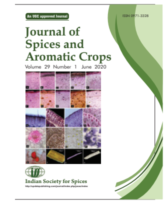
Journal of Spices and Aromatic Crops
Vol. 29 (1) : 01-20 (2020)
doi : 10.25081/josac.2020.v29.i1.6331

Indian Society for Spices



Major Indian spices- An introspection on variability in quality

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Received 11 December 2019; Revised 10 April 2020; Accepted 02 June 2020

Abstract

Indian spices like black pepper, cardamom, ginger, turmeric and cinnamon are valued for their culinary and nutraceutical properties. The quality attributes that impart these properties are essential oil, oleoresin and the aroma/pungent principles. Variability in essential oil constituents of black pepper, relevance of bulk density, codex standards and role of phenolics in deciding quality traits possess great relevance in academic and industrial applications. Curing of turmeric and maturity at harvest play a crucial role in drying and curcumin content. Geographical location has great relevance in deciding the curcumin content of turmeric. Coumarin content of cinnamon and cassia has implications in industrial application. This article provides an introspection in to the research programmes on quality attributes of spices carried out at ICAR-Indian Institute of Spices Research for the last three decades in comparison with international scenario.

Keywords: black pepper, cardamom, cinnamon, curcumin, essential oil, ginger, gingerol, oleoresin, turmeric

Introduction

Spices and herbs have played a dramatic role in the history of India. The delightful flavor and pungency of spices make them indispensable in the preparation of palatable dishes due to their colour, aroma and/or flavour characteristics. Spices used in culinary, industrial cooking and spices based pharmaceuticals can be leaf (e.g. curry leaf), buds (clove), bark (cinnamon), rhizome (ginger, turmeric), berries (black pepper), seeds (cumin) or even stigma of flower (saffron). It can be used fresh, dried, whole, chopped or ground in the preparation of foods and drinks. Spices are an important part of human nutrition and contain proteins, fibre, sugars, essential oils, minerals, pigments besides bioactive compounds such as phenolic acids, sterols and pungent principles like piperine, capsaicin etc. Many of the flavoring principles of spices come under the secondary metabolites of plant system. They add aroma to the preparations through the essential oils which contain, monoterpenes and sesquiterpenes (as hydrocarbons, alcohols, ketones etc.). These are composed of more than 70 components, some of which may represent more than 85% of total content. Many of the functional properties attributed to spices are associated with the type and concentration

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of phenolic compounds, although exact composition depends on several factors such as the plant part used, vegetative state, environmental conditions, harvesting techniques etc. In addition, they possess several medicinal and pharmacological properties which can reverse many adverse physiological disorders and are exploited in the preparation of number of medicines (Zachariah & Leela 2018).

Quality of spices in terms of oil, oleoresin, colouring principles, pungent principles and oil constituents vary in relation to variety, maturity, environment and other related factors. Major spices covered in this review are black pepper, cardamom, ginger, turmeric and cinnamon.

Black pepper

Black pepper (*Piper nigrum* L.) is cultivated for its fruit, which is usually dried and used as a spice and seasoning. The same fruit is also used to produce white pepper and green pepper. Black pepper is native to South India, where it is extensively cultivated besides some other tropical regions. The fruit, which is dried as peppercorn, is a small drupe five millimetres in diameter, dark red when fully mature, containing a single seed (Zachariah & Parthasarathy 2008). The black pepper is found extensively in the evergreen forests of Western Ghats and in the adjoining areas, almost from sea level up to an elevation of 1300 m above MSL. It is a perennial climber, climbing by means of ivy-like roots which adhere to the support tree.

Dried, ground pepper is one of the most common spices in European cuisine and it is prized since antiquity for both its flavour and its use as a medicine. The spiciness of black pepper is due to the chemical piperine. Ground black peppercorn, usually referred to simply as "pepper", may be found on nearly every dinner table in most parts of the world, often alongside table salt. Black pepper, also nick named as black gold, and 'king of spices' is the most important and widely consumed spice in the world. Compared to many other spices, properly dried black pepper (~moisture content 8–10%) can be stored in air tight containers for many years without losing its taste and aroma.

Over hundred cultivars are known, but many of them are getting extinct due to various reasons like devastation of pepper cultivation by diseases such as, *Phytophthora* foot rot and slow decline, replacement of the traditional cultivars by a few high yielding varieties etc. Cultivar diversity is richest in the state of Kerala followed by the state of Karnataka in India. Most of the cultivars are bisexual forms, unlike their wild counterparts.

Black pepper has multiple uses in processed food industry, in kitchen, in perfumery, traditional medicine and even in beauty care. Pepper is valued for its pungency and flavour, which is attributed to the alkaloid piperine and the volatile oil (Zachariah & Leela 2018). Aroma and pungency are distinct in black pepper. The pungency was initially attributed to the presence of piperine only, which is chemically trans, trans-5-(3,4-methylenedi-oxyphenyl)-2, 4-pentadienoic acid piperidide. Further investigations into the pungency of this spice by several workers lead to the information that materials other than piperine also contributed to the pungency of black pepper (Zachariah & Parthasarathy 2008).

Blackening of pepper

Fresh green pepper on drying attain attractive black colour by a natural enzymatic process which is explained as enzymatic oxidation of (3, 4-dihydroxy phenyl) ethanol glycoside by an o-diphenol oxidase (PPO) present in the fresh fruit. Conversion of green pepper to black pepper by the drying process was accompanied by a 75% decrease in total phenolic content and a complete loss of o-diphenol oxidase oxidizable phenolic fraction which suggest a major role for enzymatic phenolic oxidation during pepper blackening. Researchers characterized 3, 4-dihydroxy-6-(N-ethyl amino) benzamide as the substrate for o-diphenol oxidase (Zachariah & Parthasarathy 2008).

Black pepper essential oil

Volatile oils, also known as essential oils are complex mixtures of low molecular weight compounds extracted from plants by steam distillation and various solvents. Terpenoids and phenylpropanoids are the major constituents which provide characteristic aroma and biological properties to volatile oils. Various pharmaceutical and biological activities like antibacterial, antifungal, anticancer, antimutagenic, antidiabetic, antiviral, anti-inflammatory, and antiprotozoal properties are assigned to them.

Constituents of black pepper oil

Black pepper oil constituents of great relevance are listed below.

Monoterpene hydrocarbons and oxygenated compounds

Monoterpene hydrocarbons of interest in black pepper oil are *p*-cymene, limonene, myrcene, cis-ocimene, α-phellandrene, β-phellandrene, β-pinenes, sabinene, α and γ-terpinenes, terpinolene and α-thujene. Important oxygenated compounds of monoterpenoid nature characterized and reported as the most potent odorants of black pepper are carvone, 1, 8-cineole, cryptone, *p*-cymene-8-ol, dihydrocarvone, linalool, α-terpeneol, citronellal, nerol, geraniol, methyl citronellate, methyl geranate, α-terpinyl acetate, terpenolene epoxide etc. Optically active monoterpenes like (±)-linalool, (+)-α-phellandrene, (-)-limonene, myrcene, (-)-α-pinene, 3-methylbutanal and methylpropanol (Zachariah & Parthasarathy 2008).

Sesquiterpene hydrocarbons and oxygenated compounds

β-caryophyllene is reported as the major sesquiterpene hydrocarbon present in pepper oil. Other sesquiterpene hydrocarbons of importance in black pepper oil are α-cis-bergamotene, α-trans-bergamotene, β-bisabolene, δ and γ-cadinenes, calamenene, α-copaene, α- and β-cubebenes, ar-curcumene, β- and δ-elemenes, β-farnesene, α-guaiene, α- and γ-humulenes, isocaryophyllene, γ-muurolene, α-santalene, α- and β-selinenes, ledene, sesquisabinene and zingiberene. Some of the oxygenated sesquiterpenes of interest are β-caryophyllene alcohol, caryophyllene ketone, caryophyllene oxide, cubenol, epi-cubenol, viridiflorol, α- and β-bisabolols, cubebol, elemol and γ-eudesmol (Zachariah & Parthasarathy 2008).

Miscellaneous compounds

Eugenol, methyl eugenol, myristicin, safrole, benzaldehyde, trans-anethole, piperonal, m-methyl acetophenone, p-methyl acetophenone, n-butyrophenone, benzoic acid, phenyl acetic acid, cinnamic acid and piperonic acid are some of the aromatic compounds characterized in pepper oil (Zachariah & Leela 2018).

Cultivar, agro climatic variation, variation in maturity of raw material, differences in the method of obtaining the oil, non-resolution of constituents in early gas chromatographic analyses using packed columns etc. can influence content and composition of oil. Steam distilled pepper oils usually contain about 70–80% monoterpene hydrocarbons, 20–30% sesquiterpene hydrocarbons and less than 4% oxygenated constituents. Oils prepared by vacuum distillation of oleoresin extracts have less monoterpene hydrocarbons and more sesquiterpene hydrocarbons and oxygenated constituents.

Variability in essential oil constituents

Various researchers indicate that monoterpene hydrocarbons ranged from 69.4–85.0%, sesquiterpene hydrocarbons from 15.0–27.6% and the rest are oxygenated constituents in different black pepper cultivars. Monoterpene hydrocarbons like α-pinene ranged from 5.9–12.8%, β-pinene from 10.6–35.5% and limonene from 22.0–31.1% in different cultivars. The major sesquiterpene hydrocarbon β-caryophyllene, ranged from 10.3% to 22.4%.

Some of the improved black pepper cultivars such as Panniyur-1, Panniyur-2, Panniyur-3, Panniyur-4 and traditional cultivars such as Aimpiriyan, Narayakodi, Neelamundi, Uthirankotta, Karimunda, Kalluvally, Arakulammunda, Thommankodi, Kottanadan, Ottaplackal, Kuthiravally, Thevanmundi, Poonjaranmunda, Valiakaniakkadan and Subhakara showed wide variation in oil constituents (Zachariah & Parthasarathy 2008). Difference in biochemical profile was observed between leaf and berries of black pepper. Studies on total phenols, total starch, total carbohydrates and protein content from leaves and berries of selected black pepper cultivars in IISR farm and other research farms displayed notable differences in these constituents. Germacrene-D and elemol were found to be the major constituents of leaf oil. β-caryophyllene was high in berries and it showed more variability among berries from different varieties compared to leaf samples. Berry oil constituents such as pinene, sabinene, myrcene and limonene were not detected in the leaf oil. Different leaf metabolites showed cumulative direct effect on berry constituents (Zachariah *et al*. 2010).

Utpala *et al*. (2008) undertook studies on the spatial influence of volatile oils of pepper leaves. Maximum variability was observed with respect to beta caryophyllene and nerolidol in the leaf oil and the influence of location on these components was significant. Balasubramanian et al. (2016) made a review on spices including black pepper in which they highlighted the role of processing techniques in enhancing flavour and medicinal properties. Barnwal *et al*. (2013) explained the thermal properties of cryoground black pepper by which flavour properties can be enhanced compared to normal ground pepper. Balasubramanian *et al*. (2013) studied the physico-chemical properties of black pepper for developing processing techniques including cryogenic grinding.

Correlation of metabolites and location

Sruthi *et al.* (2013) studied the correlation of metabolites at different locations with respect to the commonly cultivated black pepper variety Panniyur-1. A significant location wise variation was obtained for both primary and secondary metabolites of Panniyur-1 black pepper berries. Variability was profound in essential oil, oleoresin, piperine, total phenols, crude fibre, starch, total fat and bulk density. One interesting finding was the altitudinal specificity of total phenols. They also observed clear altitudinal variation of β-caryophyllene and total phenols. These two constituents were low at high elevations (>500 MSL) and high at plains. Similarly, monoterpenes like thujene, α-pinene, sabinene, limonene, α-phellandrene and linalool were relatively high at higher altitudes compared to plains. Total phenols showed positive correlation with piperine, oleoresin, essential oil, crude fibre and total fat. Oleoresin showed a positive correlation with piperine, total phenol, crude fibre, essential oil and total fat and a negative correlation with bulk density and starch. Essential oil was positively correlated with piperine, total phenol, oleoresin, total fat and crude fibre but negatively correlated with bulk density and starch. The study established that there was variability in aroma quality with respect to altitude and it correlates differently with different constituents (Table 1, 2 & 3).

Pungency of black pepper

Piperine is the major constituent of pepper oleoresin. The pungency of black pepper was attributed mainly to piperine, the structure of which was later proven to be trans, trans-5-(3, 4-methylene di- oxyphenyl)-2, 4-pentadienoicacid piperidide. Subsequent studies showed other alkaloids also contribute towards pungency. The acetone extract of pepper showed the presence of 18 components accounting for 75.59% of the total quantity. Piperine (33.53%), piperolein B (13.73%), piperamide (3.43%) and guineesine (3.23%) were the major components (Zachariah & Leela 2018).

Oleoresin of black pepper

Oleoresin is the total soluble extractives in a

Table 1. Physical quality constituents of the black pepper variety, Panniyur-1 from different locations (Sruthi *et al*. 2013)

Sample*	Bulk density g L^{-1}	Total ash (%) w/w	Acid insoluble ash (%) w/w
K	460.60^{h}	5.09^{a}	0.13^{g}
C	505.80^{f}	3.89^{ef}	0.27^{c}
Z	466.70^{g}	4.17^{d}	0.16^{f}
R	547.00^{d}	3.87^{f}	0.12^{g}
L	512.00^{e}	3.99^{ef}	0.19^{e}
P	608.70^{a}	4.41^{c}	0.12^{g}
A	556.50^{c}	3.88^{f}	0.07^{i}
M	573.10^{b}	4.03^{e}	0.09^{h}
E	548.90^{d}	3.43^{g}	0.31^{a}
G	570.70^{b}	4.93^{b}	0.28^{b}
D	510.60^{ef}	3.45^{g}	0.21^{d}
CV%	6.60	2.26	5.78

*K=Kasaragod; C=Chelavoor; Z=Peruvannamuzhi; R=Panniyur; L=Ambalavayal; P=Pampadumpara; A=Appangala; M=Mudigere; E=Pechiparai; G=Thadiankudisai; D=Dapoli

Table 2. Variability in secondary metabolites of the black pepper variety, Panniyur-1 in relation to location (Sruthi *et al*. 2013)

Sample*	Essential oil (%) v/w	Oleoresin (%) w/w	Total phenol (%) w/w	Crude fibre (%) w/w	Piperine (%) w/w
K	2.8^{b}	12.73^{a}	0.63^{a}	18.60^{a}	4.49^{a}
C	2.5^{d}	8.17^{cd}	0.53^{c}	15.18^{c}	2.76^{c}
Z	3.2^{a}	9.74^{b}	0.55^{b}	16.86^{b}	3.91^{b}
R	2.0^{f}	7.42^{e}	0.51^{d}	14.62^{d}	2.55^{d}
L	2.4^{e}	7.14^{ef}	0.40^{f}	12.54^{f}	2.22^{g}
P	1.6^{h}	6.48^{g}	0.30^{h}	10.79^{g}	2.13^{h}
A	1.8^{g}	6.91^{f}	0.36^{g}	14.15^{e}	2.46^{e}
M	2.0^{f}	7.17^{ef}	0.37^{g}	14.17^{e}	2.40^{f}
E	2.0^{f}	7.98^{d}	0.46^{e}	14.61^{d}	2.56^{d}
G	2.4^{e}	5.82^{h}	0.37^{g}	12.45^{f}	2.40^{f}
D	2.7^{c}	8.43^{c}	0.46^{e}	15.19^{c}	2.49^{e}
CV%	2.13	3.50	1.55	1.85	0.92

*K=Kasaragod; C=Chelavoor; Z=Peruvannamuzhi; R=Panniyur; L=Ambalavayal; P=Pampadumpara; A=Appangala; M=Mudigere; E=Pechiparai; G=Thadiankudisai; D=Dapoli

specified solvent. From the functional point, the best oleoresin is one which contains all the flavour components of the material contributing to aroma, taste, pungency and related sensory factors which when diluted to the original concentration can truly recreates the sensory quality of the original spice (Parthasarathy *et al*. 2012).

Oleoresin of any spice is commercially very

Table 3. Correlation among different constituents of the black pepper variety, Panniyur-1 berries (Sruthi *et al*. 2013)

Correlation matrix (P<0.05)

	P	TP	O	BD	S	CF	EO	TF	PR	TFA
P	1.00									
TP	+0.83*	1.00								
O	+0.92*	+0.86*	1.00							
BD	-0.80*	-0.87*	-0.82*	1.00						
S	-0.93*	-0.84*	-0.95*	+0.83*	1.00					
CF	+0.88*	+0.90*	+0.89*	-0.83*	-0.90*	1.00				
EO	+0.71*	+0.71*	+0.64*	-0.88*	-0.64*	+0.68*	1.00			
TF	+0.85*	+0.88*	+0.89*	-0.83*	-0.89*	+0.92*	+0.68*	1.00		
PR	+0.73*	+0.60*	+0.57	-0.57	-0.60*	+0.61*	+0.64*	+0.44	1.00	
TFA	+0.78*	+0.46	+0.62*	-0.63*	-0.68*	+0.54	+0.67*	+0.57	+0.50	1.00

P=Piperine; TP=Total Phenol; O=Oleoresin; EO=Essential oil; BD=Bulk density; S=Starch; CF=Crude fibre; TF=Total fat; PR=Total protein; TFA=Total free amino acid.

Superscript (*) is given for significant correlations (P≤0.05).

important. Oleoresin replaces the spice powder for its aroma, taste, flavour and pungency. This is especially true as far as black pepper is concerned. India started exporting black pepper oleoresin in 1960s itself from the ‘Techno chemical Industries’ from Calicut (Kozhikode, Kerala) to United States and European Countries. Now there are over 16 companies functioning in and around Kochi (Kerala) involved in the production and marketing of oleoresin from almost all major spices of India. Originally solvent extract and recently super critical extraction techniques are adopted for the extraction of oleoresin. Oleoresin is a blend of essential oil, resinoids, flavonoids, phenolics and lipids. While spice powders lose their quality on storage, oleoresin has very good shelf life. However the content of piperine and oil in oleoresin are decided by the manufacturer as per the requirement of the client. Good quality oleoresin should have 35% piperine.

Quality standards and bulk density of black pepper

Weight per litre, also called bulk density is a parameter of commercial importance. In India, different commercial standards are adopted by various agencies for bulk density. Directorate of Marketing under Government of India under the brand name ‘Agmark’ has two standards for bulk density: i.e., Special (490 g L^{-1}) and Standard (470 g L^{-1}).

Based on the size, earlier Agmark has developed many grades for black pepper. Major grades recommended by Agmark are as follows. Malabar Garbled (MG Grades 1 and 2) Black Pepper, Malabar Ungarbled (MUG Grades 1 and 2) Black Pepper, Tellicherry Garbled Black Pepper Special Extra Bold (TGSEB), Tellicherry Garbled Extra Bold (TGEB), Tellicherry Garbled (TG), Pin Heads (PH Grade special and Grade 1), Garbled Light Pepper (GL Special, GL Grades 1 and 2), Ungarbled Light Pepper (UGL Special, UGL Grades 1 and 2), Black Pepper (Non-specified). Even now some of these grades are strictly followed in fixing prices for black pepper. TGSEB, TGEB and TG fetch a premium price compared to MG1 and MG 2 (AGMARK Report). As per ‘Agmark’ standards, the size of TGSEB, TGEB, TG, MG1 and MG 2 are 4.8, 4.2, 4.0 and 3.8 mm, respectively.

However, codex standards have three grades relying only on bulk density. Codex committee for spices and culinary herbs (CCSCH) has recommended different values for bulk density and other physical and chemical characteristics (Table 4 & 5). Traditional cultivar like 'Vadakkan' has almost 80% pepper with the size of TGSEB and the first black pepper hybrid variety Panniyur-1 has over 40% berries in the grade of TGSEB, TGEB and TG.

Studies on physico-chemical properties of black pepper from selected varieties in relation to market grades found proportion of varieties to grade (Jayashree *et al*. 2009). Black pepper varieties Panniyur-1, Panniyur-2, Panniyur-5, Sreekara and Subhakara were graded based on size. Cultivar Subhakara had highest percentage of berries of size between 3.8 and 4.8 mm (33.3%). Panniyur-1, 2 and 5 had more than 60% of its berries under grade TG. Bulk density ranged from 450 to 570 gram per litre. Bulk density of grades above 4.8 mm size were lower compared to grades with berry size below 3.5 mm. Oleoresin and piperine were high in lower grades and oil content was independent of all grades in all varieties. Due to the importance of bulk density in fixing price for black pepper the Black Gold League (BGL) of Chikkamagalur (Karnataka) developed a bulk density measuring device as per international standards to equip farmers to bargain for reasonable price (Zachariah unpublished).

Table 4. Codex standards for physical quality of BWG (black, white, green pepper) (CCSCH Agenda 6CX/SCH17/3/6, 2016)

Physical characteristics	Black			White			Green		
	Class I	Class II	Class III	Class I	Class II	Class III	Class I	Class II	Class III
Bulk density g L^{-1}	550	500	400	600	600	550	NA	NA	NA
Light berries % Max	2.0	5.0	10.0	1.0	2.0	2.0	NA	NA	NA
Pin heads % Max	1.0	2.0	4.0	NA	NA	NA	NA	NA	NA

Green pepper- Dehydrated green pepper

Table 5. Codex standards for chemical quality of BWG (black, white, green pepper) (CCSCH Agenda 6CX/SCH17/3/6, 2016)

Chemical characteristics	Black			White			Green
	Class I	Class II	Class III	Class I	Class II	Class III	
Moisture %	12.0	12.0	13.0	12.0	12.0	13.0	12.0
NVEE %	7.0	7.0	6.0	6.0	6.0	6.0	0.3
Volatile oil %	2.0	1.5	1.0	1.5	1.5	1.0	1.0
Piperine %	3.5	3.0	2.0	4.0	3.5	3.0	NA
Total ash %	6.0	7.0	7.0	3.5	4.0	4.0	5.0

Green pepper- Dehydrated green pepper

Pharmacological properties and phenolics

Sruthi & Zachariah (2015) found the potential of antioxidant activity and cytotoxicity exhibited by essential oil from selected *Piper* species. They reported that the essential oil of *Piper colubrinum* possesses good activity in scavenging DPPH free radicals and also reducing ferric ions. The variety IISR-Malabar Excel essential oil was found to be highly cytotoxic to cervical cancer cell line CaSki. Among the oil constituents, sesquiterpenes predominated in black pepper and *Piper chaba* essential oil whereas aliphatic compounds dominated in *P. longum*.

Phenolic compounds from four *Piper* species *viz., P. nigrum, P. longum, P. chaba* and *P. colubrinum* were characterised using LC-MS by Sruthi & Zachariah (2016). Thirteen compounds were identified in black pepper including hydroxy benzoic acids (syringic acid, protocatechuic acid), hydroxycinnamic acids (caffeic acid, ferulic acid and 4-coumaric acid) and flavonoids (luteolin-8-c glucoside and epigenin). Seven compounds were identified from *P. chaba* which were composed of hydroxy benzoic acids, phenolic aldehydes and hydroxycinnamic acids. In *P. colubrinum*, ten compounds were identified and majority were flavonoids like kaempferol-5-glucoside and epigenin-7-galactoside. Phenolics are the most abundant secondary metabolites in plant kingdom and are responsible for their defence mechanisms under different environmental conditions. These compounds show several health promoting functions like reducing risks of cancer, heart and neurodegenerative disorders. Studies conducted at ICAR-IISR conclusively proved that total phenols is the deciding factor for oil, oleoresin and piperine (Table 3).

In vitro anti-oxidant activity and cytotoxicity of sequential extracts of selected black pepper varieties and *Piper* species showed correlation between certain metabolites in imparting that property (Sruthi & Zachariah 2017). Methanol extract of IISR Malabar Excel followed by that of Panchami and among *Piper* species, chloroform extract of *P. colubrinum* expressed highest antioxidant activity. Significant positive correlation between total phenols and antioxidant activity was observed for methanol and chloroform extracts. Toxicity to cervical cancer cell lines CaSki was specifically found with chloroform extract of *P. longum* and *P. colubrinum* than other extracts. As in *Piper* species, chloroform extract of Malabar Excel was more toxic to CaSki than other black pepper varieties.

Cardamom

Aroma property of cardamom (*Elettaria cardamomum* M.), has been exploited world over in culinary ingredients as well as processed food products. Cardamom is used as a natural flavoring ingredient in three forms *viz*., whole, decorticated and ground (Zachariah 2002). The fruit is an ovoid, three-celled, loculicidally dehiscent capsule, containing many seeds which are covered by an aril. Cardamom is used as an aromatic, carminative and stimulant. The seeds have a warm, slightly pungent aromatic flavour. It is mainly used as a flavoring agent in tea and food preparations. Cardamom oil is a precious ingredient in food preparations, perfumery, health foods, medicine and beverages.

The chemical composition of cardamom varies considerably with variety, region and age of the product. The content of volatile oil in the seeds strongly dependent on storage conditions with an average yield from 2–5%. Major volatile constituents of cardamom oil are α-pinene, β-pinene, sabinene, myrcene, α-phellandrene, limonene, 1,8-cineole, γ-terpinene, terpinolene, linalool, linalyl acetate, terpinen 4-ol, α-terpineol, α-terpinyl acetate, citronellol, geraniol, methyl eugenol and trans-nerolidol. The basic cardamom aroma is produced by a combination of the major components, 1,8-cineole and α-terpinyl acetate (Chempakam & Sindhu 2008).

Volatile oil content is highest during 20–25 days before capsules reach full maturity. Ratio of the two main components 1, 8-cineole and alpha terpinyl acetate determine the critical flavor of cardamom oil. Cultivar Mysore or the commercial grade Alleppey Green grown mainly in Idukki region of Kerala has more sweet flavor in oil due to the high concentration of alpha terpinyl acetate and the cultivar Malabar represented by Coorg Green is more camphory in aroma due to high content of 1,8-cineole in oil. Typical variability in essential oil composition of Malabar cardamom grown at Sakaleshpur (Karnataka) is depicted in Table 6. It can be noted that α-terpinyl acetate is comparatively less and 1, 8-cineole is more in the oil. Black seed stage of cardamom seeds in the capsules also called 'karimkai' is ideal for consumption as well as for oil extraction (Zachariah 2002). Percentage by weight of cardamom seeds in the capsules ranged from 68 to 75. In addition to volatile oil, cardamom seeds also contain fixed oil (fat). Major fatty acids detected are oleic and palmitic acids. Elizabeth Thomas *et al*. (2009) proved the supremacy of Indian cardamom based on levels of oil constituents like 1, 8-cineole and alpha terpinyl acetate compared to International grades of Guatemala and Sri Lanka cardamoms.

Arpitha *et al*. (2019) in their study on the anti-inflammatory effect of cardamom resin found significant effect on paw edema of wistar rats when they fed aqueous and acetone extracts of cardamom. De-oiled cardamom powder (obtained by acetone extraction) was effective indicating that non-volatile compounds present in this resin fraction are responsible for the anti-inflammatory effect. Thus the authors have found that components of the non-volatile (resin) fraction of cardamom *viz*., polyphenols, fatty acids and sterols are responsible for the anti-inflammatory potential of cardamom seeds.

Ginger

Ginger, a spice used in both culinary and processed foods including beverages is the rhizome of *Zingiber officinale* Rosc. of the family, Zingiberaceae. Ginger has been found beneficial in managing varied human ailments, to aid digestion and to treat stomach upset, diarrhoea, and nausea. Ginger rhizome is utilised in household and industry in three forms *viz*., as a fresh paste, dried rhizome and powder. In many countries, especially in India and China, fresh ginger is used to prepare vegetable and meat dishes and as a flavouring agent in beverages and many other food preparations. Ginger is a natural dietary component, which has antioxidant and anti-cancerous properties (Zachariah 2008).

Crude fibre, volatile oil content and pungency level are the most important in assessing the suitability of ginger rhizomes for particular processing purposes. The relative abundance of these three components in the fresh rhizome is governed by its state of maturity at harvest. Young, tender rhizomes lifted at the beginning of the harvesting season, about 5 to 7 months after planting, are preferred for the preparation of preserved ginger since the fibre content is negligible and the pungency is mild. As the season progresses, the relative abundance (on a dry weight basis) of the volatile oil, the pungent constituents and the fibre increase. At about nine months after planting, the volatile oil and pungent principle contents reach a maximum and thereafter their relative abundance fall as the fibre content continues to increase. Table 7 illustrate the variability in quality profile of ginger germplasm accessions from Shere-e- Kashmir Agricultural University Jammu. Except a few, the oil content is below 2% and oleoresin is less than 5%. This data also establishes the influence of location on ginger quality (Zachariah 2008).

Peeling of outer skin of ginger rhizome prior to drying has a considerable influence on the volatile oil and fibre content of the end-product. Removal of the outer cork skin not only reduces the fibre content but also enhances the volatile oil loss through rupture of the oil cells which are near the skin. For this reason, the cleanly peeled Jamaican product has relatively lower volatile oil and fibre contents than other commercial dried gingers which are only

Table 6. Chemical quality of Malabar cardamom accessions from Indian Cardamom Research Institute, Sakaleshpur (Karnataka) (Zachariah unpublished)

Acc. No.	Essential oil %	Pinene	Sabinene + Myrcene	Limonene	1, 8 - cin-eole	Linalool	Terpenene -4-ol	α-ter-pinene	Linalyl acetate	α-terpinyl acetate
T1	6.0	2.53	6.95	6.09	34.50	1.10	2.68	3.34	2.28	31.09
T2	5.7	2.11	7.27	5.03	32.21	0.88	3.13	4.77	2.59	32.81
T3	4.8	2.21	7.25	5.39	34.47	0.88	3.17	4.77	2.25	34.38
T4	6.4	2.13	7.43	5.05	31.58	0.96	3.34	6.65	2.55	34.07
T5	5.0	2.08	6.08	4.66	34.56	1.02	3.02	3.96	2.57	29.23
T6	4.7	2.29	6.85	6.66	33.52	1.25	3.12	3.67	2.57	32.14
T7	6.0	2.38	7.60	5.68	33.41	0.97	3.56	3.87	2.32	33.77
T8	5.7	2.52	7.75	6.15	33.64	1.23	3.28	4.54	2.34	32.63
T9	5.3	2.29	8.10	5.19	31.59	0.82	3.52	4.61	2.61	35.72
T10	5.7	2.50	7.56	6.00	32.67	1.22	3.23	4.65	3.03	32.43
T11	5.7	1.97	6.12	5.24	30.08	1.15	3.20	4.19	2.44	31.58
T12	5.0	2.47	6.95	6.12	34.01	1.20	3.29	3.50	1.91	34.80
T13	5.0	2.22	6.62	5.04	33.15	2.99	4.01	4.00	2.09	33.39
T14	5.7	2.30	7.15	5.58	33.43	1.00	3.27	4.52	2.47	31.31

partially peeled or unpeeled. The crude fibre content of unpeeled ginger may be as high as 10-12% on a dry-weight basis, which was observed in the case of cultivar 'Bhaise' (from Sikkim) but in commercial dried gingers it is usually in the range of 2–6%. The volatile oil content of commercial dried gingers has been reported to be 0.5–4.4% but for the major types the range is usually 1–3%. They have been reported to provide 3.5–10.0% oleoresin and contain 15–30% of volatile oil (Zachariah 2008).

Essential oil of ginger

Ginger oil prepared by steam distillation of dried ginger is pale-yellow to light-amber mobile liquid whose viscosity increases on ageing or exposure to the air. The organoleptic properties of ginger oils vary to a great extent depending on the geographical source of the dried ginger. The citrus or lemon-like top note is a characteristic of Indian ginger oil, and this is even more pronounced in Australian oil (Zachariah unpublished).

Table 7. Quality profile of ginger germplasm accessions from Shere-e-Kashmir University Jammu (Zachariah unpublished)

Accession	Essential oil %	Oleoresin %	Crude fiber %
JG1	1.4	3.98	4.95
JG2	1.2	3.20	4.15
JG4	2.0	4.51	4.95
JG7	1.2	5.05	4.65
JG8	1.2	3.97	4.50
JG9	1.6	2.84	4.10
JG12	1.2	2.36	3.90
JG16	1.2	4.71	4.75
JG46	1.6	4.38	4.10
JG47	2.0	4.34	4.70
JG48	1.6	4.35	4.00
JG56	1.6	4.02	4.50
JG57	1.6	3.98	4.05
JG58	1.6	3.68	4.60
JG15	1.4	4.77	5.05

The oil yield varies between 1–2.4% and the oil consisted of 64.4% sesquiterpene hydrocarbons, 6.6% carbonyl compounds, 5.6% alcohols, 2.4% monoterpene hydrocarbons and 1.6% esters. The main compounds reported are zingiberene (29.5%) and sesquiphellandrene (18.4%). Many of the Kerala varieties like Maran, Himachal, Wayanad, Kuruppampady etc. have on an average 2% oil. Improved varieties like IISR-Varada, IISR-Rejatha, IISR-Mahima, Suprabha and Suruchi have about 1.5% oil. Due to fluctuations in weather conditions, many ginger varieties cultivated in north eastern areas have only 1–1.5% oil. Codex committee on spices and culinary herbs is recommending 1.5% oil for whole dried ginger and 1% for ginger powder (CCSCH Agenda 4.1CX/SCH19/4/4 January 2019).

Studies showed marked difference in essential oils of ginger rhizomes from India and Australia in their terpenoid compositions. The main components of Indian ginger oil were the sesquiterpenoid hydrocarbons ar-curcumene, zingiberene, α-farnesene, β-bisabolene and β-sesquiphellandrene, while the essential oil from the Australian ginger consisted mainly of the monoterpenoid hydrocarbons, camphene and phellandrene and their oxygen-containing derivatives neral, geranial and 1,8-cineole. The Australian oils were notable in exhibiting high citral contents in the range of 8% to 27% (average 19.3%) compared to 0.5% to 4% for oils from other sources. The ratio of citral a (geranial) to citral b (neral) in most samples was about 2:1 (Zachariah 2008).

Ginger oleoresin

Ginger oleoresin is generally extracted using organic solvents from powdered dry ginger and also recently by super critical extraction in Industrial scale from many countries including India. Solvents used are ethanol, isopropanol or liquid carbon dioxide. All oleoresin samples contain monoterpenes and sesquiterpenes. This product possesses the full organoleptic properties of the spice, i.e. aroma, flavour and pungency and finds applications similar to the ground spice in the flavouring of processed foods. The oleoresin is also used in certain beverages and to a limited extent in pharmaceutical preparations (Zachariah 2008).

Pungent principles

Gingerol is considered as the main pungent principle of the non-volatile solvent extract also known as the ginger oleoresin. In 1917, a crystalline, optically inactive, pungent keto-phenol was isolated from the alkali-soluble fraction of an etheral extract of ginger. This compound was named zingerone and its structure was originally proposed as 4-hydroxy-3-methoxy-phenylethyl methyl ketone. On the basis of a number of other experiments, investigators concluded that gingerol was a mixture of at least two compounds in which zingerone was condensed with homologous straight chain aldehydes (Zachariah 2008).

The pungent group includes gingerols, shogaols, paradols and zingerone that produce a 'hot' sensation in the mouth. The gingerols, a series of chemical homologs differentiated by the length of their un- branched alkyl chains, were identified as the major active components in the fresh rhizome. In addition, the shogaols, another homologous series and the dehydrated form of gingerols are the predominant pungent constituents in dried ginger. Paradol is similar to gingerol and is formed on hydrogenation of shogaol (Zachariah 2008).

Reports on Australian and Japanese gingers suggest that 6 - gingerol is the most abundant principle of ginger and it is accompanied by several other gingerol homologues and analogues, the 8 - and 10 - gingerols being prominent. Reports by various groups indicate that gingerols have the greatest relative pungency values, followed by shogaols and then zingerone. Table 8 illustrates the total gingerol content in oleoresin of selected ginger varieties prominently used for cultivation in India. Some of the Indian traditional varieties like Kuruppampady, Wayanad, Maran and Rio-de- Janeiro are superior in total gingerol from oleoresin (Zachariah 2008).

Gingerols are susceptible to chemical transformation to less pungent degradation products; and that these reactions can occur by poor handling during the preparation, storage and utilization of dried ginger and its oleoresin with consequent deterioration of quality. Bailey Shaw *et al*. (2008) conducted a trial at different locations of Jamaica at varying maturity and found the influence of location and maturity on the gingerol content of Jamaican ginger. They found that 6-gingerol was the most abundant bioactive principle in all the oleoresin samples and samples with maturity of nine months had the highest level (28.94%).

Li *et al*. (2016) using UPLC/quadrupole-time of flight Mass Spectrometry (UPLC/QTOF-MS) identified the complicated components from fresh, dried, stir-frying and carbonized ginger extracts. They found that antioxidant activity of dried ginger was the highest as its phenolic content was 5.2, 1.1 and 2.4 fold higher than that of fresh, stir drying and carbonized ginger respectively. The antioxidant activity' results indicated a similar tendency with phenolic contents: dried ginger > stir fried > fresh ginger > carbonized ginger. Processing of ginger was the main reason attributed to the decreased concentration of gingerols and decreased levels of shogaols which reduce the antioxidant effects in pace with processing. This study has great

Table 8. Total gingerol in oleoresin from selected ginger varieties (Zachariah unpublished)

Variety	Oleoresin %	Gingerol % in oleoresin
Kuruppampady	8.4	26.3
Wayanad Mananthodi	7.2	32.6
Maran	6.1	27.7
IISR-Varada	4.0	22.3
Suprabha	4.8	15.6
Himgiri	4.5	18.4
IISR-Mahima	5.5	19.6
IISR-Rejatha	4.0	13.2
Rio-de-Janeiro	7.5	18.4
Surabhi	4.9	16.5

relevance for choosing different kinds ginger samples for clinical application (Li *et al*. 2016).

Studies show that gingerols can undergo a retro aldol reaction at the β-hydroxy ketone group to yield zingerone and aliphatic aldehydes, such as hexanal. This reaction can occur by base catalysis or by the action of heat, and with oleoresins it proceeds rapidly at temperatures above 200^0C. The process is detrimental not only because it reduces the pungency level but it also produces off flavours by the liberated aldehydes. Another prominent transformation to which the gingerols are prone to is dehydration at the β-hydroxy ketone group to form the corresponding, less pungent shogaols. This reaction is markedly influenced by pH and temperature. Most desirable pH of ginger oleoresins is normally in the range of 3 to 5 and thus dehydration of the gingerols tends to proceed by the acid-catalyzed mechanism during extraction and subsequent storage (Li *et al*. 2016).

Shogaol formation can even occur during the drying of the ginger rhizome and it is more extensive with whole dried ginger than with sliced, dried ginger. This is attributed to the longer drying time required for whole ginger. Jayashree *et al*. (2014) evaluated the quality of dry ginger by different drying methods after slicing ginger rhizomes. Slicing of rhizomes significantly reduced the drying time of ginger in all drying methods. Significant reduction in essential oil and oleoresin content of dry ginger was observed in relation to length of slices. Vedashree & Naidu (2018) have illustrated optimum conditions for microwave assisted extraction of 6-gingerol. They could get 21.5% and 18.8% 6-gingerol respectively from fresh ginger and dried ginger by adopting this technique. Microwave assisted extracts exhibited higher antioxidant activity in comparison with conventional extracts. The shogaols have also been found to be susceptible to acid pH and heat treatment and they probably transform to non-pungent polymers. Thus, the pungency of oleoresins decreases steadily on storage as the gingerols are first transformed to the shogaols, which are in turn degraded.

Turmeric

Turmeric (*Curcuma longa* L.) known for its active ingredient curcumin is a popular Indian spice and an active ingredient in all forms of curry powders. Turmeric has been used for centuries in herbal medicines for the treatment of a variety of ailments such as rheumatism, diabetic ulcers, anorexia, cough and sinusitis. Turmeric rhizomes contain 2.5–6.0% curcuminoids, the group of active ingredients which are responsible for the yellow colour. Curcuminoids comprise of curcumin I (curcumin), curcumin II (demethoxy curcumin) and curcumin III (bis-demethoxy curcumin), which are found to be natural antioxidants. Curcumin (diferuloyl methane), the main curcuminoid present in turmeric, has been found to possess many beneficial biological activities such as anti-inflammatory, antioxidant, anti-carcinogenic, anti-mutagenic, anticoagulant, anti-diabetic, wound healing and anti-infective effects. The clinical use of curcumin is limited to some extent because of its poor water solubility and low bioavailability (Elizabeth Thomas *et al*. 2011; Zachariah & Leela 2015).

Ground turmeric and cryogenic grinding

Dried turmeric powder is prepared using disc type attrition mills to obtain 60–80 mesh powder for use in various end products. The rhizomes contain 4–6% volatile oil and there is a great chance of losing the oil when powdered. Since curcuminoids deteriorate on exposure to light and to a lesser extent, under heat and oxidative conditions, it is important that ground turmeric is packed in a UV protective packaging and appropriately stored. Turmeric powder is a major ingredient in curry powders and pastes. In the food industry, it is mostly used to colour and flavour mustard. It is also used in chicken bouillon and soups, sauces, gravies and dry seasonings and also as a colorant in cereals (Chempakam & Parthasarathy 2008).

Barnwal *et al*. (2014) studied the properties of cryogenic and ambient ground turmeric powder. Even though the study proved the benefits of cryogenic grinding in protecting the culinary and medicinal properties, subsequent storage of the powder is also very critical. If the cryogenically ground powder is stored in ambient condition and if the temperature goes above 40–50^{0}C, it can reverse the benefits obtained through cryogenic grinding (Report on NAIP on Cryogenic grinding of spices, 2014).

Influence of curing methods and other techniques on quality

Due to the environmental hazards in turmeric curing especially the use of old tyres as fire source (fuel) in curing units, many research groups made a comparative study on quality of dry turmeric produced by slicing and other curing methods (Jayashree *et al*. 2018). Turmeric rhizomes sliced to 5 mm size were directly dried and whole rhizomes were cured in TNAU model steam cooking and compared with traditional boiling. Curing time in both cases was 60 min. Time required for drying significantly reduced to 127 h (5 days) in slicing technique compared to 288 h (12 days) for boiled and cured rhizomes. More retention of oil, oleoresin and curcumin was observed in sliced rhizomes. Except for the advantage in storing whole dried rhizomes for long term, slicing is advantageous in making turmeric powder for immediate consumption and also it saves lot of fuel required for curing. Jayashree & Zachariah (2016) also evaluated different curing methods and its effect on drying time and quality. Many farmers in Erode (Tamil Nadu) and Nizamabad (Telangana) spent more than 20 days for drying turmeric due to improper curing. A minimum of 45–60 minutes curing can result in good quality dried turmeric rhizome without losing any curcumin.

Pradeep *et al*. (2016) analysed different drying methods for getting dried turmeric with desirable colour and quality. Their results showed that quality of unblanched sliced rhizomes dried under hot air was superior as per its physico-chemical quality and colour. They also reported that oil constituents and curcuminoids of hot air dried unblanched rhizomes were superior followed by sun drying on black surface which was energy efficient.

Essential oil and turmerones

Turmeric, dried and cured, generally yields 1.5 to 5.0% volatile oil on steam distillation. Oil present in the rhizome imparts the aromatic taste and smell to turmeric. Turmeric oil analysis indicates that it is a mixture of predominantly sesquiterpene ketones and alcohols. Two major ketonic sesquiterpenes, ar-turmerone and turmerone ($C_{15}H_{20}O$, $C_{15}H_{22}O$) are reported to be responsible for the aroma of turmeric. In addition, *p*-cymene, β-sesquiphellandrene and sesquiterpene alcohols have also been reported. The ratio of turmerone to ar-turmerone in the volatile oil of oleoresin is critical industrially and the desirable proportion is 80:20. The effect of maturity on the major components of rhizome oil from turmeric grown in Sri Lanka also indicated ar-turmerone (24.7–48.9%) and turmerone (20–39%) as the major compounds (Chempakam & Parthasarathy 2008).

GC-MS analysis of rhizome oils from five different *Curcuma* species showed variations in the major components *viz*., ar-turmerone (2.6–70.3%), *α*–turmerone (trace–46.2%) and zingiberene (trace-36.8%) (Chempakam & Parthasarathy 2008).

Geographical location

Influence of geographical location on volatile constituents was demonstrated in many studies (Chempakam & Parthasarathy 2008). Analysis of green leaves and fresh rhizomes of *Curcuma longa* L. grown in India by GC and GC-MS indicate that except for the absence of myrcene, the leaf oil largely resembled the Nigerian counterpart. The rhizome oil did not contain β-pinene but had all the other components of the leaf oil in different proportions.

Anandaraj *et al*. (2014) clearly established that genotypes and location play a great role in curcumin yield. Turmeric varieties like IISR Prabha and IISR Prathibha, which yield about 6% curcumin in Kerala yield around 3–4% curcumin in Tamil Nadu and Andhra Pradesh and much less in places like Madhya Pradesh. The study also revealed that turmeric cultivation under irrigated condition may produce a bumper yield, but it dilutes the per kilogram recovery of curcumin which is very economical for curcumin industry. Curcumin, oleoresin and essential oil contents of different grades of turmeric grown in Erode district of Tamil Nadu is illustrated in Table 8.

Curcuminoids

Studies to isolate curcumin, $C_{21}H_{20}O_6$, melting point 184–185^{0}C was successful as early as 1815. It is insoluble in water but soluble in ethanol and acetone (Chempakam & Parthasarathy 2008). The main coloured substance in the rhizomes is curcumin, [1, 7-bis (4- hydroxy-3-methoxy prenyl)-1, 6- heptadiene-3, 5-Dione] and two related demethoxy compounds, demethoxy curcumin and bis-demethoxy curcumin, which belong to the group of diarylheptanoids. Besides these three forms of curcuminoids, three minor constituents have also been isolated which are supposed to be geometrical isomers of curcumin.

Cyclocurcumin, a relatively new curcuminoid possessing nematicidal activity was isolated from the mother liquor by repeated purification as a yellow gum. It had the same molecular formula of curcumin, but differ in structure by an intra-molecular Michael addition of the enol-oxygen to the enone group. The absorption spectra of these curcuminoids vary slightly, with their maxima at 429 nm, (curcumin), 424 nm (demethoxy curcumin) and 419 nm (bis-demethoxy curcumin). The three curcuminoids also exhibit fluorescence under ultraviolet radiation and after separation on thin-layer plates, can be directly estimated by Fluorescence Densitometer when irradiated at

Table 9. Quality profile of graded turmeric from Erode, Tamil Nadu (Zachariah unpublished)

Sample grade	Curcumin %				Oleoresin %				Essential oil %			
	Salem	Erode	PTS	P8	Salem	Erode	PTS	P8	Salem	Erode	PTS	P8
Fingers												
Grade – I (Virali-1)	3.1	3.2	4.0	2.0	8.57	7.10	11.6	11.0	2.40	2.00	2.0	2.4
Grade – II (Virali-2)	3.3	2.2	2.5		8.64	7.00	10.4		2.00	2.00	2.4	
Grade – III (Virali-3)	2.6	2.3	3.0		9.28	7.60	7.40		2.40	2.00	2.0	
Bulbs												
Grade – I (Ghatta-I)	2.5	2.6	4.0		6.57	8.75	9.07		2.00	2.40	2.4	
Grade – II (Ghatta-II)	3.2	2.5	3.4		7.02	8.78	9.45		2.00	2.40	2.8	

N=3 Virali-1 (Bold); Virali-2 (Mini); Virali-3 (Bits); G-I – Bold; G-II – Bits

P8(*)=only single grade is available

350 nm. The fluorescence spectra of curcuminoids showed distinct excitation at 435 nm and emission at 520 nm. The three components, curcumin, demethoxy curcumin, and bis-demethoxy curcumin were estimated by thin-layer chromatographic separation and were found to be present in the ratio 60:30:10 (Chempakam & Parthasarathy 2008). Curcumin gives vanillic acid and ferulic acid on boiling with alkali. Oxidation with potassium permanganate yields vanillin, while hydrogenation gives a mixture of tetra hydro- and hexahydroderivatives (Chempakam & Parthasarathy 2008).

Antioxidant potential

Naidu *et al*. (2009) developed an HPLC method for qualitative analysis and quantitative separation of individual curcuminoids in curcumin removed turmeric oleoresin and studied their antioxidant activity. They found that the antioxidant potential of the curcuminoids in curcumin removed turmeric oleoresin render them useful as important nutraceutical or functional food ingredients. Elias *et al*. (2015) illustrated some important pharmaceutical facts about curcumin. As per these authors, phase I clinical studies have shown that high dose of curcumin is well tolerated by humans. Despite its safety, curcumin evades clinical use due to its poor bioavailability. Novel formulations of curcumin with piperine, soluble fibres of fenugreek, liposomes, micelles, nanoparticles, cyclodextrin and turmerone have shown enhanced bioavailability. Satapathy *et al*. (2016) attempted to render curcumin hydrophilic by making an 'inclusion compound' with gamma cyclodextrin and evaluated its neuroprotective efficacy by employing it in a model system *Caenorhabditis elegans*. They have demonstrated the potential of curcumin to ameliorate neuronal dysfunction in the worm model and suggested its use as a therapeutic molecule against Parkinson's disease.

Oleoresin

Turmeric oleoresin is an important ingredient as a food colour and also used in some of the products to impart a characteristic mild spicy aroma compatible with mustard, pickles, relish formulas, etc. Turmeric oleoresin extracted using good, clean turmeric, with curcuminoid content of 4.5 to 5% is a highly viscous, deep brownish orange product, with an yield of about 12%. Good quality oleoresin is shown to have 30 to 40% curcumin, 15 to 20% volatile oil and has a characteristic fresh, clean, woody pungent, woody-spicy aroma of turmeric. Alcohol and acetone are good extractants and (as with ginger) the yields can also be expected to be high because of extraction of non-flavour components. Extraction of oleoresin using ethylene dichloride has the advantage of having relatively selective extraction of the flavour constituents, water immiscible, non-flammable, and of having sufficiently low boiling point, but requiring no refrigeration. However certain countries do not prefer chlorinated solvents. Turmeric oleoresin is employed in institutional cooking in meat and certain processed products such as prepared mustard pickles and relish formulas, for frozen fish fillets, frozen potato croquettes, butter and cheese.

Is long term storage advisable in turmeric?

Visits made to many turmeric growing areas of Tamil Nadu revealed that due to price fluctuation, many farmers are forced to store dry turmeric for seven to eight years in ware houses in gunny bags or polyethylene bags. Major constraint for storage of dry turmeric or dry ginger in ware houses is the attack of dry rhizomes by *Lasioderma serricorne* (cigarette beetle), which makes the rhizome unattractive. Farmers are forced to adopt many unscientific methods to prevent it. Studies at various laboratories indicate that these rhizomes can be stored to a maximum of only two years in airtight containers without much quality loss. Modified atmospheric storage with nitrogen and carbon dioxide can be very effective in preventing storage pests with minimum loss in oil, oleoresin and curcumin content (Zachariah *et al*. 2019).

Cinnamon

Cinnamon and its close relative cassia are among the earliest, most popular spices used by mankind. The true cinnamon, *Cinnamomum verum* syn. *C. zeylanicum*, is a native of Sri Lanka and south India. Cassia cinnamon is derived from different sources such as Chinese cassia (*C. cassia* syn. *C. aromatica*) from China and Vietnam, Indonesian cassia (*C. burmannii*) from Sumatra and Java region and Indian cassia (*C. tamala*) from north eastern region of India and Myanmar (Burma) (Leela 2008). Sri Lanka is the major cinnamon producing country in the world and it controls 60% of the cinnamon trade in the world.

The delicate spicy aroma which cinnamon possesses is attributed to the volatile oil present in it. Volatile components are present in all parts of cinnamon and cassia. They can be broadly classified into monoterpenes, sesquiterpenes, and phenyl propenes. Cinnamon yields mainly leaf and bark oils that are used in perfumery and flavouring. The major component of leaf oil is eugenol, while that of bark oil is cinnamaldehyde. Volatile components do occur in other parts, including root bark, fruits, flowers, twigs and branches (Leela 2008).

Cinnamon as health tonic and preservative

In vitro and *in vivo* studies indicate that cinnamon possess multiple health benefits, mainly in relation to hypoglycaemic activity. The therapeutic potential of cinnamon is attributed to its anti-microbial, antifungal, antiviral, antioxidant, antitumor, blood pressure lowering, cholesterol, lipid lowering and gastro – protective properties. Many authors have isolated phenolic constituents from bark and fruits of *C. zeylanicum* and found antioxidant, radical scavenging activities and insulin-like biological activity (Zachariah *et al*. 2016). *In vitro* studies have demonstrated that cinnamon may act as insulin mimetic, to potentiate insulin activity or to stimulate cellular glucose metabolism. The use of cinnamon as an adjunct to the treatment of type 2 diabetes mellitus is a very promising information. Saranya *et al*. (2017) clearly established the linkage of high phenol and the high antioxidant activity of cinnamon bark extract. Studies conducted at the Indian Institute of Spices Research reveal the great potential of cinnamon and turmeric in lowering blood sugar and cholesterol because of the presence of phenolics much above other spices like black pepper and ginger. In many diabetic rat studies, researchers have found the potential of cinnamon in revitalising the liver and pancreas (RPF report 2017-18). Barnwal *et al*. (2014) determined thermal properties of different forms of cinnamon powder. Zachariah *et al*. (2016) also found that due to high content of phenols in cinnamon bark, its antioxidant activity persist for a long time, even though long term storage of powder reduces the volatile oil content.

Is coumarin a threat in Indian cassia

Cassia cinnamon (*C. cassia*) is reported to possess a strong and spicy taste whereas true cinnamon is sweeter. Many reports reveal that 85% of the ground cinnamon in our markets is Chinese cassia. Consumers are warned about coumarin content of cassia as it can affect liver and also tend to cause cancer. Cassia is reported to contain up to 1% 'coumarin' (2H-chromen-2-one), while true cinnamon has only trace (0.004%), which is a major factor that differentiates cassia and cinnamon. Although coumarin was suggested to be a genotoxic and carcinogenic, recent studies suggest adverse effects in humans after coumarin exposure is rare and if any is reported, it is only at high dosage and for long duration during clinical therapies. Due to the potential hepatotoxic effect in humans, Codex alimentarius commission suggested a Tolerable Daily Intake (TDI) limit for the consumption of coumarin in food. According to this, the amount of coumarin in food and beverages should be limited to 2 mg kg^{-1} food/day.

Jose *et al*. (2019) reported the availability of *C. cassia* trees with low coumarin and high levels of cinnamaldehyde in India. The tested samples contained low coumarin (<100 mg kg^{-1}) well below the stipulated levels put forth by the FSSAI and European Food Safety Authority. Considering the internationally accepted flavour of cassia oleoresin, these *C. cassia* of Indian origin can be widely propagated in the country.

Conclusion

Nutraceutical potential of major Indian spices is gaining International acceptance. The nutraceutical activity depends on the different phytochemicals present in spices. Studies have clearly established that these phytochemicals in spices vary in relation to genotypes, location, maturity at harvest and post-harvest processing techniques. Future research on these spices must be oriented keeping these facts in mind.

References

Anandaraj M, Prasath D, Kandiannan K, John Zachariah T, Srinivasan V, Jha A K, Singh B K, Singh A K, Pandey V P, Singh S P, Shoba N, Jana J C, Ravindra Kumar K & Uma Maheswari K 2014 Genotype by environment interaction effects on yield and curcumin in turmeric (*Curcuma longa* L.). Ind. Crops Prod. 53: 358–364.

Arpitha S, Srinivasan K & Sowbhagya H B 2019 Anti-inflammatory effect of resin fraction of cardamom (*Elettaria cardamomum*) in carrageenan induced rat paw edema. Pharma Nut. 10: 100–165.

Bailey Shaw Y A, Williams L A D, Junior G O, Green C E, Hibbert S L, Salmon C A N & Smith A M 2008 Changes in the contents of oleoresin and Pungent bioactive principles of Jamaican ginger (*Zingiber officinale* Roscoe) during maturation. J. Agric. Food Chem. 56: 5564–5571.

Balasubramanian S, Singh K K, Ashish Mohite & John Zachariah T 2012 Physical properties of cinnamon bark. J. Spices Arom. Crops 21: 161–163.

Balasubramanian S, Kumar R, Singh K K, Zachariah T J & Vikram 2013 Physico-mechanical properties of black pepper (*Piper nigrum* L.). J. Spices Arom. Crops 22: 131–137.

Balasubramanian S, Roselin P, Singh K K, Zachariah T J & Saxena S N 2016 Post harvest processing and benefits of black pepper, coriander, cinnamon, fenugreek and turmeric spices. Critical Rev. Food Sci. Nut. 56: 1585–1607.

Barnwal P, Singh K K, Kumar R & Zachariah T J 2013 Thermal properties of cryo-ground powder of black pepper (Panniyur 1). J. Spices Arom. Crops 22: 148–153.

Barnwal P, Singh K K, Alka Sharma, Choudhary A K, Zachariah T J & Saxena S N 2014 Biochemical, antioxidant and thermal properties of cryogenic and ambient ground turmeric powder. Int. Agric. Eng. J. 23: 39–46.

Barnwal P, Singh K K, Mohite A, Sharma A & Zachariah T J 2014 Determination of thermal properties of cryo- ground cinnamon powder. J. Spices Arom. Crops 23: 262–267.

Chempakam B & Parthasarathy V A 2008 Turmeric. In: Parthasarathy V A, Chempakam B & John Zachariah T (Eds.), Chemistry of spices (pp.97–123). Pub; CABI, UK.

Chempakam B & Sindhu S 2008 Small cardamom. In: Parthasarathy V A, Chempakam B & John Zachariah T (Eds.), Chemistry of spices (pp.41–58). Pub; CABI, UK.

Codex Committee on Spices and Culinary Herbs 2019 Fourth session Agenda 4.1, Joint FAO/ WHO food standards programme during 21-25 January 2019, Thiruvananthapuram, Kerala.

Elias G, Jaismy P J, Hareeshbabu E, Baldwin M, Bibitha K & Krishnakumar K 2015 Curcumin: Transforming the spice to a wonderful drug. Int. J. Pharmaceut. Sci. Res. 6: 2671–2680.

Elizabeth Thomas, Jaleel Kizhakkayil, John Zachariah T, Syamkumar S & Sasikumar B 2009 GC MS analysis of essential oil of export grade Indian, Guatemalan and Sri Lankan cardamoms. J. Med. Arom. Plant Sci. (JMAPS) 31: 206–208.

Elizabeth Thomas, Zachariah T J, Syamkumar S & Sasikumar B 2011 Curcuminoid profiling of

Indian turmeric. J. Med. Arom. Plant Sci. 33: 36–40.

Jayashree E, Zachariah T J & Rakhi R 2018 Comparison of quality of dry turmeric (*Curcuma longa*) produced by slicing and other curing methods by different curing methods. J. Spices Arom. Crops 27: 138–144.

Jayashree E & Zachariah T J 2016 Processing of turmeric (*Curcuma longa*) by different curing methods and its effect on quality. Indian J. Agric. Sci. 86: 696–698.

Jayashree E, John Zachariah T & Gobinath P 2009 Physico-chemical properties of black pepper from selected varieties in relation to market grades. J. Food Sci. Technol. 46: 263–265.

Jayasree E, Vishvanathan R & John Zachariah T 2012 Quality of dry ginger (*Zingiber offcinale*) by different drying methods. J. Food Sci. Technol. 51: 3190–3198.

Jose A I, Leela N K, Zachariah T J & Rema J 2019 Evaluation of coumarin content and essential oil constituents in *Cinnamomum cassia*. J. Spices Arom. Crops 28: 43–51.

Leela N K 2008 Cinnamon and cassia. In: Parthasarathy V A, Chempakam B & John Zachariah T (Eds.), Chemistry of Spices (pp.124–145). Pub; CABI, UK.

Li Y, Hong Y, Han Y, Wang Y & Xia L 2016 Chemical characterization and antioxidant activities comparison in fresh, dried, stirfrying and carbonized ginger. J. Chromatogr. 1011: 223–232.

Naidu M M, Shyamala B N, Manjunatha J R, Sulochanamma G & Srinivas P 2009 Simple HPLC method for resolution of curcuminoids with antioxidant potential. J. Food Sci. 74: C312–C318.

Parthasarathy V A, Srinivasan V, Nair R R, John Zachariah T, Kumar A & Prasath D 2012 Ginger: Botany and Horticulture. In: Jules Janick (Ed.), Horticultural Reviews, Vol. 39 (pp.273–388). Pub; Wiley-Blackwell, New Jersey.

Pradeep K, Ravi R, Jamuna P & Naidu M M 2016 Influence of blanching and drying methods on the quality characteristics of fresh turmeric (*Curcuma longa* L). Int. J. Appl. Pure Sci. Agri. 2: 32–44.

Saranya B, Sulfikarali T, Chindhu S, Muneeb A M, Leela N K & Zachariah T J 2017 Turmeric and cinnamon dominate in antioxidant potential among four major spices. J. Spices Arom. Crops 26: 27–32.

Satapathy P, Salim C, Naidu M M & Rajini P S 2016 Attenuation of dopaminergic neuronal dysfunction in *Caenorhabditis elegans* by hydrophilic form of curcumin. Neurochem Neuropharm open 2: 111.

Sruthi D, John Zachariah T, Leela N K & Jayarajan K 2013 Correlation between chemical profiles of black pepper (*Piper nigrum* L.) var. Panniyur-1 collected from different locations. J. Med. Plants Res. 7: 2349–2357.

Sruthi D & John Zachariah T 2017 *In vitro* antioxidant activity and cytotoxicity of sequential extracts from selected black pepper (*Piper nigrum* L.) varieties and *Piper* species. Int. Food Res. J. 24: 75–85.

Sruthi D & John Zachariah T 2015 Chemo profiling, *in vitro* antioxidant activity and cytotoxicity of essential oil from selected piper species. Int. J. Adv. Pharmaceut. Res. 6: 284–295.

Utpala P, Asish G R, Zachariah T J, Saji K V, Johnson K G & Mathew P A 2008 Spatial influence on the important biochemical properties of *Piper nigrum* Linn. leaves. Nat. Product Radiance 7: 444–447.

Vedashree M & Naidu M M 2018 Optimization of 6-gingerol extraction assisted by microwave from fresh ginger using response surface methodology. J. Adv. Chem. 15: 6173–6185.

Zachariah T J & Leela N K 2015 Curcumin and curcuminoids: Industrial and medicinal potential. Foods Food Ingredients J. Jpn. 220: 309–316.

Zachariah T J & Leela N K 2018 Spices: secondary metabolites and medicinal properties. In: Sharangi A B (Ed.), Indian Spices: The Legacy, Production and Processing of India's Treasured export (pp.277–316), Pub; Springer, Switzerland.

Zachariah T J, Jayashree E & Shiva K N 2019 Effect of modified atmosphere storage on the shelf life and quality of black pepper and turmeric. J. Spices Arom. Crops 28: 43–51.

Zachariah T J, Leela N K & Lijini K R 2016 Quality profile and antioxidant activity of cinnamon bark powder at varying temperature. J. Plant. Crops 44: 114–118.

Zachariah T J, Safeer A L, Jayarajan K, Leela N K, Vipin T M, Saji K V, Shiva K N, Parthasarathy V A & Mammootty K P 2010 Correlation of metabolites in the leaf and berries of selected black pepper varieties. Sci. Hortic. 123: 418–422.

Zachariah T J 2002 Chemistry of cardamom. In: Ravindran P N & Madhusoodanan K J (Eds.), Cardamom: The genus *Elettaria* (pp.69–90). Pub; Taylor & Francis, New York.

Zachariah T J 2008 Ginger. In: Parthasarathy V A, Chempakam B & John Zachariah T(Eds.), Chemistry of Spices (pp.70–96). Pub; CABI, UK.

Zachariah T J & Parthasarathy V A 2008 Black pepper. In: Parthasarathy V A, Chempakam B & John Zachariah T (Eds.), Chemistry of Spices (pp.21-40). Pub; CABI, UK.