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Original Article

Curcumin extraction from turmeric plant using magnetic Fe_3O_4 nanoparticles

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ABSTRACT

Objectives: In this study, it was aimed to obtain curcumin from the extracts of the turmeric plant by using a simple and fast magnetic separation method, unlike other standard methods.

Materials and methods: Magnetic iron oxide nanoparticles (IONPs) were prepared by chemical co-precipitation of Fe^{3+} and Fe^{2+} ions. Magnetic nanoparticles were used to extract curcumin from turmeric. In addition, curcumin was characterized and compared with commercial curcumin. Curcumin was recovered by purifying it from extracts of the turmeric plant.

Results: Fe_3O_4 nanoparticles were characterized using transmission electron microscopy, X-ray diffraction (XRD), Fourier-transform infrared spectroscopy, and Ultraviolet (UV)-visible spectra. Transmission electron microscopy analysis was used to describe the particle size and surface morphology of Fe_3O_4 nanoparticles, and the XRD device was used to explain X-ray diffraction. Curcumin was extracted from turmeric plant extracts purified with Fe_3O_4 nanoparticles. Fourier-transform infrared spectroscopy was used to determine the functional groups in the structure of turmeric, Fe_3O_4 nanoparticles, Fe_3O_4 turmeric complex, commercial curcumin, and curcumin. The UV spectrum of commercial curcumin and curcumin was also examined using the Shimadzu UV-1700 Pharma spectrophotometer. It has been established that it is recovered with a purification yield of 1.5 percent following purification.

Conclusion: These results suggest that curcumin, which has research potential in the field of health, may also be beneficial in terms of creating different scientific and economic expansions and producing new studies.

Keywords: Curcumin, iron oxide nanoparticles, magnetic nanoparticles, turmeric.

Turmeric is a perennial and tuberous herbaceous plant that belongs to the ginger family, with yellow flowers and large leaves. It is also called turmeric, saffron root, yellow dye, castor, and saffron. It is widely grown in China, India and Southeast Asia.[1] Turmeric has an important place in Indian medicine since it is used especially in cold, cough, sinusitis, rheumatic diseases, cardiovascular diseases, and skin diseases.[2-4] Curcumin substance is obtained from the turmeric plant.[5-7] It is known to have many pharmacological activities such as antioxidant, anti-inflammatory, anti-aging, analgesic, antiprotease activity, anticancer.[5,8-10] Curcumin is an antioxidant that suppresses lipid peroxidation and reduces the formation of inflammatory compounds by scavenging reactive oxygen species.[11,12] Curcumin has the ability to prevent protein accumulation that causes diseases such as Alzheimer's and Parkinson's diseases.[10,13,14]

Isolation of biomolecules is generally carried out using different electrophoretic, chromatographic, ultrafiltration or precipitation and solvent extraction methods.[15] All of these methods present considerable disadvantages when used on an industrial scale, such as expensive

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instrumentations, time-consuming processes, or large amounts of organic solvent waste.[16] Methods such as thin-layer chromatography,[17-19] high-performance liquid chromatography,[20-24] electrochemical method,[25,26] spectrofluorometry[27-29] and Ultraviolet-visible (UV-Vis) spectrophotometry[10,24,30-33] have been utilized to determine curcumin in a diversity of matrices like Curcuma longa, foodstuffs, and biological materials.

With the rapid advancement of nanotechnology, interest in magnetic nanoparticles is increasing day by day. Recently, magnetic nanoparticles have been prepared in various ways, such as sol-gel self-propagation,[34] chemical co-precipitation,[35-37] and in the tiny pools of the water-in-oil microemulsion.[38]

The prepared magnetic nanoparticles have been widely used in bionanotechnology such as magnetic resonance imaging, bioseparation, diagnostic agents, tumor hyperthermia and biomolecule immobilization.[39-51] These magnetic nanoparticles have attracted the attention of researchers with their small size, low toxicity, superparamagnetism and most importantly their specific applications.[36,51-55] In this study, curcumin, which is the miracle of nature, was obtained by purifying it quickly and easily with magnetic iron oxide nanoparticles (IONPs) without the use of expensive instruments.

MATERIALS AND METHODS

Materials

Curcumin was supplied from Alfa aesar. Iron(II)chloride tetrahydrate ($FeCl_2.4H_2O$), and iron(III)chloride hexahydrate ($FeCl_3.6H_2O$), were supplied from Merck. Turmeric and all other chemicals used were obtained from various commercial sources.

Characterization

Transmission electron microscopy (TEM) was used to examine the particle size and surface morphology of Fe_3O_4 nanoparticles. X-ray diffraction (XRD) of the nanoparticles was determined with the Bruker™ D8 Advance device (Bruker BioSciences Espanola, S.A. Madrid, Spain). Fourier transform infrared spectroscopy (FTIR) was used to determine the functional groups in the structure of turmeric, Fe_3O_4 nanoparticles, Fe_3O_4 turmeric complex, commercial curcumin, and curcumin. The UV spectrum of commercial curcumin and curcumin was measured using the Shimadzu UV-1700 Pharma spectrophotometer (UV-1700 Pharma Spec, Shimadzu, Kyoto, Japan).

Synthesis of Fe_3O_4 nanoparticles

Magnetic Fe_3O_4 nanoparticles have been prepared by the co-precipitation method according to previous literature.[54] 50 mL 1.0 M $FeCl_2.4H_2O$ and 1.75 M $FeCl_3.6H_2O$ solutions were prepared with deionized water in two different beakers. Then this solution transferred to a 250 mL three-necked flask and stirred under a nitrogen atmosphere. It was observed that the color of the solution turned dark brown immediately after addition. This color indicated that IONPs were formed.

The resulting solution was heated to 80°C for 1 hour. The precipitates were isolated from the solvent by magnetic filtration and washed several times with deionized water until neutral pH. They were dried under vacuum at 50°C for 10 hours.

Curcumin extraction using magnetic nanoparticles

0.5 g Fe_3O_4 nanoparticles and 1 g turmeric were mixed in the sonicator in a 1:1 ethanol/ water mixture for 6 hours. Then magnetic nanoparticles were separated from the Fe_3O_4-curcumin composite by magnetic decantation. The resulting composite structure was dried, and ethanol and water were added in a ratio of 1:1 and remixed in the sonicator for 1 hour. The mixture was adjusted to pH 5-6. Magnetic nanoparticles were separated from the curcumin mixture by magnetic separation with a permanent magnet. The insoluble curcumin mixture was separated and the soluble part was evaporated in the evaporator and dried in a vacuum oven at 50°C.

RESULTS

Fe_3O_4 nanoparticles were obtained according to the co-precipitation method of Fe^{2+} and Fe^{3+} ions.[54]

Characterization of Fe_3O_4 nanoparticles and Fe_3O_4-turmeric complexes

Transmission electron microscopy analysis was performed to see the particle size and

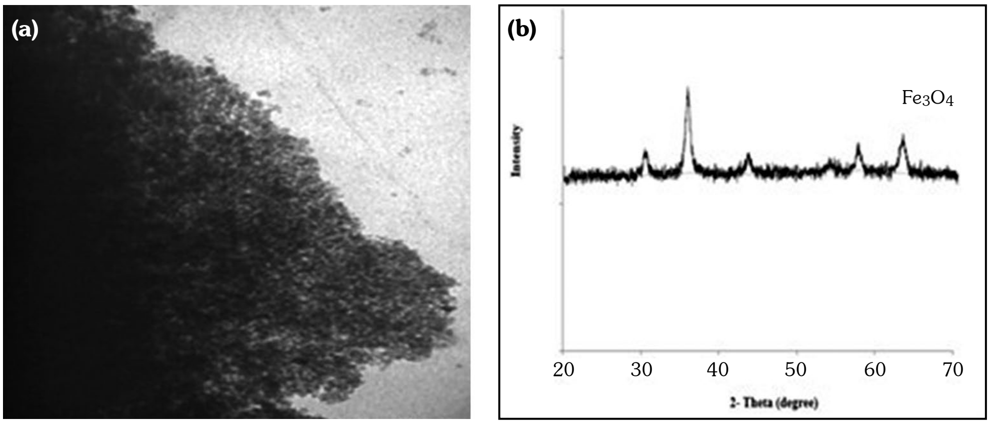

Figure 1. Transmission electron microscopy **(a)** and X-ray diffraction **(b)** result of Fe_3O_4 nanoparticles.

morphology of synthesized Fe_3O_4 nanoparticles (Figure 1a). The dense aggregates were exhibited due to the lack of any repulsive force between Fe_3O_4 nanoparticles.

Figure 1b shows XRD patterns of synthesized Fe_3O_4 nanoparticles. The characteristic peaks of the Fe_3O_4 crystal were seen at $2\theta = 30.3°$, $35.5°$, $43.0°$, $53.0°$, $57.4°$, and $63.5°$, respectively.

The properties of the Fe_3O_4 nanoparticles surface, due to the presence of under-coordinated iron (Fe) (III) sites, confer high specificity to select iron-chelating molecules from complex matrices.[17] Presenting a keto-enol functionality, curcumin tended to bind very well towards the surface of the magnetic nanoparticles. It showed that curcumin is a good ligand for the surface of Fe_3O_4 nanoparticles. This confirms the literature that curcumin has an important ability to form stable complexes with Fe (III).[16,56] Figure 2 shows the structure of the Fe_3O_4-turmeric complex.

The FTIR spectrum of the turmeric, Fe_3O_4, and Fe_3O_4-turmeric complexes, respectively, was given in Figure 3. The FTIR bands at low wavenumbers (<700 cm-1) come from vibrations from the Fe-O bonds. The FTIR bands around 604 and 534 cm^{-1} belong to the stretching vibration mode of Fe-O bonds in magnetite nanoparticles. It was observed that the stretching vibration modes of the turmeric, C-O bands,

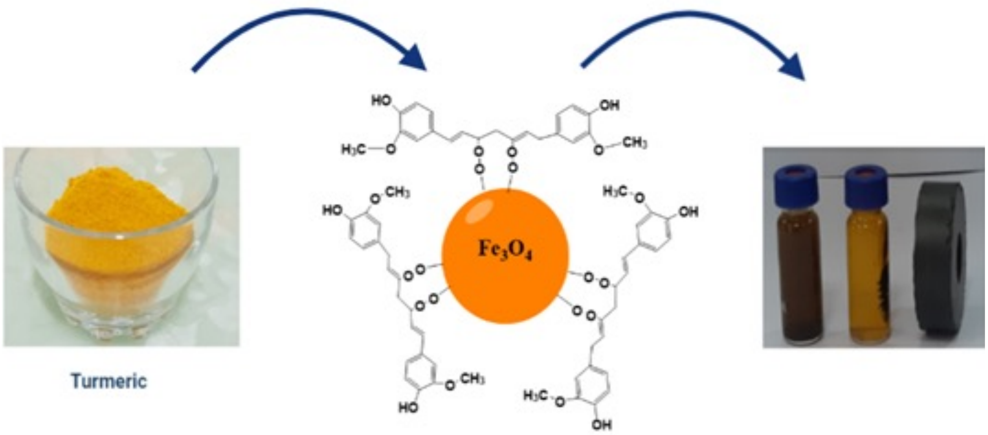

Figure 2. Fe_3O_4-turmeric complex.

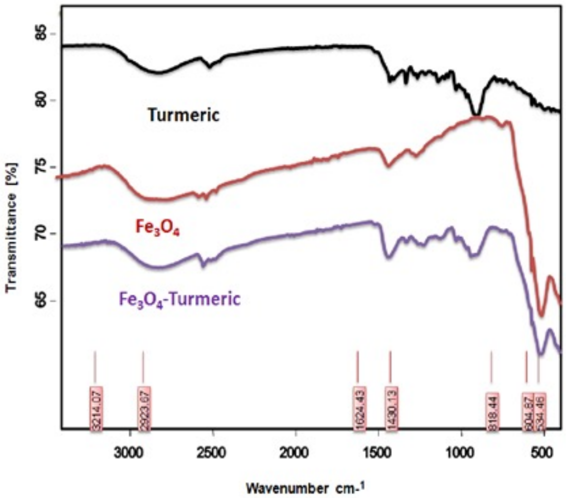

Figure 3. Fourier transform infrared spectroscopy spectrum of turmeric, Fe_3O_4 nanoparticles and Fe_3O_4-turmeric.

C=O bands, and C=C bands were at 994 cm^{-1}, 1511 cm^{-1}, and 1626 cm^{-1}, respectively. The formation of the Fe_3O_4-turmeric was assigned by the disappearance of the characteristic band at about 994 cm^{-1} and the appearance of a C=C at 1624 cm^{-1}.

Characterization of curcumin and commercial curcumin

Fourier-transform infrared spectra of curcumin obtained with commercial curcumin were compared. The FTIR spectrum of commercial curcumin of O-H, C-H, C=O and C=C bands were observed at 3508 cm^{-1}, 1626 cm^{-1}, 1506 cm^{-1}, 1426 cm^{-1}, 1203 cm-1, 1024 cm^{-1}, respectively. Similarly, the isolated curcumin bands were observed at 3271 cm^{-1}, 1600 cm^{-1}, 1508 cm^{-1}, 1203 cm^{-1} 1024 cm^{-1}, respectively (Figure 4).

The UV spectrum of commercial curcumin and curcumin was measured. The strong interaction between IONPs attached to the surface and phenolics in the compounds was demonstrated by UV-Vis spectrophotometry. The absorption spectrum of commercial curcumin and curcumin showed a maximum wide band at approximately 423 nm in Figure 5.[16,55-58]

Many researchers have studied the amount of curcumin in turmeric. Priyadarsini[59] reported that turmeric contains 2-9% curcuminoids, depending on the origin and the soil conditions in which it was grown. Lal reported that it is found in different amounts according to the production regions in India. It has reported that it is found at

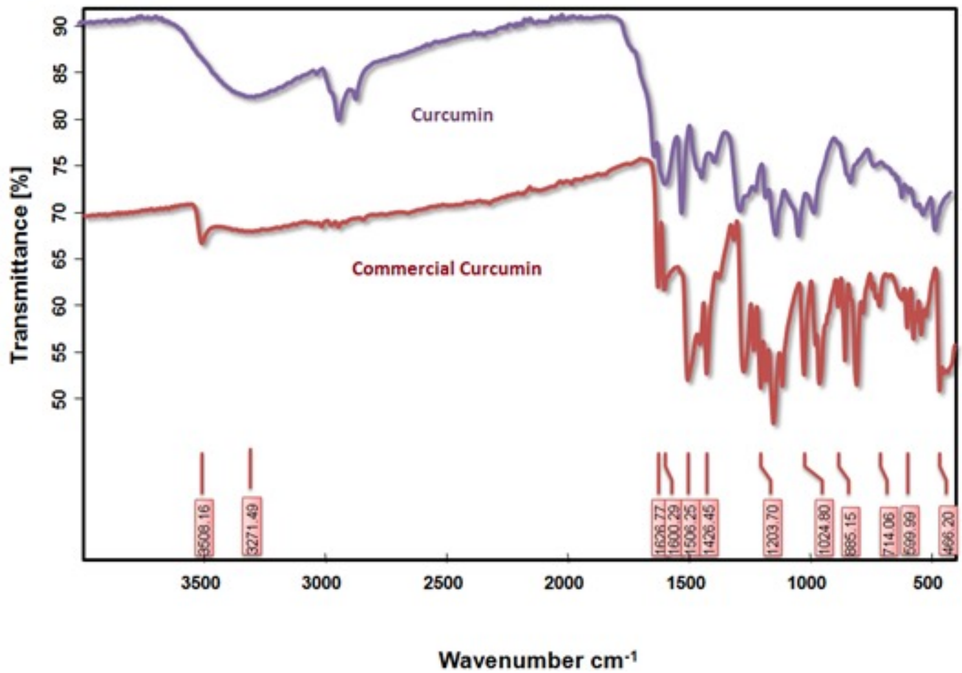

Figure 4. Fourier transform infrared spectroscopy spectrum of curcumin and commercial curcumin.

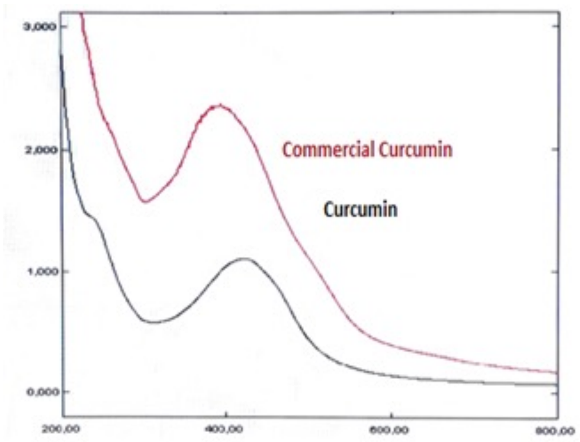

Figure 5. Ultraviolet spectrum of curcumin and commercial curcumin.

a rate of 2% in Madras and 4-7% in Alleppey.[60] In another study, Paultre et al.[61] explained that the amount of curcumin is 3-10%. From the standard curcumin calibration graph, the curcumin concentration was found to be 0.0275 mM at 423 nm. The amount of curcumin was calculated as 15 mg by using the concentration. Curcumin was recovered from the extracts of the turmeric plant by magnetic purification with an amount of 1.5%.

DISCUSSION

There is a need for alternative treatment methods in the treatment of cancer and many diseases. The therapeutic uses of medicinal plants have attracted considerable attention in recent years.

Curcumin is a natural flavonoid. It has many important properties such as anticancer, antioxidant, and antibacterial effects. Different techniques such as chromatographic, electrophoretic are used to isolate biomolecules. These methods are both time-consuming and expensive. Therefore, simpler and more economical techniques are needed for isolation.

Magnetic Fe_3O_4 nanoparticles, with their low toxicity, biocompatibility, and easy separation with the help of magnets, have attracted a lot of attention in recent years, especially in applications such as targeted drug therapy, cancer therapy, enzyme immobilization, hyperthermia, and magnetic resonance imaging. Biocatalytic applications are also used in different fields such as biomedicine, biomedical, and bioengineering. A suitable magnetic field is created by adding biomolecules or organic substances to these magnetic nanoparticles, and the separation of substances can be performed quickly and easily by using magnets.[42,51]

For the isolation of curcumin, unlike other purification techniques, the use of magnetic nanoparticles was preferred considering the advantage of a simple and fast separation technique with the help of magnets. In the study, Fe_3O_4 nanoparticles were synthesized and their structure was confirmed by characterization techniques.[37,55,56,59,63-68]

In Figure 1a, the morphology and particle size of Fe_3O_4 nanoparticles was examined by TEM analysis. The formation of nanoparticles was confirmed.[5,62,63] In addition, characteristic peaks of the synthesized Fe_3O_4 crystals were analyzed (Figure 1b). These peaks were seen by XRD analysis at $2\theta = 30.3°$, $35.5°$, $43.0°$, $53.0°$, $57.4°$ and $63.5°$, respectively.[37,56-58,62] Turmeric, Fe_3O_4, and Fe_3O_4-turmeric compound FTIR spectra were also studied (Figure 3). The stretching vibrations of Fe_3O_4, Fe-O bonds, the stretching vibrations of in the turmeric structure C-O bands, C=O bands, and C=C bands were confirmed.[37,58,61-64] Curcumin was obtained from the extracts of the turmeric plant by using the obtained nanoparticles. It was determined that curcumin from the extracts of the turmeric plant was recovered with a purification efficiency of 1.5%.

The FTIR and UV spectra of commercial curcumin and curcumin were examined and compared. Figure 5 showed a significant interaction between surface-bound IONPs and phenolics in the compounds. The absorption spectra of both commercial curcumin and obtained curcumin showed a broad band maximum at 423 nm.[16,59,65]

It is thought that this study can be beneficial in terms of the fact that curcumin, which has the potential to research in the field of health, can create different expansions both scientifically and economically and produce new studies.

In conclusion, Fe_3O_4 magnetic nanoparticles were synthesized and used to obtain curcumin from turmeric. The synthesized Fe_3O_4 magnetic nanoparticles were characterized by FTIR, XRD and TEM. The resulting curcumin compound was purified quickly and easily in the presence of magnetic IONPs without using expensive devices. Then, it was compared to commercial curcumin. Curcumin from extracts of the turmeric plant was recovered with a purification yield of 1.5%. With this method, it is predicted that biomolecules that can be easily transported from the laboratory to the industrial level can be easily purified by using an economical and environmentally friendly method, without the need for expensive devices.

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Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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