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Review Article

Phytopharmacological overview on Terminalia *arjuna* Wight and Arn

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ABSTRACT

The application of medicinal plants to maintain health and treat disease started since time immemorial and still is a part of medical practice. *Terminalia arjuna* is a tree with simple leaf, smooth and thick bark belonging to the family Combretaceae. Flowers are small, regular, sessile, cup-shaped, polygamous, white, creamy or greenish-white and robustly honey-scented and flowering from April to Julys. Its fruit is a drupe, 2.5–5 cm long, ovoid or oblong, fibrous-woody, smooth-skinned with five hard angles or wings. Ancient Indian physicians used the powdered tree bark of *Terminalia arjuna* Wight & Arn. for alleviating "hritshool" (angina) and other cardiovascular conditions. Also believed to be a natural liver tonic, Arjuna regulates cholesterol by decreasing LDL levels in the liver. Arjuna is a best hepatitis reliever and heart strengthener for humankind. Leaves of *Terminalia arjuna* are best healing for hepatitis. Its stem bark possesses glycosides, large quantities of flavonoids, tannins and minerals. Arjuna contains specific active constituents namely Arjunilic acid, Tomentosic acid, Sitossterol, Triterpine glycosides like Arjunetosides, Arjunine and Arjunetein. The bark is rich in Saponnins, natural anti-oxidants (flavonoids-arjunone, arjunolone, leteilin), gallic acid, ellagic acid, phytosterols, rich in minerals like calcium, magnesium, zinc and copper, reducing sugars & coloring matter. The Arjuna bark with its remarkable medicinal properties helps, maintain healthy cholesterol levels. Arjuna is known to possess diuretic properties This have been recorded as antioxidant, anti-inflammatory and lipid lowering effects while glycosides are cardiotonic, thus making *Terminalia arjuna* unique amongst currently used medicinal plants. In this review an attempt has been made to discuss various aspects of its ethnomedical, phytochemical, pharmacological, antimicrobial, antibacterial, antifungal, insecticidal, antihelmintic, immunomodulatory, antidiabetic, radioprotective, antimutagenic properties for benefit of mankind. Experimental studies have revealed that whole plant is highly useful staring from its use in cardiovascular tonic to asthma. There is ample evidence of its beneficial effect in coronary artery disease. The extracts of Arjuna are known to help in strengthening the heart muscles, relieving stress, and hypertension. Arjuna is effective for a variety of heart related conditions like high blood pressure, heart palpitations, rapid heartbeat and high cholesterol. These reports are very encouraging and indicate that this should be studied more extensively for its therapeutic benefits.

Key words: *Terminalia arjuna*, ethnomedicinal, phytochemical, cardiotonic

INTRODUCTION

Terminalia arjuna is a miracle herb which was used during ancient times to cure heart problems. In ancient Ayurvedic literature, Vagbhata and others have described the juice of Arjuna bark as a tonic and astringent. They have recommended it for the treatment of heart diseases. Arjuna is reported to be a beneficial herb in treating heart problems since 1200 B.C. Vagbhatta was the first to cite this in his book 'Astang Hridayam' written some 1200 years ago [1]. Subsequently, Chakradutta and also Bhawa Mishra, described its use in chest pain [2,3]. Several medicinal plants have been described to be beneficial for cardiac ailments in "Atharva Veda" an ancient treatise from which Ayurveda, the Indian system of Medicine owes its origin[4,5]. Ancient medical scientists have mentioned the properties of *Terminalia arjuna* herb. Indian medical knowledge known as Ayurveda goes back millennia. The Vedas and Puranas refer various materials of medical importance including herbs, plants and trees. In which *Terminalia arjuna* Wight & Arn. (arjuna) has prominent place and have been identified and researched for their putative lipid lowering and cardioprotective activities [6]. The plant which has shown most promising and distinct results is *Terminalia arjuna* Wight & Arn.,

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popularly known as arjuna [7]. Modern research has discovered that *Terminalia arjuna* has antioxidant properties and may be clinically helpful in cardiovascular health. A deciduous tree found abundantly in the Indian subcontinent, *Terminalia arjuna* is a heart stimulant that can prove effective in the treatment of a number of heart conditions. Found commonly in the Himalayan region, the bark of the plant is used by traditional Indian medicine for a number of herbal preparations to treat cardiac disorders.

Terminalia arjuna is a tree with simple leaf, smooth and thick bark belonging to the family Combretaceae. Flowers are small, regular, sessile, cup-shaped, polygamous, white, creamy or greenish-white and robustly honey-scented and flowering from April to July. The inflorescences are short axillary spikes or small terminal panicles and fruits are obovoid-oblong, dark brown to reddish brown fibrous woody, indehiscent drupe and ripening from February to May [8]. All the parts of the plant have been used for their therapeutic beneficiary effect from ancient times. *T. arjuna* helps to maintain a healthy heart and decrease the effects of stress and anxiety [9]. It has antibacterial [10], antimutagenic, hypolipidemic, antioxidant and hypocholesterolaemic and anti-inflammatory effects. *T. arjuna* have the capability to protect the liver and kidney tissues against CCl_4-induced oxidative stress by increasing antioxidative defense activities [11]. Its chemical constituents act as a gastro-protective agent [12]. Different types of bioactive compound have been isolated from this medicinal plant possesses enormous value in medicine among then arjunolic acid is very well known.

The aim of the present study was to deliver the literal studies of *T. arjuna* with its phytochemical and pharmacological characteristics.Also believed to be a natural liver tonic, Arjuna regulates cholesterol by decreasing LDL levels in the liver. It is advocated by Ayurveda as a liver tonic. The extracts of Arjuna are known to help in strengthening the heart muscles, relieving stress, and hypertension. Arjuna is also thought to fortify the central nervous system and to quicken individual reflexes. Recently there has been renewed interest in this plant because of its multimode cardioprotective activity. As there is no single drug till date which alone or in combination offers definite and reliable protection and/or cure from the ravages of atherosclerotic cardiovascular disorders, the time is ripe for evaluating the role of *Terminalia arjuna* in the overall management of related cardiovascular disorders. The present paper aims to review its ethnomedical, pharmacognostical, phytochemical, pharmacological, insecticidal, anthelmintic, immunomodulatory, antidiabetic radioprotective and antioxidant, antimutagenic, toxicity and side effects parameters under different conditions.

SCIENTIFIC CLASSIFICATION:

Kingdom:Plantae
Division:Magnoliophyta
Class:Magnoliopsida
Order:Myrtales
Family:Combretaceae
Genus:*Terminalia*
Species:*T. arjuna*
English Name: White Marudah

Common (Indian) Names:

Hindi: Arjun, Arjuna, Koha, Kahu, Arjan; Gujrati: Arjun - Sadada, Sadado;Canarese: Bili-Holo-Nir-Tora Matti, Maddi; Marathi: Arjuna, Arjun Sadada, Sadura; Sanskrit: Arjuna, Dhanvi, Indradruma, Kakubha, Karvirak.; Oriya: Arjuna Sahajo;
Tamil: Vellamatta;Telugu: Yerramaddi;Assam: Orj un;Bengali: Arjhan;Punjabi: Arjuna

Botanical Details: *Terminalia arjuna* is a deciduous tree found throughout India. The arjuna is about 20–25 metres tall; usually has a buttressed trunk, and forms a wide canopy at the crown, from which branches drop downwards. It has oblong, conical leaves which are green on the top and brown below; smooth, grey bark; it has pale yellow flowers which appear between March and June; its glabrous, 2.5 to 5 cm fibrous woody fruit, divided into five wings, appears between September and November. It has huge, often buttressed trunk and horizontally spreading branches. Extent of buttressing in different localities has been found to be due to local factors and is not determined genetically. Among different species of *Terminalia* the bark of *Terminalia arjuna* has its own characteristic features. In a comparative study of the barks of *Terminalia arjuna* and *Terminalia tomentosa* it was found that the bark of *Terminalia arjuna* is smooth, pinkish-grey from outside and flakes off in large, curved and rather flat pieces. The size of each piece may vary up to 15 cm or more in length, 10 cm in width and 3–10mm in thickness. Sapwood is reddish white and heartwood is brown and variegated with dark coloured streaks. The histology of *Terminalia arjuna* bark reveals the presence of single layered epidermis with hair like projections and few scattered lenticels. Underlying the epidermis is a thin layer of cortex. Periderm and secondary phloem are present in the old bark. Leaves are simple, borne sub-opposite coriaceous, often crenulating, oblong or elliptic. Their upper face is pale or dark green and the lower face is pale brown. It measures 10–15 cm long and 4–7 cm broad. A

network of 10–15 pairs of nerves is arranged in reticulate fashion. Petioles are 6–10mm long with yellowish or reddish hairs. Linear, lanceolate-like bracteoles are present. Calyx is glabrous. Its fruit is a drupe, 2.5–5 cm long, ovoid or oblong, fibrous-woody, smooth-skinned with five hard angles or wings. The lines of the wings are oblique and curved upwards.

Distribution and habitat: It is found in abundance throughout Indo-sub-Himalayan tracts of Uttar Pradesh, South Bihar, Madhya Pradesh, Delhi and Deccan region near ponds and rivers. It is also found in forests of Sri Lanka, Burma and Mauritius. *Terminalia arjuna* was introduced in Mauritius by early Indian migrants . Remarkably the tree is pest and disease free.The arjuna is usually found growing on river banks or near dry river beds in West Bengal and south and central India.

MICROSCOPY: Cork consists of few layers of tangentially running and radially elongated cells;phellogen,2to4 celled thick, phelloderm narrow, consisting of 4 to 6 rows of tangentially elongated and radially arranged cells, Phloem, very broad, traversed by uniserriate medullary rays running straight and parallel occasionally becoming slightly curved near the rosette crystal; groups of phloem fibres, lignified, thin-walled, tangentially arranged, associated with idioblasts containing clusters and rossetes of calcium oxalate. Some parenchymatous cells of cortex and secondary phloem contains reddish brown pigment and some cells contain starch grains.

Ethnomedical considerations: The bark leaves and fruits of *Terminalia arjuna* have been used in indigenous system of medicine for different ailments [13]. The bark is said to be sweet, acrid, cooling and heating, aphrodisiac, expectorant, tonic, styptic, antidysenteric, purgative and laxative. Its use has been advocated in urinary discharge, strangury, leucoderma, anaemia, hyperhidrosis, astringent and diuretic finds mention in the works of Carak [14]. The bark powder has been attributed to possess cardioprotective properties. Traditional method of its administration was to prepare an alcoholic decoction of its bark stem (asava) or give it along with clarified butter (ghrita) or along with boiled milk (kshirpak)[15,13]. Having realised the potential atherogenic properties of clarified butter and whole milk it would be interesting to examine the role of such preparations in experimental model of atherosclerosis.

Hepatitis/reliever: Arjuna is a best hepatitis reliever and heart strengthener for humankind. Leaves of *Terminalia arjuna* are best healing for hepatitis C. For heart problems, Arjuna is useful, because important part of glucocide is found in the bark of Arjuna tree.

In joining of fractured part: Embrocation of arjuna bark powder along with ghee on broken bone can joint again the fractured part. Bark arjuna after being boiled can be taken as well for contacting of bones. *Terminalia arjuna* is also good for reducing swelling of gum and mouth area. Gargling with concoction of arjuna barks can heal skin problems effectively. Tooth bleeding is stopped with use of cooked water of arjuna bark.For blood motion, diarrohoea and dysentery arjuna bark is good healer.

The Cardiotonic Properties of Arjuna: The *Terminalia arjuna* is a heart stimulant that can prove effective in the treatment of a number of heart conditions. Found commonly in the Himalayan region, the bark of the plant is used by traditional Indian medicine for a number of herbal preparations to treat cardiac disorders.As a herb widely supported by Ayurveda, Arjuna has certain properties which make it effective for cardiac treatment. The tree possesses laghu (light) and ruksh (dry) and an abundance of kashaya (astringent) Rasa. The presence of these properties make in efficacious for the treatment of Pitta and Kapha aggravation. The extracts of Arjuna are known to help in strengthening the heart muscles, relieving stress, and hypertension. Arjuna is effective for a variety of heart related conditions like high blood pressure, heart palpitations, rapid heartbeat and high cholesterol. Researches attribute these benefits to certain tannins and glycosides that have specific antioxidant properties congenial for the cardiovascular system. The anti-oxidant properties are what make it congenial for cardiovascular health.Also believed to be a natural liver tonic, Arjuna regulates cholesterol by decreasing LDL levels in the liver. It is advocated by Ayurveda as a liver tonic. The extracts of Arjuna are known to help in strengthening the heart muscles, relieving stress, and hypertension. Arjuna is also thought to fortify the central nervous system and to quicken individual reflexes.According to the Ayurvedic classical description of *Terminalia arjuna*, it is a cooling, Kapha and Pitta pacifying herb, helpful in healing wounds, countering obesity and treating urinary disorders. Ingestion Arjuna over a period of time ensures significant cardiac protection in myocardial infarction commonly known as heart attack. The herb is also proven to be helpful in the vasodilatation of blood vessels in chronic smokers and is also known to dissolve plaque clogging the arteries.

According to the Ayurvedic classical description of *Terminalia arjuna*, it is a cooling, Kapha and Pitta pacifying herb, helpful in healing wounds, countering obesity and treating urinary disorders.In traditional Indian medicine, Arjuna is recommended as an important cardiotonic plant, which is known to promote the healthy functioning of the heart and in general, acts as a heart tonic. Arjuna extracts help in regulating blood pressure and enhances the healthy functioning of the heart. Arjuna also helps in the reduction of the corrosive effects of stress and nervousness.

The Arjuna bark with its remarkable medicinal properties helps maintain healthy cholesterol levels. Arjuna is known to possess diuretic properties. It is further corroborated by modern research that Arjuna has antioxidant properties and may be clinically helpful in cardiovascular health. Studies show that Arjuna is effective for a variety of heart related conditions like high blood pressure, heart palpitations, rapid heartbeat and high cholesterol. Researches attribute these benefits to certain tannins and glycosides that have specific antioxidant properties congenial for the cardiovascular system. Taken as brewed tea, powdered, or commercially prepared in capsule form, Arjuna has been used in hundreds of preparations along with other herbs to resolve an incredible number of health issues. In locations where the plant is native, Arjuna extracts are used to address several health problems.The natural herb is believed to regulate cholesterol by decreasing LDL levels in the liver. It is advocated by Ayurveda as a liver tonic. The extracts of Arjuna are known to help in strengthening the heart muscles, relieving stress, and hypertension. Arjuna is also thought to fortify the central nervous system and to quicken individual reflexes. Sinha *et al*[16] reported that *Terminalia arjuna* protects mouse hearts against sodium fluoride-induced oxidative stress..Fluoride is a ubiquitous environmental pollutant. They have investigated the antioxidative properties of an ethanol extract of the bark of *Terminalia arjuna* against sodium fluoride (NaF)-induced oxidative stress in murine heart.The results suggest that *Terminalia arjuna* extract protects murine hearts from sodium fluoride induced oxidative stress, probably via its antioxidant properties.

In Ischaemicmitral regurgitation: The bark powder of *Terminalia arjuna*, an indigenous plant has been found to have antianginal, decongestive and hypolipidemic effect. Dwivedi *et al*[18] planned a study to evaluate the role of *Terminalia arjuna* in ischemic mitral regurgitation (IMR) following acute myocardial infarction (AMI). 40 patients with fresh AMI showing IMR were randomly divided into 2 groups of 20 each. They were given placebo or 500 mg of *Terminalia arjuna* in addition to anti-ischemic treatment. After 1 and 3 months of follow up, patients receiving adjuvant *Terminalia arjuna* showed significant decrease in IMR, improvement in E/A ratio and considerable reduction in anginalfrequency[17]

Phytochemical studies: According to World Health Organization, medicinal plants would be the best source to obtain variety of drugs [18]. Medicinal plants contain some organic compounds which provide definite physiological action on the human body and these bioactive substances include tannins, alkaloids, carbohydrates, terpenoids, steroids, flavonoids and phenols. The bio-active phytocompounds are synthesized by primary or rather secondary metabolism of living organisms. Secondary metabolites are chemically and taxonomically extremely diverse compounds with obscure function. They are widely used in the human therapy, veterinary, agriculture, scientific research and countless other areas. Medicinal plants containing active chemical constituents with high antioxidant property play an important role in the prevention of various degenerative diseases [19] and have possible benefits to the humanity. A large number of phytochemicals belonging to several chemical classes have been shown to have inhibitory effects on all types of microorganisms *in vitro*. Botanical medicines or phytomedicines refer to the use of seeds, berries, leaves, bark, root or flowers of any plant for medicinal purposes by significant number of people. Knowledge of the chemical constituents of plants is desirable because such information will be value for synthesis of complex chemical substance [20,21,22]. Phytochemical screening showed the active compounds presence in high concentration, such as phytosterol, lactones, flavonoids, phenolic compounds and tannins and glycosides. The antimicrobial activity of extract showed that greater inhibition zone against Gram negative bacteria than Gram positive bacteria. This methanolic extract showed a promising antioxidant activity, as absorption of DPPH redicles decreased in DPPH free radical scavenging assay. Flavonoids components having antioxidant property present in the methanol extract at a level of 199.00 mg quercetin equivalent/g of dried methanol extract in colorimetric method. The *Terminalia arjuna* bark extract revealed the presence of bio-active constituents which are known to exhibit medicinal as well as physiological activities [23]. In a study conducted to determine phytochemical compositions, chemiluminescence antioxidant activities, and neuroprotective effects on PC12 cells for water, methanol, and 95% ethanol extracts of the air-dried fruit of *Terminalia.* the water

extract afforded the greatest yield, and total phenolic and tannin content. The methanol extract yielded the greatest total triterpenoid content. Based on four chemiluminescence antioxidant assays, the three extracts showed various degrees of antioxidant activity. The methanol extract showed good antioxidant activity based on the horseradish peroxidase-luminol-hydrogen peroxide (H_2O_2) assay. The water extract appeared to have good antioxidant activities in cupric sulfate-Phen-Vc-H_2O_2 and luminol-H_2O_2assays. Pyrogallol-luminol assay showed the 95% ethanol extract to have good antioxidant activity. The methanol and water extracts presented neuroprotective activities on H_2O_2-induced PC12 cell death at 0.5–5.0 μg/mL [25].Arjuna contains specific active constituents namely Arjunilic acid, Tomentosic acid, Sitossterol, Triterpine glycosides like Arjunetosides I, II, III, IV, Arjunine and Arjunetein. The bark is rich in Saponnins, natural anti-oxidants (flavonoids-arjunone,arjunolone,leteilin), gallic acid, ellagic acid, phytosterols, rich in minerals like calcium, magnesium, zinc and copper, reducing sugars & coloring matter.

For phytochemical screening, some common and available standard tests were done. Antimicrobial bioassay was done through agar well diffusion method. Detection of antioxidant activity and flavonoid compounds were done through thin layer chromatography. Total antioxidant activity was measured by 2, 2-diphenyl-1-picrylhydrazyl (DPPH) in colorimetric method. Aluminum chloride colorimetric method was used for total flavonoid determination. Phytochemical screening showed the active compounds presence in high concentration, such as phytosterol, lactones, flavonoids, phenolic compounds and tannins and glycosides. The antimicrobial activity of extract showed that greater inhibition zone against Gram negative bacteria than Gram positive bacteria. This methanolic extract showed a promising antioxidant activity, as absorption of DPPH redicles decreased in DPPH free radical scavenging assay. Flavonoids components having antioxidant property present in the methanol extract at a level of 199.00 mg quercetin equivalent/g of dried methanol extract in colorimetric method. The *Terminalia arjuna* bark extract revealed the presence of bio-active constituents which are known to exhibit medicinal as well as physiological activities [24]. Mythill *et al* [25] reported that *Terminalia arjuna* triterpenoids extract containing arjunolic acid has protective effect against cyclosporine induced cardiotoxicity.

Tannins: In addition to flavonoids variety of tannins have been isolated from the bark of *Terminalia arjuna*. Some of the wellknown hydrolysable tannins from the bark are pyrocatechols, punicallin, punicalagin, terchebulin, terflavin C, castalagin, casuariin and casuarinin. Some 15 types of tannins and related type of compounds have been isolated from its bark so far [26]. Tannins are known to enhance synthesis of nitric oxide and relax vascular segments precontracted with norepinephrine. It may well be that tannins may be contributing to the reported hypotensive action of *Terminalia arjuna* bark [27]. It is also speculated that tannins may be responsible for its astringent, wound healing and anti microbial activity [27].

Minerals: The bark also contains large amounts of magnesium (4000_g/g), calcium (3133_g/g), zinc (119_g/g), copper (19_g/g) and silica [7].

Antimicrobial activity: Ear infection is one of the common diseases occurring throughout the world. Different etiological agents are responsible for ear infections.To assess the antimicrobial potential of *Terminalia arjuna* leaves and bark extracts against *Staphylococcus aureus, Acinetobacter sp., Proteus mirabilis, Escherchia coli, Pseudomonas aeruginosa* and *Candida albicans*, pathogens causing ear infections and their comparison with locally available ear drops were studied.Methanol, ethanol, acetone, aqueous (hot and cold) extracts from the leaves and bark of *T. arjuna* were tested for their antimicrobial activity.Of the three organic solvents evaluated, acetonic leaf extract was found to be best against *S. aureus.* Organic bark extract showed almost equal inhibition of all tested Gram negative bacteria except *P. aeruginosa*. However, aqueous extract of *T. arjuna* bark exhibited good activity against *S. aureus*.Organic extract obtained from the *T. arjuna* bark and leaves may be used to treat the bacterial ear pathogens especially *S. aureus*, which has shown greater inhibition zones than the herbal drops[28].

Anti-bacterial Activity: Morbidity and mortality due to diarrhoea continues to be a major problem in many developing countries. Water samples from different areas of Chittagong were collected and 22 Vibrio cholerae were isolated from the samples. In this experiment we found that 85% of the Vibrio cholerae isolated can grow at 6% NaCl whereas none of these can survive at 8% NaCl. Most of the isolates were resistant to at least 2 antibiotics. 95.45% were resistant to ampicillin, 50% to erythromycin, 63.63% to nalidixic acid, 13.63% to cephotaxine, 13.63% to ceftriaxone and 27.27% to cotrimoxazol. Arjun bark extract was used as a biological tool to resolve the antibiotic resistant V. cholerae problem. Arjun extract inhibited the growth of *V. cholerae* at all concentrations and zone diameter increased with the increase of concentrations. The regression coefficient of the

relationship between concentration and zone diameter varies from 0.75 to 0.984 for most of the isolates which indicates that there exists a linear relationship. This revealed that *Terminalia arjuna* would be a good antibacterial drug in the treatment of Vibrio cholerae infections, provided if found effective and nontoxic through in vivo studies[29].Morsheed *et al*[30] evaluated the antibacterial and cytotoxic activity of 50% ethanol extract of bark from *Terminalia arjuna* on selected four Gram positive and eight Gram negative bacterial strains. The bark extract of *Terminalia arjuna* showed potential antimicrobial activities against all of the selected strains of microorganisms and the greatest activity was observed against Shigella dysenteriae. For antimicrobial test, Disc diffusion technique was used and the zone of inhibition of microorganisms was measured in mm. In vitro cytotoxicity test was also studied by Brine Shrimp Lethality Bioassay and results illustrated significant ($p<0.05$) cytotoxicity against A. salina, that were expressed as LC50. *Terminalia arjuna* ethanol extract showed brine shrimp cytotoxicity with lethal concentration 50 (LC50) value of 50.11 µg/ml. To observe antibacterial activity four Gram-negative and two Gram-positive bacteria were tested using agar well diffusion method. The results indicate that antibacterial activity of the extract were concentration dependent ranging from 0.5-10mg/ml. The striking and distinctive feature of observed antibacterial activity of *T. arjuna* extract is that it exhibited decent activity against the multi-drug resistant Gram- negative bacteria *Coliform* spp, *Klebsiella pneumoniae, Pseudomonas aeruginosa* even at low concentrations(3mg/ml).Minimum Inhibitory Concentration(MIC) was predicted for the extract and it was varied from 3-20mg/ml[31].

Antifungal activity: Aqueous, alcoholic and ethyl acetate extracts of leaves of five *Terminalia* species (*T. alata, T. arjuna, T. bellerica, T. catappa, T. chebula*) were tested against five plant pathogenic fungi like *Aspergillus flavus, Aspergillus niger, Alternaria brassicicola, Alternaria alternata* and *Helminthosporium tetramera*). The antifungal activities of all these extracts were determined by paper disc method. Nearly all the extracts were found effective against these fungi. It was found that most of[32].

Insecticidal Activity: Hazaa *et al* [33] investigated the toxic effect of some plant extracts on cotton leaf worm, Spodoptera littoralis (Boisd.). Petroleum ether extract of some planta such as *Terminalia arjuna, Erythrine caffra, Taxodium distichum and Melaleuca cajuputi*. Treatment with each of the four plant extracts caused clear mortality on 4th instar larvae. The reduction in F1 progeny , elongation of the larval duration, and pupal period at any of the tested concentration were noticed . There was moderate gradient reduction in the pupation percentage of the different treatments (71) as compared to the control (93.3). Moderate fluctuation was observed among sex ratio (1:2.3). Percentages of adult emergence and growth were inhibited with increasing the concentrations as observed in four plant extracts (1.7) as compared to control (2.9).

Anthelmintic activity: The study was carried out to evaluate the anthelmintic activity of *Terminalia arjuna* (Roxb.) bark locally used as an anthelmintic. Lethal median concentration (LC50 values) of methanolic extract of *T. arjuna* bark in egg hatch and larval development tests against *Haemonchus contortus* ova and larva were found to be 645.65 and 467.74 µg mL-1, respectively. In adult motility assay, efficacy of the extract was evident by the mortality of *H. contortus* at different hours post exposure. *In vivo* results revealed maximum (87.3%) egg count percent reduction (ECR) in sheep treated with crude methanolic extract @ 3 g kg-1 body weight on day 11 post-treatment (PT). The data revealed dose-dependent anthelmintic activity both in the *in vitro* and *in vivo* studies, thus justifying its use in the traditional medicine [34].

Immunomodulatory Efficacy: A study was made for the evaluation of the immunomodulatory efficacy of *Terminalia arjuna* bark extract in *Aspiculuris tetraptera* infected mice. The plant extract were administrated to the infectedmice on 18 , 19 and 20 post infection days. The immunomodulatory efficacy due to plant extract was observed th th th on ITH, DTH and Lymphocyte response. PCA, DTH and Lymphocyte response reactions were found to be directly proportional to the dose of drug. PCA response was maximum (8.2 mm) in the group ITTAM and 5 minimum (5.8 mm) in the group ITTAA . DTH response was maximum (7.8 mm) in the group ITTAM and 1 5 minimum (4.9 mm) in the group ITTAA .Lymphocyte count was observed maximum (79%) in the group ITTAM 1 5 and minimum (68.6%) in the group ITTAA . Significant increase in PCA, DTH and lymphocyte responses in 1 the infected and treated mice indicates stimulated cell mediated as well as humoral immunity. Obtained results indicate that studied plant extract can be good immunnomodulatory agent and may boost the immune response of the host but. We conclude that methanol extract of Terminalia arjuna is more effective than aqueous extract of Terminalia arjuna plant[35].

Antidiabetic effect: The study was carried out to evaluate the antidiabetic effect of *T.arjuna* stembark extract and to study the activities of hexokinase, aldolase and phosphoglucoisomerase, and gluconeogenic enzymes such as glucose-6-phosphatase and fructose -1,6-diphosphatase in liver and kidney of normal and alloxan induced diabetic rats. Oral administration of ethanolic extract of bark (250 and 500mg/kg body weight) for 30 days, resulted in significant decrease of blood glucose from 302.67 ± 22.35 to 82.50 ± 04.72 and in a decrease in the activities of glucose-6-phosphatase, fructose-1,6-disphosphatase, aldolase and an increase in the activity of phosphoglucoisomerase and hexokinase in tissues. However, in the case of 250 mg / kg body weight of extract, less activity was observed. The study clearly shows that the bark extract of *T.arjuna* possesses ppotent antidiabetic activity[36]. Barman and Das[37] reported the effect of ethanolic extract of bark of *Terminalia arjuna* on blood glucose level of normal and diabetic rats. Healthy Wistar albino rats (100-150 gm) were divided into four groups of six animals each. Normal control group received normal saline (10 ml/kg/day/p.o.); diabetic treated group received ethanolic extract of bark of *Terminalia arjuna* (500 mg/kg/p.o.); diabetic standard group received Glibenclamide (0.5 mg/kg/day/p.o.) given for 2 weeks. To induce diabetes, alloxan 150 mg/kg, i.p. single dose was administered to diabetic control, diabetic treated and diabetic standard groups. Blood glucose and body weight was estimated weekly for two weeks. For mechanism of action glycogen estimation on liver, cardiac and skeletal muscle; effect on adrenaline induced hyperglycemia and intestinal glucose absorption was done. For hypoglycemic action on normal rats, blood glucose was estimated at '0' min and '120' min. The drug showed significant decrease ($P<0.01$) in blood glucose level. The test drug showed a significant ($P<0.01$) increase in glycogen content in liver, cardiac and skeletal muscle, significantly ($P<0.01$) reduced adrenaline induced hyperglycemia and intestinal glucose absorption. Blood glucose in normal rats was significantly ($P<0.01$) decreased in drug treated groups. This revealed that *Terminalia arjuna* bark possesses significant hypoglycaemic and anti-diabetic activity. A study was designd to evaluate the beneficial effects of *Terminalia arjuna* (TA) extract on hyperglycemia, lipid profile, renal damage markers and oxidative stress in the liver and pancreas of type 2 diabetes mellitus (T2DM) in rats. T2DM was induced by feeding rats with high-fat diet (HFD; 40%) for two weeks followed by single dose of streptozotocin (STZ; 40 mg/kg, intraperitoneally). Control and diabetic rats were treated with TA (500 mg/kg) for four weeks. After TA treatment, blood was drawn and rats were then sacrificed, and their liver and pancreas were dissected out for biochemical assays. The level of fasting blood glucose (FBG), glycated hemoglobin (HbA1C), total cholesterol (TC), triglycerides (TG), low density lipoprotein-cholesterol (LDL-C) and very low density lipoprotein-cholesterol (VLDL-C) significantly ($P < 0.05$) increased while high density lipoprotein cholesterol (HDL-C) and hepatic glycogen decreased in the HFD/STZ group. TA treatment augmented these effects in the HFD/STZ + TA group. The HFD/STZ group showed elevated renal injury markers in serum, including blood urea nitrogen (BUN), serum creatinine (Scr) and alkaline phosphatase (ALP), which were decreased significantly ($P < 0.05$) by TA treatment. Moreover, treatment with TA significantly ($P < 0.05$) ameliorated thiobarbituric reactive substances (TBARS), malonaldehyde (MDA) and protein carbonyl (PC), and glutathione (GSH), glutathione-s-transferase (GST) and catalase (CAT) in liver and pancreas of HFD/STZ group. The study suggests that TA is effective in reducing hyperglycemia, hyperlipidemia and oxidative stress related to the risk of diabetes. Thus, it may have a therapeutic value for the treatment of T2DM[38].

Radiaprotective and antioxidant properties: Using rat liver mitochondria as model systems, the radioprotective and antioxidant effects of the Indian medicinal plant *Terminalia arjuna* was examined. Various sohxlet fractions of the bark and the medicinal formulation arjunsal besides an active ingredient, baicalein, were examined for their ability to protect both rat liver mitochondria and cardiac homogenate against radiation and oxidative stress apart from their ability to scavenge radicals and for ferric reducing/antioxidant power. Among the various extracts from arjunsal the ones from organic solvents were found to be the most effective in DPPH, ABTS and FRAP assays. In *T. arjuna* bark, the methanolic extract showed the highest antioxidant activity. Radioprotection studies also showed that the methanolic extract was the most effective. Baicalein showed antioxidant as well as radioprotective activity. To look at the possible mechanisms for the observed antioxidant/radioprotective effects pulse radiolysis was performed to examine the reactions of baicalein with various radiation-related and biologically relevant reactive species such as hydroxyl radical (•OH), azide radical (N3•), lipid peroxyl radical (LOO•), trichloro methyl operoxyl radical (CCl3O2•) and thiyl (RS•) radical. Baicalein reacts with these radicals at almost diffusion controlled rates. The bimolecular rate constants for the reaction of these radicals were in the order of 109 dm3mol-1s-1. The above results indicate that various preparations from *T. arjuna*

and its component baicalein have significant radioprotective and antioxidant activities and the ability to react with radiation-derived or radiation-related reactive species may be the factor responsible [39]. Sivalokanathan *et al* [40] investigated to evaluate the antioxidant nature of ethanolic extract of *Terminalia arjuna* bark on N-nitrosodiethylamine (DEN) induced liver cancer in male Wistar albino rats. The results show an antioxidant activity of *Terminalia arjuna* bark against DEN-induced liver cancer

Antimutagenic activities: The antimutagenic effect of benzene, chloroform, acetone and methanol fractions from *Terminalia arjuna* was determined against Acid Black dye, 2-aminofluorene (2AF) and 4-nitro-o-phenylenediamine (NPD) in TA98 Frameshift mutagen tester strain of *Salmonella typhimurium*. Among the different fractions, the antimutagenic effect of acetone and methanol fractions was more than that observed with other fractions. Co-incubation and pre-incubation modes of experimentation did not show much difference in the antimutagenic activity of the extracts. Moreover, these fractions inhibited the S9-dependent mutagens, 2AF and Acid Black dye more effectively than the direct-acting mutagens. Studies are under way to isolate and elucidate the nature of the antimutagenic factor in acetone and methanol fractions[41].

Anti-inflammatory, immunomodulatory and antinociceptive activity: *Terminalia arjuna* back powder (400 mg/kg, po) significantly reduced formalin-indued paw oedema at 24 h but not carrageenan-induced paw oedema. It significantly increased the anti-SRBC antibody titre in the secondary phase of immune response. The same dose significantly reduced the duration of licks and bites in both phases of formalin-induced pain response and showed significant increase in tail flick latency at higher dose (800 mg/kg, po). These effects of *T. arjuna* were antagonised by pretreatment with naloxone (1 mg/kg, ip). In another series of experiments, mice pretreated with morphine for three days in increasing doses (10, 15, 20 mg/kg, ip; twice daily) showed a decreased response in antinociceptive activity of morphine (5 mg/kg, ip). Further, cross tolerance was observed with *T. arjuna* (800 mg/kg, po) in morphine tolerant animals. These findings support the hypothesis that *T. arjuna* has anti-inflammatory potential against some phlogistic agents along with some immunomodulatory activity and also has antinococeptive action probably mediated via central opioid receptors.[42].

Micropropagation: Cotyledonary node explants excised from 21 day old seedlings of *T. arjuna* produced multiple shoots when cultured on full strength MS or modified MS (1/2 strength major salts and Fe-EDTA) medium supplemented with different concentrations (0.1-1.0 mg/l) of BAP. Maximum 8.9 shoots/explant could be recorded after 30 days of inoculation on modified MS medium supplemented with BAP (0.5 mg/l). A proliferating shoot culture was established by reculturing the original cotyledonary nodes (2-3 times) on shoot multiplication medium after each harvest of the newly formed shoots. Shoots (each having 2-3 nodes/shoot) thus obtained were also used as a source of nodal explant that gave rise to 1-2 shoots when cultured on modified MS+BAP (0.5 mg/l) medium. Thus, 45-55 shoots could be obtained after 60 days of culture initiation from a single cotyledonary node. About 88% shoots rooted well after 15 hr pulse treatment with IBA (1 mg/l) in liquid MS medium followed by transfer to modified MS medium without IBA. About 80% of these plantlets were successfully acclimatized in plastic pots containing sand and soil mixture and 70% plantlets transferred in the field those survived even after 6 months of transplantation[43].

In acne management

Prepare an ointment by mixing finely powdered bar k with honey and apply it over acne eruptions. It is said to be a successful treatment in acne.

Aphrodisiac Properties

If powder of bark is taken, regularly with milk for 2 3 months or till improvement sets in, it will prove a s an effective sex stimulant.

In asthma management:

The treatment should be carried on the night of full moon. Prepare a dish from condensed milk sugar a nd rice to make a palatable kheer and put in an ope n bowl which should be covered with a thin muslin clothand exposed to moonlight, making sure that th e moonlight falls directly on the processed dish. Sprinkle10-

12 gms of powder of the arjuna bark over it and eat early next morning, but the patient must not sleep upto twelve hours afterconsuming the dish. This is said to be an effective and curative device in case o f even chronic asthma [44].

Modern research and Arjuna: Modern clinicians are just beginning to use arjuna for coronary artery disease, heart failure, and high cholesterol. The herb's components include a variety of polyphenols, which probably account for much of its activity. They include three flavonoids (arjunone, arjunolone, and luteolin), four triterpenoid saponins (arjunic acid, arjunolic acid, arjungenin, and arjunglycosides), tannins, ellagic

acid, gallic acid, and proanthocyanidinic oligomers. Arjuna also contains phyto-sterols, calcium, magnesium, zinc, and copper. Arjuna seems to work by improving cardiac muscle function and the pumping activity of the heart. The saponin glycosides might be accountable for this effect, while the flavonoids and proanthocyanidinic oligomers contribute antioxidant action and strengthen veins. Scientific information about arjuna is beginning to accumulate. Angina pectoris patients in particular may benefit from arjuna. A 1999 study indicated that arjuna was more effective than a standard drug for angina. Arjuna was effective for 80 percent of the patients, and the herb reduced the number of angina attacks from seventy-nine per week to twenty-four per week. In a recent study from India, patients with stable angina cut their heart pain in half after three months of therapy with arjuna alone. When the researchers examined the patients' overall clinical condition, treadmill results, and heart strength, 66 percent showed improvement. Arjuna is particularly effective for congestive heart failure. A recent experiment bears this out. A double-blind, placebo-controlled, two-phase trial of arjuna extract in patients with severe cases of the condition was conducted. Arjuna was added to the patients' regular drugs. In just two weeks, breathing difficulties, fatigue, edema, heart contraction, blood pressure, and walking tolerance all improved. In the second phase of the study, the subjects continued taking the arjuna for two years. Their conditions continued to improve for the first two to three months of the study's second phase, and the improvements were maintained during the entire two years. Arjuna also benefits cardiomyopathy, or weakening of the lower muscles of the heart, and may help patients recovering from heart attacks. A 1997 study of heart attack victims demonstrated that arjuna was superior to drugs alone for a wide range of related symptoms, including angina, enlargement of the heart, and impaired pumping strength.

Additional actions of *Terminalia arjuna* herb: *Terminalia arjuna* has compounds that protect against DNA damage from toxins. Compounds in arjuna may help maintain healthy cholesterol. A substance in arjuna, casuarinas, inhibits breast cancer cell growth.

Toxicity and side effects: *Terminalia arjuna* has been used in the dose of 1–2 g/day in various clinical studies. This has been found to be the optimum dose in patients of CAD. At this dosage, it is well tolerated and has fewer side effects like mild gastritis, headache and constipation. No haematological, metabolic, renal and hepatic toxicity has been reported even more than 24 months of its administration[45,46,47]. There have been few reports which have shown its hepato-renal protective property. In a recent study the aqueousextract of its bark could protect the liver and kidney tissues of mice against carbon tetra chloride (CCl4)-induced oxidative stress probably by increasing antioxidant defence activities[48]. In another study using ethanolic extract, 500 mg/kg dose of its bark stem in alloxan-induced diabetic rats, it was found that the drug reduced the lipid peroxidation and raised endogenous antioxidant enzymes in liver and kidney tissues .

Conclusions and future strategies: The herbal remedies have been employed in varius medical system for the treatment and management of different diseases.The plant *Terminalia arjuna* has been used in different system of traditional medication for the treatment of diseases and ailments of humam beings.The plant contains arjunilic acid,triterpinne glycosides,natural oxidants,gallic acid,phytosterols,rich in minerals like Ca,Mg,Zn and Co and reducing sugar and colouring matter.It has been reported as cardiotonic, hepatoprotective, immunomodulatory, antimicrobial, insecticidal, anthelmintic, antidiabetic, radioprotective, antioxidant, antimutagenic properties. The efficacy of *Terminalia arjuna* is much popular *as* an anti-ischemic agent and as a potent antioxidant . It can be considered as a useful drug for coronary artery disease, hypertension and ischemic cardiomyopathy. Its actions in different cells of the cardiovascular system need much attention. Further, a well-designed study to evaluate its toxicity from its long-term use is another priority. Such a study will provide scientific basis for its clinical use .As the global scenario is now changing towards the use of non toxic plant products, development of modern drugs should be emphasized. Clinical trials should be conducted to support its therapeutic value.The current study is therefore carried out to provide requsite phytochemical and pharmacological detail about the plant.The plant is cultivated in different parts of India on a small scale.However systematic information on different aspects of this species is still not available.In this review an attempt has been made to present this information.

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