Isolation of curcumin from turmeric

Turmeric, the dried yellow rhizome of Curcuma longa, is a common oriental spice that gives curry dishes their characteristic yellowish color and is used in Indian cooking. The active ingredient in turmeric is curcumin, which is approximately 0.5-6.0 % by weight of the root of turmeric. Since 1970, when curcumin first attracted the interest of scientific medical researchers, studies of curcumin have reported suppressive effects for the following medical conditions: High serum cholesterol levels, Free radical damage to tissues, Diabetic cataracts, Diabetic damage to pancreatic insulin-producing cells, Diabetic wounds, Rheumatoid arthritis, Inflammatory bowel disease, Crohn’s Disease, Psoriasis, Cancer, Atherosclerosis, Inherited peripheral neuropathies, Liver damage by chemicals and drugs, Microbial infections. Other four medical conditions for which curcumin seems to hold especially exciting prospects: Alzheimer’s Disease, Parkinson’s Disease, Cystic fibrosis, Ailments related to Epstein-Barr Virus.

[www.lifelinknet.com/.../Products/PriMeric.asp]
Abstract

Curcuminoids, a group of phenolic compounds isolated from the roots of Curcuma longa (Zingiberaceae), exhibit a variety of beneficial effects on health and on events that help in preventing certain diseases. A vast majority of these studies were carried out with curcumin (diferuloyl methane), which is a major curcuminoid. The most detailed studies using curcumin include anti-inflammatory, antioxidant, anticarcinogenic, antiviral, and antiinfectious activities. In addition, the wound healing and detoxifying properties of curcumin have also received considerable attention. As a result of extensive therapeutic properties of curcumin there is a need to develop newer and selective method for the isolation of curcuminoids from turmeric. This chapter is a step in this direction to improvise the quantity of curcumin isolation from turmeric roots.

Keywords: Curcuminoids, Curcuma longa, turmeric roots.
VI.1. Introduction

Curcumin (diferuloyl methane), the natural yellow pigment in turmeric, is isolated from the rhizomes of the plant Curcuma longa. It constitutes about 3-4% of the composition of turmeric. In the south and southeast tropical Asian countries, turmeric has been used for centuries as a spice to give the specific flavor and yellow color to curry. Turmeric became a very important spice to mankind when it was observed that the addition of turmeric powder in food preparation preserved its freshness and nutritive value. Turmeric, as an additive, improved the palatability. Aesthetic appeal and shelf life of perishable food items. The use of turmeric became more popular when it was found to act as a therapeutic agent for various illnesses. In the Ayurvedic system of medicine, turmeric is used as a tonic and as a blood purifier. Its role in the treatment of skin diseases and its ability to soften rough skin resulted in the prolific use of turmeric in topical creams and bath soaps in India. Turmeric is also used in home remedies in the treatment of cuts, wounds, bruises, and sprains. Its use as an anti-inflammatory and antimicrobial agent has been recognized for more than a century. The importance of turmeric in medicine took a new twist when it was discovered that the dried rhizome of Curcuma longa is very rich in phenolics, whose structures have been identified as curcuminoids (Figure 1). Phenolics are known to possess antioxidant properties. Free radical mediated damage to biological systems is recognized as the initiating agent for many diseases, such as cardiovascular diseases, cancer, and arthritis. Turmeric and its constituents show beneficial
effects on these diseases and on other illnesses. For example, the low incidence of large bowel cancers in Indians could be attributed to a high intake of natural antioxidants, such as curcumin in the diet [1]. The anti-mutagenic and anti-tumor effects of curcumin are most widely studied [1]. However, in recent years, it has been shown that the inhibition of arachidonic acid metabolism, modulation of cellular signal transduction pathways, inhibition of hormone, growth factor, and oncogene activity are some of the mechanisms by which curcumin causes tumor suppression [3]. Chemopreventive activity of curcumin is observed when administered prior to, during, and after carcinogen treatment as well as when it is given only during the promotion/progression phase (starting late in premalignant stage) of colon carcinogenesis in F 344 rats. Curcumin is also a powerful inhibitor of the proliferation of several tumor cells, as well as an anti-inflammatory agent. It exhibits anti-clastogenic, anti-fungal and anti-viral properties. However, the lack of information regarding the mechanisms of action of curcumin has precluded its clinical use in western countries. Several recent studies have given some insight into the molecular basis for the action of curcumin at the cellular level. This review looks at some of these insights into the cellular processes, molecular, and/or biochemical mechanisms that are influenced by curcumin [4-9].

![Figure VI.1](image)

Structure of some natural curcuminoids
VI.1.1. The biological source of curcumin

Curcumin genus in the plant family of Zingiberacea, is the biological source for curcuminoids, including curcumin. Curcuma longa, the yellow tuberous root that is referred to as turmeric, was taken from India to Southeast Asia, China, North Australia, West Indies, and South America. Subsequently, its cultivation spread to many African countries. India, however, remains the largest producer of turmeric in the world, with a figure of 4,87,000 metric tones in production, of which 27,750 metric tones are exported. The yellow pigmented fraction of Curcuma longa contains curcuminoids, which are chemically related to its principal ingredient curcumin. The three main curcuminoids isolated from turmeric are curcumin, demethoxy curcumin, and bisdemethoxy curcumin (Figure I). Curcuminoids are present in 3-5% of turmeric. Curcumin is the important active ingredient responsible for the biological activity of turmeric. Curcumin, C_{2}H_{2}O_{6} (m.p. 1 84°C), or diferuloyl methane was first isolated in 1815. The crystalline form of curcumin was obtained in 1910, and Lampe solved its structure in 1913. It is insoluble in water, but soluble in ethanol and acetone [4-9].

VI.1.2. Biological activities of curcumin

VI.1.2.1. Anti-inflammatory property

Inflammation is a necessary process for fighting infections. It results from a series of complex reactions, triggered by the host immunological response. Uncontrolled inflammatory responses may lead to undesirable effects, such as tissue damage. Many of the diseases, such as...
rheumatoid arthritis, are the result of sustained production of inflammatory mediators causing physical damage to joints. Many inflammatory mediators have been implicated in these complex reactions, some of which are modulated by curcumin [10-14].

VI.1.2.2. Antioxidant properties

The discovery of the antioxidant properties of curcumin explains many of its wide ranging pharmacological activities. Curcumin is an effective antioxidant and scavenges superoxide radicals, hydrogen peroxide, and nitric oxide from activated macrophages. It inhibits the inducible nitric oxide synthase activity in macrophages. Human keratinocytes are protected from Xanthinexanthine oxidase injury by virtue of the antioxidant property of curcumin. Oral administration of 30mg/kg body weight of curcumin in rats for 10 days reduces the iron-induced hepatic damage by lowering lipid peroxidation. Protection from radiation by dietary curcumin administered to mice is also attributed to the antioxidant property of curcumin. Curcumin protects renal cells and neural glial cells from oxidative stress. Interestingly, curcumin not only exhibits antioxidative and free radical scavenging properties, but also enhances the activities of other antioxidants, such as superoxide dismutase, catalase, and glutathione peroxidase. Lipid peroxidation is lower in liver, kidney, spleen, and brain microsomes from retinol deficient rats that are fed with 0.1% dietary curcumin for three weeks. Another mechanism by which curcumin protects against oxidative stress in endothelial cells is by the induction of heme oxygenase-1 [15-18].
VI.1.2.3. Effect of curcumin on lymphocytes

Mucosal CD4 (+) T cells and B cells increase in animals treated with curcumin, suggesting that it modulates lymphocyte-mediated immune functions [19]. Dietary curcumin increases antibody response in rats in vivo. In vitro, curcumin enhances IgM production in rat spleen lymphocytes. Han et al. studied the ability of curcumin to modulate proliferative responses of normal splenic and transformed B-lymphocytes. These observations indicate that curcumin arrests growth and induced apoptosis of B cell lymphomas more effectively than normal B lymphocytes. In BKS-2 B lymphoma cells, the inhibitory effects of curcumin appear to be mediated by the down-regulation of survival genes (egr-1, c-myc, bcl-XL and NF-κB), as well as the tumor suppressor gene p53. On the other hand, curcumin may be an effective adjunct in the prevention of post-transplant lymphoproliferative disorder in patients undergoing therapy with cyclosporine. A, because curcumin blocks the B-cell immortalization by EBV, which is promoted by oxidative stress induced by cyclosporin A [20-21].

VI.1.2.4. Effect of curcumin on platelet aggregation

Curcumin inhibits platelet-activating factor (PAF), ADR arachidonic acid (AA), epinephrine, and collagen mediated platelet aggregation. However, at lower doses (20-25μM), curcumin inhibits only PAF and AA mediated platelet aggregation and not those mediated by other agonists. Pretreatment of platelets with curcumin resulted in the inhibition of platelet aggregation induced by calcium ionophore A 23187, but not by the PKC activator, PMA.
Curcumin also inhibited thromboxane A2 (TXA2) formation by platelets. These observations suggest that curcumin mediated preferential inhibition of PAF- and AA-induced platelet aggregation involves inhibitory effects on TXA2 synthesis and Ca$$^{2+}$$ signaling [23].

**VI.1.2.5. Effects of curcumin on detoxification mechanisms curcumin, cell cycle, and apoptosis**

Curcumin is an apoptotic agent. While a low concentration of curcumin is known to arrest cell proliferation in the G0-G1/G2/S phase, a high concentration of curcumin induces apoptosis in rat A7r5 cells [24]. Several hallmarks of apoptosis, including DNA laddering, chromatin condensation and fragmentation, and an apoptosis specific cleavage of 28S and 18S ribosomal RNA were observed after treatment of immortalized mouse embryo fibroblast NIH 3T3, erb B2 oncogene-transformed NIH 3T3, mouse sarcoma S180, human colon cancer cell HT-29, human kidney cancer cell 293, and human hepatocellular carcinoma Hep G2 cells with curcumin [25]. Curcumin-induced apoptosis in human basal cells was shown to be dependent on a p53-signaling pathway. Curcumin was shown to accumulate in plasma membrane, endoplasmic reticulum, and nuclear envelope and to produce apoptosis-like changes in plasma membranes in rat thymocytes. The sequence and extent of primary events during apoptosis induced by curcumin have been compared with those occurring during dexamethasone-induced apoptosis in rat thymocytes (Curcumin-treated cells

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**National Cancer Institute research update**

The National Cancer Institute is currently developing curcumin as a drug for the treatment of cancer. The rationale behind this effort is based on the combination of potential chemopreventive mechanisms, the validated biological activity in preclinical studies and its proven safety to humans.

A Phase I trial assessing the safety and pharmacokinetics, studies on patients with colon polyps (in view of the inhibitory effect of curcumin on the formation of arachidonic acid metabolites) and a Phase II chemoprevention trial on patients with oral leukoplakia are included in these plans.

[http://www.curcuminoids.com/nci.htm]
exhibit typical features of apoptotic cell death, including shrinkage, transient phosphatidylserine exposure, increased membrane permeability and decrease in mitochondrial membrane potential. The level of anti-apoptotic protein Bcl-2 was decreased in the presence of curcumin [26].

**VI.1.2.6. Clinical evaluation of curcumin as an anti-carcinogenic agent in humans**

Because of their safety and the fact that they are not perceived as 'medicine,' food-derived products are of great interest in the development of chemopreventive agents, which may have a widespread long-term use in populations at normal risk. Curcumin is one such diet-derived agent that is being clinically evaluated as a chemopreventive agent for major cancer targets, including the breast, prostate, colon, and lung [27]. For developing such agents, the National Cancer Institute (NCI) has advocated co-development of a single or a few putative active compounds (including curcumin) that are contained in the food-derived agent. The active compounds provide mechanistic and pharmacologic data that may be used to characterize the chemopreventive potential of the extract, and these compounds may be useful as chemopreventives in higher risk subjects (patients with precancers or previous cancers). Other critical aspects for developing the food-derived products are careful analysis and definition of the extract to ensure reproducibility (e.g., growth conditions, chromatographic characteristics, or composition) and basic science studies to confirm epidemiologic findings associating the food product with cancer prevention [28].

**Curcumin for Cancer**

In clinical studies, a topical ointment containing five percent curcumin applied to cancerous growth on the skin in 62 patients was found to reduce foul smell, itching, pain and the discharge of fluid from the lesion (wound) in a significant majority of the patients. The foul odor was considerably reduced in more than 90 percent of the patients; pain and itching subsided in 50 percent; and fluid discharge was reduced in 70 percent of the cases. Turmeric extracts or alone in combination with betel leaf extract was effective against tumors induced by a powerful carcinogen (a nitrosamine derivative) in the mouth mucosa of hamsters. Curcumin also inhibited the action of another potent carcinogen (a nitroquinoline derivative) in inducing tumors in the mouth mucosa of rats. In a clinical study, the effectiveness of curcumin was tested in patients with oral cancer. One hundred patients were given 500 mg of curcumin three times a day for 30 days. A significant number of patients improved on the curcumin regimen and responded with dramatic clinical improvement within 15 days, while others responded more gradually throughout the 30-day treatment period.

[Turmeric and the healing curcuminoids. Muhammed Majeed, Ph.D., Vladimir Badmaev, M.D., Ph.D. and Frank Murray]
VI.1.2.7. Wound-healing properties of curcumin

Tissue repair and wound healing are complex processes that involve inflammation, granulation, and tissue remodeling. Interactions of different cells, extracellular matrix proteins, and their receptors are involved in wound healing and are mediated by cytokines and growth factors. Curcumin enhances cutaneous wound healing in rats and guinea pigs by increasing the formation of granulation tissue, biosynthesis of extracellular matrix proteins, and TGF-β1 in wounds [29]. Curcumin also accelerated wound healing in streptozotocin-induced diabetic Swiss Albino rats and genetically diabetic (C57/KsJdb/db+) mice by increasing the formation of granulation tissue, faster re-epithelialization, and increased collagenization [30]. Systemic treatment with curcumin after local muscle injury leads to faster restoration of normal tissue architecture, as well as an increased expression of biochemical markers associated with muscle regeneration [31].

VI.1.2.8. Curcumin and diabetes

Feeding diabetic rats curcumin improved their metabolic status [32]. Diabetic rats maintained on a 0.5% curcumin diet for 8 weeks excreted comparatively lower amounts of albumin, urea, creatinine, inorganic phosphorus, sodium, and potassium. On the other hand, glucose excretion or the fasting sugar level was unaffected by dietary curcumin and also the body weights were not improved to any significant extent. Diabetic rats fed a curcumin diet had a lower relative liver weight at the end of the study, compared to other diabetic groups. Diabetic rats

According to ayurveda, diabetes is a metabolic kapha type of disorder in which diminished functioning of agni leads to a tendency toward high blood sugar. Ayurvedic practitioners attack diabetes using a multiprong approach. First, they address diet modification, eliminating sugar and simple carbohydrates, and emphasizing complex carbohydrates. Protein is limited, since excessive intake can damage the kidneys. Fat is also limited because there is often a deficiency of pancreatic enzymes, making fat digestion difficult.

The most important herbs for all doshas are shilajit, gudmar turmeric, neem, amalaki, guggul, and arjuna. Turmeric with aloe vera gel (1 to 3 gms./.035 to .1 oz) is best used during the early stages of diabetes for regulating pancreas and liver functions.

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Fed a curcumin diet also showed lowered lipid peroxidation in plasma and urine. The extent of lipid peroxidation, however, was still higher in cholesterol fed diabetic groups, compared to diabetic rats fed with control diet. The mechanism by which curcumin improves this situation is probably by virtue of its hypocholesterolemic influence [33], antioxidant nature and free radical scavenging property [32].

VI.1.2.9. Antiviral properties of curcumin

In vitro, curcumin (0.32 mg/ml) moderately inhibited the activity of human simplex virus-2. Curcumin provided significant protection in a mouse model of intravaginal human simplex virus-2 challenge [34]. Curcumin is also highly effective in inhibiting Type I Human Immunodeficiency Virus, (HIV) long terminal repeat directed gene expression, and viral replication. Curcumin inhibited p24 antigen production in cells either acutely or chronically infected with HIV-1. However, curcumin failed to inhibit the HIV-I multiplication in acutely infected MT-4 cells. Nevertheless, curcumin specifically inhibited the enzymatic reactions associated with HIV-I integrase but not other viral (HIV-I reverse transcriptase) and cellular (RNA polymerase II) nucleic acid processing enzymes [35,36].

Curcumin was isolated as early as 1815. Daube in 1870 obtained it in crystalline form [37]. To our knowledge, no information has been reported in the literature about the process of isolating pure curcuminoids from turmeric. Therefore, the objective of the present study was to develop a new method for the isolation of curcumin from turmeric.
VI.2. Materials and methods

VI.2.1. Chemicals

Methanol, ethanol (HPLC grade), isopropyl alcohol, n-butyl alcohol, iso butyl alcohol, secondary butyl alcohol, iso amyl alcohol (Analytical grade) (BDH, India ltd).

VI.2.2. Procedure

Turmeric rhizomes were powdered and sieved through 30 mesh size sieve to obtain sample of uniform particle size. The resulting powder was extracted with acetone using cold percolation process in which the solvent uniformly seeps through the particle bed (sample powder), allowing the efficient diffusion of the soluble from the powder into the solvent after the contact time of 90 min. the solvent ratio was 5 volumes calculated on the dry weight of powdered turmeric rhizome. The extraction procedure was repeated for 7 times and the individual extracts combined before concentrating. The extracts were filtered and concentrated by distillation under vacuum at temperature less than 50°C to produce turmeric oleoresin.

A detailed study was carried out for isolation of curcuminoids from turmeric oleoresin extracted as above. In 100ml beaker 20 g turmeric oleoresin and 20g solvent were added, mixed well and kept aside for 48 hrs at room temperature for curcumioids precipitation. The precipitated curcuminoid crystals were purified by washing several times with the solvent.
VI.2.3. HPLC method for quantitative estimation of curcuminoids

The HPLC method described below was used to estimate the curcuminoids. The area under the peaks is measured for quantitative analysis of the sample.

Chromatographic System

- HPLC Pump: LC 10 AD - Shimadzu Make
- HPLC Detector SPD 10 A: Shimadzu Make
- Syringe: Hamilton 100 ml Syringe
- Injector: 7725i Rheodyne Injector
- Column: 250 x 4.6 mm SS column containing amino packing 5 micron particle size (NEC Phenomenex column is suitable).

Instrument Conditions

- Mobile Phase: Alcohol and methanol are mixed in the ratio 60:40 and the mixture is degassed and filtered.
- Injection size: 20 ml
- Flow rate: 1 ml per minute
- Detector: UV
- Wavelength: 254 nm
Preparation of standards

**Standard Curcumin:** 25 mg of standard curcumin is accurately weighed into a 25 ml volumetric flask and dissolved in methanol with warming, if necessary and the volume made up with methanol, followed by mixing.

**Standard Bismethoxycurcumin and standard Demethoxycurcumin:** In each case, 10 mg of the compound is accurately weighed into a 25 ml volumetric flask, dissolved and diluted to volume with methanol.

**Preparation of Sample**

25 mg of the sample is accurately weighed into a 25 ml volumetric flask, dissolved and diluted to volume with methanol.

**VI.2.4. Procedure**

Each standard preparation and sample preparation is injected, in duplicate, separately into the chromatograph. The response of the sample preparation in terms of areas under the three major peaks corresponding to BDMC, DMC and curcumin and the area under the major peaks for the respective standards is measured.

**The content of each curcuminoid is calculated as follows:**

**Content of Curcumin**

\[
\text{Sample area of curcumin} \times \text{standard weight} \times \text{standard purity} \div \text{Standard area of curcumin} \times \text{sample weight}
\]
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Content of Bisdemethoxycurcumin

Sample area of BDMC X Standard weight X Standard purity

\[ \text{Standard area of BDMC X Sample weight} \]

Content of Demethoxy Curcumin

Sample area of DMC X Standard weight X Standard purity

\[ \text{Standard area of DMC X Sample weight} \]

VI.2.5. Effect of solvents

20 gm of turmeric oleoresin was taken in different beakers and 20 gm of different solvents were added and mixed well. The mixture was kept for 48 h at room temperature for curcuminoids precipitation.

The chromatograms obtained for the standards are shown.
VI.2.6. Effect of time

20 gm of turmeric oleoresin and 20 gm n-butyl alcohol was added and curcumin precipitation was studied at different time intervals.

VI.2.7. Effect of Temperature

20 gm of turmeric oleoresin and 20 gm of n-butyl alcohol was added and incubated at different temperatures for two days.

VI.2.8. Effect of volume of n-butyl alcohol for the precipitation of curcuminoids

Different ratio of n-butyl alcohol was added to the turmeric oleoresin and incubated at room temperature for two days and yield was calculated.

VI.2.9. Effect of ageing of oleoresin

Ageing of the oleoresin was studied, after standardizing all other parameters like effect of solvent, temperature, solvent concentration and time.

After extraction of oleoresin from turmeric rhizomes, oleoresin was kept for ageing to improve the isolation of curcuminoids. Every day 20 gm of this oleoresin was taken in a beaker and to this 20 gm of n-butyl alcohol was added and dissolved well and kept aside for two days at room temperature for curcuminoids precipitation.
VI.3. Results and discussion

Effect of different alcohols for the precipitation of curcuminoids

1. Methanol
2. Ethanol
3. Isopropanol
4. n-Butanol
5. Isobutanol
6. Sec butanol
7. Isobutyl alcohol

Effect of Time on precipitation of curcuminoids

1. 12 hr
2. 24 hr
3. 48 hr
4. 72 hr
5. 96 hr
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Effect of Temperature on precipitation of curcuminoids

1. 25°C
2. 60°C
3. 20°C

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Yield</th>
<th>Purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>25°C</td>
<td>17.56</td>
<td>95.05</td>
</tr>
<tr>
<td>60°C</td>
<td>17.61</td>
<td>95.00</td>
</tr>
<tr>
<td>20°C</td>
<td>17.69</td>
<td>93.77</td>
</tr>
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</table>

Percentage of n-butanol and Oleoresin for the precipitation of curcuminoids

1. 75%
2. 100%
3. 150%

<table>
<thead>
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<th>Percentage</th>
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<tr>
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<td>92.84</td>
</tr>
<tr>
<td>100%</td>
<td>17.56</td>
<td>94.50</td>
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<tr>
<td>150%</td>
<td>17.00</td>
<td>95.10</td>
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</table>

Effect of Ageing of turmeric oleoresin for the precipitation of curcuminoids

<table>
<thead>
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<th>Number of days of ageing</th>
<th>% yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>15.00</td>
</tr>
<tr>
<td>2</td>
<td>15.50</td>
</tr>
<tr>
<td>4</td>
<td>16.00</td>
</tr>
<tr>
<td>6</td>
<td>16.50</td>
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<td>8</td>
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</tr>
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<td>14</td>
<td>18.50</td>
</tr>
<tr>
<td>16</td>
<td>19.00</td>
</tr>
<tr>
<td>18</td>
<td>19.50</td>
</tr>
<tr>
<td>20</td>
<td>20.00</td>
</tr>
<tr>
<td>22</td>
<td>20.50</td>
</tr>
</tbody>
</table>
From the above observations n-butyl alcohol was selected as the best solvent for the precipitation on the basis of yield and purity of curcuminoids as shown in graph 1. Further, the work was carried out to ascertain the time required for precipitation and it was found that 48 hrs were required to get good results (graph 2). Similarly, the procedure was repeated at different temperatures ranging from -20°C to room temperature (23±3°C), maximum yield and purity of the precipitated curcuminoids were found at room temperature as shown in graph 3. From graph 4, it was clear that the ratio of oleoresin and n-butyl alcohol plays a key role in precipitating the curcuminoids; the ratio (1:1) gave good results.

VI.4. Conclusion

The turmeric spice has been used for many centuries mainly as a food additive, primarily because of its golden yellow color. The medicinal properties of this spice were recognized in Indian folklore medicine and in Ayurveda, which is an ancient Indian traditional system of medicine. It was used as a tonic for improving health and in various combinations for the treatment of diseases such as common cold. The major break through in realizing the medicinal value of turmeric came with the isolation of phenolics called “curcuminoids”, of which curcumin is the major constituent. Even though a large number of studies unequivocally identified the numerous pharmaceutical actions of curcuminoids, its acceptance as a wonder compound is slowly forthcoming. The objective of the present investigation was to provide a novel method for extracting curcuminoids from turmeric rhizome by an appropriate solvent for obtaining high yield and purity of curcuminoids.
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References


Analytical studies

The properties of every substance from the air we breathe to the vast range of materials and products which we use in our private lives are directly or indirectly a function of chemical composition.

These properties are influenced for better or worse, by the presence or absence of one or more chemical species, sometimes at concentration levels which are barely detectable. Consider the contamination of a foodstuff with a toxic metal or compound, or the presence of even a few milligrams of asbestos per cubic meter in the air we breathe.

It is obvious therefore, that chemical composition in many instances decides the value of products and materials which form the basis of national and international trade. As a consequence, it is not surprising that there are more government regulations, standard specifications and trading agreements associated with chemical composition than all other properties put together. It is here that analytical chemistry plays its role.

Analytical chemistry is the science concerned with the systematic identification or characterization of established chemical species and their determination to known degrees of certainty at any level of concentration and in any matrix in which they may occur.