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Prof. P. K. Jha

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Documentation of Ethno-Veterinary medicinal plants by Sugali Tribe from Rayalaseema Region of Andhra Pradesh State, India

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The preliminary investigations of the ethno-botanical study of ethno-veterinary plant species in the Rayalaseema region Sugali tribe have been focused, the drug formulation, administration, and usage for several centuries have practiced by this tribe. Ethno-veterinary herbs have been employed in recipes, drug production, administration, and usage for generations to generations. The Sugali tribe, with its rich folklore and ethnoveterinary information have found, it also serves as the primary source and provides scope for additional scientific investigation into the isolation and characterization of the active principle involved in pharmaceutical utility. The folklore assertions were investigated and compared to phytochemical evidence of the corresponding crude medications. Keeping in mind that possible sources of medicinal plants with legendary origins must be safeguarded and conserved. During the field exploration, 26 crude medications (species) have documented, these belong to 26 genera and 19 families were discovered. The pattern of plant uses was constructed based on habitat (terrestrial, aquatic, or epiphytic), habit (growing form), plant part (tissue), taxonomic group (Systematic families), nativity, and occurrence (wild/cultivated). Updated nomenclature, distribution, and field pictures have been presented. Field data was meticulously documented in field notebooks, and each pharmacological substance was individually recorded using videos and images shot with GIS tags.

Keywords: *Lambadis, Primitive reports, Sugali tribe, Veterinary reports, Thandas.*

INTRODUCTION

Ethnoveterinary medicine is a subfield of science that studies the values, methods, skills, processes, and practices of animal health care (McGaw, L.J., et al., 2020). Plants are critical to the survival of ethnic populations in the northwestern Himalayas' rural regions. According to the World Health Organization (WHO), approximately 80% of the world's population relies directly on plant resources for health, particularly those living in rural regions (World Health Organization.,2000 & Dhaman et al., 2019). India is known for its biodiversity, having two major hotspots: the Western Ghats and the Eastern Himalayas (Tangjang, S et al., 2011). The high and low hills are covered in coniferous forest, with oaks growing in the depressions. Fir and spruce dominate the upper elevations, while pines cover the lower elevations. Himachal Pradesh is rich in medicinal plants, and people in some areas rely solely on them for survival. Various reports have reported the use of aromatic and medicinal herbs for a variety of therapeutic objectives (Kumar et al., 2011).

Some wild plants that yield fruit provide vital nutrients and economic benefits to many populations around the world. Most tribal societies have used plants since prehistoric times. Some factors, such as rising medicine and veterinary practice costs, have sparked a renewed interest in ethnological study (Singh V et al., 2011 & Monteiro, M.V et al., 2011). People learn ethnoveterinary knowledge via years of experience and pass it down orally from generation to generation (oral tradition). With rapid cultural change and modernisation, this ancient knowledge is being lost. As a result, there is an urgent need for scientific

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documentation of traditional knowledge in India's rural areas. Various sorts of ethnological research on the use of plants in medicinal investigations have been conducted throughout the world (Ritter, R.A et al., 2012). Ethnoveterinary traditional knowledge is applied to care for domestic animals. Plants have been employed for veterinary therapy in India since the Vedic period (González, J.A et al., 2021).

Ethno-veterinary herbs have been used for generations, as have their recipes, the preparation of medicines, their administration and their use. The rich folklore and ethno-veterinary medicinal knowledge of the Sugali tribe serves as a primary source, and there is scope for scientific research to better isolate and characterise the active principle behind the pharmacological benefits. Phytochemical evidence of the corresponding crude drugs has been used in conjunction with the folklore claims. Considering the fact that possible sources of folklore medicinal plants need to be protected and conserved (Amarasingham et al., 1964; Balaji Rao, et al., 1995). Rayalaseema is a landlocked region with an extent of 67,298 square kilometres, which constitutes 42% of the total geographical area of Andhra Pradesh. The region extends approximately from 120 3' north latitude to 160 15' north latitude and 760 55' east longitude to 79055' east longitude. Geographically, the Rayalaseema region forms the southern and south-eastern part of the Deccan Plateau. It is located almost in the centre of the southern part of the Indian peninsula. It includes the districts of Anantapuramu, Anamaya, Chittoor, Kurnool, Nandyal, Sri SathyaSai, Tirupati and YSR Kadapa. Most of the area lies at an altitude of about 300-700 metres MSL. Rayalaseema receives more rainfall from the southwest monsoon than from the northeast monsoon. The average annual rainfall is barely 672 mm. No previous report has been found from the current research region. So that the current work is carried out.

MATERIALS & METHODS

As part of the study Ethno-Botanical Study of Ethno-Veterinary Plant Species in Rayalaseema Region (Sugali Tribe), Andhra Pradesh State, India, various field trips were conducted during 2020-2023 and documented from different natural populations. The collected ethnobotanical and ethno-therapeutic data and plant samples were collected during the flowering and fruiting season. Specimens were critically observed and identified, herbarium specimens were deposited (Pullaiah 1996), indicating the method of administration, purpose and plant part used and carefully recorded in video recordings and field notes. Based on this information, the plants were collected, their herbaria prepared and identified with the help of local flora and confirmed by comparison with authenticated specimens at Deccan Regional Centre, BSI, Hyderabad, Coimbatore and Central National Herbarium (CAL), Kolkata. Review of relevant published literature

RESULTS & DISCUSSION

The preliminary investigations of crude drug resources of Sugali tribes in the Rayalaseema region, Sri Sathya Sai district, Andhra Pradesh, with their recipes, preparation of drugs, administration, and use for several centuries. 25 crude drugs (species) belonging to 25 genera and 18 families have been collected on the basis of tribal knowledge and all the data have been provided. Some important species discussed are *Dolichoderine falcata,* commonly known as Indian trumpet tree, a deciduous tree native to India and Southeast Asia. Its leaves, bark, flowers, and fruits are of great importance in autotherapeutic medicine due to their diverse bioactive properties. The use of *Boswellia serrata* in autotherapeutic medicine reflects the traditional knowledge that continues to be an important resource in rural and indigenous communities for maintaining the health of livestock. *Boswellia serrata*, commonly known as Indian frankincense, is a resin-producing tree native to India, Africa, and the Middle East.

The plant holds great veterinary importance due to its medicinal properties and traditional use in veterinary medicine (Mahaboob Peer et al., 2021; Subba Rao and Kumari, 2002-2008). Below you will find the most important aspects of its ethnological significance for veterinary medicine. The use of Boswellia serrata in veterinary medicine emphasizes its value in traditional farming systems, especially in regions where access to modern veterinary services is limited. Its natural, cost-effective remedies are in line with sustainable and ecological animal husbandry practices. Cassia fistula, commonly known as the laburnum tree, is a widely used plant in traditional medicine, including ethnic veterinary practices.

Table 1. Plant species used by the Sugali tribe in the Rayalaseema Region, for the treatment of Veterinary diseases, and the mode of administration.

Sr. No.	Name of the Species	Family	Vern. Names	Plants Parts Used	Doses and Mode of Preparation	Veterinary use
1	*Albizialebbeck* (L.) Benth.	Leguminosae	Dhirisenachekka	Bark	*Mangifera Indica, Albizialebbeck and Ficus religiosa* collect 3 species equal amount of fresh bark (20 g), prepared decoction used directly 3-4 days	Stomach Bloating
2	*Bacopamonnieri* (L.) Wettst.	Plantaginaceae	Nela Sambrani	Whole Plant	Leaf juice mixed with garlic and pepper	Udder cysts, Bloating, Pain in the stomach
3	*Boswellia serrata Roxb*.	Burseraceae	Saalarayaer Jaad	Bark	Commonly known as guggilamu, it is used from medicinal and commercial, dry material insect repellent winter season	Rheumatism and asthma, Mosquito repellent
4	*Brassica nigra* (L.) K.Koch	Brassicaceae	Tella Avalu/ Manchi Avalu	Seeds	Mix *Ferula assa-foetida, Brassica nigra, Buniumpersicum, Trachyspermumammi, Curcuma longa,* and *Zingiberofficinaleseeds* and root in equal quantities (5 g each) with garlic in hot water after taking them directly	Stomach Bloating, Stomach pain
5	*Bunium persicum* (Boiss.) B.Fedtsch.	Apiaceae	Nalla Gelakarra	Seeds	*Ferula assa-foetida, Brassica nigra, Buniumpersicum*, *Trachyspermum ammi, Curcuma longa* and *Zingiberofficinaleseeds* and root in equal amounts (5 g each) mixed with garlic in hot water after direct ingestion	Stomach Bloating, Stomach pain
6	*Cadabafruticosa* (L.) Druce	Capparaceae	Tachikamulu	Leaves	Leaf extract taken directly cures diseases	Helminthiasis, fever, weakness
7	*Canthium coromandelicum* (Burm.f.) Alston	Rubiaceae	BalizarePaka	Leaves	Fresh leaves are used directly applied.	Strength
8	*Capsicum annuum* L.	Solanaceae	Haremarcha	Fruit	*Cissusquadrangularis, Tamarindusindica(leaves), Capsicum annuum(fruit), Curcuma longa (root) mixture day by day orally*	Laziness, Loss of Apitite, Nausea

9	*Caralluma adscendens* (Roxb.) R.Br.	Apocynaceae	Kundeti Kommu	Whole Plant	Fresh leaves are used directly used	diabetes
10	*Cassia fistula* L.	Leguminosae	Relachettu	Bark	Bark & peel extract applied tongue cure diseases	Jerrys bites
11	Chloroxylon swietenia DC.	Rutaceae	Bariaechhal	Bark	*Dolichandronefalcata, Soymidafebrifuga and Chloroxylonswietenia 3species bark equal amount (10 gm) taken after dry mixture grinder. Mix powder and goat urine (5 ml) both mixture apply orally for a day once 3days cure cough and fatigue*	Couch, Fatigue
12	*Cissus quadrangularis* L.	Vitaceae	Nallarezud	Whole Plant	Stem mixture	Bone fracture
13	*Cocculu shirsutus* (L.) W.Theob.	Menispermaceae	Dhusaraku	Leaves	Fresh leaves 10 gm directly use	strength kidney stones
14	*Curcuma longa* L.	Zingiberaceae	Haldi	Root	*Ferula assa-foetida*, *Brassica nigra*, *Buniumpersicum*, *Trachyspermumammi*, *Zingiberofficinale*and *Curcuma longa* mix each species 5 gm quantity of Raw material with Garlic in Hot water	Flavour and colour, Stomach Bloating, Stomach pain
15	*Dolichan dronefalcata* (Wall. ex DC.) Seem.	Bignoniaceae	Neeruvudhi	Bark	*Dolichandronefalcata, Soymidafebrifuga and Chloroxylonswietenia 3 types of bark equal amount (10 gm) taken after dry mixture grinder. Mix powder and goat urine (5 ml) both mixture apply orally for a day once 3days cure cough and fatigue*	Couch, Fatigue
16	*Ferula assa-foetida* L.	Apiaceae	MuddaInguva	Seeds	*Ferula assa-foetida, Brassica nigra, Buniumpersicum, Trachyspermumammi, Curcuma longa* and *Zingiberofficinale*seeds and root taken equal quantity (each 5 gm) mix with Garlic in Hot water after taken direct mix	Stomach Bloating, Stomach pain
17	*Ficus religiosa* L.	Moraceae	Raagi Chekka	Bark	*Mangiferaindica, Albizialebbeck* and *Ficusreligiosa* collecting 3 species equal quantity of fresh bark (20 gm), prepared a decoction, and directly used 3-4 days	Stomach Bloating

18	*Gymnema sylvestre* (Retz.) R.Br. ex Sm.	Apocynaceae	Podapatri	Leaves	Fresh leaves are used directly use	diabetes
19	*Limonia acidissima* Groff	Rutaceae	Bikki Paka	Fruit	Fresh leaves directly use	malnutrion
20	*Mangiferaindica* L.	Anacardiaceae	Mamidichekka	Bark	*Mangiferaindica, Albizialebbeck* and Ficus religiosa collect 3 species equal amounts of fresh bark (20 g), prepared decoction used directly for 3-4 days	Stomach Bloating
21	*Phyllanthus acidus* (L.) Skeels	Phyllanthaceae	Nalli Kamalu	Fruit	Use fresh leaves directly	Strength
22	*Santalum album* L.	Santalaceae	Siri Gandham	Whole Plant	Stem powder direct use cure some diseases	Antiseptic, antiscabetic
23	Soymida Febrifuga (Roxb.) A. Juss.	Meliaceae	Somichekka	Bark	*Dolichandronefalcata, Soymidafebrifuga and Chloroxylonswietenia 3 species bark equal quantity (10 gm) taken after dry mixture grinder. Powder mixture and goat urine (5 ml) apply both mixture orally for a day once 3 days cure cough and fatigue*	Couch, Fatigue
24	*Tamarindus Indica* L.	Leguminosae	Chintaku	Leaves	*Cissusquadrangularis, Tamarindusindica, Capsicum annuum* and *Curcuma longa* mixture, day by day oral	Laziness, Loss of Apitite, Nausea
25	*Trachy spermumammi* (L.) Sprague	Apiaceae	Vamu	Seeds	*Ferula assa-foetida, Brassica nigra, Buniumpersicum, Trachyspermumammi, Curcuma longa* and *Zingiberofficinale*seeds and root taken equal quantity (each 5 gm) mix with Garlic in Hot water after taking direct mix	Stomach Bloating, Stomach pain
26	*Zingiber officinale* Roscoe	Zingiberoside	Sonti	Root	*Ferula assa-foetida, Brassica nigra, Buniumpersicum, Trachyspermumammi, Curcuma longa* and *Zingiberofficinale*seeds and root taken in equal quantities (each 5 gm) mixed with Garlic in Hot water after taking a direct mix	Stomach Bloating, Stomach pain

Figure 1 – Showing Raw Plant Material Collections- Provided with GIS Images.
A. D. E. Soyamidafebrifuga B. Swieteniamahagoni C. Chloroxylonswietenia-Bark collections. F. Dolichandronefalcata G. Boswelliaserrata_ Showing Fresh material Principle Investigator with Local healer.

Its medicinal properties are attributed to various bioactive compounds such as anthraquinones, flavonoids, and tannins. Cassia fistula is widely used in traditional animal husbandry, especially in tropical and subtropical regions, making it an invaluable resource for smallholder and indigenous agriculture. Chloroxylon swietenia, commonly known as Ceylon satinwood or East Indian satinwood, is a deciduous tree native to South and Southeast Asia. Due to its various medicinal properties, especially in traditional veterinary medicine, it is of great ethnological importance. Due to its many uses, Chloroxylon swietenia is sometimes over-harvested in the wild, which can lead to conservation issues. Sustainable practices and cultivation are encouraged to ensure its availability for future generations. *Soymi dafebrifuga* (commonly known as Indian sequoia or Rohan tree) is an important medicinal plant used in both traditional human and veterinary medicine. In ethno-therapeutic practice, it is valued for its various therapeutic properties, especially in the treatment of livestock diseases. The plant is a valuable component of ethnological veterinary medicine, especially in rural areas where access to modern veterinary care may be limited. The Sugali tribe, which has a wealth of information, is the most important source and provides the opportunity to expand scientific research to further isolate and characterise the active compounds responsible for the pharmacological benefits. Ethno-therapeutic medicine has a rich history that spans cultures and civilisations and reflects the deep connection between humans and animals. While the use of traditional herbal remedies for animals has been practised for centuries, the formal study and documentation of ethnological practices gained recognition in the second half of the 20th century. This integrated approach provides a holistic understanding of the complex relationship between local communities in the Rayalaseema region and the plant species they use for both human and veterinary purposes. Field research, interviews, and community involvement are crucial to the success of such a study, as these are just a few examples of ethno-therapeutic plant species. Local communities often have extensive knowledge of plants and their uses for animal health, and these practices are deeply rooted in cultural traditions and passed down through generations. It is important to research thoroughly and work with local communities to understand the specific uses and cultural significance of ethno-therapeutic plant species in a particular region.

ACKNOWLEDGEMENTS

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References

1. McGaw, L.J., Famuyide, I.M., Khunoana, E.T., Aremu, A.O. (2020). Ethnoveterinary botanical medicine in South Africa: A review of research from the last decade (2009 to 2019). *J. Ethnopharmacol. 257*, 112864
2. World Health Organization. *World Health Organization General Guidelines for Methodologies on Research and Evaluation of Traditional Medicine*; WHO: Geneva, Switzerland, 2000.
3. Dhiman, N., Shivani, Y.S.T. Kumar, S. (2019). Diversity of ethnomedicinal plants in Churdhar Wildlife Sanctuary of district Sirmour of Himachal Pradesh, India. *J. Appl. Pharm. Sci. 9*, 48–53.
4. Tangjang, S., Namsa, N.D., Aran, C., Litin, A. (2011). An ethnobotanical survey of medicinal plants in the Eastern Himalayan zone of Arunachal Pradesh, India. *J. Ethnopharmacol.* 2011, *134*, 18–25.
5. Kumar, M., Changan, S., Tomar, M., Prajapati, U., Saurabh, V., Hasan, M., Sasi, M., Maheshwari, C., Singh, S., Dhumal, S. (2021). Custard apple (*Annona squamosa* L.) leaves: Nutritional composition, phytochemical profile, and health-promoting biological activities. *Biomolecules*, *11*, 614.
6. Singh, V., Dasgupta, S., Jhaldiyal, V., Chauhan, D., Todaria, N. (2011). Diversity pattern of vegetation in and around proposed Kotlibhel hydroelectric project along the Alaknanda River in Garhwal Himalaya (India). *iForest Biogeosci. For. 4*, 38–43.
7. Monteiro, M.V., Bevilaqua, C.M., Palha, M.D., Braga, R.R., Schwanke, K., Rodrigues, S.T., Lameira, O.A. (2011). Ethnoveterinary knowledge of the inhabitants of Marajó Island, Eastern Amazonia, Brazil. *Acta Amaz. 41*, 233–242.
8. Ritter, R.A., Monteiro, M.V.B., Monteiro, F., Rodrigues, S.T., Soares, M.L., Silva, J.C.R.; Palha, M.D.D.C.; Biondi, G.F.; Rahal, S.; Tourinho, M.M. (2012). Ethnoveterinary knowledge and practices at Colares island, Pará state, eastern Amazon, Brazil. *J. Ethnopharmacol. 144*, 346–352.
9. González, J.A. & Vallejo, J.R. (2021). The use of domestic animals and their derivative products in contemporary Spanish ethnoveterinary medicine. *J. Ethnopharmacol. 271*, 113900.

10. Amarasingham, R.P. Bisset, N.G. Millard, P.H. & Woods, M.C. (1964). Phyto-chemical survey of Malaysia part III. Alkaloids and Saponins. Journal of Economic and Taxonomic Botany 18: 270-278.
11. Balaji Rao, N.S.Rajasekhar, D. ChengalRaju, D., Nagaraju. (1995). Folk medicine of the Rayalaseema region, Andhra Pradesh; 1. Dental protector. Ancient Science of life 14(5): 15-20.
12. Pullaiah T. & Chennaiah E. (1997). Flora of Andhra Pradesh, India. Scientific Publishers, Jodhpur.
13. ShaikMahaboob Peer, M. ChennakesavuluNaik and DasariVeeranjaneyulu(2021). Ethno-botanical Investigations on Sugali Tribes of Nallamada Mandal, Anantapuramu District, Andhra Pradesh, India. Non-Timber Forest Products. 28(2), 50-60.
14. Subba Rao G.V., Kumari G.R. (2002-2008). Flora of Visakhapatnam District, Andhra Pradesh, India, Vols: I &II, Calcutta.

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Natural edible fruits and their nutritional and therapeutic benefits

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34 edible natural fruits are discussed in the current paper along with their nutritional and therapeutic qualities. The investigation of information regarding the documentation and preservation of natural fruit plants that are consumed by the rural populace is the outcome of this study. Valuable fruit species have been discovered among the 34 naturally occurring edible fruit species, which are divided into 24 genera and 19 families. The largest families are Anacardiaceae (four species), followed by Annonaceae, Arecaceae, and Moraceae (three each), and Combrataceae, Cucurbitaceae, Euphorbiaceae, Rhamniaceae, and Rutaceae (two each). There is only one species in each of the other nine families. If we eat natural edible fruits, there are no negative impacts. The natural fruits have been discovered to have a significant number of secondary metabolites, antioxidants, and micro and macro components. This type of information could aid in raising awareness among the impoverished rural population.

Keywords: Folklore, medicinal qualities, naturally occurring edible fruits, Mahabubnagar, Telangana.

INTRODUCTION

The forest, one of the most significant natural and renewable resources, is essential to preserving the sustainability and biodiversity of natural ecosystems, which are home to a wide variety of wild edible fruits (J. Rabiei, 2022). Human activity and climate change are the main factors that can alter forest conditions, such as hydrological drought in river basins, which could endanger all of the forest's flora and wildlife (Javadinejad, 2019). Nonetheless, a number of studies have demonstrated that the edible wild plants that flourish in forests are more resilient than other plants and can withstand dry conditions. Recent nutritional research has identified a number of wild edible fruits as functional foods that can be used as a nutritious diet and to treat illnesses (A. Pieroni et al., 2018), have substantial therapeutic potential because of their bioactive components, such as flavonoids and anthocyanins, and are essential in terms of calories and nutrients (Manduzai et al., 2021). Vitamin C levels in *Capparis mitchelii* and *Flacourtia jangomas,* for example, are exceptionally high, at 220.75 mg/100 g and 223.25 mg 100 g-1, respectively. Furthermore, fruits like *Hiptage benghalensis* are high in protein, while *Garcinia xanthochymus* is well-known for its fruit, which has a high energy content of 124.92 Kcal100 g-1 (S.C. Biswas et al., 2022).

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Tribal groups around the world have relied heavily on wild edible fruits for their nutrition. They have improved the economic well-being of these communities and offered a wide variety of food options and alternative nutrition sources. By creating income and lowering poverty, these fruits have contributed to better food security and nutritional balance. They have also contributed to agricultural diversification, which has made the food system more resilient and sustainable (Kalle et al., 2020). According to recent research, wild edible fruits are a great way to get biologically active substances, including vitamins, complex carbohydrates, and vital fatty acids. These substances are essential in the fight against malnutrition (Thakur 2017), and can play a crucial role in times of famine and political unrest. These fruit species are present in almost every backyard and are widely distributed across woodlands. But because of their low market demand, lack of consumer awareness, lack of commercial growth, and lack of widespread trading, they frequently go unrecognized and garner little attention. Furthermore, because their availability varies with the season and some fruits exhibit alternating bearing, there is little information available on their use, distribution, and cultivation (Sõukand, et al., 2017; Angami et al., 2024).

Few studies have been done on the nutritional potential of these fruits in northeast India, despite the fact that numerous studies have been done worldwide

to record their nutritional and anti-nutritional qualities (Adamu 2021, Tharmabalan 2023, Dissanayake 2023, Yiblet 2024). Thus, the purpose of this study was to demonstrate the potential of edible wild fruits in this area. Additionally, the amount of wild edible fruits has decreased as a result of shifting farming, industrialization, urbanization, and the changing tastes of the general public. Despite these fruits' high nutrient content, they are nevertheless frequently disregarded and underappreciated, and many people are ignorant of their health advantages (Thakur 2017).

People have utilized plants for food, fuel, medicine, and wood since ancient times. There is no proof that natural fruits are legitimate, but documented knowledge of the use of traditional, folkloric, and ethnic knowledge of plants as medicine is highly regarded (Anonymous et al., 1994, Maheswari et al., 2000). However, very little is known about using natural fruit trees as food. A sizable section of Telangana's inhabitants, who reside in isolated forests and villages, rely on natural fruits for sustenance. Even city dwellers are quite interested in purchasing the natural, edible fruits that the villages sell. A great variety of natural fruit plants are utilized as remedies in the diet, and the plant assortment is very extensive. Regarding natural fruits from the particular study location, there was no comprehensive document (Jain et al., 1964, Durby et al., 1997, Katewa et al., 2000).

The nutritional and therapeutic qualities of natural plant fruits, as well as their edible nature, are not well documented. Due to reasons like villagers moving to cities and the introduction of high-quality food into marketplaces, folk wisdom is rapidly disappearing (Lalramnghinglova1992, Priya Ranjan 2000, Sudhakar 2000). In order to record rural knowledge about natural edible fruits in a particular Telangana state research region, an inquiry was conducted.

Research methodology

The southern portion of the particular research area was the site of several excursions (Fig. 1). During each of these trips, various data regarding the folk and forest population or the rural population were gathered at various times of the year. After speaking with a variety of users, including elderly women, village labourers, and other local shapers, the data was gathered. To verify the information, questionnaire surveys were repeated in various villages. Using the regional flora (Pullaiah 2015), fruit and plant samples were gathered and identified.

About the study area

The middle region of the Indian peninsula's east coast is home to the state of Telangana. The total size of the Telangana state is 114,840 square kilometres, or 44,300 square miles. The lowlands and the Eastern Ghats are the two primary regions that make up the area. Telangana is located between latitudes 15 50' and 19 55' north and longitudes 77 14' and 78 50' east. Telangana shares boundaries with the states of Andhra Pradesh to the south, Odisha to the east, Maharashtra to the north and north-west, Karnataka to the west, and Chhattisgarh to the northeast. The Godavari and Krishna rivers drain 79% and 69% of the state's catchment area, respectively; however, the majority of the land is desert. With an average elevation of almost 400 meters above sea level, it is a large plateau.

The areas of erosion surface that make up the majority of this plateau are (i) above 600 m, (ii) between 300 and 450 m, and (iii) between 150 and 300 m. The climate in the state of Telangana is tropical monsoon. The climate is warm across the entire state. The climate of northern Telangana is tropical and wet. The state's southern regions have hot steppe weather. The average daily temperature in the tropical wet climate is more than 20°C, and 150 to 200 cm of rain falls there each year, mostly during the summer and the south-west monsoon. The average daily temperature in the Hot Steppe type is 18°C or

Figure 1 – Specific Study area, Kosgi mandal, Narayanapeta District, Telangana State, India.

lower. In the state of Telangana, summer temperatures range from 37 to 44 degrees Celsius, while winter temperatures range from 14 to 19 degrees Celsius. There are many different types of soil in the state, and they can be divided into three main groups: laterite, black, and red.

According to Champion and Seth's (1968) classification, Telangana is home to the following types of forests: tropical wet deciduous forests, tropical dry deciduous forests, northern mixed dry deciduous forests, dry savannah forests, and tropical dry evergreen scrub**14.** Over 20 tribes have been identified in the state of Telangana. They are typically found in interior forest areas and mountainous terrain. The study report focuses on several significant natural food plants that must be documented for future food security.

ABOUT THE SPECIFIC STUDY AREA

The largest district in Telangana in terms of covered area (18432.00 sq. km) is Mahabubnagar (Figure 1). Another name for it is Palamoor. In honor of Mir Mahbub Ali Khan Asaf Jah VI, the Nizam of Hyderabad (1869-1911 AD), the name was changed to Mahabubnagar. The area was located between 15° 55' and 17° 20'N in the northern latitudes and between 77° 15' and 79° 15'E in the eastern longitudes. Mahabubnagar is the southern district of Hyderabad state under Nizam. It is bounded to the south by the River Krishna and to the east by the Guntur District of Andhra Pradesh, to the south by the Kurnool District of Andhra Pradesh, to the north by the Nalgonda and Ranga Reddy Districts, and to the west by the Gulbarga and Raichur Districts of Karnataka.

According to the 2011 census, the district has 40,53,028 residents, making up 11.52% of the state's total population with a decadal growth of 15.34%. This district's residents are economically disadvantaged. They speak three languages, and information is shared between cultures. A great variety of natural fruit plants are used as nutritional and therapeutic resources, and the plant assortment is highly extensive. Natural fruits from the particular study location were not covered in detail in any document.

RESULTS AND DISCUSSION

A total of 34 natural fruits are used in a particular research region of Mahabubnagar district, Telangana state, according to the current data on natural fruits and their nutritional and therapeutic benefits. Standard questionnaires were used to complete the documentation. A total of 34 naturally occurring fruit species from 24 genera and 19 families were deemed valuable. The top four families are Anacardiaceae (four species), followed by Annonaceae, Arecaceae, and Moraceae (three each), while Combrataceae, Cucurbitaceae, Euphorbiaceae, Rhamniaceae, and Rutaceae have two species apiece. Only one species is visible in the remaining nine families. Along with their habit, botanical name, vernacular name, family, nutritional value, and therapeutic qualities, they were thoroughly documented in the current paper. Natural fruit discoveries were anticipated to have the highest nutritional value based on ethnicity or season (Table 1). Figure 2 depicts the natural fruit plants' environment.

Figure 1 – Specific Study area, Kosgi mandal, Narayanapeta District, Telangana State, India.

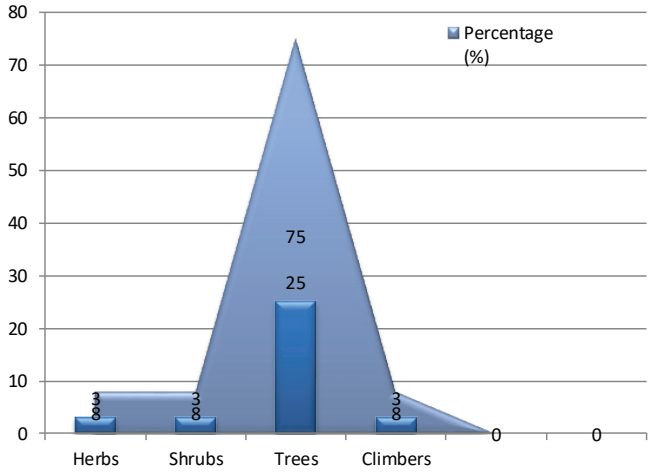
Sl. No.	Habit	Local Name	Botanical Name	Family	Nutritional and medicinal properties
1	Tree	Maredu	*Aegle marmelos*	Rutaceae	Aeromatic Tannin diarrhoea Dysentery Sweet drinks
2	Tree	Uduga	*Alangium salvifolium*	Alangiaceae	Astringent Laxative Refrigerant haemorrhages.

3	Tree	Jeedimamidi	*Anacardium occidentale*	Anacardiaceae	nuts highly nutritious, adessert and employed in sweetmeats and confectionery.
4	Shrub	Anasa	*Anana sqomosus*	Bromiliaceae	Antiscorbutic Purgative Abortifacient
5	Tree	Lakshmana phalum	*Annona muricata*	Annonaceae	wine or cognac
6	Tree	Ramaphalum	*Annona reticulata*	Annonaceae	Anthelmintic.
7	Tree	Seetaphalum	*Annona squamosa*	Annonaceae	Vitamin-C
8	Tree	Tati	*Borassus flabellifer*	Arecaceae	Source of Vitamins
9	Tree	Sarapappu	*Buchanania lanzan*	Anacardiaceae	Leprosy
10	Climber	Thonda	*Coccinia grandis*	Cucurbitaceae	Skin diseases
11	Tree	Ravi	*Ficus religiosa*	Moraceae	Scarcity laxative
12	Tree	Konda ravi	*Ficus auriculata*	Moraceae	curries or jams
13	Tree	Medi Atti	*Ficus racemsoa*	Moraceae	diabetes bagatha.
14	Tree	Velaga	*Limonia acidissima*	Rutaceae	Gum-arabic Acidity Joundice Cancer Dysphoea, Hiccough Scorpion Poisoning
15	Tree	Chimachinta	*Pithecolobium dulce*	Mimo*saceae*	Eaten raw curries Hemolytic agglutinating in human blood.
16	Tree	Nallajeedi	*Semecarpus anacardium*	Anacardiaceae	skin diseases
17	Tree	Rachausiri	*Sicca acida*	Euphorbiaceae	chetnyes pickels

18	Herb	Mulla vankaya	*Solanum anguivi*	Solanaceae	skin diseases urinary retention fever cough asthma,
19	Herb	Kamanchi	*Solanum nigrum*	Solanaceae	Delightful jam.w
20	Tree	Neradu	*Syzygium cuminii*	Myrtaceae	diabetic
21	Tree	Chinta	*Tamarindus indica*	Caesalpiniaceae	Refrigerant.
22	Tree	Mamidi	*Mangif era indica*	Anacardiaceae	vitamin C Scarcity.
23	Tree	Palachettu	*Manilkara hexandra*	Sapotaceae	Edible oil.
24	Climber	Agakara	*Mimordica dioica*	Cucurbitaceae	vegetable
25	Shrub	Nagajamudu	*Opuntia dillenii*	Cactaceae	Secretion of the bile.
26	Herb	Tigabenda	*Pavonia odorata*	Malvaceae	Highly nutrient
27	Shrub	Chittietha	*Phoenix loureiroi*	Arecaceae	astringent
28	Tree	Etha	*Phoenix sylvastri*s	Arecaceae	Restorative preservative
29	Tree	Usiri	*Phyllanthus emblica*	Euphorbiaceae	Liver, piles, stomach eye treatments C vitamin
30	Tree	Tani	*Terminalia bellerica*	Combretaceae	purgative
31	Tree	Karakaya	*Terminalia chebula*	Combretaceae	dentifrices asthma
32	Climber	Adavi draksha	*Vitis heyneana*	Vitaceae	Eaten as raw
33	Tree	Regu	*Zizyphus jujuba*	Rhamnaceae	antidote to nausea vomiting abdominal pain in pregnancy.
34	Tree	Pedda regu	*Zizyphus mauritiana*	Rhamnaceae	Cooling Chest troubles.

Due to the significance of 34 species of natural fruit plants, bellam and *Limonia acidissima* fruit pulp combine to create a tasty, refreshing beverage with export potential. A review of the literature reveals the variety of naturally occurring edible plants in India's various areas. For instance, South India's 23–25 edible natural fruit trees are very different from those recorded in North India **(**Kaushal Kumar, 2000, Debabrata Das, 2000**).** Even in South India, the variety of naturally occurring edible plants varies across Telangana and Andhra Pradesh (Viswanathan, 1997, Rajendran, 1997) and Karnataka **(**Kameswara Rao, 2000). Therefore, in order to maximize their use and conservation, it is essential to record the folk knowledge about wild fruit trees in a particular study region.

Figure 1 – Specific Study area, Kosgi mandal, Narayanapeta District, Telangana State, India.



CONCLUSION

The population is growing rapidly every day, and people are also becoming more and more reliant on farmed or fake fruits. This is leading to a shortage of medications and nutrients. Seasonal natural fruits were typically consumed by our ancestors. So that they wouldn't have any deficiencies. These days, people have forgotten about seasonal or natural fruits. Thus, the outcomes that we are witnessing. The present report explores awareness of natural fruits and their nutritional and medicinal properties. The outcome of this article is to contribute some interesting information on the conservation of traditional knowledge on natural fruits and their conservation.

References

1. Rabiei J, Khademi, M S, Bagherpour, S, (2022). Investigation of fire risk zones using heat–humidity time series data and vegetation, Appl. Water Sci., 12, p. 216.
2. Javadinejad S, Hannah D, Ostad-Ali-Askari, O, Krause S, (2019). The impact of future climate change and human activities on hydro-climatological drought, analysis and projections: using CMIP5 climate model simulations, Water Conserv Sci Eng, 4, pp. 71-88.
3. Pieroni, A, Sõukand, R, Amin, H I M, Zahir H. (2018). Celebrating multi-religious Co-existence in Central Kurdistan: the bio-culturally diverse traditional gathering of wild vegetables among Yazidis, Assyrians, and Muslim Kurds, Hum. Ecol., 46 (2): pp. 217-227,
4. Manduzai A K, Abbasi, S.M. Khan S m.,Abdullah, (2021). The importance of keeping alive sustainable foraging practices: wild vegetables and herbs gathered by Afghan refugees living in mansehra district, Pakistan, Sustainability, 13 (3): p. 1500.
5. Biswas S A, Bora, A. (2022). Evaluation of nutritional value, antioxidant activity and phenolic content of Protium serratum Engl and Artocarpus chama Buch.-Ham, wild edible fruits available in Tripura, a North- Eastern state of India, Curr. Nutr. Food Sci., 18: pp. 589 596,
6. Kalle R, Sõukand, R(2020). Devil is in the details: use of wild food plants in historical Võromaa and Setomaa, present-day Estonia, Foods, 9 (5): p. 570,
7. Thakur, D, Sharma, A, Uniyal, SK, (2017). Why they eat, what they eat: patterns of wild edible plants consumption in a tribal area of Western Himalaya, J. Ethnobiol. Ethnomed., 13 (1): pp. 1-12.
8. Sõukand, R, Hrynevich, Y, Vasilyeva,I, (2017). Multi-functionality of the few: current and past uses of wild plants for food and healing in Liubań region, Belarus, J. Ethnobiol. Ethnomed., 13 (2017), p. 10.
9. Angami, T, Wangchu, L, Debnath, P, (2024). Exploring the nutritional potential and anti-nutritional components of wild edible fruits of the Eastern Himalayas, Food Measurement Compos, 18: pp. 150-167,
10. Adamu, E, Asfaw Z (2022). Antioxidant activity and anti-nutritional factors of selected wild edible plants collected from northeastern Ethiopia, Foods, 11: p. 2291.
11. Tharmabalan, R T, (2023). Nutritional profiles of four promising wild edible plants commonly consumed by the Semai in Malaysia, Curr. Dev. Nutr., 7 (4): Article 100054.

12. I.H. Dissanayake, V. Zak, K. Kaur, K. Jaye, Z. Ayati, D. Chang, C.G. Li, D.J. Bhuyan, Australian native fruits and vegetables: chemical composition, nutritional profile, bioactivity and potential valorization by industries, Crit. Rev. Food Sci. Nutr., 63 (27) (2023), pp. 8511-8544.
13. Yiblet, (2024). Nutritional composition and antinutritional factors of five wild edible fruits grown in the mekdela district, south of wollo, Ethiopia, Sci. World J. (2024).
14. Anonymous, (1994). *Ethnobotany in India – A status report* (Ministry of Environment and Forests, Govt. of India),
15. Maheswari J K, (2000). (Ed.) *Ethnobotany and Medicinal plants of Indian Subcontinent*, (Scientific Publishers, Jodhpur) 672.
16. Jain S K, Natural food plants of the tribals of Bastar (M P), *Proc Nat Inst Sci India,* 30 (B), (1964), 56.
17. Durby W J, Gatiounglic P & Grivetti L E, *Food- the gift of Orisis*, 2 Volumes, (Academic Press, London), 1997.
18. Katewa S S, Ambica Nag & Buddadev Guria (2000). Ethnobotanical studies on natural plants for food from the Aravalli Hills, South East Rajasthan, in: *Ethnobotany and Medicinal plants of Indian Subcontinent*, (Scientific Publishers, Jodhpur): 259.
19. Lalramnghinglova H, (1992). *Food plants, Fruit plants and Medicinal plants of Mizoram*, (Environment and Forest Department, Aizawl): 149.
20. Priya Ranjan, (2000). A contribution to some natural edible plants of Indo-Nepal border area, in: *Ethnobotany and Medicinal plants of Indian Subcontinent*, (Scientific Publishers, Jodhpur): 661.
21. Sudhakar A & Vedavathy S, (2000). Natural edible plants used by the tribals of Chittoor district (Andhra Pradesh), India, in: *Ethnobotany and Medicinal plants of Indian Subcontinent*, (Scientific Publishers, Jodhpur); 321.
22. Sanjay Kr Uniyal, Anjali Awasti & Gopal S Rawat, Traditional ethnobotanical uses of plants in Bhagirathi Valley (Western Himalaya), *Indian J Traditional Knowledge*, 1(1) (2002) 7.
23. Viswanathan M V, (2000). Edible and Medicinal plants of Ladakh (J&K), in: *Ethnobotany and Medicinal plants of Indian Subcontinent*, (Scientific Publishers, Jodhpur), 2000, 151
24. Pullaiah T (2015). *Flora of Telangana.* Vol. 1-3.
25. Kaushal Kumar & Goel A K, (2000). Frequently used ethnomedicinal plants of Bihar, in: *Ethnobotany and Medicinal plants of Indian Subcontinent*, (Scientific Publishers, Jodhpur): 645.
26. Kaushal Kumar & Goel A K, (2000). Frequently used ethnomedicinal plants of Bihar, in: *Ethnobotany and Medicinal plants of Indian Subcontinent*, (Scientific Publishers, Jodhpur); 645.
27. Debabrata Das, (2000). Natural food plants of Midnapur, West Bengal, during drought and flood, in: *Ethnobotany and Medicinal plants of Indian Subcontinent*, (Scientific Publishers, Jodhpur); 539.
28. Viswanathan M V, Ethnobotany of the Malayalis in North Arcot district, Tamil Nadu, India, *Ethnobotany,* 9(1 & 2) (1997) 77.
29. Rajendran A & Henry A N, (1994). Plants used by the Tribe Kadar in Annamalai Hills of Tamil Nadu, *Ethnobotany*, 6; 19.
30. Kameswara Rao C, (2000). *Material for the Database of Medicinal plants,* (Karnataka State Council for Science and Technology for the Department of Forests, Environment and Ecology, Govt. of Karnataka, Bangalore), 458.

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Exact Solution of Conformable Fractional Ordinary Differential Equations via Conformable Laplace Transform Method

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In this article, newly defined fractional derivatives, viz., conformable fractional derivatives and conformable fractional Laplace transform, are discussed. This new framework leads to a closer alignment with well-known classical derivatives. With the use of this conformable derivative, the fractional differential equations can easily be interpreted and analyzed. The benefit of this conformable derivative approach is that it improves consistency with classical derivatives. Some properties of the conformable Laplace transform are also investigated. The efficiency of the conformable Laplace transform method is illustrated by obtaining the exact solution of some ordinary linear and nonlinear fractional differential equations in a conformable sense. This article gives a good demonstration of the conformable Laplace transform method for fractional differential equations in a conformable sense. The results obtained show that the proposed method is efficient and easy to implement on related linear problems in applied mathematics and physics.

Keywords: Conformable fractional derivative, conformable fractional integral, conformable Laplace transform, Logistic equation.

AMS subject classification: 44A10

1. Introduction

Recently, the theory and applications of the fractional calculus have tremendous applications in various fields of science and engineering [1],[2]. Many of the scientists, such as Grunwald-Letnikov, Riemann-Liouville, Caputo, Riesz, Millar-Ross, Hadmard, etc. [3],[4],[5] have defined the derivative of arbitrary order called the fractional derivative. Out of these various definitions, the Riemann-Liouville and Caputo definitions are most popular. These derivatives involve integral forms in their definitions, and hence our calculations become more complicated. Due to this, most of the researchers faced the issue in the applications of the fractional derivative in science and technology. To overcome these situations, scientists need simple and efficient definitions that satisfy the basic properties of classical derivatives. The new definitions of fractional derivative, called conformable fractional derivative (CFD), were investigated by Khalil et.al [6] in 2014. These derivatives seem to be the natural extension of classical derivatives and hence satisfy the basic properties of classical derivatives. Like the fractional differential equations, the conformable fractional differential equations (CFDE) are also arising in different fields of science and engineering [7],[8],[9]. The solution of such equations is needed for the study of geometrical and physical interpretation. Due to the appearance of CFD, the solution of CFDE becomes more complicated with existing methods. The use of the integral transform method is a powerful and easy technique to find an analytical solution of differential equations[10]. In 2015, T. Abdeljawad [11] extended the concept of CFD and introduced the fractional Laplace transform, which is later known as the conformable Laplace transform (CLT). Authors [12],[13],[14] have used the CLT to

solve various types of CFDEs. In the present study, we focus on CLT and we apply CLT to conformable ordinary differential equations of the type,

$$T^{\alpha}(\phi(t)) + \phi(t) + \phi^{n}(t) = 0,$$

$$where\ t > 0\ and\ 0 < \alpha \leq 1, \quad n = 0,2$$

with the initial condition $\phi(0) = \phi_0$ and the fractional derivative is treated as in a conformable sense.

2. Materials and Methods:

Definition 2.1: Let $y: [a, \infty) \to \mathbb{R}$ be a function with $a > 0$. The left CFD of order $\alpha\ (0 < \alpha \leq 1)$ of the function y starting from a is defined as [11],

$$T_{\alpha}^{a}(y(t)) = \lim_{h \to 0} \frac{y(t + h(t-a)^{1-\alpha}) - y(t)}{h}$$

If $a = 0$ then we write Khalil's definition of CFD as,

$$T_{\alpha}(y(t)) = \lim_{h \to 0} \frac{y(t + ht^{1-\alpha}) - y(t)}{h}$$

If $T_{\alpha}(y(t))$ exists on $[a, \infty)$ then

$$T_{\alpha}^{a}(y(a)) = \lim_{t \to a^{+}} T_{\alpha}^{a}(y(t))$$

Definition 2.2: Let $y: (-\infty, b) \to \mathbb{R}$ be function. The right CFD of order $\alpha\ (0 < \alpha \leq 1)$ of the function y terminating at b is defined as,

$$T_{\alpha}^{b}(y(t)) = -\lim_{h \to 0} \frac{y(t + h(b-t)^{1-\alpha}) - y(t)}{h}$$

If $T_{\alpha}(y(t))$ exists on $(-\infty, b]$ then

$$T_{\alpha}^{b}(y(b)) = \lim_{t \to b^{-}} T_{\alpha}^{b}(y(t))$$

In particular if y is differentiable then,

$$T_{\alpha}^{a}(y(t)) = (t-a)^{1-\alpha} y'(t)$$

and

$$T_{\alpha}^{b}(y(t)) = -(b-t)^{1-\alpha} y'(t)$$

Definition 2.3: Let $\alpha \in \mathbb{R}$ be such that $n < \alpha \leq n+1$, $n \in \mathbb{N}$ and suppose the n[th] derivative of the function y exists at t where $t > 0$, then the CFD of order α is,

$$T_{\alpha}(y(t)) = \lim_{h \to 0} \frac{y^{(\lceil \alpha \rceil - 1)}\left(t + ht^{\lceil \alpha \rceil - 1}\right) - y^{(\lceil \alpha \rceil - 1)}(t)}{h}$$

where $\lceil \alpha \rceil$ is the least integer function.

From the above definition, it is obvious that,

$$T_{\alpha}(y(t)) = t^{\lceil \alpha \rceil - \alpha} y^{(\lceil \alpha \rceil)}(t)$$

Definition 2.4: Let $\alpha \in \mathbb{R}$ be such that $0 < \alpha \leq 1$. The left conformable fractional integral (CFI) of order α of the function $f: [a, \infty) \to \mathbb{R}$ is,

$$I_{\alpha}^{a}(f(t)) = \int_{a}^{t} f(\zeta) d_{\alpha}(\zeta, a) = \int_{a}^{t} f(\zeta)(\zeta - a)^{\alpha - 1} d\zeta$$

In particular if $a = 0$ then

$$I_{\alpha}(f(t)) = \int_{0}^{t} f(\zeta) d_{\alpha}\zeta = \int_{0}^{t} f(\zeta)\zeta^{\alpha - 1} d\zeta$$

In a similar manner, the right conformable fractional integral of order α is defined as,

$$I_{\alpha}^{b}(f(t)) = \int_{t}^{b} f(\zeta) d_{\alpha}(b, \zeta) = \int_{t}^{b} f(\zeta)(b - \zeta)^{\alpha - 1} d\zeta$$

Properties of CFD:

Let $\alpha \in \mathbb{R}$ be such that $0 < \alpha \leq 1$ and $y_1$and y_2 possess CFD of order α then-

1) $T_{\alpha}(\lambda y_1 + \mu y_2) = \lambda T_{\alpha}(y_1) + \mu T_{\alpha}(y_2)$, for all constants λ, μ
2) $T_{\alpha}(y_1 y_2) = y_1 T_{\alpha}(y_2) + y_2 T_{\alpha}(y_1)$
3) $T_{\alpha}\left(\frac{y_1}{y_2}\right) = \frac{y_2 T_{\alpha}(y_1) - y_1 T_{\alpha}(y_2)}{y_2^2}$, $provided\ y_2 \not\equiv 0$
4) If y_1 is differentiable then $T_{\alpha}(y_1) = t^{1-\alpha}\frac{dy_1}{dt}$

Conformable fractional derivative of certain functions:

1) $T_{\alpha}(t^k) = kt^{k-\alpha}$, for all real numbers k
2) $T_{\alpha}(e^{at}) = at^{1-\alpha}e^{at}$, $\forall a \in \mathbb{R}$

3) $T_\alpha(c) = 0$, for all constant $c, c \in \mathbb{R}$

4) $T_\alpha(\sin at) = a\, t^{1-\alpha} \cos at$, $\forall a \in \mathbb{R}$

and $T_\alpha\left(\sin a\frac{t^\alpha}{\alpha}\right) = a\cos a\frac{t^\alpha}{\alpha}$, $\forall a \in \mathbb{R}$

5) $T_\alpha(\cos at) = -a\, t^{1-\alpha} \sin at$, $\forall a \in \mathbb{R}$

and $T_\alpha\left(\cos a\frac{t^\alpha}{\alpha}\right) = -a\sin a\frac{t^\alpha}{\alpha}$, $\forall a \in \mathbb{R}$

6) $T_\alpha\left(\frac{t^\alpha}{\alpha}\right) = 1$

Remark 2.1: The α-Differentiability of a function does not imply the differentiability of a function

e.g. $y(t) = \sqrt{t}$

Then $T_{\frac{1}{2}}(y)(0) = \lim_{t\to 0^+} T_{\frac{1}{2}}(y)(t) = 1$

But $T_1(y)(0)$ does not exist.

For classical fractional derivatives, this is not true.

Chain Rule for Conformable fractional derivative:

Theorem 2.1: Let $\alpha \in \mathbb{R}$ be such that $0 < \alpha \leq 1$. If the function $z: [0,\infty) \to \mathbb{R}$ is α-differentiable function at $t > 0$ and the function y is α -differentiable at $z(t)$ Then, the composite function yoz is α-differentiable at $t > 0$ and,

$$T_\alpha(yoz)(t) = T_\alpha(y(z(t))\, T_\alpha(z(t))\, z(t)^{\alpha-1}$$

Proof: see [11]

Conformable Laplace Transform (CLT)

Definition 2.5: Let $\alpha \in \mathbb{R}$ with $0 < \alpha \leq 1$. Suppose f is a piecewise continuous function on $[0,\infty)$ and is of exponential order then the CLT of the function f of order α is defined as,

$$L_\alpha\{f(t)\} = \int_0^\infty e^{-p\frac{t^\alpha}{\alpha}} f(t) d_\alpha t = \int_a^\infty e^{-p\frac{t^\alpha}{\alpha}} t^{\alpha-1} f(t) dt$$

We shall denote the CLT of f as $L_\alpha\{f(t)\} = F_\alpha(p)$

Conformable Laplace Transform of some useful functions:

1) $L_\alpha\{1\} = \frac{1}{p}$, $p > 0$

2) $L_\alpha\{t^k\} = \alpha^{\frac{k}{\alpha}} \frac{\Gamma\left(1+\frac{1}{\alpha}\right)}{p^{1+\frac{k}{\alpha}}}$, $p > 0$ and k is any positive integer

3) $L_\alpha\left\{e^{\frac{at^\alpha}{\alpha}}\right\} = \frac{1}{p-a}$, $p > a$

4) $L_\alpha\left\{\sin\left(\frac{at^\alpha}{\alpha}\right)\right\} = \frac{a}{p^2+a^2}$, $p > |a|$

5) $L_\alpha\left\{\cos\left(\frac{at^\alpha}{\alpha}\right)\right\} = \frac{p}{p^2+a^2}$, $p > |a|$

Some Important Properties of CLT:

Theorem 2.2: (Linearity property) Let y_1 and y_2 be functions and λ, μ be any constants then

$$L_\alpha\{\lambda y_1 + \mu y_2\} = \lambda L_\alpha(y_1) + \mu L_\alpha(y_2)$$

Theorem 2.3: Let $y: [0,\infty) \to \mathbb{R}$ be a real-valued differentiable function and $0 < \alpha \leq 1$ then,

$$L_\alpha\{T_\alpha(y(t))\} = pL_\alpha\{y(t)\} - y(0) = pY_\alpha(p) - y(0)$$

Proof: Using the def.3.1, we obtain,

$$L_\alpha\{T_\alpha(y(t))\} = \int_0^\infty e^{-p\frac{t^\alpha}{\alpha}} T_\alpha(y(t)) d_\alpha t$$

Using integration by parts, as it holds for conformable derivatives, we have

$$L_\alpha\{T_\alpha(y(t))\} = \left[e^{-p\frac{t^\alpha}{\alpha}}.\left(I_\alpha\left(T_\alpha(y(t))\right)\right)\right]_0^\infty - \int_0^\infty T_\alpha\left(e^{-p\frac{t^\alpha}{\alpha}}\right) y(t) d_\alpha t$$

$$= [0 - y(0)] + p\int_0^\infty e^{-p\frac{t^\alpha}{\alpha}}\, y(t) d_\alpha t$$

$$= pL_\alpha\{y(t)\} - y(0) \quad ,\because\ T_\alpha\left(e^{-p\frac{t^\alpha}{\alpha}}\right) = -pe^{-p\frac{t^\alpha}{\alpha}}$$

$$\therefore\ L_\alpha\{T_\alpha(y(t))\} = pY_\alpha(p) - y(0)$$

■

Theorem 2.4: If $L_\alpha\{y(t)\} = Y_\alpha(p)$ then,

$$L_\alpha\left\{e^{-a\frac{t^\alpha}{\alpha}}y(t)\right\} = Y_\alpha(p+a), \quad p > a$$

Proof: By definition of CLT we have,

$$L_\alpha\left\{e^{-a\frac{t^\alpha}{\alpha}}y(t)\right\} = \int_0^\infty e^{-a\frac{t^\alpha}{\alpha}}e^{-p\frac{t^\alpha}{\alpha}}y(t)d_\alpha t$$

$$= \int_0^\infty e^{-(p+a)\frac{t^\alpha}{\alpha}}y(t)d_\alpha t$$

$$= Y_\alpha(p+a)$$

■

Theorem 2.5: Let $y:[0,\infty) \to \mathbb{R}$ be a piecewise continuous function and $L_\alpha\{y(t)\} = Y_\alpha(p)$ then,

$$L_\alpha\left\{\frac{t^\alpha}{\alpha}y(t)\right\} = -\frac{d}{dp}L_\alpha\{y(t)\} = -\frac{d}{dp}(Y_\alpha(p))$$

Proof: By the definition of conformable Laplace transform, we obtain,

$$\frac{d}{dp}L_\alpha\{y(t)\} = \frac{d}{dp}\int_0^\infty e^{-p\frac{t^\alpha}{\alpha}}y(t)d_\alpha t$$

$$= \frac{d}{dp}\int_0^\infty e^{-p\frac{t^\alpha}{\alpha}}\,y(t)\,t^{\alpha-1}dt$$

$$= \int_0^\infty \frac{\partial}{\partial p}e^{-p\frac{t^\alpha}{\alpha}}\,y(t)\,t^{\alpha-1}\,dt$$

$$= \int_0^\infty \frac{-t^\alpha}{\alpha}e^{-p\frac{t^\alpha}{\alpha}}\,y(t)\,t^{\alpha-1}\,dt$$

$$= \frac{-1}{\alpha}\int_0^\infty e^{-p\frac{t^\alpha}{\alpha}}t^\alpha\,y(t)\,t^{\alpha-1}\,dt$$

$$= \frac{-1}{\alpha}\int_0^\infty e^{-p\frac{t^\alpha}{\alpha}}t^\alpha\,y(t)d_\alpha t$$

$$= -\frac{1}{\alpha}L_\alpha\{t^\alpha y(t)\}$$

■

Theorem 2.6: Let $y:[0,\infty) \to \mathbb{R}$ be a piecewise continuous function and $L_\alpha\{y(t)\} = Y_\alpha(p)$ then,

$$L_\alpha\left\{\frac{t^{n\alpha}}{\alpha^n}y(t)\right\} = (-1)^n\frac{d^n}{dp^n}L_\alpha\{y(t)\} = (-1)^n\frac{d^n}{dp^n}(Y_\alpha(p)),$$

$$n \in \mathbb{N}$$

Proof: Follows from Theorem 3.3 and using induction on n

■

Theorem 2.7: Let $y:[0,\infty) \to \mathbb{R}$ be a piecewise continuous function and $L_\alpha\{y(t)\} = Y_\alpha(p)$ with $\lim_{t\to 0^+}\frac{y(t)}{t^\alpha} < \infty$ then,

$$i)\ L_\alpha\left\{\frac{y(t)}{t^\alpha}\right\} = \frac{1}{\alpha}\int_p^\infty Y_\alpha(\zeta)d\zeta$$

$$ii)\ L_\alpha\{I_\alpha(y(t))\} = \frac{Y_\alpha(p)}{p}$$

Proof: See [15]

3. Results and Discussion

In this section, we implement the CLT to find the solution to the fractional order logistic equation with the conformable derivative. The fractional order logistic equation,

$$D^\alpha y(t) = y(t)[1-y(t)], \quad 0 < \alpha \leq 1$$

where D^α is Caputo's fractional derivative and Riemann-Liouville's fractional derivative is discussed in [16] and [17], respectively. Here, we obtain the solution of conformable fractional order logistic differential equations by using the CLT method. Our approach begins by solving a conformable fractional linear differential equation and then proceeds to a nonlinear logistic equation governed by a conformable derivative.

Example 3.1: Consider a conformable linear differential equation

$$T_\alpha(y(t)) + y(t) = 0, \quad where\ 0 < \alpha \leq 1 \qquad (1)$$

with initial condition $y(0) = 1$

Solution: Apply CLT on both sides of equation (1),

$$L_\alpha\{T_\alpha(y(t))\} + L_\alpha\{y(t)\} = 0$$

$$pY_\alpha(p) - y(0) + Y_\alpha(p) = 0$$

$$pY_\alpha(p) - 1 + Y_\alpha(p) = 0$$

$$Y_\alpha(p) = \frac{1}{p+1}$$

$$L_\alpha^{-1}\{Y_\alpha(p)\} = L_\alpha^{-1}\left\{\frac{1}{p+1}\right\}$$

$$y(t) = e^{-\frac{t^\alpha}{\alpha}}$$

Which coincides with a solution $y(t) = e^{-t}$ of ordinary differential equation (for $\alpha = 1$) $y'(t) + y(t) = 0$, $y(0) = 1$

In above example, if the fractional derivative is a Caputo type then solution is,

$$y(t) = E_\alpha(-t^\alpha) = \sum_{n=0}^{\infty} \frac{-t^{n\alpha}}{\Gamma(n\alpha+1)}$$

For $\alpha = 1$, it becomes

$$y(t) = \sum_{n=0}^{\infty} \frac{-t^n}{\Gamma(n+1)} = \sum_{n=0}^{\infty} \frac{-t^n}{\mathrm{n!}} = e^{-t}$$

Example 3.2: Consider a Logistic type equation

$$T_\alpha(y(t)) = y(t)[1 - y(t)] \quad ,where\ t > 0\ and\ 0 < \alpha \leq 1 \qquad \text{.... (2)}$$

with $y(0) = y_0$

Solution: Consider a given nonlinear conformable ordinary differential equation,

$$T_\alpha(y(t)) = y(t)[1 - y(t)]$$

$$T_\alpha(y(t)) = y(t) - y(t)y(t)$$

$$\frac{T_\alpha(y(t))}{(y(t))^2} = \frac{1}{y(t)} - 1 \qquad \text{.... (3)}$$

Put $\frac{1}{y(t)} = \zeta(t)$ then

$$T_\alpha\left(\frac{1}{y(t)}\right) = T_\alpha(\zeta(t))$$

$$-\frac{1}{(y(t))^2} T_\alpha(y(t)) = T_\alpha(\zeta(t))$$

With this equation (3) becomes

$$-T_\alpha(\zeta(t)) = \zeta(t)) - 1$$

$$T_\alpha(\zeta(t)) + \zeta(t)) = 1 \qquad \text{... (4)}$$

Apply CLT on both sides of eq.(4),

$$L_\alpha\{T_\alpha(\zeta(t))\} + L_\alpha\{\zeta(t))\} = L_\alpha\{1\}$$

$$p\mathrm{Z}_\alpha(p) - \zeta(0) + \mathrm{Z}_\alpha(p) = \frac{1}{p} \ ,$$

$$\text{where } L_\alpha\{\zeta(t))\} = \mathrm{Z}_\alpha(\mathrm{p})$$

$$(p+1)\mathrm{Z}_\alpha(p) = \frac{1}{p} + \frac{1}{y_0}$$

$$\mathrm{Z}_\alpha(p) = \frac{1}{p(p+1)} + \frac{\frac{1}{y_0}}{p+1}$$

$$\mathrm{Z}_\alpha(p) = \frac{1}{p} + \frac{\left(\frac{1-y_0}{y_0}\right)}{p+1}$$

$$L_\alpha^{-1}\{\mathrm{Z}_\alpha(p)\} = L_\alpha^{-1}\left\{\frac{1}{p}\right\} + \left(\frac{1-y_0}{y_0}\right) L_\alpha^{-1}\left\{\frac{1}{p+1}\right\}$$

$$\zeta(t) = 1 + \left(\frac{1-y_0}{y_0}\right) e^{\frac{-t^\alpha}{\alpha}}$$

$$y(t) = \frac{1}{\zeta(t)} = \frac{1}{1 + \left(\frac{1-y_0}{y_0}\right) e^{\frac{-t^\alpha}{\alpha}}}$$

$$y(t) = \frac{e^{\frac{t^\alpha}{\alpha}}}{\left(\frac{1-y_0}{y_0}\right) + e^{\frac{t^\alpha}{\alpha}}}$$

In particular if $y(0) = \frac{1}{2}$ then solution of equation (2) is

$$y(t) = \frac{e^{t^\alpha/\alpha}}{1 + e^{t^\alpha/\alpha}}$$

Which is compatible with the solution $y(t) = \frac{e^t}{1+e^t}$, $y(0) = \frac{1}{2}$ of the integer order logistic differential equation, $y'(t) = y(t)[1 - y(t)]$

Graphical representation of the solutions:

We illustrate the novelty of the CLT method and the conformable derivative by plotting the comparative graphs of the solution $y(t)$ obtained in [16,17] of the fractional logistic equation (2) and for different values of $\alpha = 0.85, 0.95, 1$.

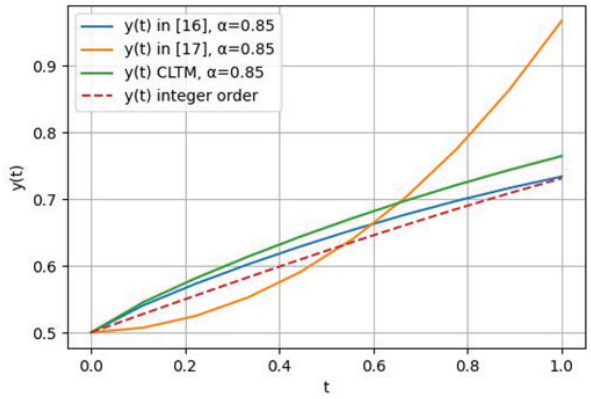

Figure 1 – Comparison of the solution for $\alpha = 0.85$ and the integer order solution

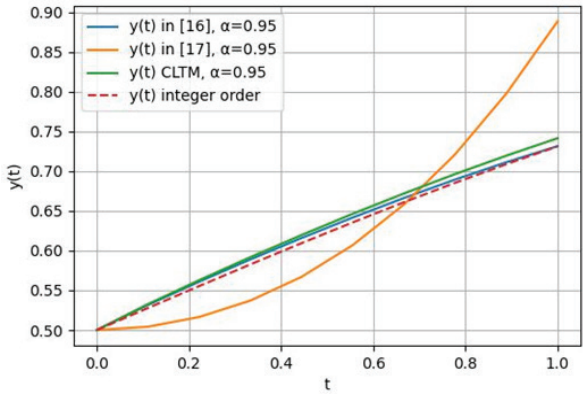

Figure 2 – Comparison of the solution for $\alpha = 0.95$ and the integer order solution.

The Figures [Fig.1] and [Fig.2] clearly demonstrate the comparison of the solutions obtained by different methods for $\alpha = 0.85, 0.95, 1$. The blue and orange curves represent the results reported in [16] and [17], respectively, while the green curve shows the solution obtained using the proposed Conformable Laplace Transform Method (CLTM). The red dashed curve corresponds to the integer order $(\alpha = 1)$ solution. The close agreement of the CLTM solution in the case of integer order demonstrates the accuracy and reliability of the proposed method.

4. Conclusion

In this study, we explored the newly introduced Conformable Fractional Derivative (CFD) and Conformable Laplace Transform (CLT), and successfully applied the CLT method to obtain a solution of a nonlinear conformable fractional logistic differential equation. A graphical comparison is also provided between the solution obtained using the CLT method based on the conformable derivative and the solutions reported in [16,17] employing the Riemann–Liouville fractional derivative and Caputo fractional derivative. The CLT method, within the framework of the Conformable derivative, simplifies complex fractional operators into algebraic forms, thereby reducing computational effort while maintaining accuracy. This makes the CLT method a valuable and robust tool for analyzing a wide range of problems involving conformable fractional dynamics. In future studies, we will investigate the solution of some initial and boundary value problems of conformable fractional partial differential equations.

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References

1. K. S. Miller and B. S. Ross, *An Introduction to Fractional Calculus and Fractional Differential Equations,* Elsevier, San Diego (2006).
2. I. Podlubny, *Fractional Differential Equations*, Academic Press, USA (1999).
3. Khalil and H. Abu-Shaab, “Solution of some conformable fractional differential equations”, *International Journal of Pure and Applied Mathematics*, vol.103, no.4, pp.667-673 (2015). DOI: https://doi.org/10.12732/ijpam.v103i4.6

4. M. Molaei, F. Saei, M. Javidi M, and Y. Mahmoudi, "New analytical Method for Solving a Class of Conformable Fractional Differential Equations by Fractional Laplace Transform", *Computational Methods for Differential Equations*, vol.10, no.2, pp.396-407, (2022). DOI: https://doi.org/10.22034/cmde.2021.40834.1775

5. K. Oldham and J. Spanier, *The Fractional Calculus Theory and Applications of Differentiation and Integration of Arbitrary Order*, Academic Press, USA (1974).

6. R. Khalil, M. Horani, A. Yousef, and M. Sababheh, "A New Definition of Fractional Derivative", *Journal of Computational and Applied Mathematics*, vol.264, pp.65-70 (2014). DOI: https://doi.org/10.1016/j.cam.2014.01.002

7. M. Caputo and M. Fabrizio, "A new definition of fractional derivative without singular Kernel", *Progress in Fractional Differentiation and Application*, vol.1, no.2, pp.73-85 (2015). DOI: http://dx.doi.org/10.12785/pfda/010201

8. M. Kaplan, "Applications of Two Reliable Methods for Solving a Nonlinear Conformable Time-Fractional Equation", *Opt. Quant Electron*, vol.49, no.312, pp.1-8 (2017). DOI: https://doi.org/10.1007/s11082-017-1151-z

9. M. Yavuz, "Novel Solution Methods for Initial Boundary Value Problems of Fractional Order with Conformable Differentiation", *An International Journal of Optimization and Control: Theories & Applications*, vol.8, no.1, pp.1-7 (2018). DOI: https://doi.org/10.11121/ijocta.01.2018.00540

10. L. Debnath and D. Bhatta, *Integral Transforms and Their Applications*, 3rd ed, CRC Press, Chapman and Hall, Boca Raton, (2015).

11. T. Abdeljawad, "On conformable fractional calculus", *Journal of Computational and Applied Mathematics*, vol.279, pp.57-66 (2015). DOI: https://doi.org/10.1016/j.cam.2014.10.016

12. M. Akrami, A. Poya, and M. Zirak, "New general single, double and triple conformable integral transforms: Definitions, properties, and applications", *Partial Differential Equations in Applied Mathematics*, vol. 12, pp.1-27 (2024). DOI: https://doi.org/10.1016/j.padiff.2024.100991

13. F. Jarada and T. Abdeljawad, "A modified Laplace transform for certain generalized fractional operators", *Results in Nonlinear Analysis*, vol.1, no.2, pp.88–98 (2018). DOI: https://nonlinear-analysis.com/index.php/pub/article/view/8

14. F. Silva, D. Moreira and M. Moret, "Conformable Laplace Transform of Fractional Differential Equations", *Axioms*, vol.7*, no.*55, pp.1-12 (2018). DOI: https://doi.org/10.3390/axioms7030055

15. M. S. Hashemi, "Invariant subspaces admitted by fractional differential equations with conformable derivatives", *Chaos, Solitons & Fractals*, vol.107, pp.161-169 (2018). DOI: https://doi.org/10.1016/j.chaos.2018.01.002'

16. I. Area, J.J. Nieto, Power series solution of the fractional logistic equation, *Physica A: Statistical Mechanics and its Applications*, vol. 573(C) (2021). DOI: https://doi.org/10.1016/j.physa.2021.125947

17. A.M.A. El-Sayeda, A.E.M. El-Mesiryb, H.A.A. El-Sakab, "On the fractional-order logistic equation", *Applied Mathematics Letters*, vol.20. no.7, pp.813-823 (2007). DOI: http://dx.doi.org/10.1016/j.aml.2006.08.013

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Dhoopan: An Ayurvedic fumigation strategy to control and prevent air-borne infections

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A vital microbiological process, sterilisation removes all microorganisms from a product, surface, or medium, including sturdy spores and vegetative cells. By eliminating or killing these microorganisms, a sterile environment devoid of possible contaminants is created. Although sterilisation has evolved throughout time, the idea itself has ancient roots. The Egyptians made one of the earliest known attempts to prevent illnesses and enhance cleanliness around 2400 BC. The prevention and treatment of illnesses are both extensively covered by Ayurveda, an age-old medical tradition that predates modern science by thousands of years. In its extensive corpus of knowledge, ancient thinkers advocated *Nirjantukikaran*, which is Sanskrit for sterilisation, as a vital hygienic technique.Detailed recipes for *Dhoopan*, a fumigation method using antimicrobial compounds (*Rakhoghnadravyas*) made from herbs and natural materials, are described in Ayurvedic writings. These formulations were formerly used to sterilise surgical units, operating rooms, neonatal care units, and maternity wards in order to protect patients and healthcare professionals from harmful microbes.

Dhoopana, an Ayurvedic approach, was utilised in this study since it is regarded as a safe and healthy substitute for sterilisation, which is desperately required. It removes the drawbacks of the present formalin gas fumigation sterilisation method.

Keywords: Sterilization, *Dhoopan*, Air-borne infection, *Rakshoghna Karma,* Ayurvedic fumigation.

INTRODUCTION

The new coronavirus that caused the COVID-19 pandemic has become a hazardous and highly contagious infection, especially in healthcare settings. This virus is incredibly effective at spreading because, in contrast to other infections, it thrives in settings characterised by overcrowding, poor cleanliness, and socioeconomic difficulties. Its rapid transmission has strained healthcare systems worldwide and disrupted the global economy, highlighting the urgent need for effective preventive strategies.

A major concern is how the micro-organisms spreads through contaminated surfaces—both inanimate objects like door handles, railings, and floors, as well as through direct human contact. Everyday items in hospitals and public spaces can unknowingly harbor microbes, especially when infection control measures are not sufficient. This underscores the importance of rigorous sanitation practices, such as frequent disinfection of high-touch surfaces and proper hand hygiene.

Certain groups face a higher risk of nosocomial infection, including the elderly, children, individuals with weakened immune systems (such as those with chronic illnesses or antibiotic resistance), and people with low vitality (*heen-satva* in Ayurvedic terms). Protecting these vulnerable populations—alongside frontline healthcare workers is critical to reducing the virus's spread and its devastating impact.

One of the oldest and most traditional methods of sterilisation is *DhoopanKarma* i.e. Ayurvedic fumigation, which uses medicinal herbal fumes, animal product fumes, etc. to keep the biological environment healthy everywhere. The term "*krimi*" in Ayurveda is associated with microorganisms that cause airborne diseases like COVID-19. Both harmful and non-harmful organisms are included in this. According to Ayurveda classics, *RakshoghnaVidhi* is recommended to prevent such *krimi* (causative infections).

Adopting these traditional practices such as Ayurvedic fumigation for air purification,may play vital rolesin preventing the spread of disease specially protecting the health care workers from acquiring nosocomial infection. By prioritizing these steps, one can collectively curb transmission, safeguard at-

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risk communities, and ease the burden on healthcare systems.

HISTORICAL BACKGROUND

Dhoopan karma is mentioned in classical Ayurvedic writings including *Charaka Samhita* and *Sushruta Samhita*, where it is prescribed for sterilization, surgical site disinfection, postpartum care, and respiratory problems (Dash & Sharma, 2018). Several ancient civilizations, including Egypt, China, and Greece, used fumigation techniques for therapeutic and spiritual purposes (Gopal *et al.,* 2019). The use of incense for healing and cleansing is mentioned in ancient Egyptian texts such as the Ebers Papyrus. Similarly, Chinese medical texts discuss the burning of plants such as Artemisia for disease prevention (Unschuld, 1986). Hippocrates, a Greek physician, also advocated fumigation to treat plague epidemics (Littman and Littman, 1973).

In *Charaka Samhita*:-

According to *Acharya Charaka*, *Janpadodhwans*refers to the mass devastation of dwelling areas or the annihilation of the inhabitants. The vitiation of the air (*vayu*), water (*jala*), area (*desh*), and time(*kala*) is the cause of these huge destructions (*Janpadodhwans*). These four circumstances are only the means via which infectious diseases proliferate. Numerous airborne diseases are caused by air vitiation. (Samal 2016).

In *Sushruta Samhita*:-

The *Sushruta Samhita* may make reference to *Samarik Vishaprayoga* and *Auopasrgikaroga* (communicable illnesses). According to *SamarikVishaprayoga*, the king and his army risk poisoning while travelling great distances to conquer other countries. The king and his troops should exercise caution during times of conflict because the adversaries may contaminate the food, water, smoke, and air, which could lead to the spread of these diseases. That's why *Acharyas* explained how to purify the air, water & land and their symptoms of vitiation.(Apexa, 2020).

In *Kashyapa Samhita*:-

In *Kashyap Samhita* there is a detail chapter on fumigation called *Dhupakalp-adhyaya*, which is original contribution of *Kashyap Samhita*in it various *dhoopanyoga* are mentioned with their utmost importance. According to *Samhita,* origin of *Dhoopan* is said to be from fire god *Agni*, who blessed the sage's children with unique technique of fumigation to get rid of *Rakshasa*, *Bhuta* and *Pishacha*.

Therefore, to reduce the vitiation of air or airborne diseases from the atmosphere, *Dhoopanchikitsa* has been mentioned in different Ayurvedic text by the various *Acharya*.

MATERIAL AND METHODS-

- **Concept of *DhoopanKarma*:-**

The *Dhoopan* process involves burning of specific medicinal substances to release therapeutic fumes, which permeate the air and surfaces, effectively neutralizing harmful pathogens—both microscopic bacteria and larger infectious agents—within a designated space. This method not only purify the environment but also aligned with Ayurveda's holistic principles of fostering health through natural and preventive measures

- **Various uses of *Dhoopan Karma*:-**

1. Preventive Aspect: It involves fumigation to provide a sterile environment for healthy organisms, preventing the development of infections, particularly in hospital areas such as *Kumaragaradhoopan*(pediatric room), *Vranitagaradhoopan*(dressing room), *Sutikagaradhoopan*(labourroom). (Ahlavati and Sharma, 2019).
2. Curative Aspect: It's beneficial for treating or preventing both harmful and non-harmful illnesses, particularly in *Jwara*(fever), *Vrana*(wound)etc. (Ahlavati and Sharma, 2019).

- **Sources of *Dhoop*:-**

1. *Sthavara* (Plant origin)- There are some herbal drugs used for *dhoopankarma -Vidanga, Nimba, Guggulu, Sarshapa*and*Vacha.* Ingredientsof*Kusthahara Gana, Kandughna Gana, Krimighna Gana, Vranahara Gana, Rakshoghna*and*BhootaghnaGana* are also used for *Dhoopan*. These drugs have potential antimicrobial properties.
2. *Jangama* (Animal origin)- *Ghrita* (clarified butter), *madhu* (honey), *kesha* (hairs), *nakh* (nails), *shringa* (horns), etc. of animals have been used for *Dhoopan* purposes. These materials are rich in keratin, which is a potent antimicrobial agent. (Eliza Ranjit et. al. 2021)
3. *Khanija* (Minerals)- *Manashila* (As_2S_2), *Hartal* (As_2S_3), *Sauviranjan* (Sb_2S_3) and sulfur compounds are the mineral drugs used for *Dhoopan Karma*.

SOME IMPORTANT *DHOOPAN DRAVYA* MENTIONED IN FOLLOWING *SAMHITA*:-

Table 1 – ***Dhoopan Dravya*** **as per** ***Charak Samhita-***

Sr. No.	***Dhoopandravya*** **(ingredients)**	Use of fumigation
1.	*Sarshap (Brassica juncea L.), Hingu (FerulafoetidaLinn), Guggulu (Commiphora wightii {Arn} Bhand.), Atsi (Linum usitatissimumLinn), Vacha (AcoruscalamusLinn), Jatamansi (Nardostachys Jatamansi DC), Brahmi (Bacopa monnieri [Linn] Wettst.)*	*Shayya* (beds), *vastra* (clothes), surrounding environment
2.	*Guggulu, Vacha, Nimb (Azadirachta indicaJuss), Sarshap,Ghrita (clarified butter)*	*Visham-jwara* (chronic fever)
3.	*Mayurpichha (plumes of peacock feather), Sirisha (Albizia lebbeckBentt.) and Ghrita*	*Vastra* (clothes), *Kaksha* (rooms), *shayya* (bed)
4.	*Agaru (Aquilaria agallochaRoxb.), Chandana (Santalum album), Ghrita, Majja (marrow), Vasa (fat)*	*Vrandhoopan* (wound healing)

Table 2 – ***Dhoopan Dravya*** **as per** ***Sushrutha Samhita-***

Sr. No.	***Dhoopandravya*** **(ingredients)**	Use of fumigation
1.	*Guggulu, Agaru, Vacha, Sarjarasa (Vateria indica Linn), Shwetasarshap (Brassica alba), Lavan (salt), Nimb, Ghrita*	*Shalya-kaksha* (operation theatre)
2.	*Sarshap, Ghrita, Neemb, Lavan*	*Vranaagar* (wound dressing room)
3.	*Haridra (Curcuma longa Roxb), Abhaya (Terminalia chebulaRetz.), Ativisha (Aconitum heterophyllum Wall. Ex Royle), Ela (Elettaria cardamomum), Musta (Cyperus rotundus Linn)*	*Vayushuddhi* (air purification)

Table 3 – ***Dhoopan Dravya*** **as per** ***Ashtang Hriday-***

Sr. No.	***Dhoopandravya*** **(ingredients)**	Use of fumigation
1.	*Mayurpiccha* (plumes of peacock), *Sarshap, Chandana*	*Agaara* (rooms), *vastra* (clothes), *Shayya* (bed) and*aasan* (chairs)
2.	*Guggulu, Vacha, Nimb, Kushtha (Sausurrealappa CB. Clarke), Haritaki, Sarshap*	*Jwara* (fever)
3.	*Guggulu, Trivritta (Operculinaturpethum [Linn] Silva Manso*.)	*Kumaragara-dhoopan* (For child's bed, clothes, pillows, blankets)

Table 4 – **Some *Dhoopanyoga*(formulations) in D*hupakalpa-adhyaya*as per*KashyapaSamhita-***

Sr. No.	***Dhoopandravya*** **(ingredients)**	Use of fumigation
1.	*Kumar dhoop* for child's growth	*Ghrita, Sarjaras, Sauviranjan* (Sb_2S_3), *Bhallatak (Semecarpus anacardium* Linn*) Daruharidra (Berberis aristata DC), Haridra, Laksha (Lacciferlacca), Tagar (Valeriana wallichii DC), Tejpatra (Cinnamomum tamala), Usheera (Vetiveriazizanioides* [*Linn*] *Nash.*), *Sarshap, Vidanga (Embeliaribes Burm.f.), Vacha, Hingu, Netrabala (Pavonia odorata)*
2.	*Agneya dhoop* for all diseases	*Gau kesh* (cow hairs), *Ghrita*
3.	*Rakshoghnadhoop* for dis-infection purposes	*Ghrit, Hingu, Dev nirmalya* (temples), *shwetsarshapa, sarpatva* (snake skin)

4.	*Shishukdhoop* for all diseases	*Ghrita, Jatamansi, Musta, Hartala (Arsenic trisulphide), Manahshila (Arsenic disulphide), Ela, Tagar, Shatpushpa (Anethum graveolens), Nagarmotha (Cyperus rotundus), Harenu (Vitex agnus-castus Linn)*
5.	*Arishta dhoop* to maintain good health	*Ghrita, Neemb-patra* (leaves)*, phala* (fruits)*, puhspa* (flowers)*, mool* (root)*, tvaka* (bark).

MODE OF ADMINISTRATION/PROCEDURE-

Dhoopan is accomplished utilizing a variety of approaches based on the need:

- Direct Burning**:** Herbs and resins are burned in an open flame to produce smoke.
- Charcoal Method**:** Herbal powders are sprinkled on heated charcoal.
- *Dhoopan Yantra***:** Special devices used to release smoke under controlled conditions.
- Room Fumigation**:** Used to sanitize hospitals and households (Patel & Mehta, 2022).

THERAPEUTIC APPLICATIONS OF *DHOOPAN:*

1. Antimicrobial and Disinfectant Properties

Dhoopan has long been used to prevent infections and purify the air. Classical literature confirms *Dhoopan's* capacity to destroy*ama* and *staphylococcus aureus* colonization. A 2021 in vitro investigation revealed that *Dhoopan* vapors suppressed the growth of E. coli and S. epidermidis by 42–56% within a six-hour period, indicating that housekeeping fumigation may lower infection levels

2. Respiratory Health

Herbal smoke inhalation is thought to alleviate sinusitis, bronchitis, and *asthma* symptoms. Certain ingredients, such as eucalyptus and *tulsi*, have bronchodilatory properties (Singh et al., 2019).The most extensively documented application pertains to *Pratishyaya* (allergic rhinitis) and *Kasa* (cough). A pilot study conducted in 2018, published in the Journal of Ayurveda & Integrative Medicine, demonstrated a 35% enhancement in nasal airflow resistance following daily *Dhoopan* over a period of seven days.

3. Wound Healing and Dermatological Uses

Due to its antiseptic qualities, *Dhoopan* is used to promote wound healing; *guggulu* and turmeric smoke have been shown to speed up tissue repair (Jain & Agarwal, 2021).The smoke produced by *GandhakDhoopan* is applied topically through smudging to treat vitiligo lesions and mild eczema, according to the *Sharangadhara Samhita*.

4. Postpartum and Gynecological Applications

Dhoopan drugs with *katu-tikta, ushan*, and aromatic properties, when ignited, transform into volatile medicated fumes. These fumes penetrate the smallest units of the genital tract tissues (due to *sooksham-srotogami*), dilate blood vessels, and facilitate blood oxidation, resulting in sufficient tissue perfusion. This antiseptic and sterilized environment promotes the disinfection of the uterine cavity, vagina, and vulva; it also reduces pH and laxity of the pubic muscles. Consequently, it aids in alleviating pain, decreasing vaginal discharge, promoting wound healing, and preventing the proliferation of microorganisms.

Yonidhoopana is a practical procedure that involves the fumigation of the vulva and vagina using medicated and disinfected smoke applied to the surface of the *yoni.* This method is indicated for *Rakshoghana* and *vyadhi* chikitsa in the fields of *striroga* and *prasuta*. The vagina is favored as a route for drug delivery because of its extensive surface area, significant vascularity, and ability to absorb the medicated fumes or any medicated substances placed within it. (Gholap S.R et. al)

5. Pediatric Diseases-

The most prevalent neurological condition in children is seizures, which can occur alone or as a symptom of other underlying issues. *Dhoopan* is used to maintain overall health and to manage seizures or side effects from antiepileptic medications. Additionally, *Navajaatshishuparicharya* (Immediate care of newborn) emphasizing *Rakshoghnakarma*, which is particularly helpful in reducing neonatal infection and enhancing the quality of life for newborns. (Singh and Subhabrat 2024).

COMPARISON OF AYURVEDIC *DHOOP* WITH MODERN STERILIZATION DRUGS:-

1. Availability: *Dhoopankarma* can be practiced on a daily basis in accordance with Indian tradition, and

Dhoopan medications are readily available in local Indian marketplaces whereas, chemical disinfectants are not easily available and generally not recommended for daily use especially in non-healthcare settings.

2. Efficacy: Various researches have proved the effectiveness of Ayurvedic *Dhoopan*medications (Balkrishna A et al., 2022). Though Ayurvedic *Dhoopankarma* cannot be claimed to be efficacious as sterilisation procedure until adequate analytical and effective studies are carried out.

3. Safety: It will always be safer for healthcare professionals to use herbo-mineral formulations for sterilisation rather than chemicals. Chemicals that are synthetically createdcan inflict serious damages to the human.

4. Cost Effective: Ayurvedic drugs are readily available and natural ingredients, making them an affordable option for disinfection and easily sourced whereas, chemical disinfectants are highly expensive with less cost effective due to factors like potential damage to surfaces, replacement costs and the need for specialized application.

DISCUSSION

The idea of *Havan* and *Yagnya* have been strongly associated with Hindu mythology since the Vedic era. According to the contemporary perspective, this is comparable to antimicrobials, which prevent illnesses by disinfecting the air. Ancient scholar's scientific understanding of diseases and their management is demonstrated by the mythological origin of fumigations and their significance are given in several classical literatures.

The process of *Dhoopan* disinfects the immediate environment and is of great significance during winter and rainy seasons wherein the chances of disease outbreak are high. It helps to restrict the growth of disease-causing pathogens, thereby preventing the outbreak of deadly pandemics like COVID 19.

Presently, *Dhoopan* is not preferably used as a fumigation method. Therefore, to re-publicize the benefits of *Dhoopan karma* and evaluate the efficacy of different *Dhoopa-kalpa* for fumigation or *Rakshoghna* (anti-microbial) purposes, now-a-days itisrequired for society's well-being. After observing the repeated use of certain drugs in a broad-spectrum, anti-microbial products may be prepared by the combination of these drugs. The anti-infective property of the fumes of these drugs should also be confirmed.

CONCLUSION

In therapeutic settings, sterilisation is essential for preventing the growth of harmful organisms that might cause infections. Sterilisation techniques have evolved throughout time, moving from simple cleaning solutions to more advanced techniques like radiation and fumigation. Nowadays, the focus is to keep operating rooms and surgical tools sterile in order to protect patients. Traditional knowledge and modern sterilisation methods have found a special convergence with the incorporation of Ayurvedic procedures like *Dhoopankarma* in modern healthcare.

Modern, traditional sterilisation methods such as formalin gas fumigation pose health risks to healthcare professionals and have a tendency to cause respiratory diseases or even cancer in the general population. Therefore, in this situation, it is a need to learn about Indian traditional *Dhoopankarma* for infection prevention and control.

Therefore, *Dhoopanchikitsa* (fumigation therapy) might very helpful in reducing and eliminating the infection spread by these airborne diseases. Fumigation therapy, also known as *Dhoopanchikitsa*, is easy to use and has the power to purify and sanitise.

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References

1. Charak Samhita by Agnivesh, revised by Charak and supplemented by Dridhbal with Ayurved Dipika commentary by Chakrapanidatta edited by Vaidya Yadavji Trikamji, 25/84.
2. Shastri A. Sushruta Samhita: Hindi commentary, Varanasi, Uttarpradesh, India: ChaukhambhaSurabharti Prakashan; (2012):289
3. Marich Kashyapa, Tiwari P. V. editor. Kashyapa Samhita Kalpa Sthana, Dhoop Kalpa Adhyay. Reprint Edition. Varanasi; Chaukhamba Vishvabharti; (2008).
4. Dash, B., & Sharma, R. Ayurvedic applications of Dhoopan in surgery and healing. *Journal of Ayurveda Research,*(2018) *7*(3), 45-52.

5. Desai, S., Patel, N., & Sharma, P. Postnatal benefits of herbal fumigation inAyurveda. *International Journal of Herbal Medicine,*(2020) *6*(4),78-85.
6. Gopal, R., Kumar, S., & Mehta, R.. Historical perspectives on medicinal fumigation. *Ancient Medicine and Healing Journal,*(2019) *5*(1),23-30.
7. Sharma H. Kashyap Samhita, Varanasi, Uttarpradesh, India. ChaukhambhaSurabhartiPrakashan; (2012) :57
8. Kumar, V., Singh, A., & Roy, D. Air purification potential of herbal smoke: A microbiological study. *Environmental Health Perspectives,*(2020) *12*(1),34-39.
9. Littman, R. J., & Littman, M. L. Galen and the Antonine Plague. *American Journal of Philology,*(1973) *94*(3),243-255.
10. Nunn, J. F. *Ancient Egyptian Medicine*. University of Oklahoma Press(2002).
11. Patel, R., & Mehta, K. Dhoopan and indoor air quality improvement: A review study. *Journal of Integrative Medicine,*(2022) *9*(3),56-67.
12. Sharma, H., Verma, P., & Tripathi, M. Ethnobotanical significance of Dhoopan in Ayurveda. *Journal of Ethnopharmacology,*(2020)*14*(5),89-97.
13. Singh, T., Gupta, R., & Pandey, V.. Herbal fumigation and respiratory health: A systematic review. *Journal of Pulmonary Medicine,* (2019) *11*(2),45-59.
14. Unschuld, P. U. *Medicine in China: A History of Ideas*. University of California Press(1986).
15. Verma, S., Nair, A., & Sharma, P. Modern approaches to Ayurvedic fumigation: A scientific perspective. *Journal of Alternative Medicine,* (2022)*15*(4), 67-78.
16. Subhabrata Sarkar, Singh BM (2024). The Rationality of DhupanaKarma(Fumigation) as a protective measure for Neonatal care in Kumaragara(Infants Adobe and NICU) (2024).
17. Samal, Janmejaya. Fundamental tenets of epidemiology in Ayurveda and their contemporary relevance. Indian Journal of Health Sciences (2016)9(1)
18. Vyas Apexa, 2020. Understanding of Infectious Disease as per Ayurvedic Perspective - A Simplified Review. Journal of Ayurveda and Integrated Medical Sciences (2020)5(1):107–112.
19. Sumitha, L & Prasad, B. 2015. Evaluation of antimicrobial and antifungal property of Dhoopana karma (fumigation) - by "Dhoop"an Ayurvedic dhoopana product. International Journal of Pharmaceutical Sciences and Research (2015)6(7):2950–2954.
20. Shrestha, S, Bedarkar, P, Patgiri, B J & Chaudhari, S. 2017. Dhoopana karma: A review through Brihatrayi. International Ayurvedic Medical Journal (2017)1(3):316–325.
21. Seema Nishant Parma Vd 'A Review OnDhoopkalpadhya Y -A Crucial Contribution of Kashyap Samhita as 'A Preventive Measure For Pandemic Situations', International Journal of Current Advanced Research, (2021) 10(08),pp. 24964 24969.
22. KaminiRotkeandPunamGauravSawarkar,Int.J.Res.Pharm. Sci.,(2020)11(SPL)(1),1622-1626.
23. Ahlavati, M., Sharma, R. Dhupana Karma in Ayurveda Text. International Ayurvedic Medical Journal, (2019)7(5):770–776.
24. Eliza Ranjit, Stephen Hamlet, Roy George, Ajay Sharma, Robert M. Love, Biofunctional approaches of wool-based keratin for tissue engineering,Journal of Science: Advanced Materials and Devices 7(2022) 100398.
25. Balkrishna A, Yagyadev S, Vipradev S, et al. Vishaghn Dhoop, Nano-Scale Particles with Detoxifying Medicinal Fume, Exhibits Robust Anti-Microbial Activities: Implications of Disinfection Potentials of a Traditional Ayurvedic Air Sterilization Technique. *Journal of Evidence-Based Integrative Medicine*. (2022);27. doi:10.1177/2515690X211068832
26. Gholap S.R. et.al; Validation of the effect of an Ayurvedic therapeutic procedure, Dashmoolkwath & Dhoopan – Fumigation with medicinal herbs during first week of puerperium: An open clinical trial; IAMJ; 2017, 5(9):2320-5091.
27. Magar V.M., Gholap S.R. Evaluation of Dhupan Karma in SutikaParicharya, World Journal of Pharmacy and Pharmaceutical Sciences, (2017), Vol 6(3):607-621.

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Evaluation of Load Carrying Capacity of Bamboo Reinforced One Way Slabs with different Surface Treatments on Bamboo

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The study aims to assess the effectiveness of various surface treatments on bamboo splints on bond strength followed by flexural load carrying capacity of slab panel. The bond strength of bamboo splints with coir rolling and sand coating was evaluated and compared with that of an untreated bamboo splint. Sand coated bamboo splint exhibit higher bond strength compared to other kind of frictional enhancement Nine bamboo-reinforced concrete slab panels were tested on universal testing machine under which load carrying capacity and deflection was evaluated according to Indian Standard code. The sand coated bamboo-reinforced slab panel displayed a load-carrying capacity comparable to that of the steel reinforced slab. Promising test results of sand-coated bamboo encourage the use of bamboo splints as a partial replacement for reinforced concrete in low-cost housing.

Keywords: Bamboo splints, Bamboo reinforced concrete, One-way slab.

INTRODUCTION

Concrete is the most widely utilized material in building construction. It exhibits high compressive strength but low tensile strength. Consequently, it is frequently reinforced with steel bars, which provide tensile strength to the concrete. Steel as a reinforcing material presents certain disadvantages, including higher cost, corrosion and non-renewability. Furthermore, steel production is a significant source of greenhouse gas emissions. Therefore, numerous researchers are endeavouring to develop a low-cost, sustainable alternative to steel using locally available materials. Bamboo, a fast-growing woody grass, reaches its optimal strength in three to four years and attains maturity in five years. The tensile strength of bamboo is considerable; for some species, the ultimate tensile strength is comparable to the yield strength of mild steel, while the strength-to-specific-weight ratio is six times greater than that of steel. Similar to steel bars, bamboo can withstand both tension and compression, whereas many other vegetable reinforcing materials cannot bear compressive loading. Additionally, the energy required to produce one cubic meter per unit stress of bamboo is 50 times lower than that required for steel.

Numerous researchers have conducted experiments to investigate the feasibility of utilizing bamboo as an alternative reinforcement in structural concrete. Agarwal et al.[1] examined the ultimate strengths and engineering properties of locally sourced bamboo strips through tensile testing. They investigated the impact of various adhesives, including Tapecrete P-151, Sikadur 32 Gel, and Araldite, on the bond strength at the interface of bamboo-concrete composites. The most effective adhesive was identified and utilized in subsequent studies of bamboo-reinforced beams and columns. The researchers conducted axial compression and transverse loading tests on plain, steel, and bamboo-reinforced columns to assess load-carrying capacity, lateral deflection, and failure mode patterns. Additionally, they performed a two-point load test on beams to evaluate their bending behavior. The results of these experiments indicated that properly treated bamboo could potentially replace steel as reinforcement in beam and column members.

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Dey et al.[2] investigated bamboo-reinforced concrete beams with varying friction properties. They achieved sufficient frictional resistance in bamboo-reinforced concrete by rolling bamboo with sand, G. I. wire, and coir. The highest bond stress was observed in G. I-rolled bamboo reinforcement. Steel stirrups were employed as transverse reinforcement to counter shear forces in the beams. The study found that beams with extended curing periods and larger reinforcement sizes demonstrated superior performance.

A study by Mishra et al.[3] examined the performance characteristics of full-scale beam-column joints reinforced with bamboo. The researchers analyzed load-deformation properties, maximum moment capacity, crack formation, and failure modes. They compared joints reinforced with untreated bamboo, water-repellent-treated bamboo, and steel. Results showed that beam-column joints using water-repellent-treated bamboo exhibited significantly higher load-bearing capacity compared to those with untreated bamboo. While steel-reinforced concrete joints demonstrated slightly superior performance, the bamboo-reinforced concrete joints showed comparable results.

Alireza et al.[4] performed tests to examine the bonding properties of a newly developed bamboo-composite reinforcement in concrete through pull-out testing. Various coatings were applied to determine the bonding behaviour between concrete and the newly developed bamboo-composite reinforcement. The results of this study demonstrate that bamboo-composite reinforcement without coating develops adequate bonding with the concrete matrix. However, an epoxy-based coating with sand particles could provide additional protection without compromising bond strength.

M.Y. Al-Fasih et al.[5]. conducted a series of experimental tests on untreated species of Bambusa Vulgaris Vittata (BV), Bambusa Heterostachya (BH), and Schizostachyum BrachycladumYellow (SB) to investigate the effect of strip shape, bamboo type, and moisture content on the tensile strength of bamboo strips. Four different cutting shapes were examined for their performance considering the presence of bark and nodes in the strip. Based on these results, the Strip cut side (SS) specimen with bark exhibited a higher tensile strength. The presence of nodes reduces the strength by more than 50%. The bamboo type has a significant impact on the tensile strength. The optimal moisture content for the bamboo material was determined to be 12% after 28 days of air drying. The performances of the BV and BH species for bamboo-reinforced concrete beams were subsequently investigated under three-point bending loading and compared with those of steel-reinforced concrete beams in the tension zone. The load-carrying capacity of the bamboo-reinforced concrete beam is significantly affected by the cross-sectional area of the bamboo reinforcement, whereas its deflection is governed by the ultimate tensile strength of the bamboo reinforcement.

Dinesh Bhonde et al.[6] , presented an experimental investigation of bamboo-reinforced concrete slabs cast in the laboratory and subjected to concentrated load at mid-span. The crack pattern, load-elongation curve, and experimental values were investigated. This study suggests that bamboo-reinforced concrete is a viable alternative to steel-reinforced cement concrete structural elements.

Mali et al.[7] investigated the effect of bamboo reinforcement on the flexural behavior of slabs in terms of load-deformation characteristics, energy absorption capacity, crack patterns, and failure modes. The test results indicated an improvement in the load-carrying and deformation capacity when the proposed bamboo strip was utilized as reinforcement in concrete slab panels compared with Plain Cement Concrete (PCC) and Reinforced Cement Concrete (RCC) slabs. Notably, the structural behavior of slabs using the newly developed bamboo reinforcement demonstrated a significant improvement in flexural performance, marginally surpassing that of steel-reinforced concrete.

Kumar et al.[5] reviewed the concept of bamboo-reinforced concrete and assessed its mechanical properties, which were found to be remarkable. The tests regarding the compressive, tensile, and flexural strengths of bamboo yielded results comparable to those of steel, suggesting its potential as a valuable material for further study, with possible implications for revolutionizing the construction industry.

The load carrying capacity of bamboo reinforced concrete slab is evaluated experimentally according to Indian standard code. These evaluated parameters may be further used to determine design aspects of bamboo reinforced concrete and its structural performances.

Locally available matured bamboo in Gujarat having age of at least 3-4 years is used which may be recognised as D. strictus according to the code IS 15912: 2018 [13]. Selected bamboo is tested after at least six weeks of felling period[13].

Experimental program and test results

Bond Strength: -

The reinforcement slippage in the concrete is prevented by increasing frictional resistance between concrete and the reinforcing material through mechanical and/or chemical bond. The factors responsible for the effective bond strength are adhesive properties of the cement matrix, compressional frictional forces on the surface of the reinforcing bars due to shrinkage of concrete and the shear resistance of concrete due to the roughness of the reinforcing bar. Ribs are provided on steel reinforcement for the same purpose, however, such kind of shear resisting mechanism is not available on bamboo surface being natural material. Therefore, mechanical bond between concrete and bamboo has been enhanced by coir rolling, sand coating using sand of fineness modulus 2.8 on the smooth surface of bamboo. Bond strength is evaluated by pulling out the bamboo through the concrete with the help of pull out test. Two types of surface treated bamboo splints and original splint without surface treatment are inserted in cube specimens of dimension 150 mm x 150 mm x 150 mm for pull out test as shown in Figure 1 as per IS10262: 2019[12] and Abhijeet dey et al.[2]. Total 9 pull out specimens were cast; 3 for each type of surface treatment. Bamboo splints were embedded in M20 grade of concrete for a length of 127.5 mm according to Abhijeet dey et al.[2] and Atul Agarwal et al.[1]. Pull out specimens were tested after 28 days of water curing the cube specimens. Experimental set up shown in Figure 2 was finalised after overcoming

Figure – 1 : Pull out specimens for bond strength

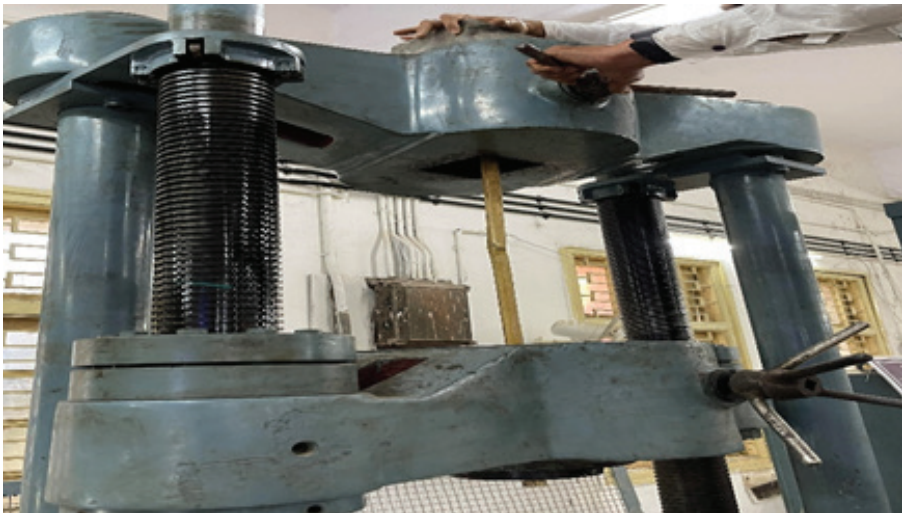


Figure – 2 : Experimental setup for pull-out test

many difficulties. The bond stress τ_b is calculated by :-

$$\tau_b = \frac{F}{S*L}$$

Where, F is the load in kN, S is the perimeter of bamboo strip, L is the embedded length of bamboo in concrete.

Table – 1 : Pull out specimens for bond strength

Sr. No.	Type of surface treatment on bamboo	Bond stress (N/mm^2)
1	Sand coated	2.13
2	Coir wrapped	1.91
3	Untreated	0.76

Bond strength of different types of treated bamboo is depicted in Table 1. As expected, bond stress is found to be the least (0.76 N/mm^2) in plain bamboo splints embedded in concrete because of smooth surface. One of the main shortcomings of bamboo is its water absorption when it is used as reinforcement in concrete. Bamboo absorbs mixing water from concrete which increases its volume due to which expansion take place in plastic condition of concrete. Over the period, bamboo loses its moisture and shrinks back almost to its original dimension leaving voids around itself. This mechanism leads to cause micro or even macro cracks on interface of bamboo with the hardened concrete which adversely affect the bond strength of bamboo[11]. Bond stress for plain bamboo shall be in the range of 0.353 to 0.55 N/mm^2 according to IS 15912 :2018[13]. Mayank Mishra et al.[3] achieved 1.35 N/mm^2 for epoxy coated bamboo and 0.60 N/mm^2 for plain bamboo. Atul Agrawal et al.[1] obtained bond stress of 0.588 N/mm^2 for epoxy coated bamboo and 0.127 N/mm^2 for plain bamboo.

One of the effective treatments is to apply thin layer of epoxy on surface to prevent absorption of water from the concrete. Sand coating is done with the help of epoxy as a binder which serves both the purposes; prevention of water absorption and increasing frictional resistance. Therefore, this type surface treatment gives highest bond stress of 2.13 N/mm^2 among all other surface treatments. It enhances bond stress by almost 3 times over untreated bamboo. Abhijeet et al.[2] reported bond strength of 5.96 N/mm^2 for coarse sand coated and 8.94 N/mm^2 for double epoxy coir rolled bamboo.

Slab: -

Ten slab panels were cast according to IS 15912:2018[13], and a point load was applied in UTM to determine the maximum load capacity and maximum deflection of the slab panel. M20 mix-grade concrete was used to cast panels, slab with steel reinforcement, 3 slab panels with untreated bamboo reinforcement, 3

Figure – 3 : Bamboo cage for bamboo reinforced concrete slab

slab panels with coir coated bamboo reinforcement, 3 slab panels with sand coated bamboo reinforcement were cast in the present investigation.

Preparation of Cage

Whole bamboo culms were halved longitudinally and split into three strips of 20 to 25 mm in width and 9 mm in thickness for use as reinforcement. All bamboo strips were cut straight and of the required length, as per IS 15912:2018[13]. Bamboo strips were sprayed with tricel insecticide chemical treatment to protect from insects and environmental defects. An epoxy coating was applied, on bamboo splints followed by rolling in fine sand and wrapping the coir and allowed to dry for 24.

Bamboo reinforced slab panel

The details of the slab specimen casting are listed in Table 2. The provision of reinforcement in bamboo slabs is based on the orientation of the bamboo splits and the spacing details mentioned in the code IS 15912: 2018[13]. M20 grade concrete was proportioned as per IS 10262: 2019[12] for bamboo reinforced slab and mild steel specimen slab. The main reinforcement is laid edge wise as combination of two splints at 150 mm c/c and subsidiary reinforcement laid flat with alternate face configuration at 120 mm c/c and whole assembly is tied with binding steel wire as shown in Figure 3.

Theoretical moment and load carrying capacity of bamboo reinforced slab is worked out using working stress design method and parameters given in IS 15912: 2018[13].

Table – 2 : Slab Details

Parameters	Value
Span	500 mm
Width	230 mm
Thickness	100 mm
Ly/Lx ratio	>2 (one way slab)
Clear cover bottom	20 mm
Clear cover side	15 mm
Width of bamboo strip average	20 mm
Thickness of bamboo strip	9 mm
Cross sectional area of bamboo strips	180 mm^2
c/c distance between main reinforcement	120 mm
c/c distance between distribution reinforcement	150 mm

Moment of resistance of section = $Q = 1.06\,bd^2$ for bamboo reinforced structure

(Table 5, cl 9.1, IS 15912:2018[10])

Q = 1.516 kN/m and Load carrying capacity = 12.48 kN (bamboo reinforced slab)

Experimental Setup

Slab panels were subjected to load in UTM as shown in Figure 4. Slab panels were placed on steel I beams along the longer side of slab to create a one-way support system. Rollers were placed between slab and I beam. One dial gauge was provided to measure central deflection.

Table – 3 : Experiment results of bamboo reinforced slab specimens

Sr No	Type of reinforcement used in slab	Maximum load (kN)	Load at first crack (kN)	Deflection at max. load (mm)	Moment capacity (kN.m)
1	Sand coated bamboo	60	31.67	1.67	7.5
2	Coir wrapped bamboo	54.16	41.6	2.23	6.77
3	Untreated bamboo	50.83	15.71	2.096	6.35
4	Steel reinforcement	67	40	1.43	8.33

Figure – 4 : Test setup in Universal testing machine

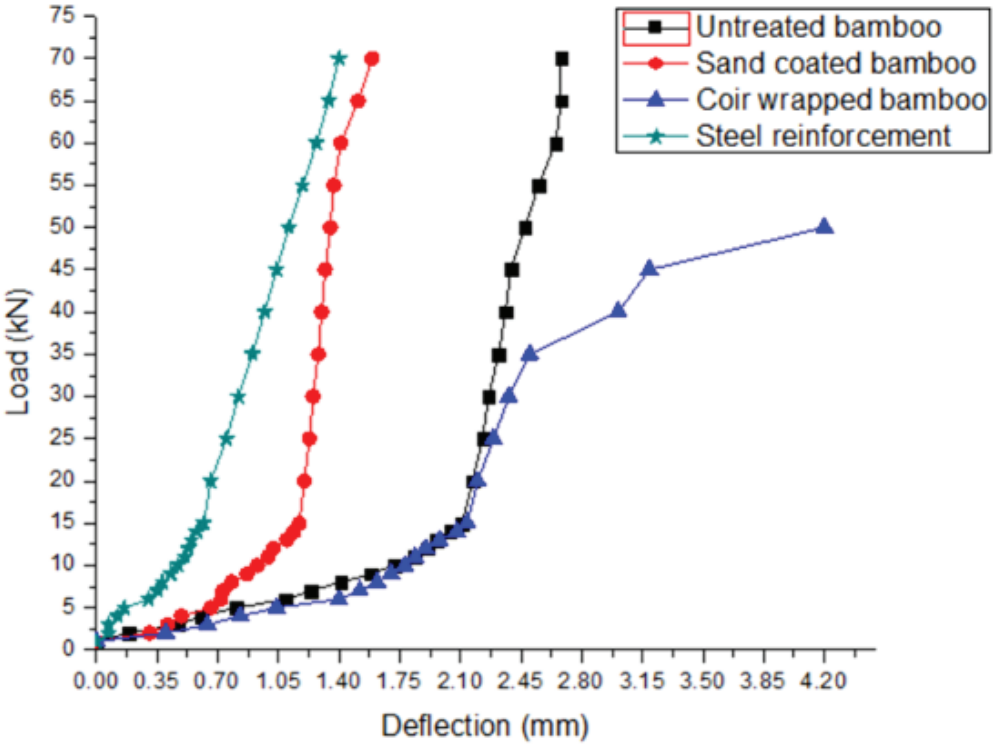
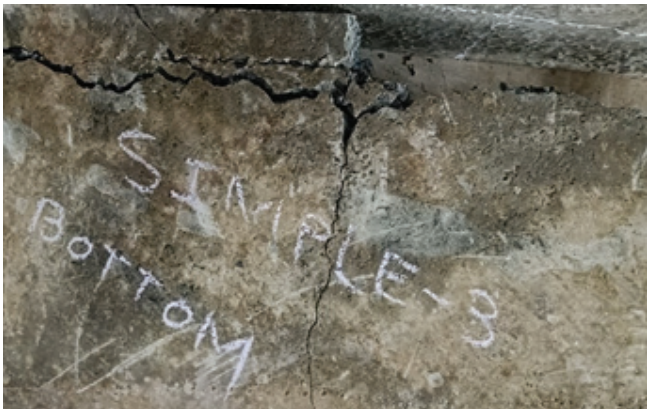


Figure – 5 : Load v/s Deflection response of slab panels

The sand-coated bamboo reinforced slab performed better than the other kind of bamboo slab specimens in terms of moment capacity and deflection as depicted in Table 3. Sand coated bamboo reinforced specimen exhibited load-deflection response almost similar that of the steel reinforced specimen. Sand coated bamboo reinforced slab panel indicated higher deflection at lower load, however, almost same deflection at ultimate load compared to steel reinforced slab panel as shown in Figure 5. It is to be noted that experimental load carrying capacity and moment capacity is much greater than theoretical calculation. This is attributed to higher factor of safety considered in theoretical calculation.

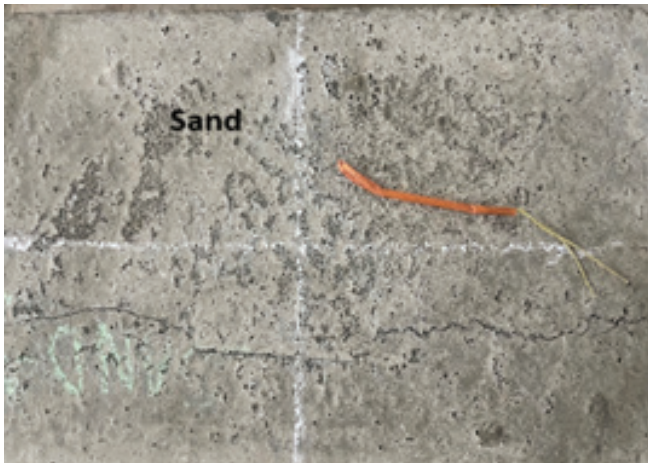
Deflection in coir wrapped and untreated bamboo reinforced slab panels was found to be 2-3 times higher than that of steel reinforced and sand coated bamboo reinforced slab panels at lower load (15 kN).

Failure pattern



(a) Untreated bamboo reinforcement slab panel

(b) Coir wrapped bamboo reinforced slab panel



(c) Sand coated bamboo reinforced slab

Figure – 6: Failure pattern of bamboo reinforced slab panels

Untreated bamboo reinforced slab exhibited combined shear failure (Figure 6(a)), coir wrapped bamboo reinforced slab exhibited combined shear and tensile failure (Figure 6(b)), while sand coated bamboo reinforced slab panel exhibited cracks along the reinforcement (Figure 6 (c)).

Conclusion

Bond strength of plain bamboo is very poor because of smooth surface and absorption of water; hence, bamboo needs special treatment on surface to enhance frictional resistance. Epoxy sand coated splint bamboo exhibits bond strength almost three times than that of plain bamboo. Thus, moderately lower tensile strength and enhanced bond strength by special surface treatment encourages use of bamboo as a reinforcement.

Shear failure was observed in untreated and coir wrapped bamboo reinforced slab panels due to inadequate bonding of bamboo splits with concrete. Load deflection response of steel reinforced and sand coated bamboo reinforced slab panel is almost same. The use of sand coating on bamboo splints not only improved the bond strength, but also potentially enhanced the overall structural integrity of bamboo-reinforced concrete slabs. This innovative reinforcement approach could lead to more sustainable and cost-effective construction practices, particularly in regions where bamboo is abundant.

Bamboo has huge potential to be used as reinforcement in concrete replacing the steel reinforcement for low-cost housing. However, design

aspects of bamboo reinforced concrete need to be exercised in the codes and structural performance shall be evaluated through series of experiments for different types of bamboo subjected to different treatments to increase bonding between the bamboo and concrete.

References

1 A. Agarwal, N. Bharadwaj, M. Damodar, Experimental investigation on chemically treated bamboo reinforced concrete beams and columns, *Construction and Building Materials,* 71, 610–617, 2014.

2 A. Dey, C. Nayanmoni, Experimental study of bamboo reinforced concrete beams having various frictional properties, *Materials Today: Proceedings,* 5, 436–444, 2018.

3 M. Mishra, M. Kranti Kumar, M. Damodar, Experimental evaluation of the behaviour of bamboo-reinforced beam–column joints, *Innovative Infrastructure Solutions*, Springer Nature Switzerland AG, 2019.

4 A. Javadian, M. Wielopolski, Ian F.C Smith, Drik E. Hebel Bond-behaviour study of newly developed bamboo-composite reinforcement in concrete, *Construction and Building Materials,* 122, 110–117, 2016.

5 M. Y. Al-Fasih, S. Hamzah, Y. Ahmad, M. A Mohd Ariffin, Tensile properties of bamboo strips and flexural behaviour of the bamboo reinforced concrete beams, *European Journal of Environmental and Civil Engineering,* 2021.

6 Dinesh Bhonde1, P. B. Nagarnaik, D. K. Parbat, U. P. Waghe, Experimental Investigation of Bamboo Reinforced Concrete Slab, *American Journal of Engineering Research (AJER)*, 03-128-131,2014.

7 R. Pankaj, D. Mali, D. Datta, Experimental evaluation of bamboo reinforced concrete slab panel", *Constructions and Building Materials*, 2018.

8 Purushtotam Kumar, Phalguni Gautam, Simardeep Kaur, Mohit Chaudhary, Anam Afreen, Tanuja Mehta," Bamboo as reinforcement in structural concrete", Materials Today: Proceedings, 2021.

9 IS: 9096 (2006), "Preservation of bamboo for structural purpose", Bureau of Indian Standards, New Delhi, India.

10 IS: 6874 (2008). "Indian standard specifications for method of tests for bamboo", Bureau of Indian Standards, New Delhi, India.

11 IS: 8242 (1976). "Methods of tests for split bamboos", Bureau of Indian Standards, New Delhi, India.

12 IS: 10262 (2019). "Indian standard concrete mix proportioning – guidelines", Bureau of Indian Standards, New Delhi, India.

13 IS 15912 (2018), "Structural design using bamboo – Code of practice", Bureau of Indian Standards, New Delhi, India.

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"The full-blown lotus growing out of the lake symbolises the emergence of the mind and its triumph over matter. The flame rising from the center of the lotus is the flame of the human knowledge, spreading light and learning for the coming generations. The motto inscribed below the lotus defines the purpose and existence of life which is love of beauty, goodness and intellectual curiosity."

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अगनबाथ अमे भरनारा
अमे दैन्यतिमिरने हरनारा.

श्री सयाजी विद्यापीठना ज्ञानदीपने धरनारा
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