



Received on 17 October 2018; received in revised form, 21 January 2019; accepted, 20 May 2019; published 01 June 2019

AUTHENTICATION OF SEVEN INDIAN TRADITIONAL TYPES OF THE HERBAL DRUG *TERMINALIA CHEBULA* WITH SCIENTIFIC UPDATES – AN ADVANCED INSIGHT

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Keywords:

Authentication, Indian medicine, *Terminalia chebula*, Adulterants, Phytochemicals, Purgation

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ABSTRACT: The fruit of *Terminalia chebula* is an essential drug used in single and in many compound formulations of Indian traditional systems like Ayurveda & Siddha and Unani systems of medicine. This herbal drug is referred to as ‘The king of medicines’ which denote it’s efficacy and potency in treating diseases. The TCF is the richest source of phenols among other plants and is cherished with lead active ingredients with high scope for drug discovery for a spectrum of diseases because of the five tastes except for the salty taste in it. As global acceptance of traditional drugs increase in the past decades, compliance with the quality in terms of standard parameters and regulatory laws on the drugs also are sharpened. Drugs of poor quality degrade the clinical efficacy and also create a query on safety concerns. Authentication of a drug to be a genuine variety is of prime importance in standardization. *Terminalia* sps. are numerous. Seven types of medicinally useful TCFs are mentioned by the Siddhar (sage) Agathiyar based on regional morphological characters and the severity of purgative activity of the types also varies. There are other *Terminalia* fruits with similar actions of TCFs specific to various Indian geographies. Chances of adulteration and substitutions become high. Hence, authentication of TCFs is tedious and this literary study is an insight into the types with scientific updates. The study also provides a preliminary review to identify the fruit odor based induction of purgation.

INTRODUCTION: Identification is the key to standardize a drug. Existence of medicinal use of *Terminalia chebula* fruits (TCF) and dates back to 4000-6000 BC (Rigveda) ^{1,2,3,4} and before 4000BC (Siddha) ⁴. Indian Scientists has recognized it as an official drug and the monograph is included in Ayurvedic, Siddha pharmacopeias of India ⁵ and is also standardized by Unani system ⁶. Gallic acid is one of the phytochemical reference substance (PRS) for TCFs ⁷.

Seven types of TCFS have been stated in *Ayurvedic Nighantus* ⁸ and *Agathiyar Gunavagadam* ⁹ along with the references of regional occurrence including forest and mountainous types and some botanical identities. The TC trees are native to Indo Burma region ¹⁰.

The starting of deforestation by shifting cultivation (burning of forests for farming) dates back to 7000 BC (Neolithic period). The rich biodiversity of India has 6 major and 16 subtypes of forests ¹¹. Present day statistical data recorded the conversion of evergreen forests to deciduous forests. The changes in the geographical and political boundaries (*e.g.*, Pakistan, Myanmar, and Bangladesh included in India before independence) and the evolutionary impact of climate on

<p>QUICK RESPONSE CODE</p> 	<p>DOI: 10.13040/IJPSR.0975-8232.10(6).2670-87</p> <hr/> <p>The article can be accessed online on www.ijpsr.com</p> <hr/> <p>DOI link: http://dx.doi.org/10.13040/IJPSR.0975-8232.10(6).2670-87</p>
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vegetation over these centuries on the biotypes of TC poses queries on the availability and selection of genuine type among adulterant and substituent of the herbal drug. In this context, there is a lack of reliable record based on traditional claims. But all the seven types mentioned in the literature are indicated to be medicinally useful.

Authentication is also essential to classify and use the specific drug for specific use; when indicated, internal or external or for rejuvenation (Kayakalpam and vayasthapan karma in Siddha and Ayurvedic terms respectively) to extract the best benefit. So, an update is essential scientifically to

validate the claims in the traditional texts (Siddha and Ayurveda) and the speciality of each type.

MATERIALS AND METHODS: Reviewing of Siddha classical texts, Siddha and Ayurvedic pharmacopoeias and scientific research publications available online in modern medical databases. The criteria included were types of TCFs, adulterants, and substituent, climatic and vegetation types of India, soil types and rainfall in each type of biogeography, morphological characters, phytochemical with relevant pharmacological activities, antioxidant in particular and the studies on purgative and anthelmintic activity of the TCF.

RESULTS: Various shapes of *Terminalia chebula* (A- G).



A Pear shaped (Unripe to ripe)



B Round Unripe



C Fleshy (Bulky)



D Elongated unripe



E Elongated (dried)



F Bulky dried



G Black



H Ripening fruit



I *T. pallida*

TABLE 1: CLASSIFICATION: TYPE I BASIC GEO TYPES IN SIDDHA WITH ANCIENT INDIAN HABITAT, MORPHOLOGICAL CHARACTERS, TYPE II ORGANOLEPTIC CLASSIFICATION AND MEDICINAL USES⁸

I. Basic types	Region	Character	Colour	Medicinal Use	II. OLC*	Medicinal use suited/not
Vijayan	Avanti	The shape of Bottle guard (Pear shape)		Vali Noi and all other diseases	K	✓
Arohini	Kanya kumari	Round, Small fruit with bigger seed		Muppini (Delirium) Iyyam (Eelai) Noi (Kapha) external application for ulcers	P, S, V (R✓) V(appetizer)	✓✓✓
Pritivi	Saurashtra	Thin Outer skin		Azhal noi (Pitha), Indicated for rejuvenation	P, K, S	✓
Amritam, Cedhagi	Khasi	Fleshy (bulky)	White (6 inches) and Black (1 inch)	Alleviates Iyyam (Kapha). Good for emaciation due to medications	P (K✓) (R✓)	
Ceevanti Aridhagi	Forest		Golden yellow color	Moolam (Piles)	P (Indigestion present with constipation) (R✓)	✓ (laxation treat piles)
Tiruvruti Mondhan	Mountain		Five colours	Treatment of ulcers	(R✓)	
Abayan	Podhigai Mountain	Varatchi gunam (dry)	Black, 2 inches	Eye Diseases, Expectorant, Laxative	(K✓) (R✓)	✓

TABLE 2: ANCIENT HABITAT OF TCFS IN PRESENT DAY INDIAN REGIONS WITH INFLUENCING FACTORS AND REGION SPECIFIC NATIVE *TERMINALIA* SPECIES

Origin and available research updates for biogeo types	Vegetation ¹¹	Altitude 1500 - 1600m ^{9, 12} and height ⁵	Ridges Keetru (Base to apex)	Rainfall in cm	<i>Terminalia</i> species in respective regions ^{9, 13, 14, 15, 16}
Vijayan around Vindhya mountains (south-eastern Rajasthan, west Madhya Pradesh, and adjoining Madhya Pradesh), west Satpura	West Tropical dry deciduous and east moist deciduous on deep black soils	450, (1,048)		80-120	Var. <i>chebula proper</i> (an ellipsoidal shape with broad base) 5 ribbed at 3000ft (900m) Size-1 to 1 1/2 inch. Abundant in North India. 2. Var. <i>Typica</i> : Deccan (Mostly dry deciduous) ceylon, Burma) young ovary and are shaggy without calyx teeth. <i>T. alata</i> , <i>T. tomentosa</i>
Arohini Kanya kumari (South India) Trichy, Chennai, Kanchipuram, Sivagangai Salem, Namakkal ^{17, 18} Andhra Pradesh ^{15, 19, 20}	Tropical dry deciduous. Mostly scattered in dry savannah forests and moist forests (Non Sal)	400 (1450)	4	(60-105) and 100-150cm	Var. <i>Pallida</i> (Canopy tree 600-800m) (South Andhra Pradesh, Maharashtra, Tiruvannamalai, Vellore and not in Kanyakumari (faintly ridged Calyx triangular teeth)-pal kadukkai, vellai kadukkai, aiyam, niravium, palsandhidham <i>T. tomentosa</i> , <i>T. alata Terminalia tomentosa</i> , <i>T. chebula</i> ²¹
Pritivi (Udhaipur) Rajasthan & Gujarat, Punjab, Western Haryana	North Thorny (Semi arid) G-south Moist deciduous mixed	200		Less than 25 & 25 to 50/60	
Amritam, Sethagi Uttarakhand, Uttar Pradesh (Khasi and outh varieties), Bihar, eastern Madhya Pradesh (east- cedi) (Rewa ²² , Satna ²³ , ²⁴), Orissa Bengal, Assam (Himalayan- south Kashmir Himachal ²⁵ Punjab and Kumaun	1. North Indian Moist deciduous (Khasi) others moist evergreen 2. Montane subtropical, Temperate, Himalayan eastern wet & western moist temperate	1500 -1800, 1300- 2100HP [†] and 1000- 2000SH [‡] 500NE 450CI [¶] and height Khasi 40m, EH [§] 25m	3 (Sedhaghi)	1. Fair (Khasi 120-250) 2. 300 or scanty	Var. <i>chebula proper</i> . Himalayas & abundant in North India. <i>Terminalia tomentosa</i> . Var. <i>Citrina</i> (syn. <i>Terminalia multiflora</i> Merr). Kumaon to Bengal. chhotanagpur. Assam and Bengal. Young ovary, are quite glabrous, with ovate fruit and a round base. 2. Only in Bihar- <i>T. chebula</i> (Var.): The fruits of these are much smaller than the other variety at 1000 ft (33m). Bihar and Orissa <i>T. alata</i> and <i>T. pallida</i> <i>T. alata</i> and <i>bialata</i>
Chotta Nagpur, Visaka pattinam, Orissa, West Bengal, Assam,	Moist evergreen			100-200 cm	

Ceevanthi (Aridhagi)	(Wild variety & subtropic dry deciduous)			80-120 cm Less Rainfall	
Thiruvruthi (Mondhan) Assam and associated mountains	Tropical wet/semi-evergreen & moist deciduous	tall, ≥ 45 m& 40 m	5	More than 250cm	Viruthi, irali, Burma (<i>T. tomentella</i>) ¹⁶ Indo Malaysia, Tibet
Abayan Western ghat ("hottest hotspots" of biological diversity in the world.) Coimbatore gigantic size. Tirunelveli, Palani, Theni, Rajapalayam, Sagar shimoga Karnataka forest (Mysore alone), Ahmedabad, Mumbai, Pune (Maharashtra), some parts of Madhya Pradesh ²⁶ and some parts of Gujarat ²⁷ Andaman	Tropical wet evergreen in specific. Semi-evergreen surrounded by Tropical moist deciduous	1450 m tall, ≥ 45 m& 40 m	5	More than 250-300 & 200-250	<i>Terminalia travancorensis</i> in Nilgris and Tirunelveli-Pei kadukkai/ kaattu kadukkai 35m height, <i>T. paniculata</i> (Evergreen forest) ven marudhu, Ilaikadukkai & <i>T. alata</i> . <i>T. crenulata</i>

***OLC-Organoleptic classification: 7 types sorted into 4 types:** 1. Karunkadukkai (K) (Black) 2. Senkadukkai (S) (Yellowish/Reddish) 3. Vari (V) (Ridged) 4. Paal kadukkai (P) (Milky/tender). The 4 types with direct reference based on indicated organoleptic characters *e.g.*, (K✓) & use suited with 7 types/not (✓) and if so the disease is projected bold. For physical vitality & mental clarity, Rejuvenatory (R) is used.

*Formation-types recognized in the Himalaya compared with the vegetation-types recognized by Champion and Seth (1968) (Source: Singh and

Singh, 1987), Duthie’s Flora of the Upper Gangetic Plain and of the Adjacent Siwalik and Sub-Himalayan tracts, (1903-1929) covers some parts of North & West Vindhyan range including Satna district²⁵.

†HP - Kangra Dt, Himachal Pradesh

‡SH - Sub Himalayan

§EH - Eastern Himalayan

||NEH - Northeast Himalayan

¶CI - Central India

TABLE 3: AVAILABLE EVIDENCES ON ANATOMICAL INVESTIGATIONS OF TCFs

Regional Reference	Od	Colour	Shape	Size (Cm)	Taste	Surface Characteristics
Delhi Yadav Babita <i>et al.</i> , 2011 ²⁸		yellowish – brown	Ovoid	L (1.3) B (2.5)	Ast	Wrinkled and ribbed longitudinally. Fibrous pericarp not adherent to the seed.
Udaipur, Rajasthan Manish Pal Singh, 201 ²⁹	A	Yellowish green to Yellowish-brown	Ovoid	L (3.3- 4.2) B (1.5 to 2)	Ast or Bitter or mixed with sour	Longitudinally ribbed
Varanasi Akhilesh Kumar <i>et al.</i> , 2017 ³⁰	P	Yellow, Brown	Ovoid	L (2.2-3.5) B (1-2.5)	Ast	Wrinkled and ribbed, Pericarp 3-5 mm
Jeypore, Odissa Powder Hardel Danendra kumar, 2012 ³¹	-	Dark brown			Ast	Wrinkled, (5-6)
Karnataka Subha, S <i>et al.</i> , 2016 ³²	A	Red tinge	Ovoid	L(3.1 4.18) B (2-2.71)	Ast, Bitter, some sour	Tapering one or both end
Kancipuram Ashok Kumar D, 2007 ³³	A	brown in color	Ovoid	L (2- 3.5) B (1.3 to 2.5)	Ast and slightly sweetish	Wrinkled longitudinally, Hard and strong

Odor- Od, Present-P, Absent-A, L-Length, B- Breadth, Ast-Astringent

TABLE 4: EFFECT OF GEOGRAPHICAL VARIATION ON THE MAIN CHEMICAL CONSTITUENTS OF TCF AND THE RELIABILITY ON THE METHOD OF CLASSIFICATION³⁴

Indian geo type	TA (21-42)	GA (0.82-1.44)	EG (0.75-1.74)
Vijayan	MP Mx	MP Mx	MP- 1.08 Mn
Arohini		KA Max	
Prithvi	G More than 40	G 1.3	Mn
Amritham	UL Mn	UL & N Mn	JH & JH Max, N H
Ceevandhi	UP HMd	UP HMd	UP HMd
Thiruvirudhi	A Mn		AMn
Abayan		KL HMd	

TA- Tannic acid, GA- Gallic acid, G- Ethyl gallate, MP- Madhya Pradesh, JH- Jharkhand, N-Nepal, UL- Uttarakhand, KA- Karnataka, G- Gujarat, KL- Kerala, Max-Maximum, Mn-Minimum, Md- Moderate HMd- Higher moderate

TABLE 5: FLAVONOIDS AND TERPENES BIOSYNTHESIS RELATIVITY WITH COUMARINS^{35,36}

	Flavonoids (15C)	Terpenes (HC)
1	Action: UV filtration, nitrogen fixation, and floral pigmentation	Simple triterpenes (30C) wax and specialized membranal components acting as signaling molecules, complex glycosylated triterpenes protect against pathogens and pests
2	Ketone containing compounds & phenylpropanoid-derived plant metabolites. Nonketones are flavanoids. Neo flavanoid-coumarin containing benzo pyrones. coumarin with gallic acids (chebulin). Catechins (flavonoids)	Nonflavonoids (e.g., triterpenes or coumarins). Resin Glandular Trichomes produce terpenes (cannabis). Non-glandulars produce cystoliths
3	Rutin, 2 methoxy quercetin, etc.	Ursolic acids, chebuloside II, arjunolic acids and associated with Beta amyryn
4	Mechanism: 4-coumaroyl-CoA enters the flavonoid biosynthesis pathway- Fe ²⁺ involved. Transferases modify flavonoid backbone with sugars, methyl groups and acyl moieties, modulating solubility and activity	Cyclization, Scaffolding (waxes), modification involving P450 (oxygenation) and glycosyltransferase genes (α -amyryn, lupeol etc.) Glycosylation (saponin) isoprenoids (Sterols and triterpenes) synthesized via the mevalonate pathway. Exist as glycosides, not simple. OH and carboxyl groups' incorporation (called acetals and esters). Acylated anthranilates are antimicrobials. C-21 acylation is common in cytotoxic triterpene glycosides. Sugar chains provide metabolic diversification

TABLE 6: ASSOCIATION OF TCF AROMA WITH PHYTOCHEMICALS – REGIONAL UPDATE

TCF	Present Indian region	Phytochemicals			
		Sn/Aq/Ac/Q/D	GI	Flv	T/TT
Vijayan					
Arohini	Telangana ³⁷			Qn	
	Trichy ³⁸		A	P	
	Chennai ³⁹		A		
	Namakkal, Kolli hills ⁴¹	Q+ Aq-A	GI- Car GI+ ⁴⁰	+	
	Kanchipuram ³³	Sn-A	P	P	T
Pritivi	Udaipur ²⁹		A		
	Gujarat, Vadodara ⁴²	Qo- A (young)	P		
	Chandigarh ⁴³		P	A	TT
	Ahmedabad seed ⁴⁴	Qo-P		P	A
	Ahmedabad Local Market ⁴⁵			P	
	Ahmedabad ⁴⁶	Aq Big - ^		P	A
	Ahmedabad TPC ⁴⁷	Sn-P			
Amrita	Lucknow ⁴⁸	Sn A			TT
	Rewa Dt of MP- May-June 2007 ⁴⁹	Anthelmintic			No PCS
	Hamirpur, Himachal Pradesh ⁵⁰		P	P	
	Hamirpur, Himachal Pradesh ⁵¹			P	
	Varanasi ⁵²		P	P	

Ceevanti/Aridhagi Tiruvruti/Mondhan Abayan	Chandigarh ⁴³		P	A	TT
	(fresh) Savar, Bangladesh ⁵³		A	P	TT
	Dhaka-Bangladesh ⁵⁴			P	
	West Bengal ⁵⁵			P^	
	West of Westbengal		P		TT
	Bankura ⁵⁶				
	Visakhapatnam ⁵⁷			Qn	
	Agasthyamalai Hills of Tirunelveli Dt ⁵⁸	Qo-P	Car Gl^	A	A
	Rajapalayam, Sivakasi ¹⁹	Qi-P	P	P	
	Maharashtra-Akola, Ahmed Nagar ⁵⁹		Car Gl	P	T
	Aurangabad, Maharashtra ⁶⁰			P	DT-A
	Sagar (WG) Karnataka ⁶¹			P++	T+++
	Udipi, Karnataka ⁶²	Qo-A	A	A	T-A
	Mangalore ⁶³		P	A	TT
	Karnataka Coimbatore ⁶⁴		P	A	T^
Erode Siddha medical center ⁶⁵			P	T	

Sennosides- Sn, Anthraquinones- Aq, Anthracenes- Ac, Quinones- Qo, Quinine-Qi, Diones- D, Increased-^, Present - P, Absent – A, Glycosides – Gl, Flavonoids- Flv, Quercetin- Qn, Terpenes- T, Diterpene- DT, The degree of activity: Weak +, Moderate+, Strong +++. Left blank –The analysis does not include the photochemical

TABLE 7: REGIONAL PHYTOCONSTITUENTS (PC) AGAINST THE TYPES WITH MEDICINAL USE AND SPECIALITY(S)- A CORRELATION³⁴

Medicinal use	TCF type	S	PC	Similar type
Direct mention of the odor as evidenced in classical texts ⁵	Amrita	Smell	EG(Ostwald like ripe)	Ceevanthi ⁹
1. Black variety, stronger purgative against chronic unexpelled old stools 2. Direct mention as best purgative). 3. Gigantic trees in WG. Var. <i>travancorensis</i> in WG- Peikadukkai (Pei Ghost)	Abayan		(Black unripe) GA	No reference as var. <i>travancorensis</i> considered as an adulterant and also not mentioned in the Hooker’s classification
Direct mention of external application in the treatment of ulcers	Arohini (Both int and ext), Thiruvrithi	Touch-ulcers	Moderate tannin, EG less (Salts and esters)	Kalika (Arohini like in Orissa), Putana
Direct indication of treatment of muppini (tridosha-Arohini) and all diseases which are humour based (Vijayan)	Arohini	Ext appl Intake	Both tannin and GA high GA High	Vijayan (TA GA & EG sufficient)

Ayurvedic Reference: 1. Vijaya – used for sarvarog (all diseases) 2. Rohini – used as varan (bearing wound healing property) 3. Putana – used as pralepa (external applications) 4. Amrita – used for shodhan (purification procedures) 5. Abhaya – used for netrarog (eye diseases) 6. Jivani – used for sarvarog (all diseases)⁶⁶.

DISCUSSION:

Unique TCFs among other Terminalia species in India: Siddhar Agathiyar honors it to be superior to

a mother. Digestible nutrients of TCFs can save the body immediately. An anti-anaphylactic drug^{68, 69} and a strong antioxidant, useful in mental ill health and cancer. It is an adaptable kayakalpa tree better tolerating to extreme biodiverse climates in India.

T. chebula is unique among 18 other species embryologically (Venkateswarlu & Rao, (1972). Two chemical markers found in common to *T. arjuna* are also significantly higher in *T. chebula* along with other markers making the TC dominant,

and this is explained by the Principle Component Analysis (PCA) scores plot where the chebula was relatively at a distance from the Arjuna⁶⁷.

Biodiversity of TCFs and the maturity dependent phenotypic images⁴² are documented in Wealth of India, 2004 and the general anatomical investigations including the history of nomenclature is also documented⁷⁰. The status of nomenclatures: Accepted names are *T. chebula* Retz. (Ayurvedic Pharmacopoeia of India)⁵, *T. chebula* var. *Tomentella* (Kurz) C. B. Clarke and *T. chebula* var. *chebula* is the synonym (www.theplantlist.org).

Traditional Descriptions Correlating with Vegetation, Morphological Characters, Edaphic Factors, and Scientific Updates: The seven varieties (I) of TCFs that can be rearranged to 4 varieties (II) based on organoleptic characters are categorized in **Table 1**. **Table 2** enumerates the impact of the environment on the morphological characters. The present-day science recognizes this fact⁷¹. The ancient classical habitat is represented as present-day Indian regions to enable easy understanding and for better correlations of any parameter discussed and the **Table 2** also provide a preliminary clue to differentiate the original variety from the substituent and adulterants specific to regions.

Conclusive vegetative terms of TCF types: 1. Temperate montane of very high altitudes and associated broad leaf moist deciduous of north 2. Montane and evergreen North East. 3. Dry deciduous of north, 4. Dry deciduous of North West, 5. Central dry deciduous west (and the eastern broad-leaved) 6. Tropical evergreen with moist deciduous, of the South 7. Dry deciduous of the South.

It is observed from the **Table 2** that in the areas of higher rainfall (around 250 cm and above) the TCFs presented with 5 ridges, fair rainfall (100-150 cm) with 4 ridges and scanty rainfall at higher altitudes with 3 ridges namely evergreen and moist, dry deciduous and temperate montane.

Ceevanti occurred in forests and sorted in the present study under dry deciduous of the north because of the research updates proving the wild habitat nature of TC trees in the north. They are

found scattered in the dry deciduous of the south (Arohini). Rohini has its habitat in the Zansi of Uttarpradesh^{72, 73}. Rohini in Indian astrology depicts the moon's nature and well-defined behavior. Round in shape, the moon has control over the mind. Indian systems pivot on a sound mind in a sound body. These explain the specificity of naming and use in north India. Arohini is found in the south. This name implies two observations regarding authenticity. 1. Arohini prescribed for Delirium (Agathiyar Gunavagadam) where the tridoshas are disturbed, leading to the ill-defined behaviour of the patient. Arohini samples from Thiruvannamalai showed the presence of OH groups by FTIR analysis which may represent the mannitol (TCF constituent) which is an osmotic laxative used in delirium⁷⁴. 2. Rohini also refers to the medicinal tree with vernacular name Kabila maram (Kabila denote yellow/ yellowish brown), naravam. Arohini is the variety which is not yellow. 'Ni' refers to 'leave off' colour & neer - water, Aavi- to evaporate. The Niravium is *T. pallida* is the (colour/ evaporation) pale variety which is found in Thiruvannamalai.

The golden yellow fruits are specific to ceevanti. Ceevanti (Haritaki) Ceevanti in Tamilnadu is with yellow flowers. Sufficient yellow crystal anthraquinone embedded fruits tend to be yellow. But ceevanti originate in deserts. Cev in Hindi denotes the pain and anth, the end. So a pain reliever useful in piles **Table 1**. Siddha literature denotes the Saurashtra variety under pritivi. Research evidence show the presence of yellow varieties in the Saurashtra region. So, the dry deciduous of the north including North West is to be under ceevanti type, and dry thorny regional fruits of the same region are to be accepted as pritivi type (Sandy deserts).

If the southern region is moist deciduous (Vadodara, Gujarat), it is then included in the Western Ghats. Ceevan/Jeevan – denote the soul. Kaya kalpa targets the enlightenment of the soul. Pritivi aid kayakalpa. Quinones are electron acceptors, the oxidoreductases (Morre DJ, 2004). Plasma membrane quinones serve as lipid soluble transmembrane shuttles (along with vitamin K, and a cytochrome b56) to transfer the $2H^+ + 2e^-$ from cytosolic NAD(P)H to $1/2 O_2$ to form apoplactic water (oxidation)⁷⁵ and these electron acceptors

when involved in photosynthesis aid the formation of vitamin K. P. coumaric acids are reported in intermediate unripe and ripe stages of the fruit. But quinones are absent in young samples of Vadodara, Gujarat⁴². The Udipi, Karnataka variety of Abhayan, in spite of showing the absence of glycosides, quinones, flavonoids, terpenoids, showed positive results for coumarins⁶².

Fruits grown under such thorny region of very scanty rainfall and high temperatures do not attain bulky appearance and obtain only a tiny pericarp. During the maturity of this pericarp, all available of anthroquinones might undergo rapid conversion to p coumaric acids followed by caffeic and ferulic acids (but absent in another study⁴² and then to Vanillic acids (diversion from the formation of lignin in parenchymatous tissues of dicots) in high temperatures and rapid ripening. Vanillic acids are high in female ginseng (*Angelica sinensis*) roots recognized for improving general well being⁷⁶. It is worth mentioning about the Indian ginseng Amukkara/Aswagandha at this point. No doubt ceevanti is a vitalizing herb.

Unmodified Coumarins as it occurs in plants, reduce clotting time without involving vitamin K coagulation (en.wikipedia.org)^{77, 78}, Ramesh & Pugalendi (2007)⁷⁹ and help improve blood circulation. Fruits of tropical dry deciduous south are small without fleshy pericarp and appear to be with bigger seeds. Fruits of subtropical dry deciduous being round should be proportionately normal (comparatively high concentration of anthroquinones) favoring slow ripening than thorny types due to temperature difference with yellow color retained to much a longer time. So the name ceevanti is honorary to dry deciduous type and rejuvenating action to pritivi.

Mondhan (Thiruvruthi) - cultivated types of banana and the sage Agathiyar might have followed the same in terming the cultivated varieties of TCFs like Tibetan, Chinese, Australian and Malaysian varieties, etc., the yield with uniform morphology. India is one of the eight vavilov's centers of origin of cultivated plants in the world⁶ and the Assam region may be more suitable for such cultivation as five types of major vegetation occur and this coincides with the five colors of TCF. Magnitudes of variability assessed through genetic studies on

TCFs have revealed that within-population source variation was high from tree to tree. The authors suggest the clonal propagation be effective for further domestication and improvement⁸⁰.

This study, with deep insights identifies the Type II classification to be based on the maturity of the fruit alone through an overview let them be on the organoleptic basis. Karunkadukkai (Black variety)-unripe green falling downturns black on drying. Colour effect prominent than the ridges. This is common in heavy rain and high temperature in evergreen and dense forests. Tannin is found especially in unripe fruits of *T. chebula*. The immature fruits are black. Senkadukkai (semmai-well formed/digestible) unripe to ripe – yellow/ maybe with a red tinge. This may turn brown on drying. Vari (ribbed) fully ripe dry variety with wrinkles. Paal kadukkai- white/ milk like variety (Milky refers to childish type): Sethagi⁹ may be elongated Himalayan variety under extreme cold with scanty rainfall.

Raj Harad is 8.5 cm in the North West Himalayas, 16 km north to Jammu District headquarter at the border with Rajauri Dt. Elevation 402 m (*T. gangetica* is also reported in this region) Mathwar harad statistically possess superior fresh and dry fruit weights, fresh pulp weight and fruit length⁸¹. The average maximum length of inflorescence was 8.0 cm at Dapoli and 11.2 cm in Delhi. For style alone, the reverse is observed⁸². In the south, *T. pallida* are the only pale type in the name of paal kadukkai. But the differentiating feature is that *T. pallida* are located at lesser altitudes. In short selection of immature dried, mature fresh, very mature dry and higher altitude very immature fresh varieties or Ostwald like ripening (if at all) from the seven geo types would represent the markers to alleviate indicated disease.

Functional nomenclature of Abhayan: Cardiac glycosides were present in Western Ghats of Maharashtra and Tirunelveli. The weakness of the heart is manifested as palpitation and reflected as fear (Bayam). Bayam is a dreadful manifestation of mental health diseases. The traditional principle attributes vata derangement for fear. Science relates fear with anxiety and distinguishes it as the specific behaviors of avoidance and escape⁸³. In Ayurveda: "haritaki" or 'abhaya' denote dispelling the fear⁸⁴

of dying and diseases' ⁸⁵; symbol of "Creative power of thought" ⁸⁶. Ellagic ^{87, 88}, gallic acids and tannin of TCFs; cognitive enhancers, and moderate cholinesterase inhibitors ⁶⁸ (improve mood, Kennedy DO *et al.*, 2006). ASU & H systems use these fruits to improve memory and brain function and are neuro protectives ⁶⁸. *In-vivo* acute anxiolytic activity of TCFs in aqueous extract decreased fear comparable to Diazepam ⁸⁹. A potent anti-stress drug, ⁹⁰.

An Indian physician Vagbhata was the first to use this product for heart conditions in the seventh century A.D. In Siddha: 'Kadu' in Kadukkai denotes the stringent promising potency to dustup disease. The suffix 'A' is to leave fear off, as confident cure of the disease is achieved by treatment with Abayan. Isosorbide dinitrate (ISN) is a potent vasodilator used for prevention of angina pectoris and cardiac problems like heart failure. The starting material for isosorbide is D-sorbitol, which is obtained by catalytic hydrogenation of D-glucose, which is in turn produced by hydrolysis of starch. Both Sorbitol and glucose are found in major quantities in TCFs (M. U Khan *et al.*).

Table 6 shows stronger quantities of cardiac glycosides in Abhayan samples. Vasodilatation activities by terpenoids and quercetin flavonoids in *Ginko biloba* showed dilation potencies by 17% (p<0.05) and 49% (p<0.001) in equivalent concentrations. Flavonoid effect is more potent. Coumarins also are vasodilators, which can be nitrated and the reactive groups are found to be esters. [The esters are of various types ⁹¹ and are in major quantities (Dattatraya G. Naik *et al.*, 2010). Ester types in TC: simple gallate, methyl, ethyl, butyl, phenyl, p-nitrophenyl ester and others like glucopyranosyl and Glycosyl (arjunglucoside-oleanane-type triterpenoids)] esters ^{58, 92-94}. Coumarins are formed involving the flavonoid biosynthetic pathway.

Constituents of TCFs and cardiac health: 1, 3, 6-Tri-O-galloyl-2, 4- chebuloyl-β-D-glucopyranoside (Chebulinic acid) is involved in rendering the cardiac effect (Guan YY *et al.*, 1996). The cardio protective effect of TCFs is documented by Chattopadhyay and Bhattacharyya, 2007. Though the cardiovascular effects of dietary Linoleic Acid

and risks are often discussed ⁹⁵, the range of linoleic acid consumption and recommendation is highlighted in recent research ⁹⁶. Linolenic acid and luteolin benefit in cardiovascular diseases ⁹⁷.

The preparations with TCF: Haritakyadi Ayurvedic eye drops of Abhaya habitat (pharmacy at Karnataka) ⁹⁸ and a Siddha distillate is documented ⁹⁹. Main constituents found in TCFs like hexadecanoic acid (methyl silylester palmitic acid (PA) ¹⁰⁰), linoleic acid (LA) and oleic acid (OA) (Zhang X *et al.*, 1997) ¹⁰¹ and others like furfurals, tetradecanoic acid (Dattatraya G. Naik *et al.*, 2010) can be attributed to the effect on eye. The first three essential fatty acids (EFAs) are also the main components in aniseed ¹⁰² and in sufficient quantities in the range of moderate (maximum around 40%) and minimum (10-20%) especially in Castor (apart from ricinoleic acid) ¹⁰³⁻¹⁰⁵ (walnut) ^{106, 107}, purple fleabane ¹⁰⁸ (used in lunacy) and also in *Lady's finger* ¹⁰⁹, *Sphaeranthus sp.* ¹¹⁰ (*S. indicus* and *S. amaranthoides* used in mental illness and detoxification of Mercury, the mercurial toxicity also causes lunatic behavior) ¹¹¹, (Fenugreek) ¹¹² all of which are good for brain, memory and eye diseases.

Though palmitic acid is not safer (booster of *in-vivo* cancers), the retinyl palmitate form is useful and increase the stability of vitamin A ¹¹³. Palmitic acid is found to be the antioxidant compound of *Mesua fera* ¹⁰³. The chemical compounds dealt above endowed in abhaya variety and which also showed significant quantitative variations between Saudi Arabia and Turkey ¹¹², scientifically validate the Indian traditional claims (bio-geo types). So, these EFAs can serve for differential authentication of TCFs. The hemolytic activity of palmitic acid ¹¹⁴ can be overcome by cis-11-eicosenoic acid (IUPAC name- arachidic acid ¹¹⁵), which decreased the hemolysis in *Staphylococcus aureus* experimentation ¹¹⁶. Anticoagulants are used in the treatment of hemolytic conditions, the presence of which in TCFs is discussed earlier. Eicosenoic acid (0.22%), 9-eicosene (6.02% / 5.13%), 1, 19-eicosadiene (0.13%) are the related compounds present in TCF ¹¹⁷. Ellagic acid, tannic acid, chebulinic acid is potent anticancer compounds present in TCFs ^{86, 90, 37, 118, 119} which can make these fruits safer to use. *S. aureus* is the underlying cause for common eye infection like conjunctivitis

(pink eye) other than the viral cause and *Escherichia coli* for the ophthalmia neonatorum. Ethyl gallate and gallic acid are anti bacterial compounds (Bhanumathi Natarajan *et al.*, 2011). TC extract has shown the same zone of inhibition against *E. coli* equivalent to that of *T. bellerica*¹²⁰. TCFs have prominent antiviral activities against influenza¹²¹, Hepatitis B (<http://nopr.niscair.res.in>), Human Immuno deficiency (Gallic acid and galloyl glucoses, Inder Pal Singh *et al.*, 2005) and Herpes Simplex-2 (abhaya habitat samples of TC). Hydrolyzable tannins like Chebulagic acids, chebulinic acids¹²² and punicalgin are the targeted antiviral compounds.

Broad - spectrum antiviral activity of chebulagic acid and punicalagin against viruses that use glycosaminoglycans for entry¹²³. Structure-activity relationship: the free hydroxyl and ether groups (R-O-R') influence the anti-rabies activity, which for this study is concerned with fear and the associated hydrophobia¹²⁴. An antiviral drug is scoped for human rabies treatment. 3- *O*-methylgallic acid in TCF is defined as the corresponding methyl ether of Gallic acid (CHEBI: 88738)¹²⁵ (Said M, 2012). 4-*O*-methylgallic acid, 3' - Methoxy quercetins¹²⁶ are present. So, authentication with associated chemical compounds will prove safety and thereby assure the quality of TCFs.

Diversity of vegetation has strong functional role in controlling ecosystem biomass cycling of water and nutrients. The physicochemical properties of the soil are a reflection of water and nutrients. The TC trees grow well in the areas of clay loam soil and sandy loam. A study on this textural class has resulted in the presence of high contents of NPK minerals. The organic carbon (SOC) increased with increase in soil depth (at higher altitudes) and a decrease in electrical conductivity, which can be interpreted as a decrease in nitrogen content. The pH also rises ranging from 5.95 – 6.53. High carbon dioxide sequestrations by SOC help the formation of healthy trees and dense forests. Deep black soils are found in the vindhya mountain, which reflects the therapeutic value of TC trees in that region.

The size of the fruit varied with the size of the tree. Recent research suggests that stem traits control the

fruit characteristics. The black fruit variety of Abhayan is 2 inches long from trees of more than 45m height and the Amrita is 1 inch⁹ long from trees of 40 m height. The TC trees of dry deciduous areas have stunted growth with small fruits. Low nitrogen favors the formation of anthocyanin as protection by plants¹²⁷. Anthocyanin-rich blue-black varieties are preferred for kayakalpam (rejuvenation). Suitable pH for the growth of TC trees is acidic to neutral, the favorable pH for the growth along with tannin-rich oak trees in forests¹²⁸. Carbon input from cover crops is reflected on the overriding cover crop effect on SOC and carbohydrate. Sucrose regulated enhanced production of phenolics, anthraquinone, flavonoids biosynthesis in *Morinda*¹²⁹. SOC influence on the stem may reflect on the strength or longevity of TCFs to get ripe in the tree itself without fall.

Table 3: The presence of odor in the Varanasi variety is notable for the purgative activity and agrees with the classical text. Ayurvedic Gandhrva haritaki- Gandhrva denotes the fragrance/ rays of the sun to guard 'soma' liquid/ a male spirit to make the female functional (Hindi Tamil Khosh, 1962) / a male deity best in singing/ castor. It is processed with castor oil along with salts. It denotes the process of purification / the induction/ detoxification to save from kapha based diseases¹³⁰. Of course, TCF is an ingredient of a formulation quoted by Maharaj Sarabhoji to tone up the voice of singers. It is supposed to improve speech and treat muffled hearing (Mandha). The aroma of drugs improves the quality of drugs enough to prove the potency. Only the acidic taste does not appear out of 5 tastes which may be confirmed by assays of acid contributors. The color specificity correlated with the yellow Saurashtrian and Delhi dry deciduous ceevanti, dark color of the odissa with Amrita type and red tinge of Karnataka with Arohini type. The details are not sufficient for assessing the shape with available evidence.

Effect of Geographical Variation on the Main Chemical Constituents of TCF and the Reliability on the Method of Classification Table

4: A Metabolomic approach through PCA revealed the profound influence of chemical content with the plant location; The Indian TCF showed higher content of two chemical markers than the Chinese variety⁶⁷.

Altitude Based: Ripe fruits have a strong unpleasant odor. Ethylene is the ripening hormone. Gallates are trihydroxybenzenecarboxylic acids. Ethyl gallates are an indication of ripened fruit. The ripening in lower altitude with higher temperatures differs from ripening at higher altitudes under photolysis by direct and high UV radiations. In blueberry fruits, ethylene does not influence ripening. The sensitivity of the fruit to ethylene is changed in high altitudes.

Odor Based: Anthrones, flavonoids, and coumarins are centered on tricyclic ketones **Table 5**¹³¹. Geraniin is the chemical constituent of TCF that offered significant antioxidant activity¹³² indicating either the quantity/potency. Biosynthesis of the terpenophenols, the Cannabinoid from marijuana¹³³ is from the substrate geranyl pyro/diphosphate (Vijaya refers to both cannabis and TCFs) **Table 5**. In most species of Terminalia, the fruits when young are pubescent but become velutinous or sericeous and then glabrous¹³⁴. The reported resin and phosphoric acids are in favour of the concept. Higher terpene content can be expected from immature fruits.

Table 6: Research done on aromatics of TCFs is depicted region wise. From this, it is clear aromatics is depicted region wise, and it is clear that there is a close association of TCFs with terpenoids. The association is more specific to Amrita and Abhaya varieties. Out of 10 wild Himalayan fruits, TCFs is one among three which are richest source of flavonoids^{135, 136}. These flavonols are of rutin type^{137, 138} present. Considering the close qualitative association of the terpenoids and flavonoids with sizes of Amrita and Abhaya fruits, respectively, the odor of Amrita is in par with statements in the traditional text and the suspected geo type. Aromatic AQs are absent in fresh plant parts and present only after drying¹³⁹. Diones was present even after 15 days of drying. Young TCFs show the absence of these quinones (Vadodara, Gujarat). Sennoside content of youngest senna leaves was high than the mature leaves and discussed further by Deepa Bai, 2019. This holds true even for terpenoids.

Purgative, antidiarrhoeal compounds and safety issues: Most of the purgative herbs exist along with existing along with the anthelmintic activity. AQ

exhibit purgative action and are insoluble in water. But the aqueous TCF extracts also show positive results for anthelmintic activity in samples from Rewa District of Madhya Pradesh⁴⁷. Better activity is shown by the alcoholic extracts. This observed difference leads to predicting the presence of a water-soluble compound or altered forms of anthraquinones or degraded forms (Photolysis) of anthraquinones (benzoic forms) responsible for the activity. M - Hydroxyl quinones are water-soluble compounds. Hydroxyl-anthraquinones in TCFs is reported¹⁴⁰.

Ellagic acid and AQ in TCFs are diones. Among seven other *Terminalia* species only the *T. chebula* species stem bark exhibit highest ellagic acid contents¹⁴¹. But they are odorless antioxidants (pubchem.ncbi.nlm.nih.gov). No evidence of purgation related action. Phloroglucinol compounds (Anthocyanin related) detected in TCFs⁴² are known for their anthelmintic activity of kamala fruits of *Mallotus philippinensis* (Euphorbiaceae) with trichomes¹⁴² and used for tapeworm infestations in India. n- hexadecanoic acid and 9,12- Octadecadienoic acid are nematicides¹⁴³. Anthocyanin-rich extract is found effective in acute and chronic diarrhea¹⁴⁴. Astringents substances in TCFs like tannic acid, chebulinic acid, gallic acid, etc., Ellagitannins are punicalgin, casuarinin, corilagin, and terchebulin¹⁴⁵ can involve controlling diarrhea.

Intake: Traditionally precipitated water extracts of TCFs purgate. Among the water constituents (gallic acid, punicalagin, geraniin, chebulic acid, chebulagic acid, and chebulinic acid) of TCFs GA is the highest antioxidant. Roasted immature young fruit laxate (Siddha). Gandhrva hariaki is a potent laxative than Triphala churna. Roasted fruits treat diarrhea and soaked ones laxate (Iran) due to high tannins and anthraquinone derivatives, respectively¹⁴⁶. Half-ripe purgate and the ripe is astringent in *T. bellerica* fruit¹⁴⁷. The fatty acids LA and OA in *T. bellerica* are reciprocal to that found in TCF¹⁴⁸. Quantitative analysis on sennosides / anthraquinones in TCFs is done only in western India and cannot be compared with other regions. A snap shot of range of important phyto-constituents (neglecting the seasonal variation) across Indian states is presented in **Table 7** along with Ayurvedic observations.

The safety of intake of anthraquinone-based TCFs and the reliability on the mode of administration is made possible. The region C in the study showed maximum levels for TA and GA. The category has to be confirmed for Chhattisgarh/Chandigarh belonging to Vijaya/Pritivi. The Vijayan and Arohini varieties are best suited for the intake, with maximum Gallic acid, more/less tannin, and sufficient EGs. Arohini and the northeastern varieties are suitable for external application. It is justified that in these varieties ethyl gallate (salts and esters) is less **Table 4** preventing the possibilities of salt irritation in ulcers on application and the tannin content is sufficient enough to heal the wound. The soluble coolant potassium, rich in TCFs, may nullify the irritant effects of the anthraquinones.

Safety: Anthraquinones can cause skin allergic reactions if applied to the skin due to dyes of fabric with azo and 2 anthraquinone structures (Skin Conditions Safety & Health Assessment & Research for Prevention Report: 2001 and www.lni.wa.gov). 9, 10-anthracenedione core structure may be largely responsible for their toxicity (RSI 2017) as a skin sensitizer. Health Canada has recently discussed the unpredictability, in the human risk evaluation of these compounds and the impact of some exposures¹⁴⁹⁻¹⁵¹.

Anthraquinone-based dyes are authorized but exhibiting the negative effects on human health (Ergun and Yilmaz 2014)¹⁴⁹. The general population may be exposed to anthraquinone *via* inhalation of ambient air¹⁵². The parent compound anthracene is a sensitizer to the eye. Chronic neurotoxic effects of anthraquinone include vision disturbances¹⁵². Anthraquinone (formal IUPAC name: 9, 10-dioxoanthracene) is relatively non-toxic^{154, 155}.

Miscellaneous Updates Significant for Future:

1. Updates project *T. Gangetica*¹³, Chambaranya¹², Vijaya¹⁵⁶ & Raj Harar⁸¹ to be best. But it is the specificity of use that decides the best variety. The occurrence of Amrita in chambaranya is referred by Prakash Chandra Gupta, 2012, Amrita and Abhaya in Champa (Madhya Pradesh)²⁶.

2. Champa denotes immature fruit of rice and the *Michelia champaka* with yellow flowers, District in

Haryana, Nepal, Bihar North Indian River¹⁵⁷, conclusively referring the Sub-Himalayan variety as per Ayurvedic texts and research articles.

3. Multi nomenclatures also add to the uncertainty: *e.g.*, *T. tomentosa* (Roxb.) Wight & Arn. is regarded by Brandis and Bishen Singh et al. 1987) to be the principle variety⁹ but in India, it is possibly *T. gangetica*. It is regarded as the synonym of *T. alata* Heyne ex Roth^{158, 159}. *T. elliptica* Willd. Synonym of *T. crenulata* (Heyne) Roth, *T. alata* Heyne ex Roth. Black murdah, Indian laurel. Karumarudhu calyx tube base pubescent¹⁶⁰.

4. Reports of terpenoid and flavonoid extraction from methanolic, ethanolic, acetone, cold water, and hot water extracts have been reported. Aromatic compounds are not detected only in 100% acetone and 100% ethanol, whereas the other solvent ratios have eluted the aromatic compounds using chromatography technique¹⁶¹.

5. Fall of TCFs in the ground due to wind and rain interferes with the ripening stages and effect of further drying and photolysis play a major role in fixing range for chemical parameters. Efforts to understand phytochemical conversions and transformations of all 6 sizes & stages of maturity¹⁶² will make it more valid to use because of traditional evidence project the six seasonal regimens with six specific suitable adjuvants^{8, 72}.

6. This study has not included chebulic acid, cardenolides, caryophyllenes, retinol and terpene derivatives like sterol & saponins, maslinic acid^{163, 164} momordicine II, a cucurbitane triterpenoid¹⁶⁵ and arjunglucoside-I¹⁶⁶. Coumarins can differentiate Amrita/Abhaya from the other varieties. It is probably not present in the intact plant but is rather formed by enzymatic activity from a glycoside of *o*-hydroxycinnamic acid (such as melilotoside as in TCFs⁴²) after harvesting and drying (new-mown hay effect). These facts support the above assumption of the effect of temperature on coumarins in ceevanti and pritivi types. The variation of phytochemicals in plucked, fallen and dried fruits in all maturity stages and effect of purification is to be validated in all regional types.

7. Tannin-containing vacuoles aid in the synthesis of haeme. Genetic sequencing studies of

cytochrome 450 may authenticate. Medicinal preparations prepared with TCFs used in Anaemia: Siddha- Bhavana kadukkai. Ayurvedic- Effective when powder mixed with honey and ghee, Haritaki, Haritaki- Loharajyog, and patented drugs¹⁶⁷⁻¹⁷⁰ (Vidhi Kamath *et al.*, 2010). Opportunity to the TCFs is not limited to tannins but also to other lead compounds discussed specific to each type¹⁷¹.

CONCLUSION: The review has set proof of significantly variant marker phytoconstituents in the geo types of TCFs. Mandatory information on the altitude; place; date of collection of TCF; seed removal in research publication would be a proud commitment in traditional India, to improve standardization, globalization and commercialization. Such dissemination of awareness and that all seven types are medicinally useful will improve research without discriminations and will conserve the *T. chebula* species. The increased availability (Higher importance value index) of the genuine drugs and data reduce adulteration and substitution. Thus adequate updates are provided to understand and authenticate regional types of TCFs.

ACKNOWLEDGEMENT: Nil

CONFLICT OF INTEREST: Nil

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How to cite this article:

Bai DD: Authentication of seven indian traditional types of the herbal drug *Terminalia chebula* with scientific updates – an advanced insight. Int J Pharm Sci & Res 2019; 10(6): 2670-87. doi: 10.13040/IJPSR.0975-8232.10(6).2670-87.

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