next 2 min, and held there for 2 min	UV 425 nm	pressurized-liquid extraction	Schieffer (2002)

components.

Capillary electrophoresis

Capillary electrophoresis (CE) is a powerful separation means, which has speedily developed and has been largely applied for analysis of pharmaceuticals, and bioactive plant components. Several factors, namely sample preparation, separation capacity, and detection level must be taken into account when used for analysis of curcuminoids (Li *et al.*, 2006).

Capillary zone electrophoresis (CZE)

Among various modes of CE, CZE is the most frequently used method because it is the simplest and most versatile CE modes (Ryan *et al.*, 2010). The level of Curcumin from turmeric isolated from Chinese herbal medicine has been determined using CZE with amperometric detector by Sun *et al.* (2002). The sample was prepared using solid phase extraction with tributyl phosphate resin as adsorbent. Using the optimized parameters, i.e. 0.015 M phosphate buffer at pH 9.7 as running buffer, at 16 kV of separation voltage, injection for 6 s at 9 kV and detection at 1.20 V, the limit of detection obtained is 3×10^{-8} M at linear concentration range of 7×10^{-4} – 3×10^{-6} M ($r=0.9986$) for curcumin extracted from light petroleum. The recovery average obtained is 80%. Because of the high sensitivity and selectivity of the developed technique, the authors claimed that the trace levels of curcumin in more complex sample matrix, such as curry powder, herbal products, or body fluids could be analyzed.

The curcuminoids from *C.domestica* Val., *C. longa* L. and *C. xanthorrhiza* Roxb. were successfully separated and quantified using CZE method with standard fused-silica capillaries and PDA at 258 nm (with internal standard of 3,4-dimethoxy-trans-cinnamic acid for quantification) and 470 nm (for curcuminoids alone) in less than 5 min. An electrolyte solution of 20 mM phosphate, 50 mM NaOH and 14 mM β-cyclodextrin was found to be suitable for analysis. LOD obtained was 10 ppm. The results obtained were compared with the photometric method specified in *European Pharmacopoeia* (Lechtenberg *et al.*, 2004). CZE using a buffer of 15 mM Na tetraborate containing 10% MeOH (v/v) at pH 10.8, 25 kV and 30 °C was successfully applied for separation and quantification of curcuminoids in 7 min using PDA 262 nm with good selectivity (Yuan *et al.*, 2005). LOD obtained was lower than that reported by Lechtenberg *et al.* (2004), i.e 0.247 – 0.426 ppm.

Micellar electrokinetic chromatography (MEKC)

MEKC has emerged as a method of choice for determination of neutral compounds. In this method, a pseudo-stationary phase is produced by the adding a micelle-forming ionic surfactant like sodium dodecyl sulphate (SDS) or cetyltrimethylammonium bromide. The separation of analyte(s) in MEKC is relied upon the hydrophobic interactions of analyte molecules with the used pseudo-stationary phase (Unger, 2009).

Watanabe *et al.* (2002) have developed MEKC for the determination of curcuminoids in some turmeric samples. Based on the solvent selection, ethanol was

the best solvents for the extraction of curcuminoids the samples. The separation was achieved using the copolymer sodium salt of butyl acrylate-butyl methacrylate-methacrylic acid solution containing 50% dimethyl sulfoxide. The calibration curve was linear over 6.25 to 100 µg/ml with correlation coefficient of 0.999. The limit of detection obtained is as low as 0.1 µg/ml. The authors stated that this technique is advantageous because of its low level of organic wastes and shorter analysis time.

Lin *et al.* (2006) also used MEEKC for curcuminoids analysis in Chinese herbal medicine. They are separated using uncoated fused-silica capillary column with a buffer consisting of 25 mM hydroxypropyl-β-CD, 10% MeOH, 0.04M sodium borate and 0.04 M sodium dodesyl sulphate at pH 9.50 less than 10 minutes. The recoveries obtained were in the range of 95.7 - 106.3%. The calibration curves exhibited good linearity in the range of 90 - 1220 µg/mL with r of 0.9996 for C, 80 - 1120 µg/mL with r of 0.9998 (DMC) and 80 - 1200 µg/mL, r of 0.9998 (BDMC).

Conclusion

It is imperative that analysis of curcuminoids in food and pharmaceutical products is very important not only for quality control aspects but also for ensuring the efficacy and effectiveness of curcuminoids as active compounds in several pharmaceutical dosage forms and functional food preparations. Spectroscopic, chromatographic, and electrophoretics-based methods were of analytical techniques which are continuously developed for quantification of curcuminoids. In the future, the use of instruments capable of providing on site application, fast, reliable, and inexpensive is highly needed.

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