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Review Article

Controversial identities of medicinal plants in classical literature of Ayurveda

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ABSTRACT

India's medical heritage across its two streams of experiential knowledge viz. the classical (codified) and folk (oral) reveals an incredible range and depth of knowledge of medicinal plants. In the classical stream of Ayurveda, across the period from 1500 BCE to 1900 CE, there is information of more than 12,000 distinct Sanskrit plant names with overlaps across texts. This information is captured in more than 200 texts viz. 6 *samhitas*, 57 *nighantus* and 140 *vyakhyas*. The information about plants has three major dimensions in codified literature viz. morphological description (*rupa gnana*), pharmacology (*dravya guna shastra*) and pharmacy (*bhaishajya kalpana*). The morphological information is however sketchy and wholly inadequate for establishing botanical identity. Thus despite the huge corpus of plant names backed by sophisticated understanding of pharmacology and pharmacy there is the fact of controversial identities of medicinal plants. Why is this the case? The author believes that the gap in morphological detailing is due to the 'experiential' pedagogy of India's health tradition. While knowledge transmission of plants included theoretical propositions and sophisticated logic related to pharmacology, it also assumed an oral, practical and experiential system of learning about the identity of plants through field work. The purpose of this research is to understand the range and depth at which we have understood the problem of controversial identities of medicinal plants, to analyze work done in the field and to propose a Trans disciplinary approach to solve the problem of controversial identities of medicinal plants in Ayurveda.

1. Introduction

1.1. Evidence of documentation of medicinal plants found in Ayurvedic literature

Ayurvedic literature has a comprehensive documentation of medicinal plants. The period of documentation can be categorized into four distinct phases. They are the Vedic period (4000 BCE – 1500 BCE), the Samhita period (1500 BCE – Seventh century), the Medieval period (eighth – fifteenth century) and the Modern period (sixteenth century onwards) [1]. The medicinal plant documentation finds a place in three of the four Vedas [2]. *Rigveda* records 67 medicinal plants while *Yajurveda* and *Atharvaveda* records 82 and 288 medicinal plants, respectively. In fact, Ayurveda is considered as *upaveda* of *Atharvaveda*. [3] Medicinal plants also find a place in the *Upanishads*, where about 31 plants are recorded [4].

Chronologically, *Samhitas* are the next source of information on medicinal plants. Among them *Caraka Samhita* (1000 BCE – 200 CE) and *Susruta Samhita* (1500 BCE to 1000 BCE) are the first to describe different types of plants and their medicinal uses [5]. *Caraka Samhita* gives exhaustive descriptions on 620 plants across 12,800 references and *Susruta Samhita* has 775 plants across 9676 references. [6,7] The texts include detailed information on various aspects of medicinal plants like therapeutic uses, classifications, pharmacology, pharmacy, time and methods of collection, incompatibility, medical recipes, parts used [8] etc. The other *Samhitas* of the period are, *Ashtanga Samgraha* (500 CE) and *Ashtanga*

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Hrudaya (600 CE). *Ashtanga Samgraha* has 755 medicinal plants spread across 20,500 references. [9] *Samhitas* written after 700 CE are *Harita Samhita, Bhela Samhita, Kashyapa Samhita, Sharangadhara Samhita* and *Bhavaprakasha Samhita* [10]. Thus far no systematic inventorisation of plants in these texts has been attempted.

The next set of major works in Ayurveda with information on medicinal plants can be seen from 8th century onwards which includes *Vyakhyas* and *Nighantus*. *Vyakhyas* are critical commentaries written on the *Samhitas*. Elaboration on identity and usage of medicinal plants, mentioned in the *Samhitas*, form an important part of *Vyakhyas*. *Nighantus* are glossaries written based on medicinal plants mentioned in *Samhitas*. There are 16 important *Nighantus* written in the period from 8th to 19th century and the last among them is *Saligrama Nighantu* with 4200 plant references. As with *Samhitas*, no complete compilation is available for medicinal plants of *Vyakhyas* and *Nighantus*.

From 16th century onwards there were efforts made by European scholars to document ethno-botanical and ethno-medical practices of people of India. These works, which involved expertise of Indian hakims and vaidyas, were the first known documentation with a botanical perspective on plants used as medicine. At a time when there were no established system of classification and naming of species (Pre-Linnaean period), these works served as the source of botanical documentation. They included illustrations, description of plant morphology and local names. For example, *Hortus Malabaricus* written in 17th century was rich with 794 illustrations, along with description of each plant in Latin and its name in four scripts. This helped Carl Linnaeus, father of taxonomy, in establishing identity of 250 new species even after about 75 years [11]. Though these were serious efforts in documenting the common botanicals used in Ayurveda, they do not help correlate Sanskrit names and synonyms of the medicinal plants in Ayurvedic literature.

Ethnobotanical works in India were initiated by Janaki Ammal in 1954. Dr. S. K. Jain, father of Indian Ethnobotany, did extensive ethnobotanical documentation of plants used by local communities in different parts of the country. It is observed that there is considerable overlap between plants used by the village communities and those mentioned in Ayurvedic literature. While folk healers use around 6400 species, the entire Ayurvedic literature documents only about 1550 species. Knowledge of folk traditions is limited by identification of medicinal plants by local names and their limited medicinal uses. They do not possess the sophisticated Ayurvedic knowledge of the pharmacology of the plant.

2. An estimate of controversial medicinal plants in Ayurveda literature

Despite extensive documentation of properties and products of medicinal plants, we estimate that around 30 percent of medicinal plants mentioned in classical literature are controversial with respect to their botanical identities [Appendix 12]. Another 35 percent of plants like the *divya aushadhas* are already lost [12]. In modern trade around 32 medicinal plants with controversial identities are extensively used (>200 MT/year) by Ayurvedic industries [Appendix 12].

3. Reasons for controversy

Why has so much loss of identity and controversy occurred? Identification of a plant mentioned in Ayurveda is not possible through etymological analysis of its nomenclature in the literature. This is because names do not reveal identity. Identity needs detailed morphological descriptions in the literature and such descriptions in Ayurvedic literature are sketchy. Thus, only such plants such as *haridra, tulsi, ardraka* etc, which have an active and unbroken living tradition of use are free of controversy. The only way to find the identity of plants in the literature is to consult living health traditions that use it. Intimate interaction with living traditions that have knowledge of plants is essential for establishing identities of controversial species. Controversy in botanical identity can also arise due to various reasons, as mentioned below.

3.1. Many texts with long chronology, loss of living traditions, additions and deletions

We estimated the number of texts written containing data on medicinal plants dating from 1500 BCE to 1900 CE, to be around 200 using Jan Meulenbeld's work. Among the 200 texts analyzed, six are *Samhitas*, 38 are texts written between 600 CE and 1000 CE [13], 80 written between 1000 CE and 1500 CE [14] and 90 between 1500 CE. to 1900 CE [15]. Important works of the period 600 CE and 1000 CE include *Ashtanga Nighantu*, *Siddhayoga* of *Vrinda* and *Madavacikitsa* of *Madhava*. Notable texts written during 1000 CE and 1500 CE are works of *Cakrapanidatta* viz. *Cikitsasamgraha*, *Dravyagunasamgraha*, *Vyagradaridrasubhamkara*, *Ayurvedadipika* (a commentary on *Caraka Samhita*) and *Bhanumati* (a commentary on *Susruta Samhita*). Some other major works of the period are *Dhanvantari nighantu*, *Kaiyadeva nighantu*, *Madanapalanighantu* and *Sharangadhara Samhita*.. Major texts written during the period 1500 CE to 1900 CE are *Bhaishajyaratnavali*, *Nighantu Ratnakara* and *Sidhabhaishajyamanimala*.

The long chronological gap between the works has affected identification of medicinal plants mentioned in these texts. For example, the group of plants called the *divyoushadhas* explained in *Caraka Samhita* [12] and *mahausadhi* in *Susruta Samhita* [17] were dropped in the later texts like *Ashtanga samgraha* and *Ashtanga Hrudaya* of *Vagbhata* which were written several centuries later. Hence the knowledge of these plants is lost. This may be because of the loss of the living tradition resulting in difficulty in identifying these groups of medicinal plants in the later centuries only on the basis of their names.

Names of medicinal plants also change over course of time which adds to the confusion on their identity. The use of plant name *Kamaci* instead of *Kakamaci* in *Siddhayoga* written by *Vrinda* is an example. *Kakamaci* was the name used in *Caraka Samhita, Susruta Samhita* and *Ashtanga Hrudaya.* There have also been new plant additions to the *Materia Medica* of Ayurveda over time [18]. There is evidence of addition of region specific medicinal plants by the authors. *Chakrapani* (11th Century), one of the greatest authors of medieval period, mentions many regional names of medicinal plants in his book *Dravyagunasamgraha* [19].

Vyakhyas on the *Samhitas* serve the purpose of explanation and interpretation of their content. There are 64 *Vyakhyas* written on *Caraka Samhita*, 34 on *Susruta Samhita* and 42 on works ascribed to *Vagbhata*. Out of these only nine, six and twelve are available in partial or full form respectively [Appendix 2, 3, 4]. The huge time gap between the writing of *Samhitas* and their commentaries has also resulted in loss of knowledge including the identity of medicinal plants. Differences among the commentators on the identity of medicinal plants are clear from their works. *Jejjata's* commentary on *Caraka Samhita* called '*Nirantara Pada Vyakhya*' is the oldest available though not complete. He mentions the differences in the views on identity of medicinal plants by other authors in his work [Appendix 5]. Other differences occur when the commentators disagree concerning identity of specific medicinal plants. For example, in case of *Ashtanga Hrudaya*, *Indu* and *Arunadatta* identify certain medicinal plants differently [Appendix 6].

Nighantus are works written specifically on medicinal plants. They classify medicinal plants and explain their detailed pharmacology. Variations in the names of plants in *Nighantus* over time

show the large extent of changes that occurred in different time periods. The example of *Shankapushpi* is explained in the following section.

3.1.1. Analysis on omission, addition and variation of names of Shankhapushpi over two millennia leading to controversy

Sankhapuspi is a classical example of medicinal plant with controversial identity. Here we give a detailed outline of the changing descriptions, synonyms and correlations of the plant across time [20].

Ethno botanical literature of last hundred years correlates eight different species of plants to *Sankhapuspi*. They are *Convolvulus pluricaulis* Choisy., *Evolvulus alsinoides (L). L.*, *Canscora diffusa* (Vahl) R.Br. ex Roem. & Schult., *Clitoria ternatea* L., *Lavandula bipinnata* (Roth) Kuntze., *Cannabis sativa* L. and *Xanthium strumarium* L (Fig. 1) [44]. A text by text review of *Sankhapuspi* in chronological order across major codified texts shows how the omissions, additions and variations of names over time resulted in the controversy of its identity.

Classical text	Time period	Information available about *Shankhapushpi*
Caraka Samhita	1500 BCE – 400 CE	Nine references on *Sankhapuspi*. No synonyms or clear morphology provided.
Susrutha Samhita	1500 BCE – 500 CE	Elleven references on *Sankhapuspi*. Suggests that the plant *Ajalomi* and *Golomi* are similar to *Hamsapadi* and *Sankhapuspi*. However, the description of *Ajalomi* and *Golomi* do not match with any of the eight species proposed in the recent ethno-botanical literature. *Golomi* is equated to another plant *Bhutakesi* by *Cakrapani*.
Astanga Samgraha	500 CE	No information is available about the morphology of *Sankhapuspi*.
Astanga hrudaya	600CE	No information is available about the morphology of *Sankhapuspi*.
Ashtanga Nighantu	800 CE	*Sankhapuspi* is mentioned as a synonym of *Sankhini*. Here the controversy starts as *Caraka Samhita* considers *Sankhini* as a different plant and explains it in another chapter. Also, *Susrutha Samhita* lists *Sankhini* and *Sankhapuspi* as separate entities under *tikta skanda*.
Paryayaratnamala	900 CE	Considers *Sankhini* and *Sankhapuspi* as separate plant entities
Dhanvantari Nighantu	1000 CE	Mentioned *Sankhapuspi* as a synonym of *Shankhini*. *Vishnukranta* is linked to *Sankhapuspi* by mentioning the synonym *Sankhapuspika* for *Vishnukranta* adding up to the confusion.
Madanapala Nighantu	1347 CE	Mentions eight synonyms for *Sankhapuspi* in which some are derived from *Dhanvantari Nighantu*.
Kaiyadeva Nighantu	1450 CE	Mentions 11 synonyms for *Sankhapuspi* with three types viz. red, blue and white flowered.
Bhavaprakasha Nighantu	1550 CE	Gives three synonyms but no clue on the morphological features of *Sankhapuspi*.
Siva kosa	1625–1700	Two new synonyms mentioned are *Yuthibhit* and *Kambumalini*. Two types mentioned viz. red flowered white flowered.
Raja Nighantu	1700 CE	Gives 12 synonyms for *Sankhapuspi*.
Nighantu Ratnakara	1867	Mentions three types of *Sankhapuspi* viz. blue, white, red.
Saligrama Nighantu	1896	Provides five synonyms in which two of them are new.
Ashtanga hrdayakosa	1936	Do not give any specific features or synonyms.

3.2. Many names for one entity

The system of nomenclature of medicinal plants in Ayurveda is different and unique. Identification and nomenclature were established by coining multiple names for each plant indicating habitat, properties, potency, taste, pharmacological actions, geographical origin and usage. A single plant thus has several names according to its different features. For example, the plant *Sankhapuspi* has 34 different names based on different features [Appendix 7]. The system of multiple names however does not carry morphological details sufficient for establishing the botanical identity of medicinal plants. The inclusion of new names by authors of different time and places adds up to a huge number of plant names [Appendix 1]. There are instances where an author coins new names for plants which in most cases are Sanskrit expressions of local names [Appendix 8]. Addition of new synonyms for plants deepens the problem of identity. [21].

3.3. No taxonomic system/sketchy morphology

Taxonomic system of identification and classification was not prevalent in Ayurvedic tradition. This is perhaps due to the experiential method of teaching. Identification was achieved through close contact with nature and transferring the knowledge through an unbroken oral tradition of practical education. Later during the medieval period authors started to outline some botanical characteristics of medicinal plants through sketchy descriptions. Incomplete outline of *Jejjata's* botanical characteristics of some medicinal plants in *Caraka Samhita* is an example [Appendix 9]. Sketchy outlines do not help establish taxonomical identification of medicinal plants. A sketchy description like *Deerghamoola* for example (meaning that which has long roots) given for several different plants is inadequate to establish the identity [Appendix 10]. Therefore once the oral tradition of first hand introduction of a plant is broken the identities of plants became obscure.

3.4. Single generic name for many plant entities

References to generic properties of plants like *Pashanabheda* and *Brahmi* in Ayurveda create controversy. This is due to the fact that these plant names refer to a property and not to a particular and unique species and the property may be carried by several species. The term *Pashanabheda* actually means those plants which breaks stone. Bapalal Vaidya lists 10 plants which are used in different parts of India having generic name *Pashanabheda* with the property of breaking down renal stones. They are *Aerva lanata* (L.) Juss., *Aerva javanica* (Madras and Andhra Pradesh, Rajasthan, Gujarat), *Ammannia baccifera* L (Kerala), *Rotula aquatica* Lour (Karnataka), *Bergenia pacumbis* (Buch.-Ham. ex D.Don) C•Y.Wu & J.T.Pan (North India, Gujarat, Kashmir), *Coleus aromaticus* Benth(Bengal), Bryophyllum pinnatum (Lam.) Oken(Bengal), *Bridelia montana* (Goa), *Ocimum basilicum* L. and *Homonoia riparia* Lour.

3.5. Common name for different plant entities

The system of giving common names to several species because of some similar characteristics also results in use of the same name for different plant entities. Common names appear for different plants with similar characters like morphology, habitat, taste, properties, and effect on *doshas*, geographical origin, uses etc. and results in controversy of identity. Appendix 10 shows some examples. From appendix it is clear how one common name is shared between different medicinal species (common name *Aksha* shared with *Rudraksha* et al.). Also there are many names for same medicinal plant. For example, *Haritaki* has got two different names *Aksha* and *Amritha* and these are shared with 3 other different plant entities.

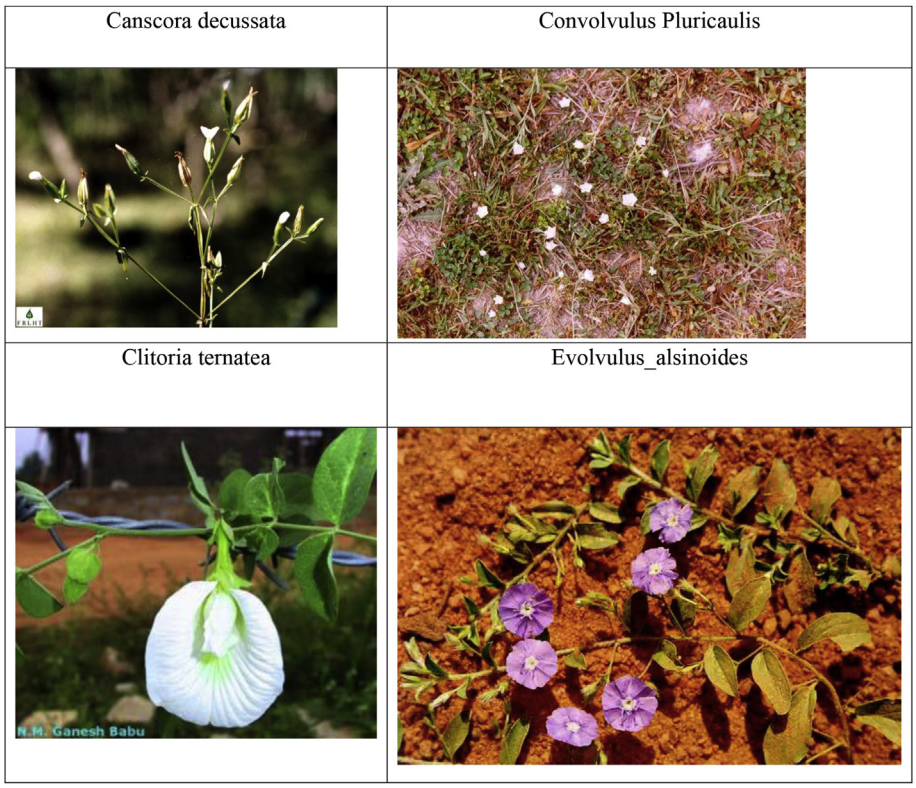

Fig.1. Four major sources of "Shankhapushpi" used in India.

3.6. Controversy due to lack of expertise in grammatical interpretation of Sanskrit language

Grammatical interpretation of Sanskrit names is important in identifying medicinal plants. For example *Susrutha* mentions the names *Meshasrnga* and *Meshasrngi* in his treatise. *Meshasrnga* which is mentioned in *Salasaradi gana* [22] of *Susrutha* is considered as a tree (identified as *Dolichandrone falcata* (Wall. ex DC.) Seem.) as all the others of the group are trees. There is also other evidence that proves *Meshasrnga* is a tree. For e.g. *Caraka* mentions small boxes made out of *Meshasrnga* wood to be used for filling medicines [23]. And Chakrapani in *Bhanumati* identifies *Meshasrnga* as a tree similar to *Putrajiva*. On the other hand, *Varunadi gana* is a group which contains trees, herbs, shrubs and creepers. One of the plants mentioned in it is also *Meshasrngi*. Here *Meshasrngi* is considered as a creeper (identified as *Gymnema sylvestre* (Retz.) R.Br. ex Sm.) as the word *Meshasrngi* in Sanskrit is feminine gender and the group includes mixture of plants with several habits.

Necessity of expertise in grammatical interpretation of Sanskrit plant names is highlighted by *Bhavamisra*. In the Chapter '*Anekartha nama varga*' (group of drugs with many meanings) [24] he lists out 114 names with two different meanings, 84 names with three different meanings, 3 names with four different meanings and 4 names with many meanings. A name can be indicative of a medicinal plant, an animal or any other substance, and has to be understood in context. Another example is cited by Dr. Bapalal Vaidya when he discusses the controversy related to *Uddalaka*. He opines in his summary that *Uddalaka* when occurs in the list of food should be taken as *Paspalum scrobiculatum* L. and when it comes as medicine it should be taken as *Cordia myxa* L [25]. Similarly he says that *gojihva* in *shaka varga* (group of vegetables) means *Elephantopus scaber* L. and as *aushadha* (medicine) means *Onosma bracteata* Wall [26]. Thus expertise in the interpretation of Sanskrit names of the Ayurvedic literature is important in the identification of medicinal plants from the literature and grammatical misinterpretations leads to controversy.

4. Folk names

The systems of traditional knowledge of medicine as practiced in India has two streams, one is the folk stream and other is the codified stream. Both the systems do not possess taxonomic descriptions but rely on oral transmission of knowledge wherein students are experientially introduced to the plant materia-medica.

Folk system also referred to as the '*Prakrit*' (meaning directly from nature) is an ecosystem and ethnic community specific oral tradition which is purely empirical in nature. It exists in rural communities of the country. The system follows a tradition of oral transmission from generation to generation within the ethnic community. The number of botanicals documented from the folk traditions of health in India is 6403 [27]. The number is derived from 154 ethnobotanical publications written over the period from 1889 to 2010. These botanicals carry around 100,000 vernacular names in 32 languages. As in the case with codified traditions, the morphological description of plants implied in folk names of plants is poor.

5. Modern efforts to document plants used in medical traditions of India

5.1. European efforts in documenting identity and usage of medicinal plants

The system of taxonomical classification and binomial nomenclature started in 18th Century [28]. Works on botanical correlation of Sanskrit and vernacular names of medicinal plants of Ayurveda thus started only about 200 years ago. The earliest ethno botanical work on medicinal and economic plants of India is 'Coloquios dos Simples e

drogas da India' by Garcia de Orta in 16th Cent. CE [29]. Other works are 'Tractado de las Drogas y Medicinas de las Indias Orientalis', a compilation by Christobal Acosta on the pharmaceutical properties of Indian medicinal plants in 1578, the *Itinerario*, published by, Jan Huyghen van Linschoten in 1596, The English herbal *"The Greate Herball"* published in 1597 by John Gerard and '*Hortus Malabaricus*' conceived by Hendrik van Rheede published from Amsterdam during 1678–1693 [30]. Though these works were the earliest attempts in documenting the health traditions, they were not rigorous enough in respect of their consultation with living traditions. The first work 'Coloquios dos Simples e drogas da India' was written based on health traditions of one small state of Goa. *Hortus Malabaricus* of 17th century was the most extensive study of medico-botanical resources of Asia but the book was written based only on field studies in the Malabar region. The example of *Vidanga* in *Hortus malabaricus* shows the limitation of consulting the living traditions. *Hortus malabaricus* explains the plant '*Basaal*' in volume 5 [31]. It is identified as *Embelia tsjeriam-cottam* (Roem. & Schult.) A.DC. which is used in the parts of Kerala as a substitute source for the plant *Vidanga* mentioned in Ayurveda. It documents limited folk uses of the plant, but not its key anthelmintic activity documented in Ayurveda literature. This suggests poor consultative process or an unwillingness of local practitioners to reveal their full knowledge. The book also illustrates a plant namely *Pu-walli*, identified as *Embelia ribes* Burm.f [32]. which is considered as the authentic source for *Vidanga. Hortus Malabaricus* mentions that the plant had no reported use in medicine while Ayurveda have extensive knowledge of the pharmacology.

Dictionary of economic products of India by George Watts (1889–1890) is another compilation based on commercial plants in India. The focus of the work is mainly on plants, plant products and animal products which were commercially used in trade.

5.2. Works by Indian Scholars in the 20th century

Around 170 works on correlating botanical to Sanskrit and vernacular names of medicinal plants were carried out during last hundred years. See appendix 11 for the list of important studies. It is clear that the work done by Dr. Bapalal Vaidya is the only work which showed some rigor in respect of field documentation. This work could however not cover the living traditions of all parts of India, perhaps due to the time and resource constraints. However, the methodology used in solving the controversy regarding mentioned plants is systematic and worthy of emulation. His methodology involves various steps as outlined below:

a) Extensive field work on living health traditions to identify the botanical source used by people in different parts of India for a specific controversial plant.
b) Etymological analysis of names of controversial plants: It is done by an analysis on the relation between the Sanskrit name, synonyms and the vernacular names of a particular controversial plant.
c) Correlation done with the help of review of classical literature: A study on details of a plant available in the classics is done to throw light on its botanical identity. E.g. *Jivanti* which is told as *shaaka sreshta* (meaning best vegetable) has been mentioned in another name '*todi*' by *Dalhana*. Also *todi* is the *Gujarati* name for *jivanti* and it's been used extensively as a vegetable in Gujarat [33].
d) Expert opinion: Opinions from Ayurveda Scholars and practitioners like the Bengali Kavirajas.
e) Scientific papers [34].
f) Hints from other systems of medicine like Unani, Sidha etc. For example while speaking about the controversial plant '*Kramuka*', he mentions about the usage of the plant in Unani for expelling intestinal worms, indirectly suggesting its purgative property. Classical references also explain *Kramuka* as a purgative [35].
g) Data collected from markets like. Shri Jasapalaji Arya of Arya vastu Bhandar, Dehradun, Jadvji Lallubhai, Mumbai.
h) References from contemporary works: For example, citing of an article by Thakur Balwant Singh under the heading '*Harenu* or *Renuka*'.

Recent work by Dr. Venugopal on publishing compendium of plants in the codified texts (*Samhitas*) is an example of rigorous literary work for listing unique plant entities. It is based on the deep understanding of rules of grouping synonyms. The outcome of the exercise is as follows. There are 1916 unique plant names mentioned in *Caraka Samhita* which can be grouped around 620 basonyms and are correlated to 630 botanicals. *Susruta Samhita* has 1856 unique plant names which are grouped under 775 basonyms. These basonyms can be correlated to 1078 botanicals. The number of unique plant names in Ashtanga sangraha is 1614. They are grouped under 910 basonyms which are correlated to 755 botanicals. The work has helped in bringing clarity in rules for assigning basonyms to a related number of synonyms and then correlating the basonyms to botanical entities.

6. Analysis of controversial medicinal plants

Analysis revealed that there are around 1540 botanicals used in the system of Ayurveda. These 1540 botanicals carry around 9500 Sanskrit names in the literature written over the period from 1500 BC to 1900 AD. Among the 9500 names, 1689 names have more than one botanical correlation. Thus, the problem of controversial identity is of high magnitude and has to be addressed starting from the first ever documentation available on medicinal plants of Ayurveda, viz the *Bruhatrayis*.

Bruhatrayis viz. *Caraka Samhita, Susruta Samhita* and *Ashtanga Samgraha* are the first, most descriptive and fundamental treatises of Ayurveda and have served as a foundation for the later texts. An analysis of botanicals in these texts was undertaken using 'Glossary of vegetable drugs in *Brihattrayi*' by Thakur Balwant Singh and K C Chunekar. The book provides an alphabetical list of all the Sanskrit names including synonymy of vegetable drugs of *Brihatrayi* along with their references. Appropriate botanical identification is incorporated in the book for non-controversial medicinal plants while critical discussions are recorded on controversial ones. The review is based on information collected from commentators of *Brihatrayi* along with the *Nighantus* of later period. The analysis helped to conclude that the number of medicinal plants with controversial identity in *Bruhatrayi* is 274. There are 301 medicinal plants which have definite identities and 320 are unidentified [Appendix 13].

The limitation of the work is that, it does not give information on the chronological addition/deletion/variations of the names that appear in *Brihatrayis* and thus does not help to solve the issue on the basis of literature research. A systematic approach would be to look at *Brihatrayis* separately and chronologically and list out medicinal plants with controversial identities. This is because of the dynamic and evolutionary nature of Ayurveda which is reflected in the chronological literature. In terms of medicinal plant documentation, there are many plants which are not seen in *Caraka Samhita* but later introduced in to *Susruta Samhita* like *Parijata*, *Chakramarda*, *Mahanimba*, *Virataru* [39]. There were also deletions like the *Divyaushadhi* of *Caraka* and *Susruta* which were dropped by *Vagbhata* in *A. samgraha*. This indicates the chronological and geographical gap between the textbooks which reflect on the identity of medicinal plants mentioned in them. Hence, it becomes important to do a text by text analysis of medicinal plants to address the issue of controversy.

6.1. Controversial medicinal plants of Caraka Samhita

An attempt was made by Dr. Venugopal, building on initial efforts of Dr. Unnikrishnan Payyappallimana and Dr. P. Ram Manohar to enlist medicinal plants mentioned in *Caraka Samhita* along with their identity status. This analysis of medicinal plant names was done based on the text *Caraka Samhita* and its commentary written in 11th century AD by *Chakrapanidatta* called *Ayurveda Deepika*. The methodology involved is as follows.

1. A list of medicinal plant names mentioned in *Caraka Samhita* was made. This list includes all the Sanskrit names given by *Caraka* for all the medicinal plants mentioned in the text. There can be many names for one plant because of the polynomial system of naming followed in the tradition.
2. Second step was to group the synonyms referring to unique medicinal plants. This is where the issue of controversy first appears. In order to group the synonyms of unique plants, one name was considered as the basonym and the remaining names mentioned in the text for the same plant were considered as its synonyms. Assigning of a basonym is based on the extent of repetitions of the name in the text and its usage in the *Nighantus.* This concept of assigning a basonym can be seen in the later literature of Ayurveda like the *Nighantus* where the authors describes a plant under one main name (basonym) and lists the synonyms under it along with its properties and uses. Though there are differences of opinion among the *Nighantus* on many synonyms and their association with a basonym, this system followed in the *Nighantus* gave every plant a popular basonym used by the physician fraternity.
3. The names which are referred to as synonyms of a unique medicinal plant by *Chakrapanidatta,* commentator of *Caraka Samhita* or by the later *Nighantus* are grouped as synonyms. For example *Chakrapanidatta* clearly states that *Amrutha phala* is a synonym of *Amalaki* (*Phyllanthus emblica*) in *Caraka samhita*, *Chikitsa stana*, 7th chapter, 147th sloka.
4. Names which have a confused botanical identity (the commentator and the later authors do not specifically relate the name to a known basonym) are tagged as controversial. For example in case of *Ambashta*, though *Chakrapanidatta* says it is *'Patha bheda'* (meaning a variety of *Patha* (*Cissampelos pariera* Linn.)), we do not know the exact botanical identification of the plant through the traditions and are listed as controversial. There are difference of opinion among the later Ayurvedic scholars on the botanical source of *Ambashta* viz. *C. pariera* Linn, *Hibiscus cannabinus* Linn., *Solanum nigrum* Linn [40].
5. The names in the text about which the commentator *Chakrapanidatta* does not give an opinion and are identified differently by different traditions of Ayurveda are also tagged as controversial. For example, with respect to plants like *Agnimantha, Pashanabheda, Daruharidra, Murva*, there is no availability of information from the commentary of *Chakrapanidatta.* But different traditions use different botanicals for the same name. In case of *Daruharidra*, both *Berberis aristata* and *Coscinium fenestratum* (Gaertn.) Coleb are used.
6. Those names about which the commentator, the later authors or the traditions do not have a clue are considered as unidentified.

Result: The analysis revealed that there are 12,670 plant references in the text in which 1915 are distinct names. Among 1915 names, 1247 are synonyms and 668 are basonyms. Among 668, 100 plant names are unidentified, 294 are identified and 274 are controversial.

Limitation: Limitation of this analysis is that it was done only based on *Caraka Samhita* and its commentary by *Chakrapanidatta*. There are other commentaries on *Caraka Samhita* which was not included for the analysis like the *Nirantarapadavyakhya* written by *Jejjata* during 9th century AD. Further analysis of medicinal plants of *Sushruta Samhita* and *A. samgraha* along with the available commentaries will give more clarity about later additions and variations of medicinal plant names. Works of medieval period like the *Nighantus* which are focused on medicinal plants of Ayurvedic Materia medica also has to be undertaken to fully catalogue controversial medicinal plants in the system.

6.2. Controversial medicinal plants in high trade

There are 174 species of Ayurvedic medicinal plants which are consumed in volumes exceeding 100 MT per year [41]. The list includes medicinal plant drugs of controversial identity like *Talisapatra, Daruharidra, Pashanabheda, Shankhapushpi*. Though controversial, the trade volume of these plants is high. For example, *Shankhapushpi* has an annual consumption of around 1000–2000 MT. As per the data, the trade on *Shankhapushpi* includes species like *E. alsinoides*, *C. ternatea* and *Canscora decussata*. It is clear that different species traded in the name of a particular controversial medicinal plant drug are either its accepted equivalents, substitutes or adulterants. The list of highly traded medicinal plants was reviewed and compared with the list of controversial medicinal plants of *Caraka Samhita*. This helped to identify 27 highly traded (more than 100 MT annually) medicinal plant drugs with controversial identities. There are 27 species of plants in high trade correlated to 18 controversial medicinal plant drugs of *Caraka Samhita* [Appendix 12].

7. Conclusion

The number of Sanskrit names formed by the system of Ayurveda for its Materia Medica is enormous. For 1540 medicinal plants used in the system of Ayurveda, there are around 9500 names mentioned in its literature including *Samhitas, Vyakhyas* and *Nighantus* spanning from around 1500 BC to 1900 AD [42]. Dr. Venugopal et al.'s work on *Brihatrayis* helped to catalogue and group medicinal plant synonyms and basonyms mentioned in *Brihatrayis.* There are 1915, 1856 and 1614 unique plant names in *Caraka Samhita*, *Susruta Samhita* and *Ashtanga sangraha* which are limited to 620, 775 and 910 basonyms respectively [43]. It is important to take up similar studies on the remaining literature of Ayurveda across time up to 1900 AD to understand its Materia medica fully. The additions and variations of names over the vast period of time in the Materia medica of Ayurveda can be understood only by a study of the literature in a chronological order.

An analysis based on the book 'Glossary of vegetable drugs in *Brihattrayi*' by Thakur Balwant singh and K C Chunekar was carried out to summarize and enlist the medicinal plants with controversial identity in *Brihatrayi*. The book enlists all Sanskrit plant names mentioned in *Brihatrayi*. The fact that the authors compared and compiled all plant names between the three texts of *Brihatrayi*, makes the study more significant. A detailed analysis of the data derived from the book in terms of the names and identity of medicinal plants of *Brihatrayi* was carried out. This helped to group the synonyms referring to unique medicinal plants in the three texts and to enlist medicinal plants with controversial identity. The data analysis based on 'Glossary of vegetable drugs in *Brihattrayi*' reveals that the percentage of plants with controversial identity in *Brihatrayi* (1500 BC to seventh century) is 30 percent (274 among 895).

Further prioritization of controversial medicinal plants mentioned in *Caraka Samhita* based on the contemporary trade in India shows that there are 27 species of medicinal plants in high trade (more than 100 MT annually) correlated to 18 controversial medicinal plant drugs. The exercise to analyze controversial medicinal plants of *Caraka Samhita* by Dr. Venugopal proposes a methodology for literary research in Ayurveda focused on identity of medicinal plants. It is very important to

conduct further studies using this methodology for the later *Samhitas* and *Nighantus*. Such a study will add value to the Materia-Medica of Ayurveda by establishing the unique species of medicinal plants mentioned in the literature and identifying regional substitutes with same or better biological effects used across texts over time.

8. Suggested research strategies

The author proposes the following strategy to resolve controversy in identification of medicinal plants of Ayurveda.

8.1. Collect textual information

Should include an analysis on etymology, synonyms, their clinical applications and chronological differences among authors about various aspects of controversial medicinal plants.

8.2. Collect information from living traditions

A survey on local health traditions and living Ayurveda traditions will help in correlating vernacular, Sanskrit and botanical names of plants and documentation of their traditional/folk practices. This helps in short listing the botanical candidates (associated with each Controversial plant) for further scientific analysis.

8.3. Collect data from regional literature

Literature review of regional medical literature will help in the identification of regionally used plants for those with controversial identity mentioned in Ayurveda.

8.4. Collect data from non-medical Sanskrit literature

Non medical Sanskrit literature is yet another source of information on plants.

8.5. Review of recent botanical correlations

Review of botanical correlations done by ethno botanists and experts in Ayurveda will help in identifying botanical candidates correlated to traditional names provided the exercise involved rigorous field studies.

8.6. Trade related studies

Studies on trade may help in identifying different botanical candidates traded in the name of medicinal plants which have controversial identities on the assumption that adulterants are not being traded.

8.7. Lab analysis

Pharmacognostical, phytochemical and pharmacological analysis of short-listed candidates based on all the above parameters will help in identifying potential candidates for their contemporary use. For the effective application of scientific analysis the traditional/Ayurvedic pharmacology has to be transmitted in to modern biological activity and tested to see if the activity corresponds to the traditional/Ayurvedic pharmacological claims.

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None

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jaim.2019.09.003.

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