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Review Article
Efficacy and Advancement of *Terminalia arjuna* in Indian Herbal Drug Research: A Review

Neelam Soni and Vinay Kumar Singh

Laboratory of Malacology, Department of Zoology, Deen Dayal Upadhyaya Gorakhpur University, 273009 Gorakhpur, Uttar Pradesh, India

Abstract

Medicinal plant *Terminalia arjuna* are used in folkoric system for the treatment of the various disease and disorder since ancient time. This study validated the folkoric system experimentally with modern drug approaches. The main objective of this review was to explore the pharmacological aspect of *Terminalia arjuna,* a indigenous medicinal plant. Medicinal plants have been recognized as major source of therapeutic agents to cure the human disease, as green medicine is healthier than synthetic products. The Arjuna was introduced into Ayurveda as a treatment for heart disease by Vagbhata (c. 7th century CE). It is traditionally prepared as a milk decoction. This plant was a known practice for thousands of years, in ancient Indian Vedas, Vagbhata mentions Arjuna in the treatment of wounds, hemorrhages and ulcers, applied topically as a powder. There is a vast variety of plants, which are rich source of bioactive compounds and several more might still be lying unexplored. The available compounds of Arjuna are more potent against snail-borne diseases and used as molluscicidal agents. Arjuna has also been found effective as an antioxidant, protect cardiovascular diseases and very helpful in regulating the hormonal system of the body. Ailments like eczema, itching, rashes scars and serious skin conditions like psoriasis can also be treated with the regular use of *Terminalia arjuna*. On the basis of ongoing literature and scientific reports the medicinal plant *Terminalia arjuna* has nature's boon to mankind.

Key words: *Terminalia arjuna,* medicinal plant, arjuna, ayurveda, ailments, molluscicidal agent, cardiovascular diseases

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Corresponding Author: Vinay Kumar Singh, Laboratory of Malacology, Department of Zoology, Deen Dayal Upadhyaya Gorakhpur University, 273009 Gorakhpur, Uttar Pradesh, India Tel: +919415855488/9807110100

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Medicinal plants have been recognized as major component of all traditional system of medicine to cure the human disease, since ancient time and till today because of green medicine is healthier than synthetic counterparts. A large number of wild medicinal plants are to be brought in to cultivation in order to explore its therapeutic potential. Keeping this view the concentrate efforts are needed to make the available compound more potent against disease and safer to environment by way of improved formulations. As per WHO reported about 80% of world population relayed on traditional medicine in India[1]. The main Indian traditional system of medicine is primarily plant based system[2]. *Terminalia arjuna* is traditionally widely used in the medical formulation of various aliment due to the presence of large number of active phytoconstituents[3]. In the Indian traditional system of medicine, the bark is used as astringent, cooling aphrodisiac, cardiotonic, tonic in fracture, ulcer, spermatorrhoea, leucorrhoea, diabetes, cough, tumor, asthma, inflammation and skin disorder[4,5]. Primarily, the ingestion of medications prepared with bark of Arjuna ensures usual functioning of the heart, provides energy to the heart muscles, promotes the functioning of platelets as well as helps in sustaining a steady blood pressure level. Arjuna helps in thickening of the serum and the sperm that is very essential for the proper fertilization of the ovum. It is helpful in increasing the sperm count. It is capable in treating polyurea condition and is also helpful regularizing the increased urine frequency[6]. It is also useful to cure obesity, hypertension and hyperglycemia[7]. Keeping in the view of the medicinal importance of the tree in traditional and Ayurvedic system of medicine an attempt has been made to review the available literature. This aim of this comprehensive review was to provide the efficacy and advancement of *Terminalia arjuna* in herbal drug research covering the area of enthnomedical, phytochemical and pharmacological.

EFFICACY AND ADVANCEMENT OF *T. ARJUNA* IN HERBAL DRUG

Classical names: *Terminalia arjuna* is known by its various classical names, such as Arjuna, Dhavala, Kaubha, Nadisaraja, Veeravrikskha, Partha and Indradru[8].

Botanical description: *Terminalia arjuna* L. (Combretaceae) is a large evergreen deciduous tree (Commonly known as Arjuna) found throughout India growing to a height of 20-25 m. It commonly grows on banks of rivers, streams and dry watercourses and distributed throughout the greater part of Indian sub-continent, Himalayan tract of Uttar Pradesh, Chota Nagpur, Orissa, west Bengal, Punjab, Deccan and Konkan[9,10]. The bark of *Terminalia arjuna* is soft and thick with grey in colour on outer surface and tinge easily flakes off in flat large pieces inside.

Leaves of *T. arjuna* are simple, borne opposite shortly acute or obtuse at the apex, glabrous 4-6 inch long and 2-3 inch wide, there are two glands near the base of the petiole. There is a morphological difference in leaf traits of this plant[11]. It has pale yellow flowers with short auxiliary spikes or terminal panicle arrangement, which appear between March and June; its glabrous, 2.5-5 cm fibrous woody fruit with smooth skinned divided into five hard wings, appears between September and November.

Phytochemistry: The major chemical constituents analysis of different parts of *T. arjuna* was carried out by various standard technique like HPLC, UPLC and LC-ESI-MS/MS analysis[12-15]. The *Terminalia arjuna* bark extract revealed the presence of bio-active chemical constituents which are known to exhibit medicinal as well as physiological activities[16]. The chemical constituent of different classes such as; hydrolysable tannins[17], triterpenoides acid (Fig. 1) and their glycosides[16,18], flavonoids[19], phenolics[20], phytosterol[21] found in stem bark portion of *T. arjuna* species. Arjunglucoside 1-3, arjunolic acid and terminoic acid were important constituent of bark (Table 1)[22].

Ayurvedic formulation: *Terminalia arjuna* is tremendous plant having enormous influence in ayurvedic system of medicines. In Rigveda, the word 'Arjuna' used either to indicate the white colour or one of taintless fame and glow like silver[41,42]. It may be the first reference of Arjuna used as medicine stated in chief or principle sutra volume of Atharvaveda, Kaushiksutra (400300 B.C.). Further synonyms and properties of Arjuna are mentioned in Bhavprakash Nighantu. Later on Chakradatta, the great ancient physician,

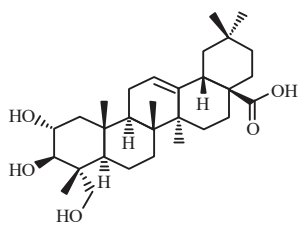

Fig. 1: Arjunolic acid

Table 1: Phytochemical and major chemical constituents of various parts of *Terminalia arjuna*

Part used	Major chemical constituents	References
Stem bark	**Triterpenoids and tannins**	
	Arjunic acid, Arjunin	Anjaneyulu and Prasad[20]
	Arjunetin, Lactone	Amalraj and Gopi[23]
	Arjunanin, Arjunolic acid	Singh *et al.*[12,13] and Soni and Singh[24,25]
	Casuarianin	Kuo *et al.*[26]
	Flavonoids and phenolics	
	Arjunolone, Baicalein	Sharma *et al.*[19]
	Catechin, Gallocatechin, Epicatechin	Rastogi and Mehrotra[27]
	Ursane triterpenoids	
	2α, 3β- dihydroxy urs-12,18 dien-28 oic acid 28-O-β-D-glucopyranosyl eater	Wang *et al.*[28]
	2α, 3β, 23- trihydroxyurs-12,18 oic-acid 28-O-β-D-glucopyranosyl eater	
	Qudranoside VIII, Kajiichigoside F1	
	Glycosides	
	Arjunoglucoside I and II	Rastogi and Mehrotra[29]
	Terminoic acid	Ahmad *et al.*[30]
	Arjunoglucoside IV, V	Wang *et al.*[31]
	Terminoside A	Ali *et al.*[32]
	Terminoglucoside I, II	Alam *et al.*[33]
Root bark	Arjunoside I, II 8- hydroxyl Hexadecanoic, Oleanoic, Arjunic acids, Arjunolic acid, β-sitosterol,	Anjaneyulu and Prasad[20]
	Terminic acid	Anjaneyulu and Prasad[34]
	Arjunoside III, IV, Arjunoside I, Arjunetin, Ellagic acid, Gallic acid Leucocyanidin	Anjaneyulu and Prasad[35]
	Arjunetoside	Upadhyay *et al.*[36]
	16-17 dihydroneridienone 3-O-β-D- glucopyranosyl-(1-6)-O-β-D galactopyranoside	Yadav and Rathor[37]
Fruit	Arjunic acid, Arjunone, Arachidic stearate, Cerasidine, Ellagic acid, Friedelin, Gallic acid,	
	Hentriacetone, Mleaolate, Myristyl oleate, β-Sitosterol	Rastogi and Mehrotra[38]
Leaves and seeds	Luteolin	Pettit *et al.*[39]
	14-16 dianhydrogitoxigenin 3-β-D-xylopyranosyl-(1>2)-O-β-galactopyranoside	Yadav and Rathor[40]

recommended uses of Arjuna bark in form of decoction with milk (Kshirpaka) or as a ghrita (a preparation with ghee)[3].

USES OF ARJUNA IN TRADITIONAL AYURVEDIC HERBALISM

Generally stem, bark, fruits and leaves of Arjuna are used in human therapeutic. Fresh leaves juice used in the treatment of earache and root paste used in headache[43]. Fruit paste was used topically as a traditional healer in south India[44]. It was also used to treat cough, sore throat and dyspepsia[45]. The bark was the main part used in Ayurveda as well as in allopathy for curing various diseases[46]. Bark ash is prescribed on snakebite and scorpion sting[47]. This act was astringent, cooling cardiotonic, antidysentery, urinary astringent, hypertension, hemorrhage, diarrhea associated with blood, cirrhosis of liver, hypertension inflammation and skin disorder[48].

Pharmacological significance: Since the time immemorial *T. arjuna* has been a herb of choice in dealing with the treatment of many cogenitous disease. It serve as a blessing in Indian traditional (Ayurvedic) as well as allopathy medicinal system[46] and posses the wide range of therapeutic properties and has the potential to treat many medical condition[2].

Cardio-protective activity: The Arjuna plant (lat. *Terminalia arjuna*) has traditionally been used to treat heart disease for centuries, that is why it got the nickname "Guardian of the heart". It was also known as hero of the famous epic "Mahabharata" because of its protective effects. Researchers studied the cardio-protective role of chronic oral administration of methanolic extract of *T. arjuna* bark in *in vitro* myocardial ischemic reperfusion injury and the induction of HSP72. The results of the study suggested that the methanolic extract of the bark powder of *T. arjuna* in rat induces myocardial HSP72 and augments myocardial endogenous antioxidants, without causing any cellular injury[49]. The ongoing researches demonstrated that *T. arjuna* ethanolic extract and aqueous extract both produced significant cardio-protection in isoproterenol induced mayocardial infraction animals[50]. The bark of *T. arjuna* was used in India as cardio-protective agent in hypertension and eschaemic heart disease[51]. The antioxidant properties of ethanol extract of bark of *T. arjuna* against sodium fluoride (NaF)-induced oxidative stress in murine hearts[52]. High amount of plant extract should not be consumed because, hepatotoxicity as well as hypothyroidism may be caused by them[53]. Arjunanin was very good cardio-protective drug used on the process of respiratory oxybrust[54]. The *T. arjuna* bark extract had a significant prophylactic and therapeutic

beneficial effect on protection of heart against ISO-induced chronic heart failure possibly through maintaining endogenous antioxidant enzyme activities, inhibiting lipid peroxidation and cytokine levels. This cardio-protective action of *T. arjuna* was comparable to fluvastatin, a synthetic drug to cure heart disease[55]. In a study of human monocystic (THP-1) and human arotic endothelial cells (HAFECs), cell was cultured by using alcoholic and aqueous extract of *T. arjuna* stem bark provide a biochemical and molecular basis for the therapeutic potential against cardiovascular disease (CDV) as it significantly inhibits the lipid peroxidation and human 3-hydroxy-3-methylglutaryl co-enzyme A (HMG-CoA)[15]. Alcoholic and aqueous extracts of *T. arjuna* showed significant inhibition in the activity of CYP3A4, CYP2D6 and CYP2C9 enzymes. Enzyme kinetics study suggested that treatments caused rapidly reversible non-competitive inhibition of all three enzymes human liver microsomes[56]. The *T. arjuna* helps in maintaining the cholesterol level at the normal rate, as it contains the antioxidant properties similar to the vitamin E. It strengthens the heart muscles and maintains the heart functioning properly. It also improved functioning of cardiac muscle and treatment of coronary artery disease, heart failure, angina and hypercholesterolemia. Its bark powder contained asthma, diuretic, prostaglandin enhancing and coronary risk factor modulating properties[50]. Experimental studies on Arjuna pertaining the various aspect of its cardiovascular functions, autonomic control of myocardial functions, molecular mechanisms of its action and cardiac histopathological aspects[57]. A new study demonstrated the therapeutic benefit of *T. arjuna* in diabetes with co-existing cardio-vascular disease[58].

Hepatoprotective activity: The preventive role of arjunolic acid against arsenic induced cytotoxicity in isolated murine hepatocytes was evaluated by Manna *et al.*[59]. The aqueous extract of *T. arjuna* bark could protect the liver and kidney tissue against CCl_4 induced oxidative stress probably by increasing anti-oxidative defense activity[51]. The anti-oxidative effect of *T. arjuna* bark against DEN-induced liver cancer was also studied[60]. It was found that aqueous and ethanol extract of *T. arjuna* bark showed the hepatoprotective potential against paracetamol/CCl_4 induced liver damage in Wistar albino rats. Pre-treatments of the rats with the ethanol and aqueous extract prior to paracetamol/CCl_4 administration caused a significant reduction in the value of serum glutamic pyruvic transaminase ($_S$GPT), serum glutamic oxaloacetic transaminase ($_S$GOP) and serum alkaline phosphatase ($_S$ALP) and serum bilirubin ($_S$B) almost comparable to silymarin, standard hepatoprotective agent. Hepatoprotective activity was confirmed by histopathological examination of control and treated rats[61]. The extract of *T. arjuna* bark was investigated for its hepatoprotective and antioxidative effect on cadmium provoked toxicity and the result of the experiment indicated that *Terminalia arjuna* (200 mg kg^{-1}) significantly reversed the effect of cadmium and proved that it has hepatoprotective and antioxidant potential[62]. The *T. arjuna* bark aqueous extract was found to be a potential therapeutic agent against alcohol induced oxidative/nitrosative stress mediated hepato and nephrotoxicity in rats[63]. Alcohol administration significantly raised the plasma concentrations of nitrogenous compounds and increased activities of alcoholic marker enzymes. Administration of aqueous bark extract to alcoholic rats significantly brought these alterations in plasma to normal and also significantly reduced the levels of lipid peroxidation and restored the enzymatic and non-enzymatic antioxidants in liver. Co-administration of alcohol along with bark extract offered protective effect against alcohol-induced stress in rats. Further, it was reported that the methanolic extract of *Terminalia arjuna* stem bark and its purified flavonoids (baicalein and quercetin) exhibit hepatoprotective effect against CCl_4 induced hepatic damage[5]. Its hepatoprotective role was due to its flavonoids content. Quercetin showed more protective effect than bicale in *in vitro*[5]. Arjunolic acid a major active constituent of Arjuna gives a promising result in the treatment of non-alcoholic fatty acid liver disease as it significantly reduced the lipid level in palmitate-oleate induced $HePG_2$ cell and also reduced the level of LDH, ALT, AST and GGT in HFD rats[64].

Anti-inflammatory and analgesic activity: Anti-inflammatory activity of *T. arjuna* bark powder was investigated by Halder *et al.*[65]. Constituents from the stem bark of Arjuna showed potent antioxidant activity and inhibited Nitric Oxide (NO) production in lipopolysaccharide (LPS) stimulated rat peritoneal macrophages[32]. The poly herbal formulation of ethanolic extract of *Datura stramonium* (leaves), *Terminalia arjuna* (bark) and *Withania somnifera* (root), have anti inflammatory effect and inhibits the enzyme cyclooxygenase (COX) leading to inhibition of prostaglandin synthesis using inflammation at third stage. The result proved the polyherbal formulation showed significant anti-inflammatory and analgesic activity[66]. The extract of *Terminalia arjuna* was used in the study of Carrageenan-induced paw edema method to study the anti-inflammatory activity and observed that extract significantly reduced the formation of edema induced by carrageenan. The extract

was also used to evaluate the centrally acting analgesic potential using formalin, hot plate and peripheral pharmacological actions using acetic acid induced writhing test in mice. The extract of the plant was found to have significant ($p<0.01$; $p<0.001$) analgesic activity at the oral dose of 250 and 500 mg kg^{-1} b.wt., in the tested models[67]. The anti-inflammatory activity of Arjuna Kaseera paka an ayurvedic formulation of *T. arjuna* (prepared in cow milk) and compared with hydroalcoholic extract. The result of the study showed that AKP has higher efficacy that could be due to the presence of milk solids. Milk solids act as adjuvant to *T. arjuna* phytoconstituents contributing to their sustained bioavailability leading to higher efficacy at lower drug concentration[68].

Anti-tumor and cytotoxic activity: *Terminalia arjuna* is herbal medicine against environmental carcinogenicity as the *T. arjuna* bark extract protects DNA against ADR induced damage[69]. The aqueous extract of stem bark showed anti-oxidant action on anti-carcinogenic activity by reducing the oxidative stress along with inhibition of anaerobic metabolism[70]. The arjunic acid was significantly activated against human oral, ovarian and liver cancer cell lines suggesting its role in anti-cancer treatment[71]. It was reported that the ethanolic extract of bark of *T. arjuna* has significant analgesic and cytotoxic effect[67]. Arjunolic acid isolated from *T. arjuna* showed the cytotoxic activity against carcinoma and lymphoma cancer cell[72]. The anti-carcinogenic anti-mutagenic potential of *Terminalia arjuna* extract *in vivo* and *in vitro* was also studied[73]. Anti-cancer potential of *T. arjuna* bark extract against some human cancer cell line was studied by Singh *et al.*[74]. The methanolic extract of Arjuna was rich in the flavonoids content responsible for its antiproliferative effect. It was studied that phytosome complex of methanolic extract of *Terminalia arjuna* bark has antiproliferative effect on human breast cancer cell lines (MCF-7) as compared to methanolic extract[75].

Gastric activity: The methanolic bark extract of *T. arjuna* showed a significant increase in the adherent mucus of the gastric wall and in the protein bound carbohydrate complexes of the gastric juice in rats treated with diclofenac sodium[76]. Anti-ulcer effect of methanol extract of *T. arjuna* against *Helicobacteron pylori* lipopolysaccharide induced gastric damage in rat were evaluated by Devi *et al.*[77]. The findings of the result suggested that Arjuna has ability to combat factor that damage the gastric mucosa.

Wound healing activity: The topical application of *T. arjuna* bark hydroalcohol extract on rat dermal wounds using *in vivo* models was assessed the wound healing capacity of *T. arjuna*. The result strongly documented that the beneficial effect was due to its tannin content[78]. Herbal formulation of Himax ointment and lotion containing *T. arjuna* extract was evaluated for its wound healing potential and the result was comparable to the standard drug nitrofurazone[79]. *The T. arjuna* bark powder mix with coconut oil was found to be potentially effective against chronic wound[80].

Antibacterial activity: Strong antibacterial activity was shown by the methanol extracts of *T. arjuna* against multi drug resistance *salmonella typhi*[81]. The *T. arjuna* plant extract have great potential to been developed as herbal ear drops to control bacterial ear infection. The leaves and bark extract as potent and effective medicine against tested bacterial responsible for ear infections than that of standard ear drop[82]. Antibacterial and cytotoxic activity of *T. arjuna* bark aqueous and methanolic extract was experimentally carried out by using the agar gel diffusion method against *Escherichia coli*, *Klebsiella* sp., *Pseudomonas* sp. and *Staphylococcus* sp. Aqueous and methanolic extract of *T. arjuna* showed inhibition against all the mentioned organism in dose dependent manner[83]. Antibacterial, antifungal brine shrimp lethality and phytotoxic effect of *Terminalia arjuna* was performed by Javed *et al.*[84]. The results showed that methanolic extract of *T. arjuna* leaves has moderate antifungal effect against *Microsporm canis* and fruit extract posses good antibacterial activity against *Staphylococcus aureus* and *Pseudomonas aeruginosa*. Moreover, dichloromethane extract of *T. arjuna* bark and fruit posses moderate phytotoxic activity. A recent study find that the *T. arjuna* bark and leaves ethanolic extract and its different solvent fraction show strong antimicrobial activity against *Bacillus subtilis*, *staphylococcus aureus*, *Eschericia coli*, *Klebsiella pneumonia*, *Pseudomonas aeruginosa* and *Salmonella typhi*, respectively[85].

Antioxidant activity: Antioxidant and free radical scavenging capacity of *T. arjuna* were studied by various scientist. Comparative study the antioxidant potential of *T. arjuna* bark and leaves ethanolic extract and its different solvent fraction was carried out by Kumar *et al.*[85]. The study demonstrated that the antioxidant properties due to presence flavonoids, tannins and oligomeric proanthocyanidins. It was observed that arjunic acid and

aglycone isolated from the fruit were strong antioxidant or free radical scavenger and more potent then ascorbic acid[86]. Casuarinin extracted from *T. arjuna* protect Cultured Madin Darby Canine Kidney (MDCK) cell against H_2O_2 mediated oxidative stress decrease DNA oxidative damage and prevent the depletion of intracellular GSH in MDCK cells[87].

Ant diabetic activity: The *T. arjuna* has known to be posses the anti-diabetic activity. The effect ethanol extract of *T. arjuna* bark in alloxan induced diabetic rats and its lipids peroxidation enzymatic and non-enzymatic activity was investigated in the liver and kidney tissue. The results of the study clearly validate the traditional used of this plant in diabetic animal[88]. The anti diabetic effect of *T. arjuna* in co-existing with cardiovascular disease was study by Borde *et al*.[58]. The result of the study demonstrated that *T. arjuna* has beneficial effect in experimental model of myocardial infarction co existing with cardiovascular disease.

Anti-viral activity: Casuannin extracted from *T. arjuna* bark was investigated for its antiviral activity against Herpes simplex type II *in vitro.* The results showed that casuarinin was virucidal and possesses anti herpesvirus activity in inhibiting viral attachment and penetration[89].

Anthelmintic activity: Anthelmintic activity of *T. arjuna* methanol extract against the hatched egg and larvae of *Haemonchus contortus* were found to be toxic at 645.65 and 467.65 μg mL^{-1} of dose, respectively. The data revealed dose dependents antihelmintic activity both *in vitro* and *in vivo* studied, thus justifying its use in the traditional medicine system[90]. Anthelmintic activity of *T. arjuna* may be only attributed to its tannin content. Antihelmintic effect of *T. arjuna* bark was also studied on *Pheretima posthuma.* The effectiveness of drug was judge on the basis of loss of spontaneous movement and death of trematode[91].

Molluscicidal activity: The molluscicides activity of *T. arjuna* bark and its different organic extract against fasciolosis vector snails *Lymnaea acuminata* and *Indoplanorbis exustus* were studied by Soni and Singh[24,25]. The results of their findings demonstrated that toxicity of column purified fraction was higher among all the treatments of *Terminalia arjuna* bark against *L. acuminata* (96h LC_{50} = 3.12 mg L^{-1}) and *I. exustus* (96h LC_{50} = 14.53 mg L^{-1}). The TLC analysis demonstrated the presence of arjunolic acid in column purified fraction and cause of its molluscicidal activity. *In vivo* and *in vitro* mode of action of molluscicidal component on key enzymes AChE, ACP and ALP activities in the nervous tissue of snail *L. acuminata* were studied by Soni *et al*.[92]. The results of the study proved that plant have concentration dependent inhibition in key enzymes i.e., AChE, ACP and ACP activities. The maximum inhibition in AChE (60.17% of control) ACP (34.66% of control) and ALP (24.01% of control) activity was observed in snail exposed to 96 h exposure of 80% of 96 h LC_{50} of arjunolic acid. Percent enzyme inhibition both *in vivo* and *in vitro* condition indicated that inhibition of ALP was more pronounced than ACP and AChE against all the treatments. The study of kinetics of inhibition of AChE, ACP and ALP by column purified fraction and arjunolic acid of *T. arjuna* bark were also studied[92]. The findings of the work clearly indicated that inhibition of AChE was non-competitive, inhibition of ACP was uncompetitive and inhibition of ALP by column purified fraction and arjunolic acid of *T. arjuna* bark were competitive-non-competitive as it is clearly from K_m and V_{max} values of uninhibited and inhibited enzymes on Line weaver plot[93]. The safety of this plant derived molluscicidal drug were evaluated against non-target aquatic biota i.e., fish *Colisa fasciatus.* The result of the work were found that toxic concentration (24h LC_{90} against *L. acuminata* and *I. exustus*) of arjunolic acid and column does not exert any effect on nervous tissue of fish[94].

Apoptosis: At least two modes of cell death can be distinguished: apoptosis and necrosis. Apoptosis is a strictly regulated (programmed) device responsible for the systematic removal of superfluous, aged, harmful, abnormal or misplaced cells. Studies were conducted to establish the effects of *Terminalia arjuna* bark extract on apoptosis of human hepatoma cell line HepG2. It was found that T*. arjuna* induced cytotoxicity in HepG2 cells *in vitro*. Apoptosis effect of *T. arjuna* on HepG2 cells may be due to the DNA damage and expression of apoptotic proteins. Depletion of GSH may be involved in the induction of apoptosis of HepG2 cells[95].

CONCLUSION

Virtually every part of the plant has a great ethnopharmacological value with wide array of the traditional as well as pharmaceutical application due to the presence of large number of bio-active chemical constituents. Experimental study has demonstrated its cardio-protective, hepatoprotective, antioxidant, anticancerous, anti-inflamatory, analgesic, antidiabetic

antihelminthic, antimicrobial, antiviral and molluscicidal effects. However, further, detailed clinical research appears worthwhile to explore the full therapeutic potential of various parts of *Terminalia arjuna* in order to establish it as a standard drug.

SIGNIFICANCE STATEMENT

This study efforts to give every aspect of literature such as; pharmacognosy, phytochemistry, pharmacological, ayurvedic traditional and clinical studies on plant and updating available research data. It can be beneficial for the new researcher and students to collect the informative knowledge of plant in comprehensive form.

REFERENCES

1. WHO., 2002. Traditional medicine strategy report. Document WHO/EDM/TRH/2002.1, World Health Organization, Geneva, Switzerland.
2. Paarakh, P.M., 2010. *Terminalia arjuna* (Roxb.) Wt. and Arn.: A review. Int. J. Pharmacol., 6: 515-534.
3. Chopra, R.N., I.C. Chopra, K.L. Handa and L.D. Kapur, 1958. Chopra's Indigenous Drugs of India. Dhur and Sons Private Ltd., Calcutta, India.
4. Dwivedi, S., 2007. *Terminalia arjuna* Wight & Arn: A useful drug for cardiovascular disorders. J. Ethnopharmacol., 114: 114-129.
5. Chaudhari, G.M. and R.T. Mhajan, 2016. *In vitro* hepatoprotective activity of *Terminalia arjuna* stem bark and its flavonoids against CCl_4 induced hepatotoxicity in goat liver slice culture. Asian J. Plant Sci. Res., 6: 10-17.
6. Choudhari, A.B., S. Nazim, P.V. Gomase, A.S. Khairnar, A. Shaikh and P. Choudhari, 2011. Phytopharmacological review of Arjuna bark. J. Pharm. Res., 4: 580-581.
7. Dwivedi, S. and N. Udupa, 1989. *Terminalia arjuna*: Pharmacognosy, phytochemistry, pharmacology and clinical use. A review. Fitoterapia, 60: 413-420.
8. Sharma, P.C., M.B. Yelne and T.J. Dennis, 2000. Database on Medicinal Plants Used in Ayurveda. Central Council for Research in Ayurveda and Siddha, New Delhi, India.
9. Warrier, P.K., V.P.K. Nambiar and C. Ramankutty, 1994. Indian Medicinal Plants: A Compendium of 500 Species. Orient Longman Pvt. Ltd., Madras, India.
10. Sharma, S., D. Sharma and N. Agarwal, 2012. Diminishing effect of arjuna tree (*Terminalia arjuna*) bark on the lipid and oxidative stress status of high fat high cholesterol fed rats and development of certain dietary recipes containing the tree bark for human consumption. Res. Pharm., 2: 22-30.
11. Wani, M.R. and S.S. Singh, 2016. Variation in leaf morphological traits of *Terminalia arjuna* Roxb. in natural population of lower parts of Achanakmar Amarkantak Biosphere Reserve (AABR) of Central India. Int. J. Adv. Res., 4: 484-491.
12. Singh, D.V., R.K. Verma, M.M. Gupta and S. Kumar, 2002. Quantitative determination of oleane derivatives in *Terminalia arjuna* by high performance thin layer chromatography. Phytochem. Anal., 13: 207-210.
13. Singh, D.V., R.K. Verma, S.C. Singh and M.M. Gupta, 2002. RP-LC determination of oleane derivatives in *Terminalia arjuna*. J. Pharmaceut. Biomed. Anal., 28: 447-452.
14. Chitlange, S.S., P.S. Kulkarni, D. Patil, B. Patwardhan and R.K. Nanda, 2009. High-performance liquid chromatographic fingerprint for quality control of *Terminalia a rjuna* containing Ayurvedic *churna* formulation. J. AOAC Int., 92: 1016-1020.
15. Kokkiripati, P.K., R.V. Kamsala, L. Bashyam, N. Manthapuram and P. Bitla *et al*., 2013. Stem-bark of *Terminalia arjuna* attenuates human monocytic (THP-1) and aortic endothelial cell activation. J. Ethnopharmacol., 146: 456-464.
16. Mandal, S., A. Patra, A. Samanta, S. Roy and A. Mandal *et al*., 2013. Analysis of phytochemical profile of *Terminalia arjuna* bark extract with antioxidative and antimicrobial properties. Asian Pac. J. Trop. Biomed., 3: 960-966.
17. Kandil, F.E. and M.I. Nassar, 1998. A tannin anti-cancer promotor from *Terminalia arjuna*. Phytochemistry, 47: 1567-1568.
18. Tripathi, V.K., V.B. Pandey, K.N. Udupa and G. Ru, 1992. Arjunolitin, a triterpene glycoside from *Terminalia arjuna*. Phytochemistry, 31: 349-351.
19. Sharma, P.N., A. Shoeb, R.S. Kapil and S.P. Popli, 1982. Arjunolone: A new flavone from stem bark of *Terminalia arjuna*. Indian J. Chem., 21: 263-264.
20. Anjaneyulu, A.S. and A.V. Prasad, 1982. Chemical examination of roots of *Terminalia arjuna* (Roxb) Wright and Arnot. Part I. Characterization of two new triterpenoid glycosides. Indian J. Chem., 21: 530-533.
21. Row, L.R., P.S. Murty, G.S.R. Subba-Rao, C.S.P. Sastry and K.V.J. Rao, 1970. Chemical examination of *Terminalia arjuna*: Part-XII: Isolation and structure determination of arjunetin from *Terminalia arjuna* bark. Indian J. Chem., 8: 772-775.
22. Verma, S.C., C.L. Jain, M.M. Padhi and R.B. Devalla, 2012. Microwave extraction and rapid isolation of arjunic acid from *Terminalia arjuna* (Roxb. ex DC.) stem bark and quantification of arjunic acid and arjunolic acid using HPLC-PDA technique. J. Sep. Sci., 35: 1627-1633.
23. Amalraj, A. and S. Gopi, 2017. Medicinal properties of *Terminalia arjuna* (Roxb.) Wight & Arn.: A review. J. Tradit. Complement. Med., 7: 65-78.

24. Soni, N. and V.K. Singh, 2015. Molluscicidal activity of *Tamarindus indica* and *Terminalia arjuna* against *Indoplanorbis exustus*: A causative agent of trematodiasis. Sci. Agric., 12: 163-170.
25. Soni, N. and V.K. Singh, 2017. Screening of molluscicidal potential of indigenous medicinal plants *Terminalia arjuna* and *Tamarindus indica* against fasciolosis vector: *Lymnaea acuminate*. Asian J. Sci. Technol., 8: 5256-5261.
26. Kuo, P.L., Y.L. Hsu, T.C. Lin, L.T. Lin, J.K. Chang and C.C. Lin, 2005. Casuarinin from the bark of *Terminalia arjuna* induces apoptosis and cell cycle arrest in human breast adenocarcinoma MCF-7 cells. Planta Medica, 71: 237-243.
27. Rastogi, R.P. and B.N. Mehrotra, 1993. Compendium of Indian Medicinal Plants. Vol. 2, CSIR, New Delhi, India.
28. Wang, W., Z. Ali, Y. Shen, X.C. Li and I.A. Khan, 2010. Ursane triterpenoids from the bark of *Terminalia arjuna*. Fitoterapia, 81: 480-484.
29. Rastogi, R.P. and B.N. Mehrotra, 1993. Compendium of Indian Medicinal Plants. Vol. 1, CSIR, New Delhi, India.
30. Ahmad, M.U., K.B. Mullah, T. Norin and J.K. Ulla, 1983. Terminoic acid, a new trihydroxytriterpene carboxylic acid from bark of *Terminalia arjuna*. Indian J. Chem., 22: 738-740.
31. Wang, W., Z. Ali, X.C. Li, Y. Shen and I.A. Khan, 2010. 18,19-secooleanane type triterpene glycosyl esters from the bark of *Terminalia arjuna*. Planta Med., 76: 903-908.
32. Ali, A., G. Kaur, K. Hayat, M. Ali and M. Ather, 2003. A novel naphthanol glycoside from *Terminalia arjuna* with antioxidant and nitric oxide inhibitory activities. Pharmazie, 58: 932-934.
33. Alam, M.S., G. Kaur, A. Ali, H. Hamid, M. Ali and M. Athar, 2008. Two new bioactive oleanane triterpene glycosides from *Terminalia arjuna*. Nat. Prod. Res., 22: 1279-1288.
34. Anjaneyulu, A.S.R. and A.R. Prasad, 1982. Chemical examination of the roots of *Terminalia arjuna*-the structures of arjunoside III and arjunoside IV, two new triterpenoid glycosides. Phytochemistry, 21: 2057-2060.
35. Anjaneyulu, A.S.R. and A.V.R. Prasad, 1983. Structure of terminic acid, a dihydroxytriterpene carboxylic acid from *Terminalia arjuna*. Phytochemistry, 22: 993-998.
36. Upadhyay, R.K., M.B. Pandey, R.N. Jha, V.P. Singh and V.B. Pandey, 2001. Triterpene glycoside from *Terminalia arjuna*. J. Asian Nat. Prod. Res., 3: 207-212.
37. Yadav, R.N. and K. Rathore, 2001. A new cardenolide from the roots of *Terminalia arjuna*. Fitoterapia, 72: 459-461.
38. Rastogi, R.P. and B.N. Mehrotra, 1993. Compendium of Indian Medicinal Plants. Vol. 3, CSIR, New Delhi, India.
39. Pettit, G.R., M.S. Hoard, D.L. Doubek, J.M. Schmidt, R.K. Pettit, L.P. Tackett and J.C. Chapuis, 1996. Antineoplastic agents 338. The cancer cell growth inhibitory. Constituents of *Terminalia arjuna* (Combretaceae). J. Ethnopharmacol., 53: 57-63.
40. Yadav, R.N. and K. Rathore, 2000. A new cardenolide from the seeds of *Terminalia arjuna* (W&A). J. Asian Nat. Prod. Res., 2: 97-101.
41. Kapoor, S., 2002. The Indian Encyclopaedia: Biographical, Historical, Religious, Administrative, Ethnological, Commercial and Scientific. 1st Edn., Cosmo Publications, New Delhi, India, ISBN-13: 9788177552577, Pages: 318.
42. Aghera, H., V. Bundela, V.J. Shukla, P.K. Prajapati and M.B. Naira, 2015. A notable review on *Terminalia arjuna* and its imperative ayurvedic formulations: An overview. Int. Ayurvedic Med. Res., 3: 1814-1821.
43. Yesodharan, K. and K.A. Sujana, 2007. Ethnomedicinal knowledge among Malamalasar tribe of Parambikulam wildlife sanctuary, Kerala. Indian J. Tradit. Knowledge, 6: 481-500.
44. Muthu, C., M. Ayyanar, N. Raja and S. Ignacimuthu, 2006. Medicinal plants used by traditional healers in Kancheepuram district of Tamil nadu, India. J. Ethnobiol. Ethnomed., Vol. 2. 10.1186/1746-4269-2-43.
45. Kabir, H., 2002. Introduction to Ilmul Advia. 1st Edn., Shamsher Publisher and Distributors, Aligarh, India, pp: 42-59.
46. Vijaya, T., V.A. Krishna and P. Sujathamma, 2015. Medicinal uses of *Terminalia arjuna* Roxb.: A review. HortFlora Res. Spectrum, 4: 176-178.
47. Jain, S., P.P. Yadav, V. Gill, N. Vasudeva and N. Singla, 2009. *Terminalia arjuna* a sacred medicinal plant: Phytochemical and pharmacological profile. Phytochem. Rev., 8: 491-502.
48. Anonymous, 1999. *Terminalia arjuna*. Altern. Med. Rev., 4: 436-437.
49. Karunakaran, G., 2015. Cardioprotective role of methanolic extract of bark of *Terminalia arjuna* against *in-vitro* model of myocardial ischemic-reperfusion injury. Ancient Sci. Life, 35: 79-84.
50. Sivakumar, V. and S. Rajeshkumar, 2014. Screening of cardioprotective effect of *Terminalia arjuna* Linn. bark in isoproterenol-induced myocardial infarction in experimental animals. Int. J. Pharma Sci. Res., 5: 262-268.
51. Manna, P., M. Sinha and P.C. Sil, 2006. Aqueous extract of *Terminalia arjuna* prevents carbon tetrachloride induced hepatic and renal disorders. BMC Complement. Altern. Med., Vol. 6. 10.1186/1472-6882-6-33.
52. Sinha, M., P. Manna and P.C. Sil, 2008. *Terminalia arjuna* protects mouse hearts against sodium fluoride-induced oxidative stress. J. Med. Food., 11: 733-740.
53. Parmar, H.S., S. Panda, R. Jatwa and A. Kar, 2006. Cardio-protective role of *Terminalia arjuna* bark extract is possibly mediated through alterations in thyroid hormones. Pharmazie, 61: 793-795.
54. Pawar, R.S. and K.K. Bhutani, 2005. Effect of oleanane triterpenoids from *Terminalia arjuna*-a cardioprotective drug on the process of respiratory oxyburst. Phytomedicine, 12: 391-393.

55. Parveen, A., R. Babbar, S. Agarwal, A. Kotwani and M. Fahim, 2011. Mechanistic clues in the cardioprotective effect of *Terminalia arjuna* bark extract in isoproterenol-induced chronic heart failure in rats. Cardiovasc. Toxicol., 11: 48-57.
56. Varghese, A., J. Savai, N. Pandita and R. Gaud, 2015. *In vitro* modulatory effects of *Terminalia arjuna*, arjunic acid, arjunetin and arjungenin on CYP3A4, CYP2D6 and CYP2C9 enzyme activity in human liver microsomes. Toxicol. Rep., 2: 806-816.
57. Khaliq, F. and M. Fahim, 2018. Role of *Terminalia arjuna* in improving cardiovascular functions: A review. Indian J. Physiol. Pharmacol., 62: 8-19.
58. Borde, M.K., I.R. Mohanty, U. Maheshwari, R.K. Suman and Y.A. Deshmukh, 2018. Natural dipeptidyl peptidase-4 inhibitor *Terminalia arjuna* mitigates myocardial infarction co-existing with diabetes in experimental rats. J. Diabetes Metab. Disord. Control, 5: 48-56.
59. Manna, P., M. Sinha and P.C. Sil, 2007. Phytomedicinal activity of *Terminalia arjuna* against carbon tetrachloride induced cardiac oxidative stress. Pathophysiology, 14: 71-78.
60. Sivalokanathan, S., M. Ilayaraja and M.P. Balasubramanian, 2006. Antioxidant activity of *Terminalia arjuna* bark extract on N-nitrosodiethylamine induced hepatocellular carcinoma in rats. Mol. Cell Biochem., 281: 87-93.
61. Vishwakarma, A.P.S., A. Vishwa, P. Sahu and A. Chaurasiya, 2013. Screening of hepatoprotective potential of ethanolic and aqueous extract of *Terminalia arjuna* bark against paracetamol/CCl_4 induced liver damage in Wistar albino rats. Int. J. Pharmaceut. Arch., 2: 243-250.
62. Haidry, M.T. and A. Malik, 2014. Hepatoprotective and antioxidative effects of terminalia arjuna against cadmium provoked toxicity in albino rats (*Ratus norvigicus*). Biochem. Pharmacol., Vol. 3. 10.4172/2167-0501.1000130
63. Hebbani, A.E., V.D. Reddy and N.C. Varadacharyulu, 2015. Protective effect of aqueous bark extract of *Terminalia arjuna* against alcohol-induced hepato and nephrotoxicity in rats. Int. J. Phytomed., 7: 143-153.
64. Toppo, E., S.S. Darvin, S. Esakkimuthu, K. Buvanesvaragurunathan and T.A. Krishna *et al*., 2018. Curative effect of arjunolic acid from *Terminalia arjuna* in non-alcoholic fatty liver disease models. Biomed. Pharmacother., 107: 979-988.
65. Halder, S., N. Bharal, P.K. Mediratta, I. Kaur and K.K. Sharma, 2009. Anti-inflammatory, immunomodulatory and antinociceptive activity of *Terminalia arjuna* Roxb bark powder in mice and rats. Indian J. Exp. Biol., 47: 577-583.
66. Sharma, M.C. and S. Sharma, 2010. Phytochemical, preliminary pharmacognostical and antimicrobial evaluation of combined crude aqueous extract. Int. J. Microbiol. Res., 1: 166-170.
67. Morshed, M.A., A. Uddin, A. Rahman, T. Hasan and S. Roy *et al*., 2011. *In vitro* antimicrobial and cytotoxicity screening of *Terminalia arjunaethanol* extract. Int. J. Biosci., 1: 31-38.
68. Dube, N., C. Nimgulkar and D.K. Bharatraj, 2017. Validation of therapeutic anti-inflammatory potential of *Arjuna Ksheera Paka*-a traditional *Ayurvedic* formulation of *Terminalia arjuna*. J. Tradit. Complement. Med., 7: 414-420.
69. Reddy, T.K., P. Seshadri, K.K. Reddy, G.C. Jagetia and C.D. Reddy, 2008. Effect of *Terminalia arjuna* extract on adriamycin-induced DNA damage. Phytother. Res., 22: 1188-1194.
70. Verma, N. and M. Vinayak, 2009. Effect of *Terminalia arjuna* on antioxidant defense system in cancer. Mol. Biol. Rep., 36: 159-164.
71. Saxena, M., U. Faridi, R. Mishra, M.M. Gupta and M.P. Darokar *et al*., 2007. Cytotoxic agents from *Terminalia arjuna*. Planta Med., 73: 1486-1490.
72. Ramesh, A.S., J.G. Christopher, R. Radhika, C.R. Setty and V. Thankamani, 2012. Isolation, characterisation and cytotoxicity study of arjunolic acid from *Terminalia arjuna*. Nat. Prod. Res., 26: 1549-1552.
73. Ahmad, M.S., S. Ahmad, B. Gautam, M. Arshad and M. Afzal, 2014. *Terminalia arjuna*, a herbal remedy against environmental carcinogenicity: An *in vitro* and *in vivo* study. Egypt. J. Med. Hum. Genet., 15: 61-68.
74. Singh, S., S.K. Verma and S.K. Singh, 2017. Analysis of Anti-cancer potential of *Terminalia arjuna*. Int. J. Adv. Scient. Res. Manage., 2: 82-87.
75. Shalini, S., R.R. Kumar and S. Birendra, 2015. Antiproliferative effect of phytosome complex of methanolic extact of *Terminalia arjuna* bark on human breast cancer cell lines (MCF-7). Int. J. Drug Dev. Res., 7: 173-182.
76. Devi, R.S., S. Narayan, G. Vani and C.S.S. Devi, 2007. Gastroprotective effect of Terminalia arjuna bark on diclofenac sodium induced gastric ulcer. Chem.-Biol. Interact., 167: 71-83.
77. Devi, R.S., M. Kist, G. Vani and C.S.S. Devi, 2008. Effect of methanolic extract of *Terminalia arjuna* against *Helicobacter pylori* 26695 lipopolysaccharide-induced gastric ulcer in rats. J. Pharmer Pharmacol., 60: 505-514.
78. Chaudhari, M. and S. Mengi, 2006. Evaluation of phytoconstituents of *Terminalia arjuna* for wound healing activity in rats. Phytother. Res., 20: 799-805.
79. Mukherjee, P.K., K. Mukherjee, M. Rajesh Kumar, M. Pal and B.P. Saha, 2003. Evaluation of wound healing activity of some herbal formulations. Phytother. Res., 17: 265-268.
80. Dudhamal, T.S., 2016. Wound healing activity of *Arjuna* bark powder in *Dushta vrana* (Non healing venous ulcers)-a case report. J. Ayurvedic Herbal Med., 2: 102-103.

81. Rani, P. and N. Khullar, 2004. Antimicrobial evaluation of some medicinal plants for their anti-enteric potential against multi-drug resistant *Salmonella typhi*. Phytother. Res., 18: 670-673.
82. Aneja, K.R., C. Sharma and R. Joshi, 2012. Antimicrobial activity of *Terminalia arjuna* Wight & Arn.: An ethnomedicinal plant against pathogens causing ear infection. Braz. J. Otorhinolaryngol., 78: 68-74.
83. Jethinlalkhosh, J.P. and A. Antony, 2013. Antibacterial and cytotoxic activity of aqueous and methanolic extract of *Terminalia arjuna*. Int. J. Res. Pharm. Sci., 4: 36-39.
84. Javed, T., S. Riaz, M. Uzair, G. Mustafa, A. Mohyuddin and B. Ahmad, 2016. Biological activity of *Terminalia arjuna* on human pathogenic microorganisms. Pak. J. Pharmaceut. Res., 2: 23-27.
85. Kumar, V., N. Sharma, A. Sourirajan, P.K. Khosla and K. Dev, 2018. Comparative evaluation of antimicrobial and antioxidant potential of ethanolic extract and its fractions of bark and leaves of *Terminalia arjuna* from North-Western Himalayas, India. J. Tradit. Complement. Med., 8: 100-106.
86. Sun, F.Y., X.P. Chen, J.H. Wang, H.L. Qin, S.R. Yang and G.H. Du, 2008. Arjunic acid, a strong free radical scavenger from *Terminalia arjuna*. Am. J. Chin. Med., 36: 197-207.
87. Chen, C.H., T.Z. Liu, T.C. Kuo, F.J. Lu, Y.C. Chen, Y.W. Chang-Chien and C.C. Lin, 2004. Casuarinin protects cultured MDCK cells from hydrogen peroxide-induced oxidative stress and D NA o xidative damage. Planta Med., 70: 1022-1026.
88. Raghavan, B. and S.K. Kumari, 2006. Effect of *Terminalia arjuna* stem bark on antioxidant status in liver and kidney of alloxan diabetic rats. Indian J. Physiol. Pharmacol., 50: 133-142.
89. Cheng, H.Y., C.C. Lin and T.C. Lin, 2002. Antiherpes simplex virus type 2 activity of casuarinin from the bark of *Terminalia arjuna* Linn. Antivir. Res., 55: 447-455.
90. Bachaya, H.A., Z. Iqbal, M.N. Khan, A. Jabbar, A.H. Gilani and I.U. Din, 2009. *In vitro* and *in vivo* anthelmintic activity of *Terminalia arjuna* bark. Int. J. Agric. Biol., 11: 273-278.
91. Bodke, Y.D., M.A. Sindhe, R.K. Gupta and H. Manjunatha, 2013. Antioxidant and anthelmintic activity of *Terminalia arjuna* Roxb. stem bark extracts. Asian. J. Pharmaceut. Clin. Res., 6: 33-37.
92. Soni, N., D.K. Singh and V.K. Singh, 2017. Inhibition kinetics of acetylcholinesterase and phosphatases by the active constituents of *Terminalia arjuna* and *Tamarindus indica* in the cerebral ganglion of *Lymnaea acuminata*. Pharmacogn. J., 9: 148-156.
93. Soni, N. and V.K. Singh, 2016. Molluscicidal activity of *Terminalia arjuna* and *Tamarindus indica* against harmful snail. FSc. No. 8089, Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur, India.
94. Soni, N. and V.K. Singh, 2019. Toxicological safety assessment of molluscicides against non-target aquatic biota; *Colisa fasciatus*. Int. Ann. Sci., 7: 21-27.
95. Sivalokanathan, S., M.R. Vijayababu and M.P. Balasubramanian, 2006. Effects of *Terminalia arjuna* bark extract on apoptosis of human hepatoma cell line HepG2. World J. Gastroenterol., 12: 1018-1024.