CHAPTER I

INTRODUCTION

1. General background

1.1 General

Turmeric is the spice obtained from the rhizomes of herbaceous plant, Curcuma longa Linn or Curcuma domestica Valeton, Family Zingiberaceae, which is the native of Tropical South-East Asia, where it has been known and used for thousands of years as a spice and a common house hold medicine. The plant is cultivated in Sri Lanka, India, China, Haiti, Indonesia, Jamaica, Malaysia, Pakistan, Peru, Phillippines, Taiwan, and Thailand.[21] World production is estimated to be about 160,000 tons,[21] of which India produces about 90 percent.

The mature rhizomes are ground to give an aromatic yellow powder, employed as a colouring ingredient of curry powder, in traditional medicine and as an insect repellant. The main yellow pigment is curcumin, which is accompanied by two related minor curcuminoids, demethoxycurcumin and bisdemethoxycurcumin and a number of sesquiterpenes including turmerone and ar-turmerone[18,21,23,27]

There are two types of cultivated turmeric[21]

a). Curcuma longa Linn or Curcuma domestica Valeton which is known as the common turmeric

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b) . Curcuma aromatica Salisb which is known as the wild turmeric

1.2 Curcuma species in Thailand [1]

There are several species of Curcuma in Thailand such as

C. aeruginosa Roxb (ว่านมหาเมฆ)

C. alismatifolia Gagneb (ขมิ้นโคก)

C. amarissima Roscoe (ขมิ้นขม)

C. aromatica Salisb (ว่านนางดำ)

C. comosa Roxb (ว่านชักมดลูก)

C. longa Linn or C.domestica Valeton (ขมิ้น)

C. parviflora Wall (กระเจียวขาว)

C. sessilis Gage (อาวแดง)

C. sparganifolia Gagnep (กระเจียวบัว)

C. xanthorrhiza Roxb(ว่านชักมดลูก)

C. zedoaria Roscoe (ขมิ้นอ้อย)

C. zerumbet Roxb (แฮ้วดำ)

C. roscoeana Wall(ขมิ้นแดง)

1.3 Botanical name and common names [21,31,32,35]

Curcuma longa Linn or Curcuma domestica Valeton

English - Turmeric;Yellow ginger;Yellow root;Indian saffron

Chinese - Yu-chin

French - Curcuma; Safran de Inde

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German - Kurkuma-Gelbwurzel

Italian - Curcuma

Japanese - Ukon

Thai - Khamin; Khamin kaeng; Khamin yok; Khamin hua; Khamin chan;Kheemin;Min;Taa-yo;Sa-yo;Turmeric

1.4 Uses

1.4.1 Reported Therapeutic Uses In Indian medicinal systems, turmeric is used to some extent as a stomachic for flatulence, dyspepsia, digestive disturbances, tonic antiseptic, carminative, blood purifier, antiperiodic alterative.[21] In Malaysia, turmeric is rubbed on the abdomen of woman after child birth and applied as an ointment to the cut umbilical cord of the baby.[14,21] A decoction of the rhizome is applied to relieve catarrh, it also relieves pain of purulent ophthalmia and is used as a cooling eye wash.[21] Milk boiled with the rhizome and sugar is said to be beneficial for sore throats and the common cold.[21] A paste made from the powdered rhizomes and lime is a remedy for inflamed joints.[21] In small-pox and chicken-pox, a coating of turmeric powder is applied to facilitate scabbing.[21] Ointments made of turmeric powder, hemp leaves, onion and warm mustard oil or linseed oil gives relief when piles are painful and is effective in eczema, itches, skin sores. The water extract of the fresh rhizome with lime is sometimes applied to wounds, bruises, sprains and leech bites.[21] It acts as an antiparasitic for many skin affections and is externally applied indolent ulcers. Turmeric is

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used internally as an anthelmintic.[21] Turmeric oil has antiinflammatory, antiarthritic and feeble antiseptic properties.[21] It is an antacid in small doses, acts as a carminative, stomachic, appetizer and tonic.[21] In large doses (2-4 ml) however, it appears to act as an antispasmodic, inhibiting excessive peristaltic movements of the intestine. It stimulates bile flow and causes contraction of the gall bladder.[21] Turmeric oil inhibits growth of Staphylococcus aureus and S. albus in concentrations up to 1 in 5000 part. It also kills P.caudanan in 10-30 min in dilutions of 1 in 30,000 part and also inhibited Micrococcus pyogenes variety aureus in 1:1 million dilution.[21,28] Turmeric oil also showed antibacterial activity against gram-negative and gram-positive organisms. The oil shows antifungal activity against pathogenic fungi in sugar cane. Significant fungistatic activity was shown against Aspergillus niger in vitro. Curcumin was devoid of activity.

1.4.2 Use in food industries. The soft, lighter coloured rhizome is used as a condiment in curry powder, pickles, vegetable, egg, meat and fish preparations.[12,21] It is accepted as a constituent of prepared mustard.[34] Turmeric and turmeric oleoresin, with or without an approved diluent may be used under the Federal Food, Drug Cosmetics Act for colouring foods. Its bright yellow pigment is used for colouring butter, cheese, magarine, liqueurs, fruit drinks, confectionery, cakes, jellies. It may be used in alcoholic solution. Bakers use it to give a yellow colour to bread and rools. The maximum acceptable daily intake of turmeric for man is 0.5 mg per kg

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body weight.[21] At 0.04% level in the diet, it was found to slightly lower the cholesterol in the liver.[21] The maximum usage levels for turmeric, turmeric oleoresin and turmeric extract in various foods given by the Flavouring Extract Manyfacturers Association are shown in Table 1

Table 1. The maximum usage levels for turmeric, turmeric oleoresin and turmeric extract in various foods given by the Flavouring Extract Manufacturers Association.

Type of products. \ maximum levels (ppm)	Turmeric	Turmeric oleoresin	Turmeric extract
Beverages (non-alcoholic)	-	-	0.78
Condiment	750	640	59
Gelatins and puddings	0.05	-	-
Meat	200	20-100	43
Pickles	690	200	40
Soup	30-50	-	30-40

1.4.3 Use as a dye. Curcumin has been classified as CI* Natural Yellow 3 with colour index no.75300.[9] It, the colouring

* CI = colour index

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matter of turmeric is said to be the only vegetable colouring matter which dyes cotton and silk directly to be a bright yellow. In Thailand, the water extract of pulverized turmeric is infused with 7 parts lime water and 4 parts water and used as a dye.[2,4,5]

1.4.4 Use in cosmetics. Turmeric is said to give a glow to the skin. It is used in cleaning the skin and as a preventive of skin infections. Women in the Far East apply it to their faces as a cosmetics. It is thought that the application of turmeric tends to suppress the growth of hair on the skin of females. Turmeric water extract is used as a cosmetic lotion.[7] It is rubbed over the body after a bath or the powder dusted over children after bathing.[4,17,21] Turmeric is used as an antibacterial and antiinflammatory natural dye for some cosmetics such as shampoos, lotions.

1.4.5 Use as an insecticide. Petroleum-ether extracts of C.longa Linn showed insecticidal properties against houseflies. Synthetic pine oil and oil of curcuma is effective for the control of houseflies, mosquitoes and leeches.[8,21] Sprays of acetone solution of turmeric oil and DDT were toxic to houseflies and mosquitoes. Toxicity of DDT was increased by turmeric oil.

1.5 Market Potential

India produces the largest quantity of turmeric 60,000-100,000 acres are under cultivation and about 130,000 tons of cured

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turmeric are produced annually 92 percent of which is consumed in India and some of which is exported[21,23] (see Table 2). Sri Lanka was the second largest importer of turmeric from India but today she is self-sufficient. West Asian countries prefer the bulbs which the European and American markets take the fingers. In 1979,England imported turmeric that was valued 54.7 million baht.[3]

There are two important forms of turmeric in the market. Round turmeric representing the ovate or pear shaped, fleshy main rhizomes and Long turmeric, the more slender, elongated, somewhat cylindrical and branched secondary rhizomes.(Alleppy and Madras).[21] The Alleppy is the more esteemed since it is claimed to hold its colour better than the Madras when exposed to light in glass containers. The commercial supplies of this drug have been imported from India, the United Kingdom, China, Japan, Haiti and Jamaica.

In Thailand, turmeric finds the market in traditional medicine in the country and for exportation as spice and food ingredient.[2,4,5] The domestic market is increasing since turmeric will be used more as food colourant and in the basic health program. The Thai Commodity Company, the only important export company of crude drug in Thailand, wants 1,000 tons for exportation.[27] At present the material is not yet available. Japan buys dried turmeric rhizomes 100 tons/year through the Takeda Company in Bangkok.[27] The survey of turmeric market in Thailand in 1979/1980[27] is shown in Table 3., page 8.

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TABLE 2 : Turmeric Exports from India

Year	Quantity (metric tons)
1969/70	7,025.5
1970/71	11,109.3
1971/72	14,172.6
1972/73	6,731.3
1973/74	7,921.4
1974/75	9,526.0
1975/76	6,800.0
1976/77	11,755.0

TABLE 3 : The survey of the turmeric market in Thailand in 1979/1980

Turmeric market	Quantity (metric tons/year)
Manufactures	6.036
Wholesalers	39.80
Retail drugstores	not available

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2. The crude drug curcuma

2.1 Botany of the plant[17,21,23,31,32]

Natural Order : Scitaminae

Family : Zingiberaceae

Genus : Curcuma

Curcuma longa Linn is a perennial herb, 2-3 ft.high. Stem is short with tufted leaves. Leaves are very thin, oblong-lanceolate, tapering to the base, 2-3 ft. long, in tufts up to 1.2 m. or more, including the petiole which is about the length of the blade. It has 6-10 leaves from a node and several tufts in a rhizome. Flowers are yellow or pale yellow and cone-shaped spikes which are 10-15 cm. long. Peduncle is 15 cm. or more that enclosed in a sheathing petiole. Flowering bracts are pale green. Flowers arise from 2 buds situated in the axils of bracts and mature successively. Fruit is inconspicuous.

The rhizome is brownish yellow in colour and consists of a control bulbous portion bearing several finger-like lateral offshoots. The turmeric of commerce, the rhizomes are ovate oblong, pyriform or cylindrical and often short-branched. They are 2-7 cm. long, 1-1.8 cm thick that have root scars and annulations. Rhizomes are rough and hard. The internal colour varies form yellow to orange. When fractured, the break, is clean not splintery or fibrous, surface is resinous or waxy in appearance. The smoothed transverse

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surface exhibits a paler or sometimes darker ring separating the stele from the cortex. This appearance of the interior of the rhizomes is due to the prolonged boiling they undergo, by which not only is the starch gelatinised, but the colouring matter previously restricted to certain scattered cells, become uniformly diffused through out the rhizome.

Turmeric rhizome has the abundant groups of parenchymatous cells, which are filled with gelatinised starch and permeated with a bright yellow colouring matter which is soluble in aqueous mounts; in cleared preparations the cells are seen to be rounded to oval in outline with thin, slightly irregular walls. The fairly abundant fragments of pale brown cork composed of thin-walled cells which appear large and polygonal in surface view. Fragments in sectional view show that the cork consists of from two to five layers of cells and that it occurs inside the cortex; the epidermis and several layers of cortical cells are occasionally found associated with the cork. The epidermis composed of a layer of straight-walled tabular cells, polygonal to elongated in surface view; the walls are sometimes slightly thickened and pitted; very occasional rounded stomata and cicatrices occur and covering trichomes may also be present. These fragments are rather indistinct and not easily detected. The covering trichomes are unicellular, elongated, conical and bluntly pointed with moderately thickened walls which may be faintly striated; the somewhat enlarged bases have pitted walls. The trichomes are found

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scattered and, occasionally, attached to fragments of the epidermis. The vessels, which are fairly abundant; they are mostly large and reticulately thickened with regularly arranged rectangular pits. A few vessels with spiral or annular thickening also occur. Starch granules (the majority of the starch is gelatinised) are very occasionally. They are mostly simple, flattened, oblong to oval or irregular in outline with a small point hilum situated at the narrower end; very faint transverse striations may be visible on a few of the granules.

2.2 Chemical constituents.

2.2.1 Essential oil.[2,4,17,18,21,23,27] Turmeric contains two groups of constituents: the ingredients of the essential oil and the components of the yellow pigments. Essential oil of turmeric is not highly valued in the spice industry compared to the non-volatile resin fraction. On steam distillation, the dried cut tubers yield 1.3-6% of an essential oil. In India, the volatile oil content was 2.5-7.2%. The release of oil during distillation was slow because of the presence of high-boiling sesquiterpene derivatives . Volatile oil is an orange-yellow, occasionally slightly fluorescent liquid, with an odour reminiscent of the tubers. The aroma of turmeric is due to a mixture of the sesquiterpene ketones: ar-turmerone ($C_{15}H_{20}O$) and turmerone ($C_{15}H_{22}O$) with constitute the main fraction of the volatile oil. But turmerone is thermally unstable and is also

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unstable in ambient temperature in the presence of air, yielding its dimer or the more stable ar-turmerone. The compositions of curcuma oil[21] are shown in Table 4.

TABLE 4: Compositions of Curcuma Oil

Composition	Percent
Borneol	0.5
Cineol	1.0
d- α -Phellandrene	1.0
d-Sabinene	0.6
Zingiberene	25.0
Sesquiterpene alcohols	9.0
Sesquiterpene ketones (50% turmerone and 40% ar-turmerone)	58.0
α and Λ-Atlantone	Small amount

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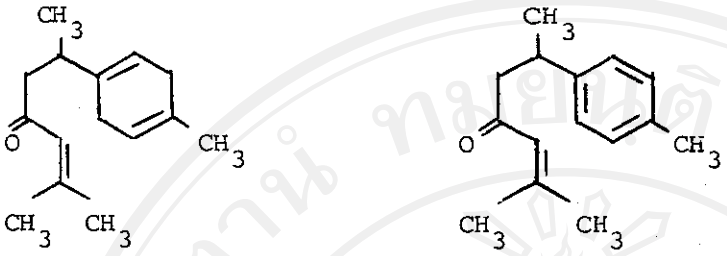
The structural formulas of turmerone, ar-turmerone, are shown as Figure 1.

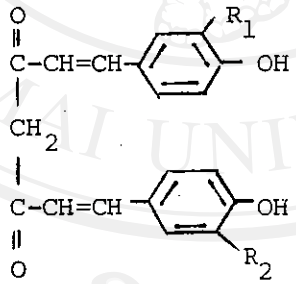


turmerone ar-turmerone

Turmerone (2-methyl-6-(4-methyl-1,4-cyclohexadiene-1-yl)-2 hepten-4-one), ar-Turmerone (2-methyl-6-(4-methylphenyl)-2-hepten-4-one)

Figure 1 Structural formulas of turmerone and ar-trumerone

2.2.2 Pigments[4,9,18,23,24,26,27]. For the colours, the main yellow pigment (1-5%) is curcumin, which is accompanied by two related minor curcuminoids, demethoxycurcumin and bisdemethoxycurcumin. The structural formulas of curcumin, demethoxycurcumin and bisdemethoxycurcumin are shown as Figure 2.



Curcumin $R_1=R_2=OCH_3$:Diferuloylmethane;m.p 183°, 46.9%

Demethoxycurcumin $R_1=OCH_3$;$R_2=H$: (p-hydroxycinnamoly)-feruloylmethane; m.p 168°, 23.9%

Bisdemethoxycurcumin $R_1=R_2=H$:bis-(p-hydroxycinnamoyl)-methane; m.p 224°, 29.2%

Figure 2. Structural formulas of curcumin, demethoxycurcumin and bisdemethoxycurcumin.

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Curcumin is insoluble in water; slightly soluble in the ether, soluble in alcohol and glacial acetic acid. It dissolves in alcohol forming a deep yellow solution which changes to reddish-brown incontact with alkalies, reverting to yellow with acid. The colour content of different varieties of Indian turmeric has been studied. The total colour expressed as curcumin in 12 varieties of Indian turmeric from 1.8-5.4%. The bright yellow colour of turmeric was found by the thin-layer chromatography, to be due to curcumin and to two other related pigments with the same absorption maximum (425 nm) in visible region. The colouring matter is extractable by solvents such as methanol, ethanol, acetone and ethylene dichloride. In fact, hexane has been suggested as a solvent for removing the bitter principles of turmeric, which affecting the curcumin content.

2.2.3 Other components.[21,23] Curcuma oleoresin is a dark yellow to brownish-yellow, viscous mass of faint odor of the spice, obtained from the rhizome by extraction with a volatile solvent, usually petroleum-ether, or alternatively with acetone, ethanol, ethylene dichloride, hexane, isopropanol, methanol, methylene chloride, trichloroethylene, or propylene glycol. Oleoresin is used in flavor work as replacement for the powdered rhizome. It is by far superior in this respect to the essential oil of curcuma, for the flavor is richer, more woody-sweet, free from terpene-like notes, resembling

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ginger oleoresin but less pungent than this. An emulsion of this oleoresin may be encapsulated or spray dried. One pound of oleoresin is said to replace 5-7 pounds of ground turmeric. Saromex turmeric oleoresins of Bush Boak Allen, are extractives incorporates in a salt "S", dextrose "D" or other innert base. A maximum of 3% tricalcium phosphate is added as a drying agent in the case of salt-based products.

2.3 Cultural Practice[4,21,23,27]

2.3.1 Cultivation. Curcuma longa Linn is a plant in the same family as ginger, and it is cultivated in the same manner. The rhizome is the part of the plant used in propagation.

2.3.1.1 Soil and preparation. Since the rhizome is the part used, the soil which will allow the expansion of the rhizome and rich in nutrient is necessary. The soil should be loamy or alluvial, loose and friable. Gravelly-stiff clay and stony soils are unsuitable for the development of the rhizome. Ill-drained soils, alkaline soils are unsuitable. Turmeric cultivated on the hills from sea level up to about 4,500 ft. is reported to be of a better quality than that raised in the plains. The optimum temperature is a hot climate. The bed for planting should be raised sufficiently, 6 inches in average, to prevent soaking of the under ground part of the plant too long in the heavy rain, and also to prevent the exposure of the root after raining in case of cultivation which is made

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on the slope of the hills. The richness of the soil in potassium has the increasing effect on the yield and the colour content of the rhizome. The best N:P:K ratio for curcuma was 60:60:120 kg/ hectare. The plant part used for propagation is the finger extended from the main rhizome. The fingers of the rhizomes collected this year are separated from the main bulb and stored under the sand for next season cultivation.

2.3.1.2 Propagation. The turmeric fingers are removed from the store place in March and piled on the ground in sunshine in a rather flat heap and then covered with straw which is damped with water from a shower pot every day. The fingers will become rotten if there is too much water. The pile is turned up frequently. The bud will appear on each finger within 30 days. The budding fingers are put in the prepared bed in rows of 50 cm. apart, and with 30-40 cm intervals in each row. Cover the budding fingers with layer of soil about 2.5 cm thick, Light irrigation is required if there is no rain at this moment. The best month for the propagation of the Zingibers is May or June, since it is the beginning of the rainy season.

2.3.1.3 Care and management. Curcuma is an easy plant to manage. It grows well if the soil is good and there is sufficient rain. After the first leaf appears within 20-50 days, the other leaves, rather bright green colour, follow rapidly. The leaves are large, of proximate size 13 x 35 cm. Leaf number varies

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from four to six and the leaves could so well cover the soil that only one weeding is required in the first 30 days period after emergence. The farmyard manure may be given after three months. It is recommended for use both from the physiological and economical points of view. Practically, no plant diseases or insect infectation appear.

2.3.1.4 Harvest. Rhizomes are harvested during the dry weather. When the leaves and aerial stems have begun to die down, they are cut close to the ground, with a sickle, the soil is dug with an iron hoe and the clumps are lifted out carefully, adhering soil is removed and the roots are cut off rhizomes are then broken up. The 10 months rhizome gives the best quality product for medicinal use. To obtain large aromatic rhizomes the roots are sometimes left in the soil for a second rainy season, where by they have 2 vegetative periods, thus forming a wide branching, i.e they are harvested 1 year and 9 months after planting.

2.3.2 Processing.[4,15,21,23,27]

2.3.2.1 Curing. The bulbous and finger-shaped parts of the rhizome are separated, and the long fingers, which generally command a higher price in the market, are broken into convenient pieces. Good rhizomes are those which are not brown or loose inside and free of worms and other insect damage. Adhering dirt and fibrous roots are removed and the rhizomes are subjected to a process of curing and polishing rhizomes must be cured within 10 days after harvest, in order to obtain maximum amount of curcumin. Mother rhizomes

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and fingers are cured separately , because the former take longer time for cooking than the latter. The curing process is as follows: The rhizomes are put into an earthenware pot. The water is added until it covers the turmeric to a depth of 2-3 inches. The pot and contents are heated gently with lid close, until the turmeric becomes soft. In order to get rid of the raw smell of turmeric, it is necessary to prolong the cooking period, until the turmeric is boiled. Subsequently it is treated with an emulsion of castor seed paste, alum and lead chromate. The turmeric is thus contaminated with lead. In a new method developed at the Central Food Technological Research Institute, Mysore, the tubers are boiled in lime water, sodium carbonate or sodium bicarbonate solution. Subsequent treatment with a solution containing 20 gm of sodium bisulphite and 20 gm conc. hydrochloric acid was adequate to give the desired yellow tint to 150 lb of tubers. Overcooking and undercooking of turmeric is avoided. For the product is then liable to insect attack. The duration of cooking varies in different localities from about 30 mins to 6 hrs. When sufficiently cooked, a thin pointed stick penetrates easily through them. The cooked rhizomes are allowed to cool gradually while standing on the fire and spread out in the sun in a thin layer to dry.

2.3.2.2 Drying. Drying takes 10-15 days, during which time the turmeric must be covered in the night to protect it from dew. While in the sun it is turned over several times to ensure uniformity in drying. Drying is complete when the material becomes hard and

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brittle, giving a metallic sound when broken. This is also a test for the quality of turmeric. The dried rhizomes are peeled or polished by rubbing on a rough surface or by trampling, to remove the outer skin and to give them an attractive colour and polish. There are several better methods of peeling or polishing the turmeric. The simplest is to shake the rhizomes mixed with stones, in a long narrow gunny bag or bamboo basket. The preferred method is one where a polishing drum is used. Cured and polished turmeric is brittle and has a shining yellow colour. Its market value depends on its colour.

2.3.2.3 Powdering. Turmeric powder can be obtained by grinding the fresh rhizomes cut into coarse pieces, with a cutting machine or in a mill, into a fine yellowish powder, which passes through a 74 mesh screen. Turmeric powder is a little reddish in colour. Lead chromate was formerly mixed with turmeric powder, to obtain the required yellow colour, but its use is now banned.

2.4 Standards and specifications[21,24,27]

2.4.1 Requirements in Indian Pharmacopeia. The cured product is sorted out into fingers, bulbs, rounds and splits, and graded large and small according to market requirements. The secondary lateral rhizomes are known as "fingers", the main stem producing the rhizomes as "bulbs". The latter may be cured either whole or cut into halves or quarters, then they are known as "splits". The fingers are considered

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superior in quality. In India there is compulsory pre-shipment inspection and quality control. Graded consignments are labelled with "AGMARK" grades, which are based on such factors as flexibility, size of the rhizomes, colour, percentage of foreign matter (including chaff, dried leaves, clay particles, dust, dirt and other extraneous matter) and defective bulbs (including immature small fingers, bulbs, shrivelled fingers or bulbs internally damaged, hollow and porous bulbs, cut bulbs, scorched rhizome and other types of damaged bulbs except weevilled bulbs). The requirements of turmeric are described in Indian Pharmaceutical Codex and Indian Standard 3576 as Table 5,6. , page 20-21.

Table 5 : Turmeric Rhizome-Requirements in Indian Pharmaceutical Codex

Requirements	Percent
Length of rhizome	15 mm.min
Moisture	12% max
Extraneous matter	2% max
Defective rhizomes	5% max
Pieces	7% max
Ash	9% max
Acid-insoluble ash	1% max
Alcohol-soluble extractives	8% max
Essential oil	4% max
Foreign organic matter	2% max

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Table 6: Turmeric;Whole-Requirements in Indian Standard 3576

Type	Grade	Flexibility	Surface	Pieces,% by wt. max	Extra-neous Matter% by wt. max	Defec-tive rhizome% by wt. max	Percent-age of bulbs by wt. max
Fingers (general)	Special	Hard to touch; breaks with a metallic tang	Free from wrinkles	2	0.5	0.5	1.0
	Good	-do-	Not highly shrivelled	3	1.0	1.0	3.0
	Fair	Hard	-do-	5	2.0	1.5	5.0
Fingers (Alleppey)	Good	Hard to touch	-do-	5	1.0	3.0	4.0
	Fair	-do-	-	7	1.5	3.0	5.0
Bulbs (Round)	Special	-	-	-	0.5	1.0	-
	Good	-	-	-	1.0	3.0	-
	Fair	-	-	-	2.0	5.0	-

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2.4.2 Requirements in other compendias. The standards of curcuma rhizome are described in various pharmacopoeias as Table 7

Table 7: The standards of curcuma rhizome described in various pharmacopoeias.

Reference	Volatile oil content	Total ash	Acid-insol ash	Curcuminoid content	Ethanolic extractive	Foreign org matter	Artificial color
AP	-	NMT 9.0%	-	-	-	-	None
JP PH	-	NMT 9.0%	-	-	-	-	None
IND PH	NLT 4.0%	NMT 9.0%	NMT 1.0%	-	NLT 8.0%	NMT 2.0%	-
KORPH	-	9.0%	-	-	-	-	None
PL PH	3-3.5%	-	-	-	-	-	-
BP	3-5%	6.5-7.5%	-	-	-	-	None

The drug is official in the pharmacopoeias of Indonesia, Nepal, the people's republic of China, Pakistan, Social Republic of Vietnam, and in the preparation of Thai pharmacopoeia, but the percentage of the constituents are not available.

2.4.3 Turmeric Powder Requirements. The requirements of turmeric powder are as follows. Turmeric powder shall be prepared by grinding clean dry turmeric rhizomes. It shall have its characteristic taste, flavour and be free from musty odour. It must be free

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from dirt, mould growth, insect infestation, any colouring matter such as lead chromate, preservative and extraneous matter such as cereal or pulse flour or any added starch.

Requirements for turmeric powder are as following

Passes through 300-micron I.S.sieve

Moisture	10% max
Total ash	7% max
Acid-insoluble ash	1.5% max
Lead	2.5% max
Starch	60% max
Solubility	Insoluble in water;soluble in ethanol
Colour reaction	A dark red-brown colour develops after addition of 1 drop of boric acid solution(1 in 50)

2.4.4 Turmeric Oleoresin-Requirements. Oleoresin is obtained by solvent extraction of the dried rhizome of curcuma with the subsequent removal of the solvents. It is a deep red or orange red, somewhat viscid liquid, with characteristic odour. Some types are not homogeneous and may contain a crystalline lower layer. Due to its colour, it can be determined spectrophotometrically. Its solubility is depended on varying types of oleoresin, no definite solubility information is given. The residual solvent is less than 30 ppm and its maximum viscousity is 1,000 centipoises.

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2.5 Quality Control

The criteria for the quality examination, according to the pharmacopoeia and reliable method are

2.5.1 Moisture content.[13,16,27] The moisture content in turmeric powder can be determined by Marconi moisture meter.

2.5.2 Volatile oil content.[13,16,27] The yellowish volatile oil in turmeric powder is obtained by steam distillation. After collection of the distillate in a graduate tube and its volume is measured. The volume of the distillate is a measure of volatile oil content in the sample.

2.5.3 Total ash content.[13,16,27] The determination of total ash content is a measure of the amount of the residue unvolatilised substances after drug sample is ignited. The procedure for determining total ash content in plant material is as follows: Place 2-4 gm of the ground material in a suitable tared crucible, previously ignited and weighed. Spread the material into an even layer and weigh accurately. Incinerate the material by gradually increasing the heat, not exceeding 450°C until free from carbon; cool in desiccator and weigh. If a carbon-free ash can not be obtained by this way, cool the crucible and then add 15 ml of alcohol, break up the ash with a glass rod, burn off the alcohol and again heat the whole to a low redness. Cool, weigh the ash. Calculate the content in gram of ash per 100 grams of air-dried material.

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2.5.4 Determination of acid-insoluble ash.[13,16,27] The acid-insoluble ash is the residue obtained by boiling the total ash with diluted hydrochloric acid, collecting the insoluble matter in a filter, washing and igniting. After cooling to room temperature the residue is weighed. This method for measuring the amount of silica, especially sand and siliceous earth present in drugs. The procedure is as follows: To the curcible containing the residue obtained from the determination of total ash, add 25 ml of hydrochloric acid T.S., cover with a watch glass and boil gently for five minutes. Rinse the watch glass with 5 ml of hot water and add the rinsing to the original crucible. Collect the insoluble matter on an ashless filter paper and wash with hot water until the filtrate is neutral. Fold the filter paper and transfer the filter paper containing the insoluble matter to the original crucible, dry on an oven and ignite to constant weight. Calculate the content in gram of acid-insoluble ash per 100 grams of air-dried material.

2.5.5 Volatile and Nonvolatile Ether Extract.[13,16,27] The determination of ether extractives is a method designed to measure the amount of a certain constituent or group of related constituents in drugs. This method is not suitable for the determination of volatile ether extract in spices which are high in volatile oils, such as cloves. The procedure is as follow: Extract 2 gm. of ground material for 20 hrs in a continuous extraction apparatus with anhydrous ether. Transfer the extract to a weighed evaporating disc and allow the solvent

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to evaporate at room temperature. Store the residue for 18 hrs over conc. H_2SO_4 and weigh total ether extract. Heat the extract gradually until a constant weight obtained at 110°. The weight loss is a measure of volatile ether extract whereas the weigh of the residue is the amount of nonvolatile ether extract.

2.5.6 Total curcuminoid content.

2.5.6.1 Spectrophotometric method.[9,27] A spectrophotometric method is recommended by the American Spice Trade Association and FAO Food and Nutrition for estimation of curcumin in turmeric, in which the absorbance of an ethanolic extract of turmeric powder is measured at 425 nm in a 1 cm cell. The procedure is as follow: Weigh 0.1 gm of turmeric powder into the extraction flask. 30 ml of ethanol is added and refluxed for 2½ hr. The extract is cooled and filtered quantitatively into a 100 ml volumetric flask, throroughly washed and diluted to the mark with ethanol. 20 ml of the extract is pipetted into a 250 ml volumetric flask and diluted to volume with ethanol. The absorbance of the extract and of the standard solution is measured at 425 nm in 1-cm cells against the ethanol blank.

2.5.6.2 High-Performance Liquid Chromatography.[6,29] Curcumin and two other related pigments content of turmeric are determined by HPLC method using ultraviolet spectrophotometric detection. The compounds of interest were separated on a 4.6 nm x 15 cm column packed with Nucleosil C_{18}(5 μ) and eluted with a mixture of

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acetonitrile:water:acetic acid (51:49:5)。 Other HPLC method for determining curcumin and two other related pigments, was HPLC with electrochemical and ultraviolet spectrophotometric detectors. Separation was carried out on a 5 nm x 25 cm column packed with 5 μ ODS-Hypersil and eluted with a mixture of acetonitrile:buffer (PH 4。4) 50:50 or tetrahydrofuran:buffer (PH 4。4) 45:55。

2.5.6.3 Detection of turmeric in foods by rapid fluorometric method。[20,21] Turmeric was detected in foods by fluorometric method。 A fluorometric method based on the fluorescence of curcumin can be applied to pickles, salad dressings and baked goods。 In this method, an extract with n-butanol is scanned for a 520 nm peak on a spectrophotofluorometer。 In the case of enriched baked goods, riboflavin is removed first for this also causes fluorescence。 In a water-saturated n-butanol solution, the excitation maximum of curcumin is 435 nm and the emission maximum 520 nm。

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3. Purpose of the study

The purposes of this work are:

1. To study the effect of phosphorus and potassium in the fertilizer to the production and quality of the volatile oil in cultivated curcuma.

2. To study the effect of phosphorus and potassium in the fertilizer to the production of the curcuminoid compounds (pigments) in cultivated curcuma.

Curcuma longa Linn (turmeric) is widely used in local medicine for the therapeutic values of the volatile oil in the drug. Curcuma is used enormously in the food industries for the pigment and flavour values. Therefore, the important criteria for the evaluation of the quality of curcuma are the volatile oil content and the total curcuminoids (pigments) content.

The internal color of curcuma rhizomes varies from yellow to orange brown according to the environmental conditions of cultivation, e.g. the soil, altitude, temperature, light, rainfall, and nutrients. There are reports of the effects of fertilizers to the total yield of the rhizomes and volatile oil. But the reported studies on the quality of the oil, which is determined by the turmerone and arturmerone content, and the studies on the individual curcuminoid compounds produced have not yet been found.

One of the factors which could be controlled to certain extent in the cultivation of curcuma under natural conditions is the fertilizer. Therefore, the effect of phosphorus and potassium in the fertilizer

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in curcuma growing was studied in order to lead to the knowledge of optimum conditions to obtain the better quality curcuma crude drug and the better quality curcuma for food industries as well.

In Thailand, the standard requirements of curcuma, both for therpaeutic uses and for commerce have not yet been set. Thus, the average quality of local curcumas should be studied as a comparison. Curcumas from not less than 15 provinces from every part of Thailand were therefore analysed for the particular purpose.

The studies aimed in part to serve the national policy of more self-reliance in drugs through the Basic Health Care Program in which curcuma could be utilized and to widen the export market of curcuma through the better quality products.

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