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Biological studies on leaves of Tropical Almond (*Terminalia catappa*) (A Review)

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Abstract

For centuries, medicinal plants have been an essential component of both traditional and modern medicinal treatments. Many people favor remedies derived from herbs over conventional medicine. Tropical Almond (Terminalia catappa) exhibited biological activities for instance anti-indigestion, antimicrobial, antifungal, anticancer, diapho-retic, anti-dysentery, anti-indigestion antibacterial, antidiabetic, anthelmintic, hematological and antitumor activities antihypertensive, anti-peroxidation, antidiabetic, anti-dysentery, hepatoprotective, cognitive enhancement, dermatitis, hepatitis, pyrexia (fever), diarrhea Scabies, leprosy, to dress rheumatic joints, intestinal parasites, dysentery, neurodegenerative and metabolic diseases, acting as a hemostatic, and reducing fever and antirheumatic properties. Antiparasitic Activity, Anti-depressant, Immunomodulator Antiaging activity, Toxicology, Radical scavenging and Antioxidant activity and Wound-healing activity.

Keywords: Tropical Almond (*Terminalia catappa*), Biological activities

INTRODUCTION

Terminalia catappa is a tropical tree species commonly found in coastal regions of Pakistan, including the port city of Gwadar located in the southwestern province of

Balochistan. Situated on the shores of the Arabian Sea, Gwadar's hot and arid climate provides an ideal habitat for Terminalia catappa. Also known as Indian almond or tropical almond, the tree is a member of the Combretaceae family and can grow up to 25 meters in height, boasting large, glossy leaves that turn red or yellow before falling. The tree produces edible fruit resembling a small peach. The botanical name of Terminalia catappa is commonly referred to as Badam or Indian Almond. Its flowers are typically white or pale green, blooming from February to May. Although Terminalia catappa can reach heights of 30-40 feet, it is considered moderately challenging to cultivate (etree.pk). However, there is no readily available information on the specific number and distribution of the tree species in Gwadar.

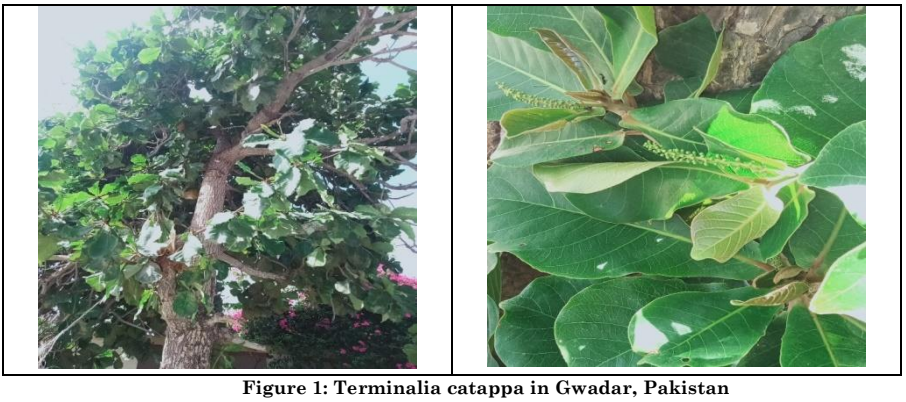

Figure 1: Terminalia catappa in Gwadar, Pakistan

There are different sorts of plants present inside the world, each having different characteristics and properties. An example of such one is medicinal plants. Medicinal plants have been usable for centuries for their Medicare properties. A survey carried out by (WHO) suggests that 80% of the world chose herbal medicine beneficial to treat insignificant health problems. Terminalia catappa is a type of tree that can tolerate shade and salt and is often used as a decorative plant. It is typically found on tropical and subtropical beaches, and is known by different names in various regions. In addition to being an ornamental plant, the leaves of Terminalia catappa is folk remedy used in India as dermatitis and use as hepatitis in Philippines. This particular type of plant has the ability to thrive in sandy soil that is well-drained. It has the capacity to tolerate high levels of salinity in its root area, and it is also resistant to strong winds and salt sprays. Within coastal areas, this has a significant role in providing various non-timber goods and services.

The bark, leaves, and fruit of this plant have been used for various medicinal purposes in different countries, such as Malaysia, the Philippines, and India, including treating dermatitis, acting as a hemostatic, and reducing fever. Some pharmaceutical companies are currently conducting experiments to discover the health benefits of medicinal plants like Terminalia catappa and their potential use in medicine. The medicine made from such plants can be more efficacious with lesser side effects such as *Terminalia catappa*. Medicinal almonds are used traditionally as medicine and food for prevention of a wide variety of neurodegenerative and metabolic diseases. traditional medicinal plant almond and used for health promotion (Ademiluyi et al., 2018;

Oyeleye., 2017). There are numerous bioactive components present in T. catappa, such as p-coumaric acid, protocatechuic acid, catechin and 2-prenylated benzoic acid, also contain syringic acid, vanillic acid, stearic acid, palmitic acid and 3, 4, 40-tri-O-methyl ellagic acid. These compounds have been studied for their potential health benefits (T.D.G. Baratelli et al. in 2012 and E. Chukwuma et al. in 2015).

The variety of wide medicinal plants that obtain advancement well-being has been appropriate to the existence of polyphenolic elements (Vermerris et al, 2006). Higher phenolic components also higher antioxidant activities of almond leaf prove better health promotion. polyphenols and antioxidant properties are significantly higher in almond leaves. So, disease pmanagement related to oxidative stress and neurodegeneration are possibly more effective in almond leaves. (Olubukola ,2020). Stopping or balance out free radicals in living organism, antioxidant compounds are capable of performing their safety roles (Gandhi, 2012; Oboh, 2005) as polyphenolic component is high , the antioxidant activities is greater, and fighting ability against numerous incurable diseases which are associated to oxidative stress like neurodegeneration amidst, hypertension and others (Scalbert et al., 2005). To analyze the aquarium water quality impact in an aquarium used Indian almond leaves consisting Betta fish because hardy fish have tolerance for changing water quality, more easily accessible in tropical state and relatively less expensive (Shams et al 2021). Tropical almond (*Terminalia catappa*) serve as good inhibitors for stainless steel (Chidinma Martina 2018). To remove palladium and platinum ions from solution through the process of biosorption, appropriate research was achieved on leaf biomass (panel Prakorn 2012). The crude Almond leaves extract's common reagents are used for analysis of chemicals, which is one of the paths in the establishment of environmentally friendly and cheaper methodology for green analytical chemistry (Delhaize 1995). Silver nanoparticles (AgNPs) consequently including to the available drugs synthesized by terminalia catappa used in counterattacking multidrug resistant agents and pathogens (Oluwafayoke 2018). Several kinds of flavonoids are present in Indian almond leaves (kaempferol and quercetin). A variety of biological activities of flavonoids have been proven that are consistent with them and degenerative diseases, like cancer, diabetes, cardiovascular diseases, and cataracts are controlled by them (Block ,1992; Steinmetz, 1996; Knekt, 2002). Almond leaves are rich in different kinds of tannins, astringent which are bitter plant polyphenols that both bind and denature or precipitate protein molecules. Traditionally, almond leaves have been known for their anti-indigestion, antihypertensive, anti-peroxidation, antidiabetic, anti-dysentery, , hepatoprotective, cognitive enhancement, and antirheumatic properties (Ankur et al, 2017. Oyeleye et al, 2017. Young et al, 2000). Traditional remedy using juice of the leaves against numerous elements that damage the skin, like scabies and leprosy, to dress rheumatic joints the leaves themselves are useful. People suffering from diseases like intestinal parasites dysentery, ingestion of younger leaves are useful, and are also considered helpful in removal of colic in babies (Tan R 2001). The leaves extract of almond use in the treatment of wound (Nugroho et al 2019). Bioactive sources are possible by almond (*T. catappa*),

Effective antioxidants recovery from the almond leaves would assess the efficacy of different extraction solvents. (Omenna, 2015). Eating almonds can be beneficial for reducing the risk of heart disease and lowering levels of LDL and cholesterol. This is because almonds contain monounsaturated fats, vitamin E, and

phenolic compounds like 2-prenyl-4-O-ß-D-glucopyranosyl-oxy-4-hydroxybenzoic acid and catechin, also contain 2-prenylated benzoic acid protocatechuic acid, which provide antioxidant activity and contribute to the health benefits of almonds. (Omenna EC et al, 2015). the potential medicinal benefits of T. catappa, also known as the Indian almond or tropical almond tree. Penicillin and punicalagin, which are compounds found in the leaves of this tree, Research has demonstrated that the leaves of this tree can suppress the replication of the human immunodeficiency virus (HIV) in H9 lymphocytes that have been infected. Additionally, the leaves have been traditionally used in Asian countries to treat various conditions such as hepatitis, pyrexia (fever), diarrhea, and dermatitis.

Furthermore, there are some reports that suggest that water extracts of T. catappa have a protective effect against genotoxicity that is induced by specific chemicals, such as bleomycin in Chinese hamster ovary cells, and hepatotoxicity induced by C14 (Yang SF et al., 2010). In The Caribbean region, used for treating gastric and urinary infections, and it contains various bioactive components such as acid and prenylated benzoic acid (Omenna EC et al, 2015). Bioactive compounds such as cyanidin 3-glucoside, corilagin and ellagic acid bioactive compound used as anti-HIV properties, inhibitors xanthine oxidase, pentosans and gallic acid are found in T.catappa fruit part. The gum extracted from this plant comprises of xylose and mannose (1%), uronic acids (19%), L-arabinose (59%) and D-galactose (20%). The leaves of the plant have no agro-economic or food value and are instead used as a bioresource to synthesize silver nanoparticles (AgNPs) and gold nanoparticles. Bioactive components like kaempferol, phenols, polyphenols, and tannins, which can reduce Ag+ ions to Ag0 and thus facilitate the formation of AgNPs. These components have not been utilized before, but they have potential antioxidant and flavonoid properties. Many research reports have claimed that the leaves of this plant are considered to be a suitable source for synthesizing silver nanoparticles (AgNPs) (Devaidiga A et al., 2017). A study showed that African almond leaves can be chemically activated and pyrolyzed at 700°C can serve as an environmentally friendly adsorbent that can remove methylene blue dye from water (Jamiu Mosebolatan Jabar et al, 2022).

Terminalia catappa L. is a medicinal plant that is used to treat gastritis and has been found to have preventive and curative effects on gastric ulcers, as well as anti-Helicobacter pylori properties (Laísa Pinheiro Silva et al. in 2015). In synthesis, silver nanoparticles in the food industry, using phytochemicals from the leaf aqueous extract can inhibit the formation of Listeria monocytogenes biofilms (Lakshmanan et al., 2022). The oral management of its aqueous leaf extract did not produce any stress, proinflammatory, systemic and organ toxic effects in Wistar male rats (Franklyn et al. in 2021). Fibers from fallen leaves were were combined with recycled polypropylene, a matrix to create composites.. The use of fibers in their natural state with the steam explosion method after treatment . The resulting sustainable polymer composites showed potential for use in packaging, with development and cost-effectiveness compared to pure polypropylene (Cinthya H. S. et al. in 2020).

Almond trees are commonly used for their medicinal and economic value but are susceptible to mistletoe infestations, which can affect their phytoconstituents and biological activities. A study suggests that feeding Drosophila melanogaster with a high sucrose diet and almond leaves may activate antioxidant and hypoglycemic genes and cause disruptions in insulin signaling and redox status, similar to diabetic states.

(Olubukola H. et al., 2022). A study examined the active compounds present in Terminalia catappa that are responsible for their effectiveness against malaria parasites (Mudi et al., 2009). Another study evaluated the potential of TCA may decreasing oxidative stress and inflammation caused by hyperglycemia in a diabetic rat model (Franklyn Nonso Iheagwam et al., 2021). Tannin extracted from almond leaves was used as a natural mordant to improve the dyeing properties of cotton fabric dyed with turmeric powder, while also reducing environmental problems and health risks associated with metallic mordants (Hnin Phyu Lwin, et al., 2018). Additionally, Soxhlet extraction of TCSE were investigated the analgesic as well as antioxidant, also having better radical saving ability (Annegowda et al, 2010). It has medicinal properties that is recognized as a pharmacopeia vegetable in the Caribbean. One of its derivatives, FrAq from the leaves, has been effective in avoiding and treating both acute and chronic gastric ulcers, as well as exhibiting promising activity against the bacteria Helicobacter pylori. (Laísa Pinheiro et al., 2015). Terminalia catappa leaves are known to contain various hydrolysable tannins like punicalagin, terflavins A and B, penicillin, tergallagin, chebulagic acid, tercatain geraniin, corilagin and granatin B. (Tanaka et al, 1986). Punicalin and punicalagin are two of the hydrolysable tannins found in T. catappa leaves, and haveing inhibitory properties on HIV replication causing cytotoxicity in purified HIV reverse transcriptase and infected H9 lymphocytes (Nonaka et al, 1990). The TCLAE was found to have antinociceptive (pain-relieving) activity in rats. The mechanism of action may involve both central and peripheral pathways. (Saurabh Arjariya et al 2017).

Terminalia catappa has potential therapeutic benefits for sickle cell disease and for treating GBM brain tumors. The study by A.M. Hassan (2021) suggests that the stem bark and leaves of the plant could be used as agents for sickle cell disease therapy. On the other hand, another study found that TCE (Terminalia catappa extract) could reduce the cell migration and invasion of human GBM cells, indicating that it could be used as a potential therapeutic compound for treating GBM brain tumors (Hsiao-Hang Chung et al., 2021). the diverse range of applications for this plant, from its potential use in traditional medicine to its ability to inhibit bio-corrosion on steel surfaces (Marta Pramudita et al.,2020) and produce biochar from waste materials (Joshua et al, 2021). The anti-trypanosomal properties of the LE is also noteworthy, as it suggests potential use in treating trypanosomiasis, a neglected tropical disease (Deborah A et al., 2021) Terminalia catappa L. leaves contain flavonoids such as kaempferol and quercetin, which have potential wound healing properties use after tooth extraction to stop bleeding (Ni Made Sirat et al., 2021). By using almond leaves for biogas production, it helps to reduce pollution in the environment while providing a sustainable energy source. (EZEKOYE et al.,2013).

DISTRIBUTION AND OCCURRENCE

Naturally widespread in Indian and Pacific Oceans sub tropic and tropic zones and planted extensively throughout the tropics, including Brazil, the Caribbean, and East Africa, Asia, India, Pakistan frequently naturalized in Australia, Polynesia, Madagascar, South and Central America (Mallik et al., 2013). In Florida and Puerto Ricoit is also naturalized. introduced very early in Hawaii, now naturalized near beach shores of low altitudes (Tomson et al., 2006).

DESCRIPTION

Terminalia catappa Trees are about twenty miters tall and trunk is about two miter dbh. longitudinally Brownish black bark. Branches spread to form rows. Branchlets are close to apex and massively brownish yellow hairy, leaves are covered with apparent leaf scars. Leaves of t-catappa take turns to cramped into pseudo-whorls at apices of branch-lets, petiole is about 0.5–2 cm, tomatoes', plump leaf blade are oblanceolate from oboval and from proximal half it is narrow about 12–30 × 8–15 cm, both surfaces are comparatively soft hairy or glabrous when younger, base narrow, shorten or cordate, acicular or apex obtuse; lateral veins are arranged in pairs of 10-12. Inflorescences contralateral simple, slim spikes, long, 15–20 cm, many of them are flowered and shortly white tomentose arbor. (Flora of China Editorial Committee, 2017).

Biophysical limits:
The plant species under consideration can thrive in areas that have an altitude of 0-800 meters. They grow best in regions that have an average annual temperature between 15 to 35 degrees Celsius and receive 750 to 3,000 mm of rainfall per year. These plants can adapt to different types of soils such as olitic limestone, sands, loamy sands, silts, loam, and clays, and can tolerate neutral to moderately alkaline soil conditions. They can also grow in strongly acidic soils, but it is important to have good drainage on clay soils. (Mallik Jony et al., 2013).

Reproductive Biology
The Terminalia catappa species undergoes a foliage change and sheds flowers during certain seasons. The fact that the plant flowers up to three times a year and has a system of self-incompatibility suggests that it has evolved effective reproductive strategies to ensure genetic diversity. It is also fascinating that the seeds can float and remain viable, allowing for long-distance dispersal through ocean currents. The role of various insects (Diptera, Hemiptera, Coleoptera Hymenoptera and Lepidoptera) and animals in pollination and seed dispersal highlights the interconnectedness of different species in ecological systems. (Mallik Jony et al., 2013).

Phytochemistry:
The plant leaves of Terminalia catappa contain a extensive variety of phytochemicals having medicinal properties. Flavonoids and tannins are recognized for their antioxidant properties, which can potentially safeguard cells from harm induced by free radicals.. Tannins are also known for their antibacterial and antifungal properties. Alkaloids and glycosides having anti-inflammatory and analgesic, while phenols having antioxidant and antimicrobial properties. Saponins are acknowledged for their diverse health benefits, which include reducing cholesterol levels and exhibiting anti-inflammatory effects. The presence of these phytochemicals in Terminalia catappa leaves may contribute to its traditional use as a medicinal plant for various ailments (Ayoola, 2011. Bhowmik, 2012. Daya, 2013. Okoh, 2011. Peter, 2013. Ramachandra, 2007).

Leaves profile

The *terminalia catappa* leaves are established in close curls, upturned branches are often packed to-ward the upturned ends. The leaf blade is mainly ovate and simple; pairs of secondary veins are (5-)8-12. The tips of the leaf are blunt rounded. Soft, distressed and brown hairs covered new leaves. Adult leaves are mainly leathery, shiny and green, turning off bright yellow to dark red before leaves fall. Throughout the season the trees are briefly deciduous, or twice in a year they will lose their leaves in some environment. (Tomson et al., 2006).

Figure 2: whole plant of terminalia catappa

***T-Catappa* classification and Nomenclature**

Terminalia catappa Taxonomic Classification

The taxonomic classification of TC includes the following: Kingdom Plantae, Division Angiospermae, Class Dicotyiedones, Order Myrtales, Family Combretaceae, Genus Terminalia, and Species catappa.

The family *Combretaceae* is comprised of approximately 500 species of flowering plants, distributed primarily throughout subtropical and tropical areas worldwide. This family includes 14 genera.190 species included in the terminalia genus some of them have commercial importance like timber plants and ornamentals (Orwa, 2009). *Combretaceae* other tree species and terminalia often preferably, pagoda-like, the branches are often consisting of flattened sprinkler of leaf rosettes and arranged in spiral (Stevens, 2012). the genus that includes Excel, Smith and Coode. The 'catappa' name is held from Malaysia, viz. Ketapang is genus from *Terminalia catappa's* species (Wheatley, 1992). Indian or sea almond is most widely determined for this species.

Identity

The preferred scientific name for the Singapore almond is Terminalia catappa. This tree is also commonly known by its preferred common name, Singapore almond.

The EPPO code assigned to Terminalia catappa is TEMCA. In addition to its preferred common name, Singapore almond, this tree is also known by other trade names such as Andaman badam and Indian almond.

Figure 3: leave of Terminalia Catappa

T. CATAPPA PHARMACOLOGICAL ACTIVITY

TC is a ironic cause of various phytochemicals like gallic acid, ellagic acid, flavonoids and corilagin, which are responsible for its pharmacological activities. These compounds have been isolated from leaves, fruits, and bark. The plant has been traditionally utilized for medicinal purposes, and it has been discovered to have a variety of pharmacological activities, including antimicrobial, antibacterial, antioxidant, antidiabetic, anthelmintic, hematological and antitumor activities. TC use as a natural remedy can be a safer alternative to synthetic drugs with fewer adverse effects (Mallik Jony et al., 2013).

Leaves used as medicine

The leaves have diapho-retic, anti-dysentery, anti-indigestion and several other medicinal uses. In Tonga and Samoa treating mouth infection by using young leaves, and leaves are used for washing fractures in the Cook Island. Additionally, the leaves are used in the Philippines as a curative for headaches and pain (Tomson et al, 2006). Tannins are present in leaves, and it is astringent. The leaves, squashes to treat dysentery. The almond red leaves act like vermifuge while the young leaves sap is cooked from the kernel with oil which is used to medicate leprosy. For coughs, leaves juice is consumed. Medication of jaundice infusion of leaves is used. To cure pain and headache and pain used young leaves. Externally, to cure pain of breasts the leaves could be applied or applied to the body numb parts when it is heated. For swollen rheumatic joints dressing leaves will be used. For calming and refreshing the leaves are applied to the sides and top. For medication of yaws fruit and bark and leaves are used (Thomson 2007).

LITERATURE REVIEW

Previous Studies

For centuries, medicinal plants have been an essential component of both traditional and modern medicinal treatments. Many people favor remedies derived from herbs over conventional medicine (Azaizeh H et al., 2003). China have access to safe, effective, and affordable healthcare options. (Katewa SS et al., 2004). Consequently, medicinal plants have developed a crucial component of the human healthcare system. (WHO World Health Organization et al., 2002). Furthermore, The effectiveness of medicinal plants, increasing costs of conventional medicines, and cultural preferences have led to a greater interest in using these plants for healthcare purposes (Heinrich M et al, 2000.

Tabuti JR et al, 2003). Numerous plants have been identified as possessing antioxidant and antimicrobial properties. (Bharti R et al., 2012. Namita P, et al., 2012).

Due to the rise of multiple drug resistance, there has been a significant surge in the quest for potent antimicrobial agents sourced from plants (Sharma SK et al., 2013). TC has been described to exhibit anti-inflammatory and hepatoprotective properties. Additionally, its fruit is typically associated with antidiabetic properties (fan YM et al, 2004. Sharma et al, 2017. Laisa et al, 2015. Ladele et al, 2016. Chu SC et al, 2007. Katiki et al, 2017). TC having aphrodisiac, anti-HIV reverse transcriptase and anticancer properties (Sharma R et al., 2017). T.catappa's seeds make up two-thirds of its composition, with the remaining third being pulp. In developed nations, people consume the seeds. The composition of this food item is high in fat, with a content of 51.8%, where the majority of the fat is made up of oleic acid (up to 31.5%) and linoleic acid (up to 29%). It also contains other nutrients such as magnesium (8%), carbohydrates (16%), crude protein (23.8%), potassium (9.3%), and calcium (8.3%). In Taiwan, TCL are frequently used as a traditional medicine to treat liver-related disorders. The fallen leaves of the tree are boiled in water to make a tea that is consumed for its health benefits. Abundant hydrolysable tannins, with the exception of caffeine, have been discovered in T.catappa's leaves, including corilagin, certain, granatin B chebulagic acid, punicalagin, penicillin geraniin and penicillin (Chyau CC et al., 2002).

Terminalia catappa used to treat various disorders like eye problems, leprosy, and anti-clastogenic properties. Additionally, these leaves are believed to be useful in reducing travel-related nausea and eliminating intestinal parasites. They are also used to control bleeding during tooth extraction (Ahmed MS et al., 2014). Almonds are a valuable product of food medicinally and nutritionally. *T-catappa* hasditional cholesterol lowering effect and low-density lipoprotein (LDL), reducing risk of heart diseases almond is ingested. Such health care functions associated with almond consumption having health care functions can be apply to the vitamin E antioxidant activity and also monounsaturated fats, the presence of phenolics, these phenolics within stem, leaf, root of the almond plant (Subashinee et al., 2002). Extensively it is grown as an ornamental tree and its leaves give deep shadow to grow. The almond fruit has a slightly acidic taste and is edible.

The wood is used for canoe making and has high water resistance. In traditional medicine all parts of plants are used for numerous purposes. Synthetic antioxidants like butylated hydroxyanisole, butylated hydroxytoluene, gallic acid esters, tertiary butylated hydroquinone is used in the food manufacturing industry because its carcinogenic potential is recognized (Jeong, 2004). Because of anticarcinogenic characteristics plants obtain natural antioxidants, contradictory and also related to other medicinal benefits, so much acknowledgment is provided (Iqbal, 2005. Sultanna, 2009). Numerous studies have shown that the antioxidant property of plants is because of divergent bioactive happenings, phenolic compounds are most common (Shumalia, 2012. Shahidi, 1997). The dietary antioxidants having vitamin C, carotenoid, polyphenols and tocopherols functioning well proved health maintenance development, minimizing risk of chronic diseases risk is minimized by meals rich in vegetables and fruits (Lim et al., 2002. Onigbinde, 2005). To minimize the risk of certain diseases by adding nuts, vegetables and sprouts to diet, including cancer, atherosclerosis, diabetes, aging-related disorders and inflammation (Pinelo et al.,2004). Flavonoids and other

phenolics which are bioactive compounds/antioxidants associated with health developing properties (Subashinee et al.,2002). Dietary antioxidants consisting of polyphenolic compounds, Vitamin C, E and carotenoids dietary antioxidants are considered to be the effective nutrients for oxidative stress developing diseases prevention.

BIOLOGICAL USES OF *TERMINALIA CATAPPA* LEAVES

Antimicrobial activities of TCL

The extracts of T. catappa leaves contain several bioactive compounds that contribute to their antimicrobial properties. Medicinal plants are a valuable source of antimicrobial agents, and the effectiveness of plant-based chemicals with potential antimicrobial activities must be scientifically evaluated against pathogenic microbes to verify their efficacy. Infectious diseases are a significant challenge to the health and well-being of all living organisms. These microorganisms can cause severe illnesses in plants, animals, and humans. Antimicrobial drugs have been used indiscriminately, leading to the development of resistance by microorganisms to many antibiotics. (Ahmad I, et al 2017). Extracts of T. catappa contain bioactive components with potent antimicrobial activity and have the potential to serve as a source of valuable medicinal compounds. However, additional chemical and pharmacological studies are necessary to fully explore their medicinal properties.

Nevertheless, it is crucial to conduct further research to determine the plant's toxicity and lethal dosage for safe and effective administration, which can help prevent adverse side effects (J. O. IHUMA1 et al 2021). Research has shown that T. catappa leaves and fruit extract possess antibacterial properties against different microorganisms, including corynebacteria, enterococci, salmonella, staphylococci, Escherichia and shigella. The aqueous fraction and crude ethanolic extract of the TC extract, and its sub-fractions, like ethylacetate and petroleum ether, have all demonstrated notable antibacterial activity (Shahina Naz, et al., 2007).

Hepatoprotective activity

According to the research, the TCCE's chloroform fraction obtained from T. catappa leaves' ethanol extract has a safeguarding impact on mice that have experienced acute liver damage induced by carbon tetrachloride (CCl4). The protective effect was noticed in mice when given orally at a dosage of 10 or 30 mg/kg before the administration of CCl4. The protective effect was demonstrated by the restoration of the modified activities of sALT and serum aspartate aminotransferase, which serve as indicators of liver damage.

Furthermore, the study analyzed the changes in the appearance level of IL-6 in the liver tissues of mice subjected to CCl4-induced hepatotoxicity. The study revealed that TCCE significantly inhibited the excessive transcription of the IL-6 gene stimulated by CCl4. This outcome was consistent with the decrease in the production of IL-6 protein, particularly in the central vein area of the liver tissue sections.

Based on the study's findings, the safeguarding impact of TCCE against CCl4-induced acute liver injury in mice may be associated with the suppression of IL-6 overexpression in liver tissue. However, these components responsible for the observed

hepatoprotective outcome and their mechanism of action require further investigation (Jing GAO Huan Dou, et al. 2004).

Anticancer Studies of Terminalia

Cancer is a multifaceted and heterogeneous set of illnesses defined by the unregulated proliferation and dissemination of abnormal cells within the body. It can start in almost any organ or tissue and can have many different forms, which makes it a challenging disease to understand and treat. The abnormal cells that make up a A cancerous growth has the potential to infiltrate adjacent tissues and organs, as well as metastasize to other areas of the body via the lymphatic system or bloodstream, which is why early detection and treatment are so important (World Health Organization, 2019).The uncontrolled proliferation and division of anomalous cells within the body cause cancer. These cells have the ability to infiltrate adjacent tissues and organs and can further disseminate to other parts of the body via the bloodstream or lymphatic system, ultimately resulting in the formation of fresh tumors in different organs.. Cancer can affect people of all ages and can occur in almost any part of the body. Lung cancer, prostate cancer, breast cancer, colon cancer, and skin cancer are some of the frequently occurring types of cancer. Treatment for cancer typically involves a combination of surgical procedures, chemotherapy, and/or radiation therapy, which are determined based on the type and extent or stage of the cancer. (Ko et al. 2003).

The study found that the leaf extract induced apoptosis (programmed cell death) in the cancer cells, suggesting its potential as an anticancer agent. The researchers discovered that the extract demonstrated substantial cytotoxic effects on both cancer cell lines in a dose-responsive manner. Additionally, the extract caused cell cycle detention at the G1 phase and initiated apoptosis in both cancer cell lines. The investigation proposed that T. catappa leaf extract could serve as a promising natural agent for cervical cancer treatment (Lee et al. (2019). Similarly, another study by Wang et al. (2017) found that a flavonoid compound isolated from TCL exhibited effective anticancer action against human liver cancer cells. These findings suggest that T. catappa leaves may contain bioactive compounds with potential anticancer properties that warrant further investigation (Wang et al, 2017).

The study's findings indicate that both TCLE and punicalagin possess the capability to prevent gene mutations and inhibit the production of intracellular free radicals during bleomycin-induced genotoxicity in CHO cells, thus indicating their potential in cancer prevention. Further studies are needed to confirm these effects and evaluate their potential in cancer treatment (Chen et al, 2000). TCL ethanolic extracts have potential anticancer effects on SCC4 cells by inhibiting their migration and invasion capacities. This inhibition may be due to the suppression of activities and levels of proteins involved in these processes such as u-PA and MMP-2, MMP-9. Furthermore, T. catappa may hinder the phosphorylation of JNK1/2, ERK1/2, and Akt, which are responsible for regulating cell signaling pathways involved in cell survival, proliferation, and migration. Moreover, T. catappa may also inhibit the appearance of nuclear proteins for gene expression (Yang et al, 2010). T. catappa shows promising potential as a natural source of chemo preventive compounds against cancer. It is important to note that while natural compounds can be effective and have fewer side effects compared to conventional cancer therapies, they should not be used as a

replacement for medical treatment without proper consultation with a healthcare professional.

Anti-inflammatory and modulatory activity

Many non-communicable diseases such as cancer, diabetes, cardiovascular disease and neurodegenerative diseases are thought to arise due to chronic inflammation and oxidative stress playing a role in their pathogenesis. Inflammation cause DNA damage, tissue damage and cell death, which can trigger the development of diseases. Oxidative stress arises when there is a mismatch between the production of ROS and the body's ability to counterbalance them with antioxidants. ROS can result in damage to DNA, lipids and proteins which can also contribute to the onset of diseases (Camps and Garcıa, 2014). It also linked to many non-communicable diseases, including obesity, diabetes, cancer, cardiovascular diseases, and more. Prolonged inflammation can lead to impaired tissue function and damage, and it has been linked to the initiation and advancement of various illnesses. For instance, in obesity, the buildup of fat in adipose tissue can trigger long-term, low-level inflammation, which may play a role in insulin resistance and the onset of type 2 diabetes.

In cancer, inflammation can promote tumor growth and metastasis by creating a pro-tumorigenic microenvironment. In cardiovascular diseases, inflammation can developed atherosclerosis and plaque formation in blood vessels, which can lead to heart attacks and strokes. (Ghosh et al., 2015). Phytochemicals and natural product anti-inflammatory properties and potential have been studied to be used as alternative therapies to conventional anti-inflammatory drugs. These natural compounds have been found to have fewer adverse effects and provide multiple health benefits beyond their anti-inflammatory effects (Ambriz-Pérez et al., 2016). Some phytochemicals found in Terminalia species, such as flavonoids, tannins, and terpenoids. For example, the anti-inflammatory activity of Terminalia chebula has been attributed to its high content of gallic acid and its derivatives. Similarly, studies have attributed to its high content of polyphenols, including tannins and flavonoids (Gautam et al, 2009. Lago et al, 2014). Particularly in animal models of acute and chronic inflammation induced by TPA. The activity was found to concentrate on the chloroform fraction, which contains the compounds ursolic acid and, 3beta, 2alpha, 23-trihydroxyurs-12-en-28-oic acid, both of which exhibit strong anti-inflammatory activity. (Fan YM, et al., 2004).

Fetal hemoglobin is a type of hemoglobin that is produced during fetal development and has a higher affinity for oxygen than adult hemoglobin. Aimola et al. (2014) suggested that the compound isolated from T. catappa leaves may be useful in treating conditions where there is a deficiency in fetal hemoglobin, such as sickle cell anemia.

Antifungal Activity of Terminalia

Aspergillus flavus and A. niger are known to produce mycotoxins that can contaminate food and feed crops, causing health problems in humans and animals. Trichophyton rubrum is a common cause of fungal skin infections like ringworm and athlete's foot. On the other hand, yeast fungi such as Candida albicans can cause a range of infections from mild thrush to severe systemic infections in immunocompromised individuals (Gonçalves et al., 2019). The antifungal potential of extracts from TPS, such as Terminalia catappa L. bark and Terminalia chebula Retz. fruit, has been observed

against opportunistic yeasts like Candida albicans, C. glabrata, C. krusei, and C. tropicalis (Vidya et a., 2019). Additionally, the leaf extract from Terminalia catappa L. has been found to exhibit C. glabrata and C. albicans antibiofilm activity, indicating its potential as an antifungal agent against pathogenic fungi (Gonçalves et al., 2019).

Antiparasitic Activity

Numerous studies have investigated the antiparasitic activity of TCLE against various parasites. For instance, a study informed that the TCL ethanol extract exhibited significant antimalarial action against Plasmodium falciparum, the causative agent of malaria. Additionally, the ethanol extract of Terminalia macroptera leaves has been shown to possess significant antileishmanial activity against Leishmania major. Overall, the studies indicate that extracts derived from Terminalia have potential antiparasitic properties and could be considered as alternative treatments for parasitic infections. Nonetheless, additional research is necessary to comprehensively understand how they work and to assess their safety and effectiveness in human subjects (Goun et al, 2003).

Wound-healing activity

Wound-healing activity is an important property of medicinal plants that has been extensively studied. Terminalia species have been found to possess wound-healing properties because of bioactive compounds. These compounds are known to accelerate wound healing by promoting collagen synthesis, angiogenesis, and the proliferation of fibroblasts.

The study reported that the utilization of T. catappa ointment resulted in a substantial decrease in wound area when compared to the control group. This outcome suggests that the ointment has the potential to be employed as a wound-healing agent.

Various studies have also demonstrated the wound-healing properties of Terminalia species. For example, T. chebula has been found to enhance wound healing by boosting the rate of epithelialization, collagen deposition, and angiogenesis. Additionally, T. arjuna has been proven to speed up wound healing by enhancing the tensile strength of the wound site. Overall, Terminalia species have shown promising results in promoting wound healing, and their bioactive compounds have the potential to be used as alternative treatments for wounds (Khan AA, et al 2014).

Antidiabetic activity

Diabetes has become a major health concern worldwide, affecting millions of people in all countries. The World Health Organization has reported that the prevalence of diabetes has increased from 4.7% in 1980 to 8.5% in 2014 globally. It is projected that by 2030, diabetes will become the seventh leading cause of death worldwide. Several factors, including sedentary lifestyles, unhealthy diets, and obesity, have contributed to the rising prevalence of diabetes (Berry et al 2007). Studies have shown that natural medicines derived from plants, such as T. catappa, have the potential to serve as complementary or alternative treatments for diabetes and may offer good clinical opportunities for discovering novel substances that have the ability to lower blood sugar levels and reduce lipid levels in the body, which can be used to manage diabetes and its associated complications. Research has revealed that the aqueous and cold extracts obtained from the fresh and young leaves of T. catappa possess the ability to lower

elevated blood glucose levels and lipids in animal models with alloxan-induced diabetes. Additionally, histopathological investigations have provided evidence supporting the antidiabetic potential of T. catappa extracts (Ahmed et al, 2005). Studies have also indicated that T. catappa fruit extract and T. catappa fallen dry leaf decoction can reduce cholesterol levels in rats, demonstrating their potential as hypocholesterolemic agents (Ibegbulem et al, 2011). The inhibition of α-glucosidase and α-amylase enzymes is important in controlling postprandial hyperglycemia in type 2 diabetes. TCLME exhibited significant inhibition of these enzymes. The extract exhibited up to 73.2% inhibition of α-glucosidase enzyme and up to 54.04% inhibition of α-amylase enzyme, suggesting that T. catappa may have potential as an antidiabetic agent by controlling blood glucose levels (Divya et al. in 2014).

Anti-depressant

The hydroalcoholic extract of T. catappa was found to have an antidepressant effect in a study. The use of TC extract was observed to effectively reverse the changes in hippocampal neurotransmitter concentrations and levels of AchE, cortisol, monoamine oxidase, and BDNF that were induced by CMS. The extract was observed to regulate monoamine neurotransmitters, BDNF, cortisol, AchE levels, and repair oxidative stress, thus suppressing depression-induced stress (Chandrasekhar et al., 2017).

Immunomodulator

The immunomodulatory and anti-inflammatory effects of ETCB could be attributed to the presence of phenolic compounds in it. Research has demonstrated that ellagic acid exhibits antioxidant and anti-inflammatory characteristics, whereas gallic acid has been found to have antibacterial, antiviral, anti-inflammatory and antioxidant effects. Catalamine, is a lesser-known compound that has been reported to have neuroprotective effects (Abiodun OO et al., 2016).

Antiaging activity

T. catappa also exhibits anti-aging properties. TC hydrophilic extract has been found to pull together DPPH-free radicals and keep erythrocytes from hemolysis induced by AAPH. Moreover, T. catappa inhibits collagenase action and promotes type I procollagen protein expression, which is essential for maintaining skin elasticity and preventing aging. T. catappa has been found to suppress the expression of MMP-1, -3, and -9, which are linked to skin aging and the formation of wrinkles, by hindering the phosphorylation of ERK, JNK, and p38. These results indicate that T. catappa could potentially serve as an anti-aging agent (Wen KC, et al 2011).

Toxicology

toxicity studies on animals do not necessarily translate to the same effects in humans, it suggests that the tested doses of T. catappa extract are safe for consumption and do not cause any adverse effects in rats during the treatment period, However, it is imperative to conduct further research to establish the safety of T. catappa extract for human consumption before it can be recommended for widespread use. Additionally, it is significant to study the dosage and period of use, as well as any potential interactions with medications or medical conditions. It is always recommended to consult with a

healthcare professional before using any herbal supplements or alternative treatments (Azrul et al. 2013).

Radical scavenging and Antioxidant activity

Almond leaves possess significant antioxidants and radical scavenging activity. Oxidative stress refers to a condition where there is an unequal distribution between the production of ROS and the capacity of cells and tissues to remove or repair the damage caused by ROS. This occurs when the production of ROS surpasses the antioxidant defense mechanisms of the body, resulting in oxidative damage to cellular components such as carbohydrates, proteins, lipids, and DNA. This damage can cause numerous degenerative diseases like diabetes, cardiovascular disease, neurodegenerative diseases, cancer and others. Antioxidants help to reduce the damage caused by ROS by neutralizing them and preventing them from causing harm to cells and tissues. (Wolf SP, et al., 1987. Diaz MN et al. 1997. Croce CM. et al., 2008). synthetic antioxidants such as BHT and BHA, both shown to have potential side effects such as DNA damage, carcinogenicity, and endocrine disruption. As a result, there has been an increased interest from plant sources as a safer alternative. These natural antioxidants, such as those found in almond leaves, can help to protect against oxidative stress and the resulting damage to cells and tissues (Madhavi DL, et al., 1995). Phenolic compounds are a class of plant-based compounds that have gained significant attention for their potential health benefits, including their antioxidant properties. These compounds are known to act as hydrogen donors and radical scavengers, which can help protect cells and tissues by free radical caused damage to it. Some phenolic compounds examples include flavonoids, tannins, and phenolic acids, which are commonly found in fruits, vegetables, and other plant-based foods.

Studies have shown that increasing the consumption of these antioxidant-rich foods can help decrease the hazard of several chronic diseases (Orhan DD, et al., 2012). Studies have indicated that antioxidants can function as free radical scavengers and aid in mitigating the effects of oxidative stress in various diseases and conditions (Chew YL et al., 2011). Phenolic compounds perform as free radical scavengers by donating hydrogen atoms or electrons, and they can also chelate metal ions that catalyze free radical formation. Flavonoids, which are a type of phenolic compound, have been extensively studied for their antioxidant activity and their potential health benefits. Other phenolic compounds, such as phenolic acids and stilbenes, have also been shown to possess antioxidant properties and have potential therapeutic applications. Overall, plant-derived antioxidants have great potential in preventing and treating diseases (Pukumpuang et al, 2012. Kulisic et al, 2004. Katalinic et al, 2006. Letelier et al, 2008). TCLAE has shown potential in suppressing mitomycin C-induced micronuclei, indicating its possible anti-genotoxic effect. Furthermore, it has also been found to inhibit LPO and hydrogen peroxide establishment suggesting its antioxidant properties (Liu et al, 1996).

Punicalin and punicalagin are two major tannin components found in T. catappa. Studies have shown that these compounds possess potent antioxidant activity and can effectively scavenge free radicals. The antioxidant effects of these compounds include the prevention of lipid peroxidation and the formation of superoxide (Lin et al, 2001). The nature of the extraction solvents has a significant impact on the antioxidant activity of extracted materials from almond plants (Anwar et al, 2010. Sultanna et al,

2009). As bioactive substances are potentially caused by the almond (*T.catappa*), the effectiveness of the numerous extraction solvents is evaluated towards recovery of almond leaves with strong antioxidants. Therefore, the convenient process is terribly appealing to researchers for the fast quantification of antioxidant effectiveness and fast quantification in preventing diseases (AOAC), the antioxidant elements extraction from the almond leaf using various solvent processes. Positively modulating cholinergic and monoaminergic signals are antioxidative abilities and effective in NDs management (Kou et al., 2017).

Inhibitory effects and phenolic profile of Almond leaves

polyphenols are a main focus of study in the field of natural products due to their numerous health benefits. They have been found to possess strong antioxidant properties and are effective in scavenging free radicals. In addition, polyphenols have been found to have anti-inflammatory, antibacterial, antiviral, and anticancer properties. They are commonly found in fruits, vegetables, herbs, and spices (Kahkonen et a., 1999. Chen et al, 2008). The total phenolic content of a plant extract is often used as an indicator of its antioxidant potential, as a higher content of phenolics may suggest a higher antioxidant activity. However, it's important to note that the specific types and concentrations of phenolics present in a plant extract can also influence its antioxidant activity. (Orak HH et al., 2012). The leaves of T. catappa contain several major phenolic compounds, including apigenin, quercetin, luteolin, epicatechin, ellagic acid, gallic acid and 1-O-b-galloyl glucose, which are responsible for its antioxidant properties (Ambika et al, 2014).

A progressive deterioration of neuronal structures called neurodegenerative disease (ND) that culminates in cognition loss. In memory, attention, behavior, language, relational acquisitions and problem-solving diseases are identified by non-impairment which affects mainly the older population generating dementia (Prince., 2013). About 47 million people globally are noted to be presently influenced by dementia and in 2050 approximately 135 million people are expected. medical, social and economic challenges on the patients pose great health conditions and the caregivers (Giovanna, 2019). change in neurotransmissions caused by oxidative stress development mostly monoaminergic transmission and cholinergic process in veracious NDs like Alzheimer's disease created by causative factors (Finkel et al., 2000; Kou et al., 2015). polyphenolic constituents are in large amounts in almond leaf, and therefore, promote better health effects promotion. To the observed antioxidative effects leaves rich flavonoid and phenolic components might likely be added.

The Almond leaves extricate inhibitory activities on lipid peroxidation, free radicals, monoaminergic enzymes and cholinergic enzymes suggest mitigating the ability of neurodegenerative diseases and oxidative damage. Hypertension is a prevalent cause of premature death in asymptomatic adults. Failure to control high blood pressure elevates the likelihood of severe health problems such as stroke, ischemia, heart attack kidney disease, blindness, and erectile dysfunction (Zimmet et al, 2001). Hypertension typically results from an elevation in the volume of blood being pumped by the heart and the constriction of the arteries. Additionally, there exists a direct association between systolic blood pressure and the occurrence of hemorrhagic stroke. (Kanter, et al., 2004). The growing hazardous factors like physical inactivity, obesity and unhealthy diet has contributed to the rise in hypertension cases globally,

and consequently, its impact on longevity (Kunes et al, 2009). The overexpression of the RAAS is a significant contributing factor to the onset of hypertension (Hammoud et al, 2007). ACE plays a critical role in the Renin-Angiotensin-Aldosterone System that contributes to an increase in blood pressure. Inhibiting ACE activity is a promising strategy for regulating the excessive stimulation of RAAS (Halliwell et al, 2003). There has been a significant surge in interest in identifying natural antioxidants, with the aim of safeguarding the body and reducing numerous chronic diseases progression (Prior et al, 2003). Deferent antihypertensive drugs that can effectively lower blood pressure, a significant number of patients remain unresponsive to treatment, resulting in severe hypertension (Kloet et al, 2013). These drugs are often costly and lack a definitive cure, requiring amalgamation therapy (Kagathara et al, 2009).

Indian almond leaves effect on quality of aquarium water

The phytochemical components are present in large quantities in IAL, tannins, flavonoids and triterpenoids and flavonoids are mostly present (Vrushabendra, 2006). Antimicrobial and antioxidant properties are present in Tannins (Tasneem, 2018; Rajesh, 2015) for treatment of various diseases and wounds. It has an impact (Sunday, 2017- Terças, 2017). For fish breeding IAL is useful to create a suitable environment. In aquarium fishkeeping is becoming popular, many hobbyists and fish breeders giving extra effort and spending spare time on protecting freshwater fish. Tetras, Cichlids and Betta freshwater fish are more preferred by people to stay in the aquarium (Hanson D, 2013). Deficient water quality can instantly kill fish, so it is more essential for monitoring the quality of aquarium water. The pH, DO, turbidity, BOD5, temperature, and ammonia parameters of water are usually determined for aquatic life. particularly the aquarium fish breeders choose water conditioners used for water excellence parameters stabilization, for this Betta fish and tetras fish are mostly used and the leaves work as “poor man’s water conditioner” (Prod, 2017; Nugroho, 2016; Hidayat ,2016; Surely, 2016). As the dosage of IAL increases, there is a corresponding decrease in pH levels, while BOD5 and total coliform levels increase. Using IAL for Betta fish results in a significant improvement in their survivability (S Shams et al.,2021).

Powder can enhance the growth and survival of juvenile snakehead fish

Given the high economic value of Snakehead (Channa striata) in Indonesia, where it is utilized as an ingredient in food and drug processing, there is a considerable demand for this species. However, overfishing of C. striata from the wild has led to a decline in population and endangered its habitat. To address this issue, the use of Terminalia catappa leaf powder has been investigated as a means of increasing the juvenile C. striata growth performance and survival, with a focus on determining the optimal dosage. (Firman P et al., 2021).

TCLE on diabetic mice, duodenal digestive enzyme activity

Diabetes has become a prevalent illness affecting people of all age groups in today's world. The use of synthetic drugs to treat diabetes can have harmful effects on the body and cause side effects in the long run, leading to the need for drugs made from natural components to prevent these side effects. This study focuses on examining the impact of Indian Almond extract on the duodenal digestive enzymes of diabetic mice (MC Trops Vol 1 No 2, 2020). Using synthetic drugs to treat diabetes can have harmful long-term

effects on the body, which is why there is a need for drugs made from natural ingredients to avoid side effects (Jemi et al, 2020). Providing organic supplements to mice is a promising approach as the organic active components in these supplements can improve body metabolic functions and immune system. chemical digestion occurs in the stomach and intestine with the help of assistance digestive enzymes like lipase, protease and amylase (Supriyatna, 2015). Diabetes occurs when there is a disruption in insulin secretion, leading to a disturbance in the digestive process by digestive enzymes.

Therefore, it is crucial to have proper treatment to manage this disease. While synthetic drugs have become popular due to their affordability, they can have dangerous long-term effects on the body, making it necessary to explore natural ingredients as alternatives to prevent side effects. Flavonoids can stabilize amylase by acting as strong inhibitors, preventing the breakdown of carbohydrates and absorption into the bloodstream, thereby reducing blood sugar levels to normal limits. (Gustina, 2017. Yulianty, 2015). Indian Almond leaves contain flavonoids that can promote the beta cells regeneration and stimulate insulin secretion, thereby decreasing blood sugar levels. Flavonoids can also decrease glucose absorption. In mice, flavonoids have been found to reduce blood glucose levels through a mechanism similar to that of oral hypoglycemic drugs (sulfonylureas), which involves stimulating insulin secretion in the pancreas (Sasmita, 2017). Individuals with diabetes experience a decrease not only in HDL cholesterol but also in the activity of the LPL enzyme. As a result, the conversion of VLDL to intermediate-density lipoprotein (IDL) is disrupted (Roslizawaty, 2016). According to the study, the P1 group of mice that were administered 250 mg/kg BW of dried Indian Almond leaf extract exhibited the least activity of the lipase enzyme compared to the control group and other treatments. This result may be attributed to the oxidation of the flavonoid compounds present in the dried extract. (Nayatillah et al. 2016). Additionally, it has been reported that the level of flavonoids is higher in green leaves compared to dried leaves because the drying process can cause a decrease 15-78% flavonoid levels (Jemi Marthin et al. 2020).

TCLE Palliates Redox Imbalance and Inflammation in Diabetic Rats

Diabetes mellitus (DM) is a long-lasting disease that arises from a deficiency in insulin secretion, action, or both, leading to high blood glucose levels and disruptions in the metabolism of carbohydrates, proteins, and lipids. This chronic metabolic and endocrine condition also increases the risk of vascular complications caused by dysfunction of various organs or systems (F. N. Iheagwam et al, 2019. J. O. Yesufu et al, 2020). Chronic diseases are associated to the interplay between inflammation and oxidative stress. Similar to other non-communicable diseases, studies have shown progression, and complications of type 2 diabetes mellitus (T2DM) (M. Alipour et al, 2012. M. Brownlee et al, 2005. D. Pitocco et al, 2013. F. Prattichizzo et al, 2018). When there is an imbalance in the cellular redox balance cause oxidative stress, resulting in the loss of integrity of biomolecules and damage to membranes. Excessive intake of dietary fat and carbohydrates can trigger the onset of diabetes and worsen the disorder and its related complications by interfering with insulin release and action (E. Ferrannini et al, 2016. P. Rorsman et al, 2013. J. R. Speakman et al, 2011).

Chronic inflammation is a hallmark of many chronic diseases, including diabetes, and can contribute to the advancement and progression of the disease (O. O.

Oguntibeju et al, 2019). The mechanisms by which this occurs are complex and involve multiple pathways, including the activation of stress-activated kinases, the depletion of antioxidant defences. These processes ultimately lead to organ and tissue damage, which can manifest as diabetic nephropathy, neuropathy, retinopathy, and cardiovascular disease, among other complications. (E. G. Butkowski et al., 2017). In addition, hyperglycemia can also activate pathways to produce the pro-inflammatory chemokines and cytokines, which can intensify the inflammatory response and contribute to tissue damage in diabetes-related complications. (A. Dayre, et al., 2016). The efficacy of oral antioxidant agents, such as vitamins, in preventing diabetic complications remains uncertain despite their potential antioxidant properties, as studies involving human subjects have demonstrated that they do not reduce oxidative stress (K. Luc, et al., 2019). This is partly due to their inability to regulate blood glucose levels, play a significant role in the pathogenesis of oxidative stress associated with diabetes and inflammation. Instead, management of blood glucose levels through lifestyle modifications and/or medication, more effective in reducing inflammation and oxidative in diabetic patients (A. Ceriello et al, 2009. S. W. Choi et al, 2018. S. Golbidi et al, 2011. D. Rajendiran et al, 2018). The research examined whether an aqueous extract of Terminalia catappa leaves could improve hyperglycemia-induced oxidative stress and inflammation in diabetic rats induced through a high-fat diet/low-dose streptozotocin. The study also assessed the extract's impact on gene expression relevant to inflammation and redox status. The results indicated that TCA extract triggers the Nrf-2 gene, which reduces oxidative stress and inflammation. This study adds to the growing body of research on the potential of medicinal plants and natural antioxidants in managing T2DM and preventing associated complications (A. B. Jebur, et al., 2016. H. V. Annegowda, et al 2010. E. E. Ben, et al 2019. E. E. Ben, et al 2021. F. A. Dada, et al., 2021).

T- catappa leaves use for the silver nanoparticles (agnps) one-pot Bio fabrication

One of the fundamental logical field nanotechnologies today since information from fields of Biology, chemistry, physics, Informatics, medical and Engineering. it combines biomaterials and novel nano, and nano apparatus are measured by instruments of nanotechnology, designed, process for research and compete the reaction, characteristics, components at sizes beneath 100 nm of living and non-living matter (Logothetidis, 2014). The almond plant leaves have a bioactive potential beginning; to evaluate the activity of the aqueous extraction is captivating to synthesis the biogenic silver nanoparticle (Wijeratne et al, 2006). The study involved the use of almond plant leaf extract for synthesizing silver nanoparticles (AgNPs). The larvicidal activity to synthesized AgNPs was estimated against the mosquito Aedes aegypti fourth instar larvae. The AgNPs were characterized by using various techniques including UV-Visible spectroscopy, FTIR, EDX, and FESEM. The findings indicated that the extract of almond leaves can be utilized with efficacy for the synthesis of AgNPs, thereby providing an additional option for combatting multidrug-resistant pathogens (Ayandiran et al, 2018).

Numerous medicinal applications have been noted by nanoparticles (Nasrollahi, et al.,2009). The antifungal activities have been revealed from studies (Adelere, et al., 2017). The antimicrobial activity of a synthesized green nanoparticle is

also noted. Anti-inflammatory activity has been noted by nanoparticles, antiangiogenetic (Baharara, 2014) antiplatelet activity (Shrivastava S, 2009) and antiviral (Park, et al., 2014) also noted. Recently plant extract has been utilizing for nanoparticles green synthesis because of ironic bioactive compounds (Ahmed, 2016; Thirumurugan, 2011; Benakashani, 2016). The almond plant's leaves contain potentially valuable bioactives, making it an interesting source for aqueous extraction (which is often treated as agrowaste) for the biogenic synthesis of silver nanoparticles. Almonds have been reported to be a valuable food item both nutritionally and therapeutically. (Wijeratne SSK, et al., 2006. Sarwar, S. et al., 2012).

TCL Retort-heating carbonization

With the growing concern about the impact of fossil fuels on the environment and climate change, there has been an increased interest in finding alternative sources of energy that are sustainable and environmentally friendly. Biomass, which includes plant materials, agricultural and forestry residues, and organic wastes, has been explored as a potential source of renewable energy. Similarly, waste materials, like plastics, use as potential energy source through processes such as pyrolysis and gasification (Oyedun et al, 2014). Converting waste materials through thermochemical processes can be an effective way to recover their energy value and reduce waste accumulation. Thermochemical processes involve heating the material at high temperatures in an oxygen-limited or oxygen-free environment, which breaks down the complex organic molecules into simpler compounds like gases, liquids, and solids. The gases produced can be used as fuel for power generation, while the liquid and solid products can be used as feedstock for various industrial applications such as biofuels, fertilizers, and chemicals.

The use of thermochemical processes for waste-to-energy conversion has the potential to reduce reliance on fossil fuels, decrease waste disposal costs, and promote a more sustainable and circular economy (Block et al, 2018. Canlas et al, 2019. Hevira et al, 2015. Sathishkumar et al, 2015. Arasaretnam et al, 2010). Municipal solid waste (MSW) typically includes a wide range of materials such as food waste, yard waste, paper, plastic, and other materials generated by households and businesses. According to the US Environmental Protection Agency (EPA), in 2018, about 52% of the MSW generated in the US was made up of paper, yard trimmings, and food waste, which are primarily biomass materials. Plastics made up about 12% of MSW, while other materials such as metals, rubber, textiles, and glass accounted for the rest (EPA, 2021; Duru, Ikpeama, and Ibekwe 2019). This suggests that coconversion of biomass and plastic waste can be a viable approach to generate biochar. Additionally, the hybrid biochar produced in this study may have improved properties compared to biochar produced solely from biomass. The globular features on the surface of biomass biochar observed through SEM analysis suggest that the biochar has a porous structure with smaller interstitial spaces and voids. Overall, SEM analysis provides valuable information about the physical structure of biochar and its potential applications in environmental engineering. Overall, the study highlights the potential of using low-temperature char-optimised processes to produce biochar from a combination of waste materials, which can have practical applications in sustainable waste management and environmental engineering. (Joshua O et al.,2021).

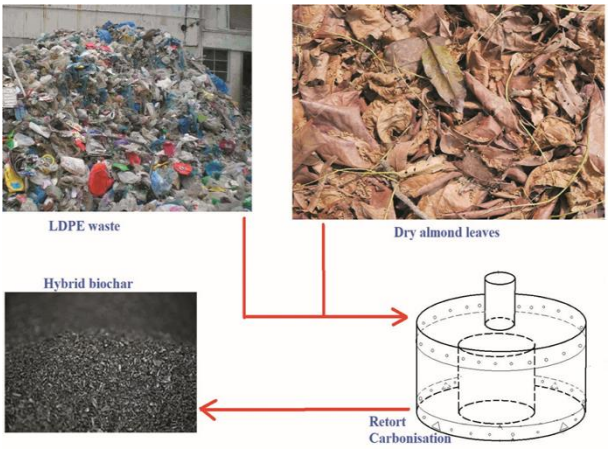

Figure 4: leaves biomass convertion and co-conversion with LDPE wast process.

Other Uses of tropical almond leaves:

A yellow-green dye comes from the leaves (David Jacke Chelsea Green 2006). The leaves are all together shaded by its tree, quite immediately, usually two times in a year. Unlike most tropical trees, initially the leaves turn yellow in most tropical trees, then before falling they turn bright red, giving them a well-managed 'autumn color' (Flora and Malesiana Series 1).

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