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MORPHOLOGICAL AND PHOTOMICROGRAPHIC COMPARISON OF THE RHIZOMES OF TWENTY THREE VARIETIES OF *CURCUMA LONGA* (TURMERIC) FROM TEN DIFFERENT STATES OF INDIA

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Abstract:

The morphological and anatomical **comparison** of twenty three economically important varieties of *Curcuma* L. from ten different states of India namely, Rajapore, Salem, Krishna, Waigaon (Maharashtra), Armur, Narendra, Devi (Uttar Pradesh), Kandhamal, Kedaram, Sudarshana (Odisha), Pragati (Chattisgarh), Rajapore, Pragathi, Suguna (Karnataka), Chinnanandan, Perianaderi, Salem (Tamil Nadu), Lakadong (Meghalaya), Muvattupuzha, Alleppey (Kerala), Duggirala, Amruthpani (Andhra Pradesh), Suroma (Nagaland) were studied and compared state-wise. All the varieties obtained and studied were geographically diversified show similarity in their morpho-anatomical characteristics. Some differences were noticed with respect to morphological characters such as shape, size and colour of rhizome and lateral branches, colour of the cut surface, aroma and taste of powder after curing and drying etc. Differences were also observed in some anatomical characters after powder microscopy of cured, dried and powdered rhizomes such as nature of nature of cork cells, presence of oil cells, trichomes, vascular bundle, shape of starch grains, and oleoresin cells, etc. Two samples of same 'Rajapore' variety from Maharashtra and Karnataka, 'Salem' variety from Maharashtra and Tamil Nadu, "Pragati' from Chhattisgarh and Karnataka were collected and compared morphologically and microscopically and differences were noticed.

Keywords: *Curcuma longa*, variety, powder microscopy, morphology, oil cells, trichomes, starch grains

Introduction:

History of turmeric (*Curcuma longa*) and several other species of the curcuma genus grow wild in the forests of Southern Asia including India, Indonesia, Indochina, nearby Asian countries, and some Pacific Islands including Hawaii. All of these areas have traditional culinary and medicinal uses going back to pre-history.[1-3] In the Indian Ayurvedic system of herbal medicine, turmeric is known as strengthening and warming to the whole body.[4] Traditional uses in India include to improve digestion, to improve intestinal flora, to eliminate worms, to relieve gas, to cleanse and strengthen the liver and gallbladder, to normalize menstruation, for relief of arthritis and swelling, as a blood purifier, to warm and promote proper metabolism correcting both excesses and deficiencies, for local application on sprains, burns, cuts, bruises, insect bites and itches, for soothing action in cough and asthma, as antibacterial and anti-fungus, and in any condition of weakness or debility.[5]

There are many varieties of *Curcuma longa* developed and commercially grown at various geographic conditions. Morphological or organoleptic variations have been observed in case of *Curcuma longa* obtained from various geographical sources which may affect its quality. While characterizing *Curcuma longa*, it becomes important to analyze it morphologically. Fresh rhizomes collected from various geographical sources may vary with its colour, odour, size, shape, type (mother/finger) etc. characteristics. Pharmacognostic and phytochemical evaluation can be used for confirming the identity of *Curcuma longa* rhizome. In this study, twenty three samples of *Curcuma longa* collected from ten different states of India were primarily compared with each other by taking various morphological characteristics into the consideration.[6-7]

Currently C*urcuma longa* is a part of the international commerce. The original rhizomes of *Curcuma longa* is likely to be collected and processed for preservation and transportations a great distance from the consumer end. The

consumer, researchers, manufacturers and herbalists come across only the size-reduced or powdered material and require microscopic means of identification and confirmation. Also it becomes very important to study the powdered rhizomes microscopically which has been collected from different geographic sources for its comparative analysis. Microscopic evaluation is indispensable in the initial identification of herbs, as well as in identifying small fragments of crude or powdered herbs, and in the detection of adulterants as well as identifying the plant by characteristic tissue features.[8] Every plant possesses a characteristic tissue structure, which can be demonstrated through study of tissue arrangement, cell walls, and configuration when properly mounted in stains, reagents, and media. Currently C*urcuma longa* is a part of the international commerce. The original rhizomes of *Curcuma longa* is likely to be collected and processed for preservation and transportations a great distance from the consumer end. The consumer, researchers, manufacturers and herbalists come across only the size-reduced or powdered material and require microscopic means of identification and confirmation. Also it becomes very important to study the powdered rhizomes microscopically which has been collected from different geographic sources for its comparative analysis. Hence this study deals with the comparative powder microscopic analysis of twenty three samples of *Curcuma longa* collected from different states of India.[9]

Materials and methods:

Procurement of Samples:

Twenty three fresh rhizomes samples of Curcuma longa were obtained from various places of ten states of India and named with different codes as shown in Table no. 1. Two samples of same ‘Rajapore’ variety from Maharashtra (T7) and Karnataka (T13), ‘Salem’ variety from Maharashtra (T10) and Tamil Nadu (T19), “Pragati’ variety from Chhattisgarh (T8) and Karnataka (T18) were collected. Rhizomes were washed with fresh water to remove dirt and other extraneous materials and taken for further processes.

Morphology of fresh rhizome samples:

All twenty three fresh samples of Curcuma longa obtained from various sources were taken for morphological study after proper washing with normal water. Colour, odour, shape, size were the characteristics for comparative investigation.10 Length of 25 fresh tubers of each sample was recorded in mm and diameter of cut surface of 25 fresh tubers was recorded in mm.

Curing:

Turmeric rhizomes were cured before drying, which involved boiling the rhizomes until it became soft. Curing was done by boiling each sample in water for 45 min until froth appears at the surface and the typical turmeric aroma was released. During this process, the coloring material was diffused uniformly through the rhizome and starch was gelatinized.7 The curing was carried out for each sample by taking following advantages into the consideration –

- Reduction of drying time
- More even colour distribution throughout the rhizome
- A more attractive (not wrinkled) product that is easier to polish

Morphology of cured and dried rhizome samples:

After curing, each sample was separately dried under shade to avoid deterioration of targeted phytoconstituents. Drying was done by spreading the boiled rhizomes on separate paper sheet for 2 to 3 days until it appeared harder and dried enough. Morphology of the dried mature rhizomes was examined by the naked eye and described based on remarkable visual characters like colour, size, shape, odour, type (Mother/Finger) etc.

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Morphology of powdered samples:
Dried rhizomes were crushed into powder prior to the analysis. The rhizomes of each sample were separately reduced to a 60 mesh powder in a grinder which gave particles of a reasonable size for morphological comparison. Colour, taste, odour, texture etc. were the parameters used for the comparison of each powdered sample.
Powder Photomicrography:
Preparation of powder samples: Each powdered sample was boiled with a 5 percent solution of potassium hydroxide until thoroughly softened. If the powders were still dark in color approximately 0.5 ml of 10 volume hydrogen peroxide was added and boiling continued until the powders were sufficiently bleached. The contents were poured, after cooking, into a small dish containing distilled water and allowed to remain for about 15 minutes. The powders were then transferred to dilute acetic acid; finally soaked in glacial acetic acid, from which they were transferred to clove oil and allowed to remain until quite cleared. The cleared powders were washed in amyl alcohol, and mounted on a microscope slide in a saturated solution of chloral hydrate in glycerol. This procedure destroys starch grains and calcium oxalate crystals due to solvent action but the remaining structures stand out clearly and can be easily photomicrographed.7
Clearing with Chloral Hydrate
To observe elements such as fibers, vessels and calcium oxalate crystals, the powders were first cleared by boiling in saturated chloral hydrate solution and then mounted in chloral hydrate plus glycerol. Staining by various agents could be done in this mountant. Starch grains were best observed by mounting uncleared powder in aqueous mount with iodine solution.
Preparation of Samples for observation
Several slides of each powdered sample were prepared in different mounting media like chloral hydrate, glycerol, and distilled water. For this purpose, one or several drops of the medium were placed in the center of a clean slide. A small amount of the cleared powder was sprinkled on this fluid. An early cleaned cover slip, held with tweezers, was then carefully placed on the slide starting from one edge in contact with the mounting medium; the glass was then lowered into place. This avoided entrapment of large air bubbles. Small air bubbles were removed by placing the slides in a vacuum desiccator for a short period. Air bubbles from chloral hydrate mounts were removed by repeatedly and gently heating the sample over a micro burner; this produced the desired brightening of the sample at the same time. The chloral hydrate solution was replaced by adding fresh drops on one side of the mount and at the same time soaking the other side with filter paper. By this procedure the oily solution could be removed and replaced by clear mountant. Acetone wash through the mount followed by chloral hydrate solution was absolutely useful. To prevent drying of aqueous and chloral hydrate mounts during observation, a small amount of glycerol was added.11 In all cases, the prepared mounts were observed first under a magnifying glass and then at low magnification (5x, 1Ox) of the microscope. High magnification (40x) was used to observe structural details.12 The primary microscopy was followed by staining with special co l or reagents. The special mountants used are referred to in the appropriate part of the following text. Details of all reagents used are included in the Table No 2.

Results:
Morphological Results:
On detailed study, distinct variations were observed in the morphological characters viz., colour, shape, size of fresh rhizomes and lateral branches along with the colour of the cut surface of cured and dried samples as well as aroma, taste of powdered samples. In most of the samples, the rhizome was branched cylindrical curved shape.
The shape of the rhizomes was found identical in almost all varieties. In all the candidate varieties, rhizome and lateral branches were marked with annular scars covered with scale leaves. The lateral branches were small or large

finger-shaped. The characters such as diameter, colour of the cut surface, aroma etc. of the cured and dried rhizome and lateral branches were also noticed.

The colour of fresh rhizomes of almost all samples was found identical, orange to yellow except the colour of samples like T11 (Yellowish grey), T13 (Reddish Yellow), T4 (Pinkish Brown). The odour or aroma of fresh rhizomes of all samples was found aromatic but it was strongest in case of T23. The highest average length of fresh rhizome was observed in sample of T23 (119.85±24.37mm). The highest average diameter of fresh rhizome was observed in sample T7 (24.18±3.72mm).

After curing and drying, rhizomes of all samples shrunk and tapered with reduced size and found wrinkles on surface. Colour changed to pale brown to dark brown. But the aroma was same, aromatic. The highest average length of cured and dried rhizome was observed in sample T23 (66.3±14.94mm). The highest average diameter of cured and dried rhizome was observed in sample T19 (18.79±1.95mm).

The powdered samples of cured and dried rhizomes showed considerable variations in case of colour, aroma and taste. Yellow colour of powdered rhizomes was identified in case of T7, T11, T9, T17, T4, T22. Bright to Dark yellow colour was observed in case of T7,T14 and T16, T1, T5, T2, T8, T18, T3, T15, T23 whereas orange colour was identified in case of T4, T12, 19 and T21. Most sample candidates were found with aromatic odour with slight difference. T17, T13, T22, T12, T19, T15, and T21 were found odorously strong aromatic. The bitter taste of rhizome was identified in most the powdered samples. Pungent taste was identified in case of powdered samples like T17, T13, T18, T22, T15 and T21.

Figure No. 1 shows fresh rhizomes of Rajapore variety (T7 and T13) from Maharashtra and Karnataka, Salem variety (T10 and T19) from Maharashtra and Tamil Nadu as well as Pragati variety (T8 and T18) from Chhattisgarh and Karnataka which were found almost similar morphological characters. The colour of Rajapore variety from Karnataka found different reddish yellow than Maharashtra. The comparative results were noted and tabulated in Table No. 3.

Microscopic Results:

The photomicrography of all powdered samples was done and observations were recorded photographically. Photomicrographic features of twenty three samples were compared with each other which showed differences in case of all factors which were observed like cork cells, Parenchymatus cells, vascular bundle, trichome, etc. The presence of vessels in samples was commonly found with distinct feature. Starch grains were observed with little variations in case of its shape and quantity.

Longitudinally fractioned cork cells were observed in sample T16 and T11. Brick shaped cork cells were observed in T13, T22, T3, T23, T6 and T1. Polygonal to rounded cells of parenchyma were observed in all samples. But it was not identified in case of T8. Intact vascular bundle was identified in most of the samples with other parenchyma. In case of T16 and T1, vascular bundles were seen attached to cortex cells. In all cases vascular bundle was observed with pigment cells. Vessels were observed in almost all samples. Scaleriform type of vessels was observed in T11, T17, T13, T12, T15, T20 and T21. Annular vessels were identified in case of T6. Very dense oval shaped starch grains were observed in sample of T13. Fusiform shaped starch grains were observed in T7, T11 and T17. Trichomes identified in most of the samples were unicellular, short and straight with acute apex but in case of T14, T18, T22 and T17 it was found long. No trichomes were identified in case of T9, T13, T4, T3 and T6.

As shown in Figure No. 2 and Table No. 1, two samples of Rajapore (T7 & T13), Salem (T10 & T19) and Pragati (T8 & T18) obtained from different geographical locations showed slight variations in their powder microscopy. Cork cells observed in T13 were brick shaped than cork cells of T7. Fractions of cork cells of T8 were found without intact structure when compared with same of T18. Parenchymatus cells observed in T13 were hexagonal in shape and same were found polygonal in T7. Vascular bundles were identified in all of the samples except T8. Vessels seen were simple-fractioned in T7, T10 & T19, scaleriform in T13, long-spiral in T8 and fibrous in T18. Fusiform

starch grains were seen in T7 whereas dense and oval starch grains were observed in most of the samples. Trichomes were not seen in sample T13.

Tables and Figures:

Table No. 1: Procurement of Samples

S. No.	Sample code	Variety	Source (Farmer's Name, Address, and Contact No.)		
Maharashtra					
1	**T7**	Rajapore	Mr. Sudam Mule	At. Lon Bk, Ta. Basmat, Dist. Hingoli (MS) -431512	7387819686
2	**T10**	Salem	Mr. Krishnaji Yadav	At. Po. Ankali, Dist. Sangli, Maharashtra-416416	9145781458
3	**T14**	Krishna	Mr. Vithal Raut	At.Abhaikheda Po. Kolar Manora, Dist. Washim, Maharashtra- 444404	8446043102
4	**T16**	Waigaon	Mr. Arvind D. Kakad	Punoti Kh, Barshitakali, Dist Akola Maharashtra-444401	8010109194
Utter Pradesh					
5	**T1**	Armur	Mr. Satya Prakash Singh	Pokharbhainda, Bankata, Kaptanganj, Dist. Kushinagar, U. P.-274203	8958928747
6	**T5**	Narendra	Mr. Indesh Pandey	Village- Sirhir, Allahabad, U.P-212301	5320102758
7	**T11**	Devi	Shri Ajai Kumar Singh	Bhoji Pura, Ghanghoua Ghanghori, Bareilly, Uttar Pradesh- 243202	7055999555
Odisha					
8	**T2**	Kandhamal	Mr.Tapan Pradhan	At: Kaijanga, PO: Sisilo, Balianta, Dist: Khordha, Odisha 752102	9778982730
9	**T9**	Kedaram	Shri A. S. Samantaray	Dengausta, Pudamari, Berhampur, Odisha -760010	9437233189
10	**T17**	Sudarshana	Mr Dhruba Charan Sahoo	Belpahar, Dist Jharsuguda Odisha- 768218	9938503025
Chhattisgarh					
11	**T8**	Pragati	Mr Surendra Balchandran	Ghortal, Rajnandgaon, Chhattisgarh- 491557	8668230077
Karnataka					
12	**T13**	Rajapore	Mr.Sudesha Mayya	Baevu road Allimaranahalli village, Taluk, Kanakapura, Karnataka-562117	9845243165

13	**T18**	Pragathi	Mr.Sudhakar Sapalya	Kuma, Dharwad, Karnataka 580005	9342103631
14	**T22**	Suguna	Mr.Perne Gowda	Karki, Dist. Hunnavar, Karnataka - 581341	8256265269
Tamilnadu					
15	**T4**	Chinnanandan	Mr. B.Ramanathan	55 East, Agraharam, Kodumudi, Tamil Nadu - 638151	7558109956
16	**T12**	Perundurai	Mr. Senniappan Raju	1/345, KSP Thottam, Perundurai, Erode, Tamil Nadu - 638057	8012285561
17	**T19**	Salem	Mr. K.Balachandran	144 A, Pudur, Panamarathupatty (Po), Salem – 636122.	9443193861
Meghalaya					
18	**T3**	Lakadong	Mr. Lupen Sangma	Near Paromont Market, Priang, Meghalaya- 793150	8014237348
Kerala					
19	**T15**	Muvattupuzha	Mr.K.K.Ravi	Kadathy, Muvattupuzha, Kerala-682316	9847833833
20	**T23**	Alleppey	Mr. Mohammed Jishan	5/1474- A Wayanad Road , Calicut Kerala- 673014	9846389944
Andhra Pradesh					
21	**T20**	Duggirala	Mr. Veerla Venkaiah	Pedapalem, Guntur, Duggirala, Pedapalem, Andhra Pradesh-522305	8186896960
22	**T21**	Amruthpani	Mr. Kondamudi Ramaiah	Ramachandrapuram, Andhra Pradesh- 532432	9550954341
Nagaland					
23	**T6**	Suroma	Mr. Kolom Rabi	KVK, Dimapur, Lumami, Nagaland- 798627	3692268255

Table No. 2: Reagents used

Sr. No.	Reagents	Purpose	Preparation
1	Distilled Water	Cleaning and Mounting of samples	
2	Ethanol	Solvent for staining reagents, softening of materials and cleaning of samples	
3	Glycerol	Mounting reagent	1:2 Solution of glycerol with distilled water
4	Chloral hydrate solution	Bleaching to make tissues clear in appearance	50 g Chloral hydrate dissolved in 50 ml distilled water
5	Iodine Solution	Staining reagent	Dissolved 8.8 g of Potassium Iodide in 30 ml warm water and into that, 2.2 g of Iodine crystals were dissolved

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6	Phloroglucinol-HCL Solution	Staining reagent	0.3 g Phloroglucinol powder dissolved in 10 ml absolute ethanol. To this, 5 ml of conc HCL was mixed.
7	Safranin Solution	Staining reagent	20 mg Safranin powder dissolved in 20 ml distilled water

Table No. 3: Comparative Morphology of *Curcuma longa* Samples of same variety from different places

Sample Code	**Variety (State)**	**Fresh Rhizomes**					**Cured & Dried Rhizomes**				**Powder**		
		Colour	**Odour**	**Shape**	**Avg Length in mm**	**Avg Diameter in mm**	**Colour**	**Odour**	**Avg Length in mm**	**Avg Diameter in mm**	**Colour**	**Odour**	**Taste**
T7	Rajapore **(MH)**	Orange to greyish yellow	Aromatic	Cylindrical, Finger like, Branched	110.6± 52.32	24.18 ±3.72	Pale Brown	Slightly aromatic	59.53± 15.33	17.66± 2.05	Yellow	Aromatic	Bitter
T13	Rajapore **(KA)**	Reddish Yellow with brown circular ridges	Aromatic	Fingers Curved & Cylindrical	101.16 ±14.75	21.18 ±3.88	Blackish Brown, Wrinkles on surface	Aromatic	57.41± 21.63	16.53± 2.79	Orange	Strong Aromatic	Strong Bitter, Pungent
T10	Salem **(MH)**	Orange to Grayish yellow	Aromatic	Cylindrical, Finger like, Branched	101.4± 35.49	19.37 ±7.63	Brown	Aromatic	44.38± 11.58	17.01± 2.41	Dark Yellow	Aromatic	Bitter
T19	Salem **(TN)**	Orange Yellow	Aromatic	Cylindrical, Branched	107.52 ±17.22	22.76 ±3.21	Dark Brown, Wrinkles on surface	Aromatic	52.46± 14.68	18.79± 1.95	Orange	Strong Aromatic	Bitter
T8	Pragati **(CH)**	Orange Yellow mixed with	Aromatic	Cylindrical, Branched	116.77 ±18.41	23.75 ±4.42	Dark Brown, Wrinkl	Aromatic	62.77± 18.44	18.02± 2.49	Bright Ye	Aromatic	Bitter

		grey tubers					es on surface				llow		
T18	Pragati **(KA)**	Orange	Aromatic	Cylindrical, short branched	106.76 ±19.11	22.18 ±4.01	Brownish, Wrinkles on surface	Aromatic	60.22± 18.54	18.44± 1.75	Dark Yellow	Aromatic	Bitter, Pungent

'±' indicates standard deviation. **MH-** Maharashtra State, **KA-** Karnataka, **TN-** Tamil Nadu**, CH-** Chhattisgarh

.

Table No. 4: Comparative Microscopic Characters of Powdered Turmeric Samples of same variety from different places

Variety	**State**	**Sample Code**	**Cork Cells**	**Parenchymatus Cell**	**Vascular Bundle**	**Vessels**	**Starch Grains**	**Covering Trichome**
Rajapore	**MH**	**T7**	Thick walled, Polygonal	Polygonal	Intact	Fractions	Oval to Fusiform	Unicellular, Short length
	KA	**T13**	Brick Shaped	Hexagonal to Polygonal	Intact, transversely cut	Scalariform	Very dense oval shaped	Not seen
Salem	**MH**	**T10**	Thick walled, Rounded cells	Polygonal	Seen with pigment cells	Fractioned vessels seen	Oval & dense	Unicellular, Short, Straight with acute apex
	TN	**T19**	Polygonal, Thick walled	Polygonal to rounded	Intact with parenchyma	Fractions & simple	Oval & dense	Unicellular, short
Pragati	**CH**	**T8**	Fractions of cork cells	Shape not identified	Not identified	Long, spiral vessel fibers seen	Oval to irregular	Unicellular, short, Straight with acute apex
	KA	**T18**	Thick walled, polygonal	Polygonal	Intact vascular bundle	Fibrous	Oval to irregular	Unicellular, long, Straight

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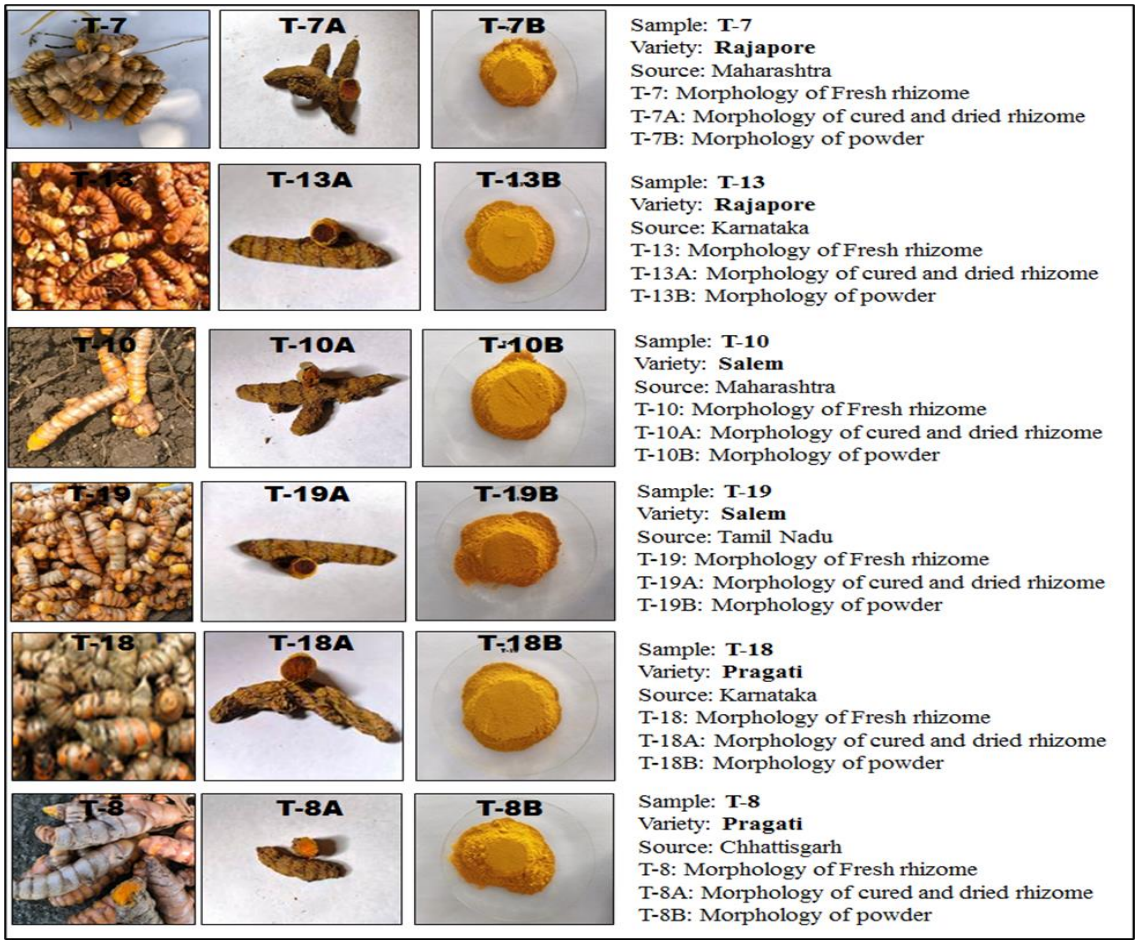

Figure No. 2: Comparative Photomicrographs of Powdered Turmeric Samples of same variety from different places

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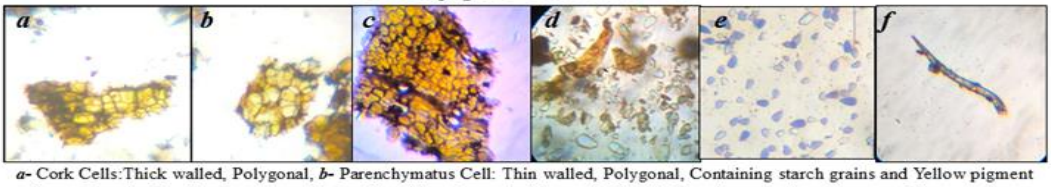
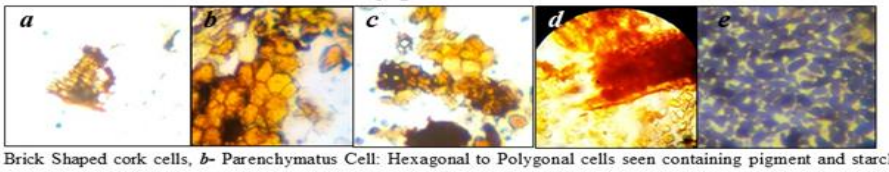
T7: Rajapore- Maharashtra



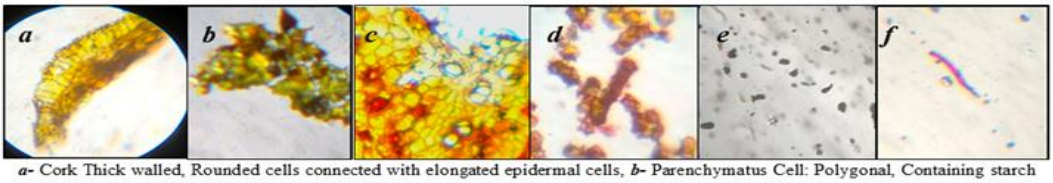
a- Cork Cells:Thick walled, Polygonal, *b-* Parenchymatus Cell: Thin walled, Polygonal, Containing starch grains and Yellow pigment cells, *c-* Vascular Bundle: Intact vascular bundle with xylem and phloem, *d-* Vessels: Fractions of sclerenchymatus fiber vessels , *e-* Starch Grains: Oval to Fusiform, *f-* Covering Trichome: Unicellular, Short length, Curved at base, very less in number

T13: Rajapore- Karnataka



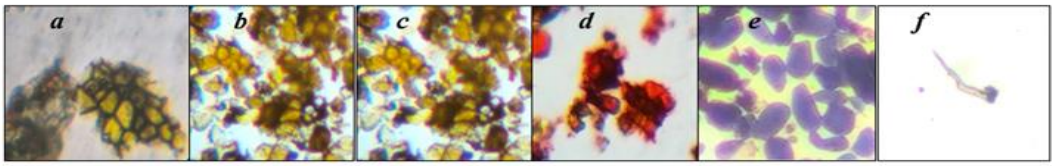
a- Cork Brick Shaped cork cells, *b-* Parenchymatus Cell: Hexagonal to Polygonal cells seen containing pigment and starch grains. Stone cells and cells containing oleoresin also seen, *c-* Vascular Bundle: Intact Vascular bundle transversely cut seen with pigment cells and other parenchyma, *d-* Vessels: Scaleriform vessels Scattered with other Parenchymatus cells, *e-* Starch Grains: Very dense oval shaped violet starch grains were seen when fine powder treated with iodine solution.

T10: Salem - Maharashtra



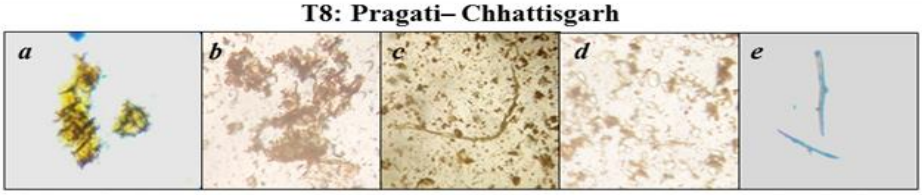
a- Cork Thick walled, Rounded cells connected with elongated epidermal cells, *b-* Parenchymatus Cell: Polygonal, Containing starch grains and Yellow pigment cells seen with stone cells, *c-* Vascular Bundle: Vascular bundle with pigment cells and other cortex cells, *d-* Vessels: Fractioned vessels seen, *e-* Starch Grains: Oval shaped and quantitatively less, *f-* Covering Trichome: Unicellular, Short, Straight with acute apex

T10: Salem – Tamil Nadu



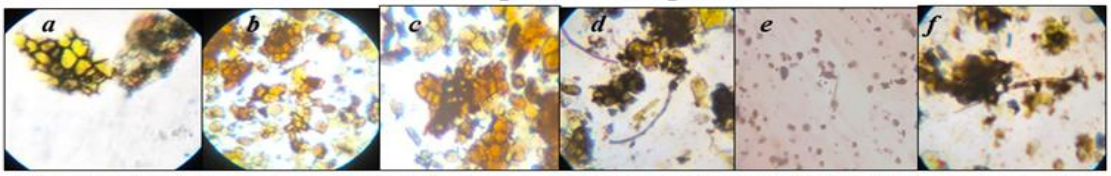
a- Cork Polygonal, Thick walled outer cork cells attached to cortex, *b-* Polygonal to rounded cells seen containing pigment and starch grains. Stone cells and cells containing oleoresin, *c-* Vascular Bundle: Transverse fraction of Vascular bundle seen with pigment cells other parenchyma, *d-* Vessels: Fractions of simple vessels, *e-* Starch Grains: Oval to irregular shaped starch grains, *f-* Covering Trichome: Unicellular, short, with acute apex

T8: Pragati– Chhattisgarh



a- Cork Fractions of cork cells, *b-* Parenchymatus Cell: Shape not exactly identified but pigment cells and starch grains seen with Stone cells and oleoresin cells, *c-* Vessels: Long, spiral Sclerenchymatus vessel fibers seen, *d-* Starch Grains: Oval to irregular shaped starch grains and quantitatively high, *e-* Covering Trichome: Unicellular, short, Straight with acute apex

T18: Pragati– Chhattisgarh



a- Cork Thick walled, polygonal outer cork cells attached to cortex, *b-* Parenchymatus Cell: Polygonal Parenchymatus cells seen containing pigment and starch grains. Stone cells & oleoresin cells, *c-* Vascular Bundle: Vascular bundle seen with resin and oil cells, *d-* Vessels: Fibrous vessels , *e-* Starch Grains: Oval to irregular shaped starch grains, *f-* Covering Trichome: Unicellular, long, Straight with acute apex

Discussion:

All twenty three varieties of *Curcuma longa* obtained from ten different states of India showed morphological similarity in case of shapes but variations in colour, aroma and size. After curing and drying, rhizomes of all samples showed shrinking in size and wrinkling on surface. Cured and dried rhizomes when powdered showed remarkable morphological variations like difference in colour, aroma and taste. Powder microscopy showed variation in colour and type of vascular elements present in the varieties. The study showed the presence of scaleriform vessels and long, narrow fibres in all the candidate samples. It was observed that presence of vessels might be a diagnostic feature in the identification of powder of Curcuma longa. In the present study, compact, brick shaped cork cells were observed in some samples. Almost all the parenchyma cells of ground tissue were packed with starch grains. The starch grains were simple, big, with different shapes such as oval, fusiform, and irregular. The shape of the starch grains varied remarkably and possesses a slight projection at one end. Very dense oval shaped starch grains were observed in sample of the variety Rajapore which was obtained from Karnataka. Maximum number of oleoresin cells was found in all samples which justifies the bright yellow colour of the rhizomes. Many parenchymatous cells possessing yellow -orange content were identified in all the varieties as curcumin cells and oil cell.

Conclusion:

Twenty three rhizome samples of different varieties of *Curcuma longa* were subjected to morphological and anatomical analysis. Comparative morphological study of the rhizomes of all samples revealed that it has yellow colour, aromatic odour and bittery taste. The microscopic comparison revealed that the elements like pigment and oil cells in parenchyma, vascular bundles, and types of vessels, appearance of trichomes, shape and density of starch grains can be used to differentiate the quality of *Curcuma longa*. The morphological and microscopical variations seen in same varieties obtained from different geographic locations were considerable.

Conflicts of Interest:

The authors declare that there is no conflict of interest.

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