26

Turmeric

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26.1 Introduction

Turmeric of commerce is the dried rhizome of the plant *Curcuma domestica* Val. syn. *C. longa* L. Turmeric is used in curry powder, chicken bouillon, sauces, gravies, dry seasonings, backing mixes, processed cheese pickles, relishes, breading soups, beverages, and confections (Peter, 1999) in addition to its use in medicine, religious functions and as biopesticide.

The genus *Curcuma* originated in the Indo-Malayan region (Purseglove, 1968). Considerable species diversity of *Curcuma* occurs in this region. However, about 40 species of the genus including *C. longa* are indigenous to India indicating the Indian origin (Velayudhan *et al.*, 1999). The antiquity of turmeric dates back to the Assyrians of 600 BC. Ethnobotanical evidence indicates that the use of turmeric has been in India since very ancient days. It is believed that the crop spread out from India to distant Asian countries under the influence of the Hindu religion. According to Marco Polo (1280) the spread of turmeric to China took place in AD 700 (Ridley, 1912). Burkill (1966) believed that the crop spread to West Africa in the thirteenth and to East Africa in the seventeenth centuries, respectively. It was introduced to Jamaica in 1783 (Velayudhan *et al.*, 1999). Though turmeric is now grown in India, Pakistan, Malaysia, Myanmar, Vietnam, Thailand, Philippines, Japan, China, Korea, Sri Lanka, Nepal, South Pacific Islands, East and West Africa, Malagasi, Caribbean islands, and Central America, India is the major producer and exporter of turmeric at present.

The genus *Curcuma* belongs to the family *Zingiberaceae* and contains 49 genera and 1400 species. In addition to *Curcuma longa*, *C. zedoaria* Rosc. and *C. xanthorrhiza* Roxb. are also minor sources of curcumin colour. Velayudhan *et al.* (1999) recognized six taxonomic varieties within *C. longa* based on numerical taxonomic analysis, namely *C. longa* var. *typica*, *C. longa* var. *atypica*, *C. longa* var. *camphora*, *C. longa* var. *spiralifolia*, *C. longa* var. *musacifolia* and *C. longa* var. *platifolia*. Most of the *C. longa* found in India belong to *C. longa* var. *typica* or *atypica*.

Turmeric is an erect perennial herb, grown as an annual crop. The above ground morphology of the plant is mainly represented by an erect pseudostem bearing leaves and inflorescence. There may be 2–3 pseudostems (tillers) per plant. The height of the pseudostem varies from 90–100 cm depending on the variety. Leaf number ranges from 7–12. In fact, it is the leaf sheath which forms the pseudostem. The leaf sheath is usually green in colour. Lamina may be lanceolate or elliptic in shape, thin with acuminate tip. The colour of lamina is usually green above and pale green below, with a length of about 30–40 cm and width 8–12 cm. Inflorescence is a cylindrical, fleshy, central spike of 10–15 cm length, arising through the pseudostem. Flowers are subtended by bracts in the spike. The bracts are adnate for less than half of their length and are elliptic, lanceolate and acute. The upper bracts are white in colour while the lower bracts are green. One to four flowers are borne in the axil of the bract, opening once at a time. About 30 flowers are produced in a spike (Nazeem and Rema Menon, 1994). The calyx is short, usually toothed and split nearly halfway down on one side. The corolla is tubular, thin and whitish with a yellow tip. Usually the upper most and lower most bracts will be sterile. Seed set is observed in turmeric and seeds are viable. Seeds are produced in capsules and there will be from one to numerous sunken capsules in an inflorescence depending on the flowers fertilized.

At the base of the pseudostem, below the ground, rhizomes are formed consisting of mother rhizome(s), primary, secondary and even tertiary fingers, the whole forming a compact clump. Rhizomes grow symbodically and are of orange brown, pale yellow or reddish yellow colour.

C. longa is considered to be a triploid with a somatic chromosome number of 63 ($2n = 3x = 63$).

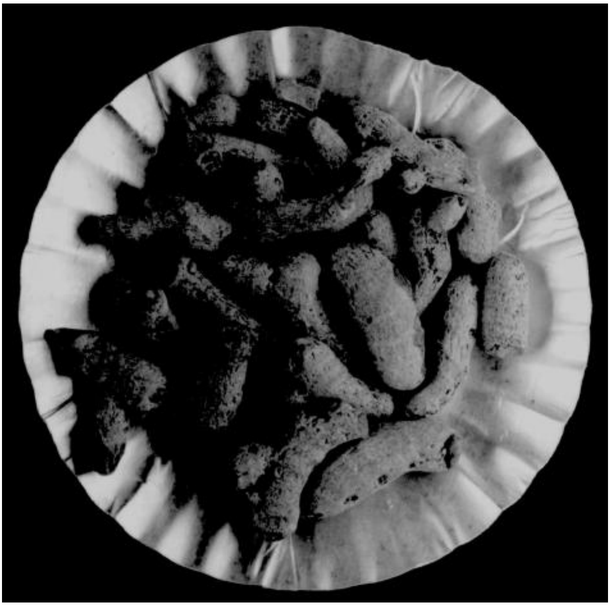
26.2 Production

India is the major producer and exporter of turmeric in the world. In India turmeric is grown over 1.34 ha with an annual production of 5.43 lakh tonnes. India exported 23 000 t of turmeric during 1996–97 to 67 countries (Peter, 1999). Turmeric is exported as turmeric dry, turmeric fresh, turmeric powder, turmeric oleoresin and turmeric oil. The major turmeric importing countries from India are Iran, Japan, South Africa, Singapore, Sri Lanka, USA, UAE, Malaysia, Germany and Bangladesh. Export of turmeric by item from India during 1994–96 is given in Table 26.1.

There are about 60 turmeric cultivars (land varieties) available in the country. Some of the important local cultivars are 'Duggirala', 'Tekurpet', 'Sugandham' 'Amalapuram', 'Lakadong', 'Alleppey', 'Rajapuri', 'Mydukur', 'Wynad local', etc. Cultivars like 'Alleppey', 'Wynad local', 'Lakadong', 'Edapalayam', 'Thodupuzha', etc., are rich in curcumin content (>7%). In addition to these land varieties, there are about 17 improved varieties in India. The important improved turmeric varieties are 'Prabha', 'Prathibha' (Fig. 26.1), 'Sudarsana', 'Suguna', 'Co-1', 'Sugandham', 'BSR 1', etc. (Sasikumar *et al.*, 1996). Maturity of these varieties is 7–9 months. The yield (fresh) of the improved varieties is 20–40 t/ha.

Table 26.1 Export of turmeric from India during 1994–96

Item	1994–95 Quantity (t)	1995–96 Quantity (t)
Turmeric dry	16,727.9	19,189.5
Turmeric fresh bulk	5964.1	800.9
Turmeric powder	6093.7	7385.9
Turmeric oil	0.3	0.1
Turmeric oleoresin	159.0	149.1



26.1 Prathibha

26.3 Post-harvest processing

Harvested turmeric is washed well to remove the adhering soil; roots removed, the fingers and mothers are separated. Mother and finger rhizomes are boiled separately for about 40–60 minutes under slightly alkaline condition (100 g of sodium bicarbonate or sodium carbonate in 100 l of water) in copper, galvanized iron or earthen vessels and sun dried on bamboo mat or clean drying floor for 10–15 days so as to bring down the moisture content to 10%.

Another method of curing is by taking cleaned mother and finger rhizomes (approx. 50 kg) separately in perforated trough of convenient size made of GI or MS sheet with extended parallel handle. The trough containing the fingers are immersed in water using a paddle. The alkaline solution is then poured into the pan so as to immerse the rhizome, which are then boiled until they become soft and dried. The dry recovery of cured turmeric varies between 15–30% depending on variety, location and cultural practices.

Dried turmeric is subjected to polishing either manually or mechanically in power operated drums (Purseglove *et al.*, 1981). A weight loss of about 5–8% is expected due to full polishing. Polished rhizomes are made attractive by artificially colouring them with turmeric powder. During polishing itself turmeric is added to the drum either as powder or as emulsion.

Rama Rao *et al.* (1975) described an indigenous method of storing turmeric. The cured product is stored in suitable pits dug on a raised site. The bottom and sides of the pits are lined thickly with dried grass or similar material. After filling up the pits with the cured turmeric they are covered with mat or grass and finally with earth. The produce can be stored for one year like this. At Sangli, India, farmers usually store turmeric like this in pits dug in the field. Dealers usually store the cured turmeric in fresh jute bags or in sound, clean, dry, heat-sealed polythene bags in dry, cool, warehouses (Purseglove *et al.*, 1981). After harvest, fresh turmeric is kept in gunny bags or baskets or heaped open in well-ventilated sheds.

Turmeric is available as whole, ground, oleoresin and oil. Turmeric is used mainly as fine ground turmeric in cooking in the West while those in the growing countries buy turmeric mostly in whole or split form. Importing countries in the West buy ground turmeric, turmeric oleoresin and oil.

26.3.1 Ground turmeric

A sophisticated grinding process is not needed for ground turmeric, since there would not be much loss of quality while grinding turmeric. Usually clean, dry, stone-hard fingers are powdered through the use of hammer mills followed by disc-type attrition mills to obtain 60–80 mesh powder. Accessory equipment for pre-cleaning includes an aspiration system (which removes the light extraneous matter), destoners and magnetic separators for fine iron contamination, vacuum fumigators, and the noise reducing fixtures, dust collection systems, mechanical or closed circuit pneumatic conveying system, blending and automatic packaging system, now employed by most big spice grinders for optimizing the output and for assuring hygienic and flavour quality. The smaller spice manufacturers in the West and Asia use simple cleaning and grinding equipment and partly mechanized packaging systems (Govindarajan, 1980).

Turmeric powder is packed in bulk in containers such as fibre hard drums, multi-wall bags and tin containers suitably lined or coated to prevent moisture absorption, loss of flavour and colour. For the retail trade the unit packages are in flexible packagings such as low and high density polyethylene, polyvinyl chloride, glassine or in glass packages.

Storage studies conducted on turmeric powder using different packaging materials have shown that aluminium foil laminate or double pouch of glassine or low density polyethylene offered good protection for the stored product for about six months without loss of quality and colour (Balasubramanian *et al.*, 1979).

26.3.2 Turmeric oleoresin

Turmeric oleoresin is being used increasingly by the processed food industries in the West to impart colour and aroma. Oleoresin is a mixture of compounds, namely curcumin, volatile oil and other active ingredients, non-volatile fatty and resinous material extractable by solvents, used singly, in sequence or in combination. Turmeric oleoresin is orange-red in colour and consists of an upper oily layer and a lower crystalline layer (Krishnamurthy *et al.*, 1976). For commercial use, it is usually mixed with a non-volatile edible solvent such as vegetable oil, propylene glycol or polyoxy ethylene sorbitan fatty acid esters in order to disperse the extracted material and to render it free flowing and 'soluble' (Purseglove *et al.*, 1981).

Turmeric oleoresin is obtained by solvent extraction of ground spice. Acetone is a good solvent for oleoresin extraction. Soxhlet apparatus or cold percolation is used for extraction. Curcumin, the principal colouring matter forms about one third of a good quality oleoresin. Yield of oleoresin varies from 7–15% depending on varieties. Govindarajan (1980) has given the detailed steps for industrial extraction of turmeric oleoresin.

26.3.3 Turmeric oil

Turmeric contains 3–5% volatile oil, which is obtained by steam distillation of turmeric powder, for about 8–10 h. Turmeric oil is pale yellow in colour with peppery and aromatic odour. The oil contains about 60% turmeron, 25% zingiberene and small quantities of d-α-phellandrene, d-sabinene, cineole and forneol.

26.3.4 Curry powder

Turmeric powder is the major component (about 40–50%) of curry powder. Curry powder is a spice mixture used for seasoning dishes containing vegetables, meat, fish, eggs or vegetable plus meat or fish (i.e. curry) in the orient. In the West also curry powder is used for seasoning dishes. India has been the principal exporter of curry powder to many countries like the UK, Australia, Fiji, etc.

Turmeric powder provides colour and background aroma to the curry powder. Govindarajan (1980) has given typical curry powder composition, quality standards, packaging details, etc.

26.4 Quality specifications

Cured turmeric is sorted as fingers, round, split or non-specified and marketed under its varietal name, which is usually based on the place of production such as ‘Alleppey’, ‘Erode’, ‘Duggirala’, ‘Nizamabad’, ‘Rajapuri’, ‘Cuddappah’, etc., from India. The Indian ‘Agmark’, standards include separate gradings for different varieties. ‘Special’, ‘good’ and ‘fair’ are some of the grade specifications. Govindarajan (1980) has given the specification for turmeric (whole and ground).

1. Turmeric whole is the primary (bulbs, rounds) and secondary (fingers) rhizomes, harvested at full maturity, cured, dried to about 10% moisture level, polished and either coloured or not coloured.
2. The cured rhizomes, cleaned and dried, are ground to powder without any added matter.
3. Whole or powdered turmeric should have the characteristic fresh aroma and taste of turmeric and be free from foreign aroma such as mustiness. It must also be free from living insects, moulds; practically free from dead insects, insect fragments and rodent contamination visible to the naked eye or specified magnification.
4. Turmeric fingers should not be less than 15 mm in length, hard, smooth and the core colour should be lemon yellow or bright yellow with only admissible levels of small pieces and bulbs (Table 26.2).
5. Turmeric whole should not contain more than 2% by weight (lower limit for superior grade) extraneous matter. The admissible level of defective rhizome allowed in different varieties of turmeric is given in Table 26.2.
6. The limits for chemical characteristics specified for turmeric powder are presented in Table 26.3.

American Spice Trade Association (ASTA) cleanliness specification effective from 21 May 1997 for turmeric allows only a maximum of three dead whole insects; 5 mg/1b mammalian or other excreta, 3% by wt. mould, 2.5% by wt. insect defiled or infested material and 0.5% by wt. extraneous foreign matter in turmeric (Sivadasan, 1998).

Whole, dried or fresh turmeric is usually free from adulteration. However, turmeric powder is adulterated with foreign starch (tapioca, arrowroot, cereal floor), husks, coal tar colours, lead chromate, etc. Adulterated turmeric powder will have low curcumin content. Depending upon the adulterant used, the curcumin content of the samples vary from 0.37–2.07% (Balasubramanian *et al.*, 1979). Gas chromatographic methods are available to detect volatile oil of other *Curcuma* sp. used for admixing the turmeric powder. Similarly, specific tests are now available to detect each of the above adulterants in ground turmeric (Govindarajan, 1980).

Table 26.2 Indian specification for turmeric grade

Grade	Pieces (max. wt. %.)	Foreign matter (max. wt. %.)	Defectives (max. wt. %.)	Bulks (max. wt. %.)	Characteristics
Fingers (general)					Finger-like shape, breaks with a metallic twang; well set and close grained; perfectly dry, free from weevil damage, over boiling, etc.
Special	2.0	1.0	0.5	2.0	
Good	3.0	1.5	1.0	3.0	
Fair	5.0	2.0	1.5	5.0	
Fingers (Alleppey)					
Good	5.0	1.0	3.0	4.0	As above
Fair	7.0	1.5	5.0	5.0	
Fingers (Rajapuri)					
Special	3.0	1.0	3.0	2.0	As above, admixture of other turmeric varieties are allowed at a maximum of 2.5 and 10% in 3 grades, respectively.
Good	5.0	1.5	5.0	3.0	
Fair	7.0	2.0	7.0	5.0	
Bulbs (rounds)					
Special	–	1.0	1.0	–	Be well developed, smooth round and free from rootlets The 'Rajapuri' type has higher allowance of 3.0, 5.0 and 7.0% defectives in 3 grades, respectively.
Good	–	1.5	3.0	–	
Fair	–	2.0	5.0	–	

Source: Govindarajan (1980).

26.5 Chemical structure

Turmeric is valued mainly for its principal colouring pigment, curcumin, which imparts the yellow colour to turmeric, besides other nutritive constituents like potassium (Peter, 1999) (Table 26.4).

The main colouring constituent of turmeric and other yellow *Curcuma* species is curcumin, having a molecular formula of $C_{21}H_2O\ O_6$. In fact, besides curcumin there are a few other related pigments which imparts the yellow colour, all together called curcuminoids (Verghese, 1999). Curcumin [1,7-*bis* (4-hydroxy-3-methoxy-phenyl)-1,6-heptadiene-3,5-dione]; demethoxy curcumin [4-hydroxy-cinnamoyl (4-hydroxy-3-methoxycinnamoyl) methane and *bis*-demethoxy curcumin [bis-(4-hydroxy cinnamoyl methane] together make the colouring pigment in the turmeric rhizomes (see Fig. 26.2).

The curcumin content in different turmeric varieties varies from 2–8% (spectrophotometric estimation). However, Verghese (1999) reported the total colour in eight *C. longa* varieties ranging from only 2.3–3.9%, by HPLC analysis. 'Alleppey' type recorded maximum colour. The distribution of the curcuminoids is also reported to vary with different samples (Table 26.5) (Verghese, 1999).

In the pure form curcuminoids separate as an orange yellow crystalline powder, insoluble in water, slightly soluble in ether, soluble in alcohol and in glacial acetic acid. Verghese (1999) is of the opinion that the melting point of curcumin is an unworthy

Table 26.3 Analytical specification for turmeric (whole and powder)

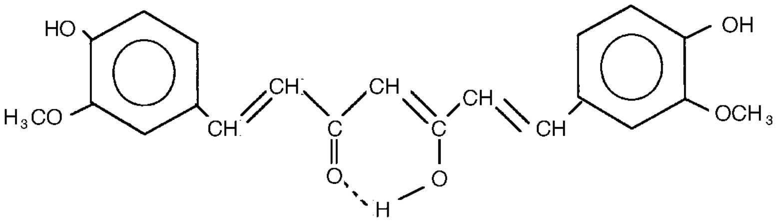
Sample	Moisture max. (% wt.)	Ash		Starch max. (% wt)	Crude fibre max. (% wt.)	Vol. oil max. (% wt.)	Colour as curcumin min. (% wt.)	Lead max. ppm	Chromate test
		Total max. (% wt.)	Acid insol. max. (% wt.)						
Whole BP	8–10	6–9	–	–	4–6	2–5	–	–	–
US	9	7	0.5	–	6	4	5	–	–
DDR	–	7	–	–	–	2.6	3–4	–	–
Powder India	10	7	1.5	60.0	–	–	–	1.5	Negative
WHO	10	7	1.5	–	–	–	–	3	Negative

Note: The chromate test is negative if there is no violet colour developed when dilute acid soluble ash from 2 g of sample (4–5 ml) is reacted with 1 ml of 0.2% alcoholic solution of diphenyl carbazide.
Source: Govindarajan (1980).

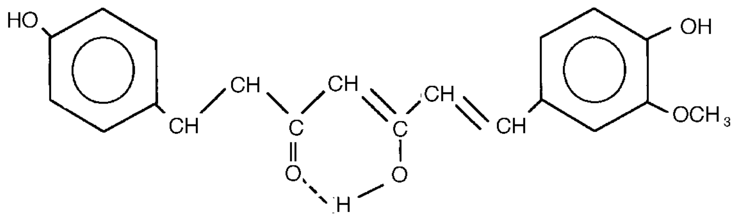
Table 26.4 Nutritional composition of turmeric

Constituent	Quantity per 100 g
Water (g)	6.0
Food energy (Kcal)	390
Protein (g)	8.5
Fat (g)	8.9
Carbohydrate (g)	69.9
Ash (g)	6.8
Calcium (g)	0.2
Phosphorous (mg)	260
Sodium (mg)	30
Potassium (mg)	2000
Iron (g)	47.5
Thiamine (mg)	0.09
Riboflavin (mg)	0.19
Niacin (mg)	4.8
Ascorbic acid (mg)	50

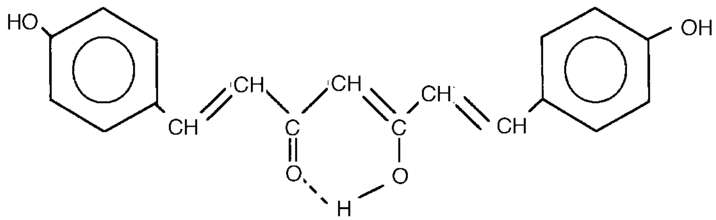
Source: Peter (1999).



(a) Curcumin



(b) Demethoxy curcumin



(c) *bis* -Demethoxy curcumin

Fig. 26.2 Structures of (a) curcumin, (b) demethoxy curcumin and (c) *bis*-demethoxy curcumin.

Table 26.5 Concentration of curcuminoids in typical curcumin samples by HPLC analysis

Sample	Curcumin (%)	Demethoxy curcumin (%)	*bis*-demethoxy curcumin (%)	Total (%)
1. Curcumin puriss (Fluka)	53.5	17.2	9.6	80.3
2. Curcumin crys. natural (Koch-light)	80.8	7.1	1.0	89.9
3. Pure curcumin (Chr. Harsen)	64.9	11.3	6.4	82.6
4. Curcumin/(Syndiferuloyl methane (ICN) (1)	79.6	12.2	1.6	93.4
5. Curcumin (ICN)	58.3	16.6	7.0	81.9
6. Curcumin (Biomol)	66.3	15.3	4.0	85.6
7. Synthite 1	71.0	23.2	2.8	97.0
8. Synthite 2	68.6	23.0	3.0	94.6

Source: Verghese (1999).

quality parameter and need not be mentioned in any specifications, as many different melting points are reported by many workers for curcuminoids!

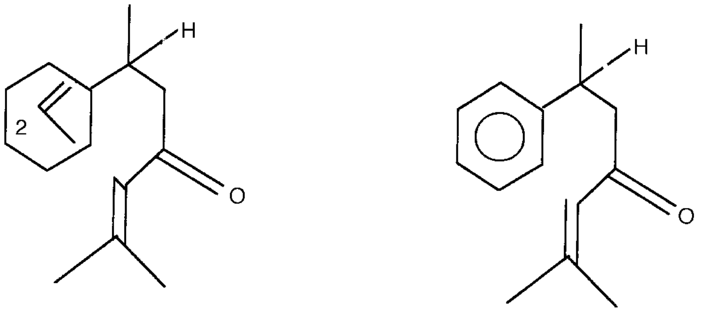
Curcumin exhibits strong absorption between 419 and 430 nm in organic solvents and on this property revolves the spectrophotometric methods of the American Spice Trade Association (1968) and Essential Oil Association (EOA) (1965), though now the HPLC method is available (Tonnesen and Karlson, 1983). The EOA stresses the fact that 'turmeric extracts are evaluated strictly in colour' and this is best expressed in terms of colour value (cv), which is equivalent to ten times the specific extinction coefficient in ethanol at 422 nm (c.f. Verghese, 1999). Verghese (1999) further reported that the specific extinction coefficient in ethanol of curcumin at 420–430 nm varies between 1528 and 1586, of demethoxy curcumin at 420–430 nm between 1513 and 1580, and of *bis*-demethoxy curcumin at 419–430 nm between 1565 and 1682. By repeated crystallization from ethanol, the dye yielded specific extinction coefficient 1596 at 425 nm in ethanol (c.f. Verghese 1999). Coupling this observation and the values already reported in the literature, specific extinction coefficient 1600 was recommended as a reasonable yardstick for assaying curcumin and this fits the HPLC data excellently (Verghese, 1999).

However, for most routine, quality control work, it is sufficient to measure the extinction of an alcohol extract at the absorption maximum at 420–455 nm, taking the precautions of using neutral alcohol and avoiding exposure to direct sunlight, and calculate the curcumin content by using the molecular absorption value (Govindarajan, 1980).

Turmeric oil has a major role in the aroma and flavour of turmeric though the oil as such is not used. Turmeric oil is comprised of oxygenated sesquiterpenes which are accompanied by smaller quantities of sesquiterpene hydrocarbons, monoterpene hydrocarbons and oxygenated monoterpenes (Purseglove *et al.*, 1981). Among the various constituents of the oil, sesquiterpenes, *ar*-turmerone and turmerone comprise 50 per cent of the oil (see Fig. 26.3) (Purseglove *et al.*, 1981).

26.6 Use in the food industry

Turmeric powder is used in mustard paste and curry powder as both colour and aroma are important in these products. Turmeric oleoresin is used mainly in the brine pickles



(a) Turmerone (b) *ar*-Turmerone

Fig. 26.3 (a) Turmerone, (b) *ar*-Turmerone.

(Eiserle, 1966; Cripps, 1967) and to some extent in mayonnaise and relish formulations; in non-alcoholic beverages such as orangeades and lemonades; gelatins; in breading of frozen fish sticks; potato croquettes; butter and cheese in the form of powder or granules for garnishing and even in ice creams (Perotti, 1975). In all these cases, its function is predominantly to colour the product and it merely replaces the synthetic colours such as tartrazine, formerly used (Govindarajan, 1980).

In Asian countries whole, dry or fresh turmeric, ground or turmeric powder with other spices like chillies, coriander, pepper, cumin, etc., are used for making vegetable and meat dishes and soup-like dishes. Turmeric powder mixed with seasame, coconut or groundnut oil is used for pickling mango, lime, gooseberry, garlic, etc. (Govindarajan, 1980).

The colours in the Food Regulation Act came into force in UK in 1996. Part III, Schedule 5 of this Regulation specifies the limits for curcumin in various food items (Table 26.6) (Henry, 1998). Curcumin is included in the list of colours with a restricted use because of the fact that it has been allocated only a temporary, low ADI value (acceptable daily intake). The ADI value indicates the amount of a food additive that can be taken daily in the diet without risk, expressed as mg/kg/bodyweight (Henry, 1998). The Joint Expert Committee on Food Additives (JECFA) has allotted curcumin a temporary ADI value of 0–1.0 mg/kg/bodyweight/day. Curcumin is specifically permitted as a colour in the EU though many countries simply list it without a specification for its colour strength.

Pure 95% curcumin, as it is usually obtained, is not an ideal product for direct use by the food industry since it is insoluble in water and has poor solubility in other solvents. Hence in many countries curcumin is dissolved in a mixture of food grade solvent and permitted emulsifier such as Polysorbate 80 for converting into a convenient application form. In this form the product contains about 10% curcumin.

Curcumin gives a bright yellow colour even at low doses. The usual dose level of curcumin is in the range of 5–200 ppm. Numerous blends are available commercially to suit the colour of the product (Henry, 1998). Vanilla ice cream for example is coloured with a combination of curcumin (200 ppm) and norbixin (12 ppm). Similarly in yoghurt 5 ppm curcumin will give an acceptable colour. For cakes and biscuits the required colour is achieved using a blend of curcumin (10–15 ppm) and annatto (10 ppm).

Turmeric oleoresins although permitted universally as a spice oleoresin, are not a permitted colour in EU (Henry, 1998). Turmeric powder, extracts and curcumin exhibit antioxidant property as observed by the induction period and oxygen absorption of coconut, groundnut, safflower, sesame, mustard, cotton seed oil and ghee at 95C to 220C for period up to 144 h. In foods, the antioxidant property of turmeric was effective in preventing peroxide developments (Khanna, 1999).

Table 26.6 Limits specified for curcumin in various food items ('Colours in Food Regulation Act 1995' Schedule 5, Part III)

Food	Maximum level
Non-alcoholic flavoured drinks	100 mg/l
Candied fruits and vegetables, mostarda di frutta	200 mg/kg
Preserves of red fruits	200 mg/kg
Confectionery	300 mg/kg
Decorations and coatings	500 mg/kg
Fine bakery wares (e.g. viennoiseric, biscuits, cakes and wafers)	200 mg/kg
Edible ices	150 mg/kg
Flavoured processed cheese	100 mg/kg
Desserts including flavoured milk products	150 mg/kg
Sauces, seasonings (for example, curry powder, tandoori pickles, relishes, chutney and piccalilli)	500 mg/kg
Mustard	300 mg/kg
Fish paste and crustacean paste	100 mg/kg
Pre-cooked crustaceans	250 mg/kg
Salmon substitutes	500 mg/kg
Surimi	500 mg/kg
Fish roe	300 mg/kg
Smoked fish	100 mg/kg
'Snacks': dry, savory potato, cereal or starch-based snack products: extruded or expanded savoury snack products	200 mg/kg
Edible cheese rind and edible casings	quantum satis
Complete formulae for weight control intended to replace total daily food intake or an individual meal	50 mg/kg
Complete formulae and nutritional supplements for use under medical supervision	50 mg/kg
Liquid food supplements/dietary integrators	100 mg/l
Solid food supplements/dietary integrators	300 mg/kg
Soups	50 mg/kg
Meat and fish analogues based on vegetable proteins	100 mg/kg
Spirituous beverages (including products less than 15% alcohol by volume), except any mentioned in Schedule 2 or 3	200 mg/l
Aromatized wines, aromatized wine-based drinks and aromatized wine-product cocktails as mentioned in Regulation (EEC) No. 1601/91, except any mentioned in Schedule 2 or 3	200 mg/l
Fruit wines (still or sparkling), cider (except cidre bouche) and perry aromatized fruit wines, cider and perry	200 mg/l

Source: Henry (1998).

The fate of curcumin *in vivo* is yet to be understood thoroughly. Studies by oral administration of curcumin to rats indicated that curcumin is metabolized to a certain extent in the liver and that curcumin and its metabolites are excreted via bile and faeces (Tonnesen, 1986).

26.7 Functional properties

Many reviews are available on the medicinal uses of turmeric (Kirtikar and Basu, 1948; Anon., 1950; Srimal, 1993; Verghese, 1999; Khanna, 1999). In the traditional systems of medicine turmeric is used against many ailments.

The biological activity of turmeric is as anti-inflammatory, hypocholestremic, choleratic, antimicrobial, antirheumatic, antibacterial, antiviral, cytotoxic, spasmolytic, hypersensitive, antidiabetic and antihepato toxic (Govindarajan, 1980; Tonnessen, 1986; Velayudhan *et al.*, 1999). Turmeric is also credited with anticancerous properties (Kuttan *et al.*, 1985, Rao *et al.*, 1995).

Curcuminoids, turmeric oil, total extracts are all credited with medicinal properties (Khanna, 1999). However, the biological activity of the components of these constituents differ considerably (Verghese, 1999). It is reported that the proportions of curcuminoids play a considerable role in optimum bioprotective activity of turmeric. The concept of 'Curcumin C3 complex' stamped with specific concentration limit of the individual curcuminoid is an off shoot of this finding (Verghese, 1999).

The dried rhizome of turmeric is used widely as a spice, as a colouring agent and as a folk medicine. The yellow pigment curcumin and demethoxyylated curcumins found in both turmeric and ginger are known to possess potent antioxidant activity (Kikuzaki *et al.*, 1994; Kikuzaki and Nakatani 1993). Curcumin suppressed the oxidation of methyl linoleate in organic homogeneous solution and aqueous emulsions, soybean phosphatidylcholine liposomal membranes and rat liver homoganate induced by free radicals (Noguchi *et al.*, 1994). A mechanism for the dimer production is proposed and its relation to curcumin's antioxidant activity is discussed in Masuda *et al*. (1999). The results indicated that the dimer is a radical-terminated product formed during the initial stage of the process.

In vitro and *in vivo* studies have established the effectiveness of curcumin, volatile oil or total extracts of turmeric against many organisms such as *Micrococcus pyogenous* var. *aureus*, *Staphylococcus* sp., *Paramacium caudatum*, *Trichophyton gypseum*, *Mycobacterium tuberculosis*, *Salmonella typhi*, *Vibrio cholerae*, *Cornybacterium diphtheria*, *Aspergillus niger*, etc. (Khanna, 1999).

Aqueous extract, fresh juice and essential oil of turmeric are also credited with biopesticidal properties (Kapoor, 1998; Saju *et al.*, 1998; Bora and Jaya Samuel, 1999). *In vitro* and *in vivo* studies have established the efficacy of turmeric constituents against various plant pathogens such as *Ralstonia solanacearum*, *Xanthomonas oryzae* pv. *oryzae*, *Helminthosporium sacchari*, *Colletotrichum gloesporoides*, *Rhizoctonia solani*, etc. Turmeric oil is also effective as a mosquito repellant, housefly deterrent and in aphid vector control (Khanna, 1999; Saju *et al.*, 1998).

26.8 References

AMERICAN SPICE TRADE ASSOCIATION (ASTA). 1968. Official Analytical Methods, 2nd edn, American Spice Trade Association, New York, p. 53.

ANON. 1950. *The Wealth of India*. Raw Materials (Ed.) Sastri, B.N. Vol. II, CSIR, New Delhi, pp. 402–5.

BALASUBRAMANIAN, N., KUMAR, K.R. and ANANDASWAMY, B. 1979. Packaging and storage studies on ground turmeric (*C. longa* L.) in flexible consumer packages. *Indian Spices*, **16**(12): 10–13.

BORA, L.C. and JAYA SAMUEL 1999. Use of medicinal plants for management of bacterial blight in rice and bacterial wilt of tomato in Assam. In: Sasikumar, B. *et al.* (Ed.) *Biodiversity, Conservation and Utilization of Spices, Medicinal and Aromatic Plants*. Indian Institute of Spices Research, Calicut, pp. 315–21.

BURKILL, T.H., 1966. A dictionary of economic products of the Malay Peninsula Kualalampur, Ministry of Agriculture & Co-operatives, Malaysia.

CRIPPS, H.P., 1967. Oleoresin turmeric, application in pickle production. *Glass Packer Process,* **46**: 24.

EISERLE, R.J. 1966. The role of oleoresin turmeric in the pickling process. *Glass Packer Process,* **45**: 48.

EOA SPECIFICATION STANDARDS, NO. 271 (1965). Essential Oil Association of USA, New York.

GOVINDARAJAN, V.S. 1980. Turmeric – chemistry, technology and quality. *CRC Critical Reviews in Food Science and Nutrition*, **12**: 199–301.

HENRY, B. 1998. Use of capsicum and turmeric as natural colours. *Indian Spices*, **35**(3): 7–14.

KAPOOR, A. 1998. Antifungal activities of fresh juice and aqueous extracts of turmeric and ginger. *J. Physiol. Res.* **10**(1–2): 167–81.

KHANNA, N.M. 1999. Turmeric – Nature's precious gift. *Curr. Sci.* **76**: 1351–6.

KIKUZAKI, H. and NAKATANI, N. 1993. Antioxidant effects of some ginger constituents. *J. Food Sci.,* **58**: 1407–10.

KIKUZAKI, H., KAWASAKI, Y. and NAKATANI, N. 1994. Structure of the antioxidant compounds in ginger. In: Ho, C.-T., Osawa, T., Huang, M. T. and Rosen, R. T. (Eds) *Food Phytochemicals for Cancer Prevention II Teas, Spices, and Herbs.* ACS Symposium Series No. 547, Washington, ACS Press, pp. 237–47.

KIRTIKAR, K.R. and BASU, B.D. 1948. *Indian Medicinal Plants*, Vol IV. Bishen Singh and Mahendrapal Singh, Dehra Dun, pp. 2417–2426.

KRISHNAMURTHY, M.N., PADMA BAI, R., NATARAJAN, C.P. and KUPPUSWAMY, S. 1976. Colour content of turmeric varieties and studies of its processing. *J. Food Sci. Technol.* (India) **12**: 12–14.

KUTTAN, R., BHANUMATHY, P., NIRMALA, K and GEORGE, M. C. 1985. Potential anti-cancer activity of turmeric (*C. longa* L.), *Cancer Lett.* **29**: 197–202.

MASUDA, T., HIDAKA, K. SHINOHARA, A., MAEKAWA, T. TAKEDA, Y. and YAMAGUCHI, H. 1999. Chemical studies of antioxidant mechanism of curcuminoids: analysis of radical reaction products from curcumin. *J Agric. Food Chem*, **47**: 71–7.

NOGUCHI, N., KOMOU, E., NIKI, E. and WILLSON, R.L. 1994. Action of curcumin as an antioxidant against lipid peroxidation. *Yukagaku*, **43**: 1045–51.

NAZEEM, P.A. and REMA MENON. 1994. Blossom biological and hybridization studies in turmeric (*C.longa* L.). *South Ind. Hort.* **42**(3): 161–7.

PEROTTI, A.G. 1975. Curcumin – A little known but useful vegetable colour. *Ind. Ailment. Prod. Veg.* **14**(6): 66.

PETER, K.V. 1999. Informatics on turmeric and ginger. *Indian Spices*, **36**(2&3): 12–14.

PURSEGLOVE, J.W. 1968. *Tropical Crops: Monocotyledons.* Longman, London.

PURSEGLOVE, J.W., BROWN, E.G., GREEN, C.L. and ROBIN, S.R.J. 1981. Turmeric. In: *Spices*, Vol. II, Longman, New York, pp. 532–80.

RAO, C. V., RIVERSON, A., SIMI, B. and REDDY, B. S. 1995. Chemoprevention of colon carcinogenesis by dietary curcumin, naturally colouring plant phenolic compound. *Cancer Res*. **55**: 259–66.

RAMA RAO, M., RAMA CHENNA, REDDY, K. and SUBBARAYADU, M. 1975. Promising turmeric types of Andhra Pradesh. *Indian Spices*, **12**(2): 2–5.

RIDLEY, H.N. 1912. *Spices*. Macmillan, London.

SAJU, K.A., VENUGOPAL, M.N. and MATHEW, M.J. 1998. Antifungal and insect repellant activities of essential oil of turmeric (*C. longa* L.). *Curr. Sci.* **75**: 660–2.

SASIKUMAR, B., RAVINDRAN, P.N., JOHNSON K. GEORGE and PETER, K.V. 1996. Ginger and turmeric breeding in Kerala. *Proc. Sem. Crop Breeding in Kerala* (Ed.) P.I. Kuriachan, Dept. of Botany, University of Kerala, Kariavattom, pp. 65–72.

SIVADASAN, C.R. 1998. Import regulation and quality requirements for spices in USA. In: *Quality Requirement of Spices for Export* (Eds.) Sivadasan, C.R. and Madhusoodana Kurup, P. Spices Board, Kochi, pp. 5–20.

SRIMAL, R.C. 1993. Curcumin – a modern drug. *Indian Spices*, **30**(2&3): 21 and 25.

TONNESEN, H.H. 1986. Chemistry, stability and analysis of curcumin: A naturally occurring drug molecule. Oslo, 91.

TONNESEN, H.H. and KARLSON, J. 1983. High performance liquid chromatography of curcumin and related components. *J. Chromatography*, **259**: 367–71.

VELAYHUDAN, K.C., MURALIDHARAN, V.K., AMALRAJ, V.A., GAUTAM, P.L., MANDAL, S. and DINESH KUMAR. 1999. *Curcuma Genetic Resources*. Scientific Monograph No. 4. National Bureau of Plant Genetic Resources, New Delhi.

VERGHESE, J. 1999. Curcuminoids, the magic dye of *C. longa* L. rhizome. *Indian Spices*, **36**(4): 19–26.