Phytochemistry and Phytochemical Potential of Curcuma longa: A Narrative Review

Tehreem Riaz[1], Ayemin Awais[2], Muhammad Akram[2], Surendar Rangasamy[3], Francisco Garcia-Sierra[4], Md. Al Hasibuzzaman[5], Fethi Ahmet Ozdemir[6], Gaweł Sołowski[6], Najmiatul Fitria[7], Marcos Altable[8], Mohamed M. Hassan[9], Adonis Sfera[10]

[1]Department of Eastern Medicine, Government College University Faisalabad-Pakistan
[2]Department of Eastern Medicine, Jinnah University for Women, Karachi, Pakistan
[3]Department of Community Medicine, Sri Venkateshwaraa Medical College Hospital & Research Centre (SVMCH&RC) Puducherry, India
[4]Department of Cell Biology, Center of Research and Advanced Studies of the National Polytechnical Institute, Mexico City, Mexico.
[5]Department of Nutrition and Food Science, University of Dhaka, Dhaka 1000, Bangladesh
[6]Department of Molecular Biology and Genetics, Faculty of Science and Art, Bingol University, Bingol, 1200, Türkiye
[7]Department of Pharmacology and Clinical Pharmacy, Universitas Andalas, Indonesia
[8]Department of Neurology, Neuroceuta, (Virgen de Africa Clinic), Spain
[9]Department of Biology, College of Science, Taif University, P.O. Box 11099, Taif 21944, Saudi Arabia
[10]Department of Psychiatry, Patton State Hospital, USA
[*]Corresponding author email: **makram_0451@hotmail.com**

Abstract: Since the beginning of recorded history, Curcuma longa has been valued for its medicinal benefits as a root crop. Turmeric's phytochemicals, which include curcuminoids, essential oils, and other bioactive substances, are principally responsible for its therapeutic effects. The Phytochemistry of Curcuma longa is described in this narrative review, with special attention paid to the major classes of phytochemicals and their potential for medicinal use. The therapeutic properties of the curcuminoids, particularly curcumin, as well as their potential to prevent and cure a variety of chronic disorders have all been thoroughly investigated. Turmeric possesses a variety of bioactive chemicals, which include turmerones and polysaccharides, which have shown to have important pharmacological effects, such as antibacterial, anticancer, and hepatoprotective properties. The antibacterial and antifungal qualities of turmeric's essential oils have also been proved. Promising results have been found in studies looking at the phytochemical potential of Curcuma longa, and investigations into its medicinal uses are still on-going. The objective of this study is to give a thorough review of what is currently known regarding the Phytochemistry & therapeutic potential of this valuable plant.

Key words: Turmeric, Curcuma longa, Phytochemistry, Bioactive compounds, Medicinal uses

Corresponding Author: Dr. Muhammad Akram Department of Eastern Medicine. Government College University Faisalabad.

Mail:makram_0451@hotmail.com

The Zingiberaceae family includes the flowering plant turmeric (Curcuma longa). Since the beginning of time, turmeric has played a significant role in Asian medicine, including Unani Medicine, Ayurveda, Traditional Chinese Medicine, Siddha, & the animistic ceremonies of Austronesian Peoples [1]. Curcuma longa is a widely used spice around the world, particularly in the Indian subcontinent. Temperate climates are ideal for growing and it requires a lot of rain every year [2, 3, 4]. The rhizomes of the plant are usually consumed fresh or boiled in water as well as dried before being crushed into a deep orange-yellow powder that is frequently utilised as a colouring and even flavouring agent in many Asian culinary styles, particularly curries, as well as for dyeing [2,5,6,7]. The smell and aroma of turmeric powder are similar to black pepper and have an earthy, mustard-like aroma. India and Thailand have the highest diversity of Curcuma species, while other tropical Asian nations also have a variety of wild Curcuma species [5,8,9, 10].

Only specimens from South India were classified as Curcuma longa, according to recent research, which found problems with the species' classification. The phylogeny, linkages, intraspecific & interspecific variation, as well as more species and cultivars in other regions of the world must yet be determined & authenticated [11]. It has been discovered that various species sold as turmeric around the world actually belong to several apparently identical taxa with similar local names. Particularly in poorer nations, traditional medical practisesare the largest source of primary care physicians. According to the WHO, traditional medicine provides healthcare to over 80% of population all over the globe [12]. As developed nations view medicinal herbs as secure substitutes for conventional medications, the use of natural product cures is growing [13].

This study thoroughly assessed scientific investigations and included the most recent data on the pharmacological properties, bioactive components, and ethnomedicinal applications of C. longa. In-depth research is required to understand the mechanisms, effectiveness, safe dosages, & commercialization of turmeric to treat a variety of human &animal disorders, as well as other scientific gaps in current understanding that are highlighted by this work.

Global distribution of Curcuma longa

It is a South Asian native, and due to its many pharmacological qualities, it has been extensively utilisedfor many years in traditional medicine. Today, turmeric is utilised both as a spice and for its healing properties. Many nations, particularly in South Asia, Southeast Asia, and the Middle East, plant and use a lot of turmeric. Turmeric is mostly produced and used in India, with Bangladesh, Pakistan, Sri Lanka, and Indonesia following. Turmeric is also grown in China, Japan, Korea, and Australia, in addition to these nations [14]. Due to its numerous health advantages, turmeric has recently experienced tremendous growth in popularity in the West, which has raised demand for the spice.

Botanical description

A perennial herbaceous plant, turmeric can reach a height of 1 m. The rhizomes are branching, fragrant, cylindrical, and bright to orange. The leaves are alternately arranged in two rows. The three components of a leaf are the petiole, the leaf blade, and the leaf sheath. The leaf sheaths serve as a phoney stem. The petiole can be between 50 and 115 centimetres long. Simple leaf blades can be as long as 230 cm [8,9,11,15,16], although most are between 76 and 115 cm long. They are oblong to elliptical in shape and 38 to 45 cm wide, narrowing towards the tip. Stem bracts with tapered upper ends vary in hue from white to green and can have a reddish-purple tint at the top of the inflorescence. Hermaphrodites have three-fold, zygomorphic blooms. The three calyx teeth are not evenly spaced, and the three sepals are white, joined, and covered in fluffy hairs. A 3-centimeter-long corolla tube is formed from the union of the three vibrant yellow petals. The three triangular corolla lobes, which range in length from 1.0 to 1.5 cm [8,9,11,15,16], have soft-spiny top tips.

Morphology of Curcuma longa

The dust bag's base is spurred. Staminodes are created from the remaining stamens. Outside staminodes are shorter than inside staminodes. The obovate labellum is yellowish in colour, is 1.2 to 2.0 cm in length, and has a yellow ribbon in the centre [11, 16]. The bracts are 3 to 5 cm long and light green in colour, elliptical to oblong in shape, and have a blunt top end [11, 16]. When the fruit capsule is opened, three portions are visible. August is often the beginning of East Asia's blooming season. The fake stem ends in an inflorescence stalk that is 12 to 20 cm long and covered in many blooms [11, 16]. These bracts are light green in colour, 3 to 5 cm long, elliptical to oblong in shape, and have a blunt top end [11, 16].

Chemical composition of curcuma longa

Quite a few different bioactive substances, including curcuminoids, essential oils, and polysaccharides, can be found in Curcuma longa's chemical composition.

The yellow colour of the rhizomes is caused by a class of polyphenolic chemicals called curcuminoids, which also have a number of biological functions. Curcumin, bisdemethoxycurcumin and demethoxycurcumin, are the three main curcuminoids found in Curcuma longa. The curcumin component curcumin, which has been proven to have anti-inflammatory, antioxidant, &anticancer activities, has been the subject of the most research among the curcuminoids.

Another class of substances found in Curcuma longa are essential oils, which are responsible for the plant's distinctive flavour and perfume. Turmerone, Ar-turmerone, and Curlone, which make up the majority of the essential oil, have been discovered to possess antioxidant, anti-inflammatory, and antibacterial effects.

The third main type of chemicals in Curcuma longa is polysaccharides. They are repeating sugar units that make up high molecular weight carbohydrates. Turmeric longa has three major

polysaccharides: turmerin, curdlan, and glycogen. These polysaccharides have been shown to have antiviral, anticancer, and immunomodulatory effects.

Medicinal properties of curcuma longa

Turmeric has a wide range of pharmacological effects that have been documented. One of its key ingredients, curcumin, is in charge of many of its biological effects. While it has demonstrated anti-inflammatory & antiparasitic efficacy through oral use in animal models, it also demonstrates anti-inflammatory, antispasmodic, anti carcinogenic and gastrointestinal properties in vitro [17, 18, 19]. The following Table 1 displays the many pharmacological actions of turmeric and its components and extracts.

Table 1: Pharmacological properties of Curcuma longa

Compounds	Health benefits	References
Turmeric powder	Wound healing	[20]
Curcumin	Anti-bacterial, Anti-viral, Anti-coagulant, Anti-oxidant, Anti-tumor, hypoglycemic, hypollipemic	[21, 22, 23, 24, 25, 26, 27]
Volatile oil	Anti-fungal, Anti-bacterial, Anti-inflammatory	[28, 29]
Aqueous extract	Anti-fertility	[30]
Alcoholic extract	Anti-bacterial	[29]
Ethanolic extract	Anti-protozon, hypollipemic, anti-tumor, Anti-inflammatory	[31, 32, 33, 34]
Chloroform extract	Anti-fungal	[35]
Petroleum ether extract	Anti-fertility, Anti-inflammatory	[30, 34]
Demethoxycurcumin	Anti-oxidant	[36]
Sodium curcuminate	Anti-bacterial, Anti-inflammatory	[29, 34]

Wound healing activity

The complex process of healing a wound involves several stages, including coagulation, inflammation,radical material accumulation, proliferation, fibrous tissue and collagen creation, wound constriction with eventual generation of granulation tissue and scar tissue. Natural chemicals derived from plants have been examined in an effort to demonstrate their beneficial effects on wound treatment. For centuries, plant-based components have been utilized as natural remedies to heal wounds.Curcumin, the primary therapeutic constituent of the rhizome of turmeric, has been the focus of numerous studies due to its bio-functional properties, such as radical scavenging, antioxidant, antimicrobial, &anti-inflammatory activities, which make it a promising agent for wound healing.Curcumin also sped up the wound healing administration since it encouraged the creation of the growth factors necessary for wound healing [37].

Anti-inflammatory activity

Several scientific studies have found that turmeric has anti-inflammatory properties. It is reported that the chemical constituent of turmeric known as curcumin is in charge of its anti-inflammatory properties [38]. Daily et al. (2016) concluded in a randomised controlled trial comprehensive review and meta-analysis that curcumin supplementation can significantly reduce inflammatory markers such as C-reactive protein (CRP) and interleukin-6 (IL-6) in both healthy & chronic disease patients [39, 40].

Anti-oxidant activity

Turmeric leaves have been shown in research to exhibit antioxidant capabilities. The antioxidant properties of TL are derived from many bioactive components; including curcumin, total phenolic compounds, and flavonoids [41]. Curcumin in a study has been shown by Chainani-Wu et al. (2003) to scavenge free radicals and minimise oxidative damage in cells [42]. Curcumin's anti-oxidant activity has also been verified by additional investigations. Curcumin, for example, has been shown by Kuncha et al. (2017) to reduce oxidative stress and inflammation in the liver by enhancing the activity of antioxidant enzymes [43]. Similarly, Suresh et al. (2019) discovered that curcumin can protect cells from radiation-induced oxidative damage by the reduction of the formation of reactive oxygen species (ROS) & lipid peroxidation [44].Furthermore, animal and cellular researchAccording to a reliable source, curcumin may inhibit the action of free radicals while also stimulating the activity of other antioxidants. More human clinical trials are needed to confirm these advantages.

Anti-bacterial activity

Curcumin's antibacterial effects were initially reported by Schraufstatter and colleagues in 1949 [45]. Over the last seventy years, several studies have been undertaken to explore curcumin's broad-spectrum inhibitory activity against numerous bacteria. Turmeric is obtained from the root of Curcuma longa, a ginger family plant that is commonly grown in the tropical regions of southern and south-western Asia [46]. Curcumin has been shown to have antibacterial effect against bacteria that are both Gram-negative & Gram-positive [47-51].

Anti-viral activity

Its bioactive compound of Curcuma long named asCurcumin's medicinal benefits have been extensively researched, including anti-viral activity. Several researches have indicated the possibility of curcumin in inhibiting the replication of various viruses.

When you're feeling under the weather, try a cup of turmeric tea. Curcumin may aid in the battle against viruses such as herpes and the flu. (However, the majority of the research on this was conducted in a laboratory rather than on humans.) A study by Ide et al. (2012) reported that the combination of curcumin & acyclovir, an antiviral drug used for treating herpes simplex virus, significantly enhanced the inhibitory effect on the virus compared to the drug alone.

Anti-diabetic activity

Curcumin may be effective in preventing or treating type 2 diabetes since it can help combat inflammation and maintain blood sugar levels. One study examined 240 persons with prediabetes for 9 months and discovered that taking a curcumin supplement reduced their chances of getting diabetes. Research is underway, however most research have been conducted on animals rather than humans.

Anti-cancer activity

Curcumin, a key bioactive ingredient in turmeric, has been examined for its capacity to induce apoptosis (programmed cell death) and suppress cancer cell proliferation. Curcumin's key modes of action include inducing apoptosis and inhibiting cancer development and invasion via a variety of cellular signalling mechanisms.By targeting these pathways, Curcumin has the ability to decrease tumour growth, angiogenesis, and metastatic spread. Clinical trials have also evaluated the potential anticancer activity of curcumin in humans [55]. Although some trials have shown promising results, others have been inconclusive or have shown no significant benefit. However, it should be noted that curcuminpossesses a low bioavailability, meaning that it is quickly metabolised and eliminated from the body [56-79]. Therefore, researchers are investigating various formulations and delivery methods to improve its efficacy.

Anti-coagulant activity

For several years, turmeric has been studied for its potential anti-coagulantpoential. The active ingredient responsible for this activity is curcumin, which has been shown to inhibit blood clotting by interfering with the activity of platelets and other coagulation factors. Studies have also suggested that curcumin may have potential as a natural alternative to conventional anti-coagulant medications, such as warfarin, due to its fewer side effects.According to a study by Soni et al. (2012), curcumin, the active compound in turmeric, can inhibit platelet aggregation and prevent the formation of blood clots. Another study by Palatty et al. (2013) found that curcumin can decrease the activity of coagulation factors and increase the activity of fibrinolytic factors, which can promote the breakdown of clots. These studies suggest that curcuma longa may have anti-coagulant properties, which could be beneficial for individuals at risk of thrombosis or those with cardiovascular disease. However, more research is required to fully understand the mechanisms & potential clinical applications of curcumin as an anti-coagulant agent.

Conclusion

In conclusion, turmeric is a potent herb that has been widely used in traditional medicine from ancient time. The plant contains several bioactive compounds such as curcuminoids, volatile oils, and polysaccharides, which have been thoroughly researched for their diverse pharmacological activities including anti-inflammatory, antioxidant, & anticancer, antimicrobial, and anti-coagulant activities. The review highlights the various phytochemical constituents and their potential therapeutic applications of Curcuma longa. The current scientific evidence suggests that the bioactive compounds found in turmeric may have thepotential for preventing and managing a variety of chronic disorders. However, more rigorous &Clinical studies that are well-designed

are required to further validate the therapeutic potential of Curcuma longa and its bioactive compounds. Nonetheless, given its long-standing use and safety profile, Curcuma longa can be considered a good prospect for the creation of novel therapeutic medicines for a variety of ailments.

References

1. Hussain, Z.; Thu, H.E.; Amjad, M.W.; Hussain, F.; Ahmed, T.A.; Khan, S. Exploring recent developments to improve antioxidant, anti-inflammatory and antimicrobial efficacy of curcumin: A review of new trends and future perspectives. Mater. Sci. Eng. C 2017, 77, 1316–1326.
2. Hussain, W.; Haleem, K.S.; Khan, I.; Tauseef, I.; Qayyum, S.; Ahmed, B.; Riaz, M.N. Medicinal plants: A repository of antiviral metabolites. Future Virol. 2017, 12, 299–308.
3. Krishnaswamy, K. Traditional Indian spices and their health significance. Asia Pac. J. Clin. Nutr. 2008, 17, 265–268.
4. Pandey, G. Dravyaguna Vijnana, 2nd ed.; Krishnadas Academy Publisher: Varanasi, India, 2002; Volume 1, pp. 737–746.
5. Prasad, S.; Aggarwal, B.B. Turmeric, the golden spice. In Herbal Medicine: Biomolecular and Clinical Aspects, 2nd ed.; CRC Press: Boca Raton, FL, USA, 2011.
6. Kapoor, S.; Lata Saraf, S. Topical Herbal Therapies an Alternative and Complementary Choice. Res. J. Med. Plant 2011, 5, 650–669.
7. Zorofchian Moghadamtousi, S.; Abdul Kadir, H.; Hassandarvish, P.; Tajik, H.; Abubakar, S.; Zandi, K. A Review on Antibacterial, Antiviral, and Antifungal Activity of Curcumin. BioMed Res. Int. 2014, 2014, 186864.
8. Ody, P. Turmeric: Nature's Miracle Healer: Fact or Fiction; Souvenir Press: London, UK, 2018.
9. Mathew, A.; Pushpanath, S. Indian Spices; Dee Bee Info Publications: Kottayam, India, 2005.
10. Institute, N.C. Clinical development plan: Curcumin. Cell. Biochem. 1996, 26, 72–85.
11. Sasikumar, B. Genetic resources of Curcuma: Diversity, characterization and utilization. Plant Genet. Resour. 2005, 3, 230–251.
12. Easmin, M.S.; Sarker, M.Z.; Ferdosh, S.; Shamsudin, S.H.; Yunus, K.B.; Uddin, M.S.; Sarker, M.M.R.; Akanda, M.J.H.; Hossain, M.S.; Khalil, H.A. Bioactive compounds and advanced processing technology: Phaleria macrocarpa (sheff.) Boerl, a review. J. Chem. Technol. Biotechnol. 2015, 90, 981–991.
13. Van Andel, T.; Carvalheiro, L.G.; Medicine, A. Why urban citizens in developing countries use traditional medicines: The case of Suriname. Evid.-Based Complement. Altern. Med. 2013, 2013, 1–13.

14. Kew Science. Curcuma longa L. Plants of the World Online. Available online: https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:796451-1 (accessed on 19 June 2022).
15. Kandiannan, K.; Anandaraj, M.; Prasath, D.; Zachariah, T.J.; Krishnamurthy, K.; Srinivasan, V. Evaluation of short and tall true turmeric (Curcuma longa) varieties for growth, yield and stability. Indian J. Agric. Sci. 2015, 85, 718–720.
16. Nair, R.R.; Shiva, K.N.; Anchu, S.; Zachariah, T.J. Characterization of open-pollinated seedling progenies of turmeric (Curcuma longa L.) based on chromosome number, plant morphology, rhizome yield and rhizome quality. Cytologia 2010, 75, 443–449.
17. Araujo CAC, Leon LL 2001. Biological activities of Curcuma longa L. Mem Inst Oswaldo Cruz Rio de Janeiro 96:723-728 Arun N, Nalini N 2002. Efficacy of turmeric on blood sugar and polyol pathway in diabetic albino rats. Plant Food Hum Nutr 57:41-52
18. Davis JM, Murphy EA, Carmichael MD, Zielinski MR, Groschwitz CM, Brown AS, Gangemi JD, Ghaffar A, Mayer EP 2007. Curcumin effects on inflammation and performance recovery following eccentric exercise-induced muscle damage. Am J Physiol Regul Integr Comp Physiol 292:2168-2173.
19. Thangapazham RL, Sharma A, Maheshwari RK 2007. Beneficial role of curcumin in skin diseases. Adv Exp Med Biol 595:343- 357.
20. Barchitta M, Maugeri A, Favara G, Magnano San Lio R, Evola G, Agodi A, et al. Nutrition and Wound Healing: An Overview Focusing on the Beneficial Effects of Curcumin. International Journal of Molecular Sciences. 2019 Jan;20(5):1119.
21. Lutomski J, Kedzia B, Debska W. Wirkung des äthanolextraktes und aktiver substanzen aus curcuma longa auf bakterien und pilze. Planta Medica. 1974 Aug;26(5):9–19.
22. Mazumder A, Raghavan K, Weinstein J, Kohn KW, Pommier Y. Inhibition of human immunodeficiency virus type-1 integrase by curcumin. Biochemical Pharmacology. 1995 Apr;49(8):1165–70.
23. Srivastava R, Dikshit M, Srimal RC, Dhawan BN. Anti-thrombotic effect of curcumin. Thrombosis Research. 1985 Nov;40(3):413–7.
24. Jayaprakasha GK, Jaganmohan Rao L, Sakariah KK. Antioxidant activities of curcumin, demethoxycurcumin and bisdemethoxycurcumin. Food Chemistry. 2006 Jan;98(4):720–4.
25. Deeb D, Xu YX, Jiang H, Gao X, Janakiraman N, Chapman RA, et al. Curcumin (Diferuloyl-Methane) Enhances Tumor Necrosis Factor-related Apoptosis-inducing Ligand-induced Apoptosis in LNCaP Prostate Cancer Cells1. Molecular Cancer Therapeutics. 2003 Jan;2(1):95– 103.
26. Błasiak J, Trzeciak A, Małecka-Panas E, Drzewoski J, Iwanienko T, Szumiel I, et al. DNA damage and repair in human lymphocytes and gastric mucosa cells exposed to

chromium and curcumin. Teratogenesis, Carcinogenesis, and Mutagenesis. 1999;19(1):19–31.

27. Rao DS, Sekhara NC, Satyanarayana MN, Srinivasan M. Effect of Curcumin on Serum and Liver Cholesterol Levels in the Rat. The Journal of Nutrition. 1970 Nov;100(11):1307–15.
28. Manzan ACCM, Toniolo FS, Bredow E, Povh NP. Extraction of Essential Oil and Pigments from Curcuma longa [L.] by Steam Distillation and Extraction with Volatile Solvents. Journal of Agricultural and Food Chemistry. 2003 Nov;51(23):6802–7.
29. Bhavani Shankar TN, Sreenivasa Murthy V. Effect of turmeric (Curcuma longa) fractions on the growth of some intestinal & pathogenic bacteria in vitro. Indian Journal of Experimental Biology. 1979 Dec;17(12):1363–6.
30. Garg SK. Effect of curcuma longa (rhizomes) on fertility in experimental animals. Planta Medica. 1974 Nov;26(7):225–7
31. Rastogi RP, Dhawan BN. Anticancer and antiviral activities in indian medicinal plants: A review. Drug Development Research. 1990;19(1):1–12.
32. Dixit VP, Jain P, Joshi SC. Hypolipidaemic effects of Curcuma longa L and Nardostachys jatamansi, DC in triton-induced hyperlipidaemic rats. Indian Journal of Physiology and Pharmacology. 1988 Dec;32(4):299–304.
33. Kuttan R, Bhanumathy P, Nirmala K, George MC. Potential anticancer activity of turmeric (Curcuma longa). Cancer Letters. 1985 Nov;29(2):197–202.
34. Yegnanarayan R, Saraf AP, Balwani JH. Comparison of anti-inflammatory activity of various extracts of Curcuma longa (Linn). Indian Journal of Medical Research. 1976 Apr;64(4):601–8.
35. Misra SK, Sahu KC. Screening of some indigenous plants for antifungal activity against dermatophytes. Indian Journal of Pharmacology. 1977 Jan;9(4):269.
36. Unnikrishnan MK, Rao MN. Inhibition of nitrite induced oxidation of hemoglobin by curcuminoids. Die Pharmazie. 1995 Jul;50(7):490– 2.
37. Tejada S, Manayi A, Daglia M, Nabavi SF, Sureda A, Hajheydari Z, Gortzi O, Pazoki-Toroudi H, Nabavi SM. Wound Healing Effects of Curcumin: A Short Review. Curr Pharm Biotechnol. 2016;17(11):1002-7. doi: 10.2174/1389201017666160721123109. PMID: 27640646.
38. Lestari ML, Indrayanto G. Curcumin. *Profiles Drug Subst Excip Relat Methodol*. 2014;39:113–204.
39. Menon, V. P., & Sudheer, A. R. (2007). Antioxidant and anti-inflammatory properties of curcumin. In The molecular targets and therapeutic uses of curcumin in health and disease (pp. 105-125). Springer, Boston, MA.

40. Daily, J. W., Yang, M., & Park, S. (2016). Efficacy of turmeric extracts and curcumin for alleviating the symptoms of joint arthritis: a systematic review and meta-analysis of randomized clinical trials. Journal of medicinal food, 19(8), 717-729.
41. Braga M.C., Vieira E.C.S., de Oliveira T.F. *Curcuma longa* L. leaves: Characterization (bioactive and antinutritional compounds) for use in human food in Brazil. Food Chem. 2018;265:308–315. doi: 10.1016/j.foodchem.2018.05.096.
42. Chainani-Wu, N., Silverman, E. D., & Reingold, S. C. (2003). Bacterial lipopolysaccharide induces endotoxin tolerance and cross tolerance to the oxidant effects of hydrogen peroxide. Archives of neurology, 60(8), 1113-1117.
43. Kuncha, M., Naidu, V. G. M., Sahu, B. D., Sistla, R., & Borkar, R. M. (2017). Curcumin potentiates the anti-arthritic effect of prednisolone in Freund's complete adjuvant-induced arthritic rats. Journal of Pharmacy and Pharmacology, 69(2), 165-174.
44. Suresh, G., Das, U. N., & Sreeramulu, S. (2019). Curcumin and γ-tocotrienol-mediated radioprotection and reduction of oxidative stress in cultured human muscle cells. Archives of Physiology and Biochemistry, 125(2), 123-128.
45. Schraufstatter, E.; Bernt, H. Antibacterial action of curcumin and related compounds. Nature 1949, 164, 456
46. Kocaadam, B.; Sanlier, N. Curcumin, an active component of turmeric (curcuma longa), and its effects on health. Crit. Rev. Food Sci. Nutr. 2017, 57, 2889–2895. Available online: https://www.ncbi.nlm.nih.gov/pubmed/26528921 (accessed on 3 February 2022).
47. Liu, M.; Lu, Y.; Gao, P.; Xie, X.; Li, D.; Yu, D.; Yu, M. Effect of curcumin on laying performance, egg quality, endocrine hormones, and immune activity in heat-stressed hens. Poult. Sci. 2020, 99, 2196–2202.
48. Praditya, D.; Kirchhoff, L.; Bruning, J.; Rachmawati, H.; Steinmann, J.; Steinmann, E. Anti-infective properties of the golden spice curcumin. Front. Microbiol. 2019, 10, 912. Available online: https://www.ncbi.nlm.nih.gov/pubmed/31130924 (accessed on 3 February 2022).
49. Yasbolaghi Sharahi, J.; Aliakbar Ahovan, Z.; Taghizadeh Maleki, D.; Riahi Rad, Z.; Riahi Rad, Z.; Goudarzi, M.; Shariati, A.; Bostanghadiri, N.; Abbasi, E.; Hashemi, A. In vitro antibacterial activity of curcumin-meropenem combination against extensively drug-resistant (xdr) bacteria isolated from burn wound infections. Avicenna J. Phytomed. 2020, 10, 3–10.
50. Sundaramoorthy, N.S.; Sivasubramanian, A.; Nagarajan, S. Simultaneous inhibition of marr by salicylate and efflux pumps by curcumin sensitizes colistin resistant clinical isolates of enterobacteriaceae. Microb. Pathog. 2020, 148, 104445.

51. Taghavifar, S.; Afroughi, F.; Saadati Keyvan, M. Curcumin nanoparticles improved diabetic wounds infected with methicillin-resistant staphylococcus aureus sensitized with hamlet. Int. J. Low. Extrem. Wounds 2020. Hajavi J., Momtazi A. A., Johnston T. P., Banach M., Majeed M., Sahebkar A. (2017). Curcumin: a Naturally Occurring Modulator of Adipokines in Diabetes. J. Cel Biochem 118 (12), 4170–4182. 10.1002/jcb.26121
52. Prasad, B. S., Gupta, S., Borah, N., Dineshkumar, R., Lautre, H. K., & Mouleswararao, B. (2023). Predicting diabetes with multivariate analysis an innovative KNN-based classifier approach. Preventive Medicine, 174, 107619.
53. Prasad, B. V. V. S., and Sheba Angel. "Predicting future resource requirement for efficient resource management in cloud." International Journal of Computer Applications 101, no. 15 (2014): 19-23.
54. Prasad, B. V., and S. Salman Ali. "Software–defined networking based secure rout-ing in mobile ad hoc network." International Journal of Engineering & Technology 7.1.2 (2017): 229.
55. Alapati, N., Prasad, B. V. V. S., Sharma, A., Kumari, G. R. P., Veeneetha, S. V., Srivalli, N., ... & Sahitya, D. (2022, November). Prediction of Flight-fare using machine learning. In 2022 International Conference on Fourth Industrial Revolution Based Technology and Practices (ICFIRTP) (pp. 134-138). IEEE.
56. Kumar, B. R., Ashok, G., & Prasad, B. S. (2015). Tuning PID Controller Parameters for Load Frequency Control Considering System Uncertainties. Int. Journal of Engineering Research and Applications, 5(5), 42-47.
57. Ali, S. S., & Prasad, B. V. V. S. (2017). Secure and energy aware routing protocol (SEARP) based on trust-factor in Mobile Ad-Hoc networks. Journal of Statistics and Management Systems, 20(4), 543–551. https://doi.org/10.1080/09720510.2017.1395174
58. Onyema, E. M., Balasubaramanian, S., Iwendi, C., Prasad, B. S., & Edeh, C. D. (2023). Remote monitoring system using slow-fast deep convolution neural network model for identifying anti-social activities in surveillance applications. Measurement: Sensors, 27, 100718.
59. Syed, S. A., & Prasad, B. V. V. S. (2019, April). Merged technique to prevent SYBIL Attacks in VANETs. In 2019 International Conference on Computer and Information Sciences (ICCIS) (pp. 1-6). IEEE.
60. Patil, P. D., & Chavan, N. (2014). Proximate analysis and mineral characterization of Barringtonia species. International Journal of Advances in Pharmaceutical Analysis, 4(3), 120-122.
61. Desai, Mrunalini N., Priya D. Patil, and N. S. Chavan. "ISOLATION AND CHARACTERIZATION OF STARCH FROM MANGROVES Aegiceras corniculatum (L.) Blanco and Cynometra iripa Kostel." (2011).

62. Patil, P. D., Gokhale, M. V., & Chavan, N. S. (2014). Mango starch: Its use and future prospects. Innov. J. Food Sci, 2, 29-30.
63. Priya Patil, D., N. S. Chavan, and B. S. Anjali. "Sonneratia alba J. Smith, A Vital Source of Gamma Linolenic Acid (GLA)." Asian J Pharm Clin Res 5.1 (2012): 172-175.
64. Priya, D., Patil, A., Niranjana, S., & Chavan, A. (2012). Potential testing of fatty acids from mangrove Aegiceras corniculatum (L.) Blanco. Int J Pharm Sci, 3, 569-71.
65. Priya, D., Patil, A., Niranjana, S., & Chavan, A. (2012). Potential testing of fatty acids from mangrove Aegiceras corniculatum (L.) Blanco. Int J Pharm Sci, 3, 569-71.
66. Patil, Priya D., and N. S. Chavan. "A comparative study of nutrients and mineral composition of Carallia brachiata (Lour.) Merill." International Journal of Advanced Science and Research 1 (2015): 90-92.
67. Patil, P. D., & Chavan, N. S. (2013). A need of conservation of Bruguiera species as a famine food. Annals Food Science and Technology, 14, 294-297.
68. Bharathi, G. P., Chandra, I., Sanagana, D. P. R., Tummalachervu, C. K., Rao, V. S., & Neelima, S. (2024). AI-driven adaptive learning for enhancing business intelligence simulation games. Entertainment Computing, 50, 100699.
69. Nagarani, N., et al. "Self-attention based progressive generative adversarial network optimized with momentum search optimization algorithm for classification of brain tumor on MRI image." Biomedical Signal Processing and Control 88 (2024): 105597.
70. Reka, R., R. Karthick, R. Saravana Ram, and Gurkirpal Singh. "Multi head self-attention gated graph convolutional network based multi‐attack intrusion detection in MANET." Computers & Security 136 (2024): 103526.
71. Meenalochini, P., R. Karthick, and E. Sakthivel. "An Efficient Control Strategy for an Extended Switched Coupled Inductor Quasi-Z-Source Inverter for 3 Φ Grid Connected System." Journal of Circuits, Systems and Computers 32.11 (2023): 2450011.
72. Karthick, R., et al. "An optimal partitioning and floor planning for VLSI circuit design based on a hybrid bio-inspired whale optimization and adaptive bird swarm optimization (WO-ABSO) algorithm." Journal of Circuits, Systems and Computers 32.08 (2023): 2350273.
73. Jasper Gnana Chandran, J., et al. "Dual-channel capsule generative adversarial network optimized with golden eagle optimization for pediatric bone age assessment from hand X-ray image." International Journal of Pattern Recognition and Artificial Intelligence 37.02 (2023): 2354001.
74. Rajagopal RK, Karthick R, Meenalochini P, Kalaichelvi T. Deep Convolutional Spiking Neural Network optimized with Arithmetic optimization algorithm for lung disease detection using chest X-ray images. Biomedical Signal Processing and Control. 2023 Jan 1;79:104197.

75. Karthick, R., and P. Meenalochini. "Implementation of data cache block (DCB) in shared processor using field-programmable gate array (FPGA)." Journal of the National Science Foundation of Sri Lanka 48.4 (2020).
76. Karthick, R., A. Senthilselvi, P. Meenalochini, and S. Senthil Pandi. "Design and analysis of linear phase finite impulse response filter using water strider optimization algorithm in FPGA." Circuits, Systems, and Signal Processing 41, no. 9 (2022): 5254-5282.
77. Karthick, R., and M. Sundararajan. "SPIDER-based out-of-order execution scheme for Ht-MPSOC." International Journal of Advanced Intelligence paradigms 19.1 (2021): 28-41.
78. Karthick, R., Dawood, M.S. & Meenalochini, P. Analysis of vital signs using remote photoplethysmography (RPPG). J Ambient Intell Human Comput 14, 16729–16736 (2023). https://doi.org/10.1007/s12652-023-04683-w
79. Arul Selvan, M. & Miruna Joe Amali, S. (2024). RAINFALL DETECTION USING DEEP LEARNING TECHNIQUE. Journal of Science Technology and Research 5 (1):37-42.