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***Terminalia arjuna* (Roxb.) Wight & Arn.: Competent source of bioactive components in functional food and drugs**

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Abstract

Medicinal plants have been a major source of therapeutic agents to cure human diseases, since ancient time. *Terminalia arjuna* is one kind of widely used medicinal plant used in various indigenous system of medicine like Ayurveda, Siddha and Unani. This review has been conducted to pile up phytochemical, pharmacological information and application in ayurveda and food products about the *T. arjuna* that is available in different scientific literatures. Many studies of this plant have been reported to contain phytochemical constituents like triterpenoids, glycosides, flavonoids, tannins, β -Sitosterol, minerals (calcium, magnesium, zinc, copper etc.), which exhibit various pharmacological activities like antimicrobial, anticancer, cardioprotective, antifungal, antidiabetic, antioxidant, anti-inflammatory, hypolipidemic, anthelmintic, insecticidal, wound healing, antiacne, gastroprotective etc. The present comprehensive review is therefore an effort to give detailed information on botanical description, phytochemical constituents, phytochemical, pharmacological studies and application in ayurveda and food products of *T. arjuna*.

Keywords: *T. arjuna*, cardiogenic, anticancer, ayurvedic formulations, food products

1. Introduction

Man uses medicinal plants in many ways to meet his basic need that is food, clothing and shelter since ancient times. Plants have also been used as medicines for thousands of years all over the world. As per World Health Organization (WHO) 80% of world population still depend on medicinal plants. Mostly developed countries still rely on plant based medicines for primary care WHO 1978. Major traditional medicines which are been used has chemical compounds derived from medicinal plants. The attention among population increased due to their effectiveness, lesser side effects, increasing cost of modern medicines, cultural acceptability and lack of current medical alternatives [1]. Thus there has been a shift in universal trend from synthetic to herbal medicine, which we can say "return to nature" for the prevention of diseases and ailments. Due to its rich biodiversity of medicinal plants and abundance of traditional medicinal system the world is now looking towards India. In India large number of plant species are available for treatment of various diseases but in the modern medical system very few plant species are utilized.

Globally, medicinal are being studied in order to develop new molecules for use in pharmacology, nutraceuticals, food supplements, folk medicines etc. *T. arjuna* is one kind of widely used medicinal plant for health issues. In this regard one such plant is *T. arjuna* (Roxb.) Wt. and Arn. Which is a deciduous and evergreen tree distributed throughout India growing to a height of 20-30 m above ground level. The Classical names are Arjuna, Dhavala, Kakubha, Nadisarja, Veervriksha, Partha, Indradru [2,3]. The most common names of *T. arjuna* is Arjuna, Arjun (Hindi), Marudhu (Tamil and Malayalam), TellMaddi/Yella maddi (Telugu), Arjhan (Bengali), Sadaru (Marathi), Sadado/ Sadad (Gujrati), (Kannada) Neer Matti [1]. The bark powder has been found to possess cardioprotective properties, anti-ischemic, antioxidant action, hypercholesterolemia effect, fungicidal, antibacterial, antimicrobial, anti-inflammatory, immunomodulatory and antinociceptive activity. It is also have properties to cure obesity, hypertension and hyperglycemia [4]. The higher antioxidant potential of *T. arjuna* stem bark is due to the presence of higher amount of phenolic and flavonoids [5]. *T. arjuna* based phytochemicals can be used on daily bases as tonic to maintain the healthy cardiovascular system because it is considered as one of the best heart tonic [6,7].

The aim of present review is to highlight the Ayurvedic formulation, food products and phytochemical, pharmacological investigation carried out on this plant so that more pharmacological studies could be conducted to investigate the unexploited potential. It could be used in development of functional foods.

2. Botanical description

2.1 Scientific classification

Kingdom- Plantae
Sub kingdom- Tracheobionta
Division- Magnoliophyta
Sub Division- Spermatophyta
Class- Magnoliopsida
Order- Myrtales
Family- Combretaceae
Genus- *Terminalia*
Species- *arjuna*.

2.2 Habitat

The tree is large about 60-80 feet in height, evergreen with a spreading crown and having drooping branches, new leaves appear in hot season (February to April). This tree is exotic in India [8]. In India it is found in Uttar Pradesh, South Bihar, Madhya Pradesh, Delhi and Deccan region near ponds, rivers and bank of streams. Two trees of 26 feet and 32 feet in girth at 5 feet from the ground have been recorded in the village of Manipur in Jammu and Kashmir [3].

2.3 Cultivation. *T. arjuna* grown manually through ripe seeds, coppicing, pollarding, root suckers, stumps and air layering. It grows slowly in the initial phase but later on grows fast. It attains 2-3 meters height in three years [9].

2.4 Macroscopic characteristics

2.4.1 Leaves- The length of leaves are 15-25cm and 6- 7.5cm width. The leaves are simple, alternate thick- coriaceous, base obtuse- subcordate. Margin are crenate- serrate, apex is obtuse or subacute, pale green above, pale brown beneath, shallowly crenate- serrate, petiole is 0.6-0.9 cm long, oil gland observed at abaxial side of leaf near petiole [10].

2.4.2 Bark- The outer surface of the bark appeared smooth, pale greenish yellow while the inner surface is finely longitudinally striated and pinkish in color. Bark has pieces that are flat, curved and recurved in shape.

2.4.3 Flower- White or Yellowish flowers are found in groups. Flowering occurs in summer and fruit appears in winter or spring season.

2.4.4 Fruit- Fruits are 1-1.5 inch in diameter and 5-7 longitudinal lobes. These are glabrous with 5-7 wings, woody and fibrous. Fruit is drupe and is often notched near the top, marked with oblique upward curving striations.

3. Ethanobotany

T. arjuna is a plant which has various important uses in the traditional system of medicine. Traditionally stem bark, fruit, leaf and roots of *T. arjuna* are used to maintain good health. Out of several medicinal plants described, *T. arjuna* is one of the medicinal plants known to be beneficial for various cardiac ailments, in "Atharva Veda" "Vagbhattacharya" was the first one to cite the use of in the treatment of heart diseases

in his book 'Astang Hridayam' and the same was authenticated by Chakradattam and Bhavamisram. The plant is highly valued for its stem bark an important constituent in an Indian Medicine System. The bark has sweet, cooling and tonic effects. It acts as aphrodisiac, demulcent, styptic, anti-dysenteric, expectorant, alexitric, lithontriptic tonic. It is also good in some clinical conditions like fractures, ulcers, cough, excessive perspiration, fatigue, asthma, bronchitis, anemia, hypertension, urethrorrhoea, spermatorrhoea, leucorrhoea, diabetes, inflammation and skin disorders. The bark ash is also prescribed for snakebite and scorpion sting. The fruit of *T. arjuna* has tonic and deobstruent in effect. The juice of leaves is advocated for earache.

3.1 Ayurvedic formulation of *T. arjuna*

Kashaya and *Ksheerapaka* are two main ayurvedic formulations. *Kashaya* is water decoction and *Ksheerapaka* is milk extract. These *Kashaya* are mainly prepared by boiling the plant material in specified quantity of water till the active ingredients are extracted. This liquid is then strained through a muslin cloth and is used fresh. Decoctions can be used both internally and externally [11, 12].

Ksheerpaka is milk extract used from ancient time as a food and base of medicament. It possess high nutritive and medicinal value. *Ksheerpaka* is highly acceptable by healthy individuals and patients because of its important components like proteins, lipids, fatty acids, vitamin, enzymes and minerals. Qualities of milk have been potentially used as a medicine by combining it with different herbs as in the case of *Ksheerpaka*. It has been studied that on gradual increase in the temperature of milk, solubility of fats and proteins also increases, which may enhance the extraction of the medicinally important active constituents [13].

4. Phytochemical constituents

The chemical constituents of *Arjuna* present in root bark, stem bark, leaves, seeds and fruits. Root contains triterpenoids and glycosides, fruit contains triterpenoids and flavonoids, Leaves and seeds contain flavonoid and glycosides. But bark is considered most important constituent from medicinal point because it contains flavonoids, glycosides, polyphenols, tannins, triterpenoids, saponins, sterols and minerals such as calcium, magnesium, zinc, copper, amino acids also [14, 15]. Bark had 34% ash content consisting entirely of pure calcium carbonate. Aqueous extract of *T. arjuna* is reported to have 23% calcium salts and 16% tannins [9, 16]. The extracts of *T. arjuna* bark were also prepared by sequential method with various organic solvents such as ethanol, methanol, butanol, acetone, hexane, chloroform, ethyl acetate etc. All the active constituent of *T. arjuna* in stem bark, root, fruit, leaves and seeds are well characterized in table 1. The chemical structures of these compounds were confirmed by using various advanced techniques like thin layer chromatography (TLC), HPLC, reverse phase liquid chromatography (RP-HPLC) and ESI-LC-MS/MS analysis. For example Anti-oxidant compounds from leaves of *T. arjuna* has been isolated through silica column chromatography and by using different spectroscopic techniques [17].

4.1 Triterpenoids and glycosides

T. arjuna bark contain large amount of triterpenoids. Triterpenoids isolated from its bark are mainly arjunin, arjunetin, arjunic acid, arjugenin. Arjunoglycoside [1, 2] are also reported in stem bark [18]. Triterpane, terminoside A [19, 20]

and two more glycosides namely Termiarjunoside 1, Termiarjunoside 2 has found from bark [21]. Arjunglucoside IV and V, Arjunasides A-E were isolated from the ethanolic extract of the stem bark of *T. arjuna* [22].

4.2 Flavonoids

T. arjuna bark contains a very high level of flavonoids compared to other commonly used plant item. Flavonoids detected from its bark are namely arjunolone, flavones, bicalein, quercetin, kempferol and pelargonidin. The aqueous extract of *T. arjuna* contains 70% polyphenols having a molecular weight greater than 3.5 kDa [23]. Flavonoids are very important because of its anti mutagenic and antibacterial property. It is also act as strong anti- proliferative and antioxidant agents due to presence of free radical scavenging action of various phenolic contents.

4.3 Tannins

Various constituent of tannins are found in bark of *T. arjuna*. The constituent are Pyrocatechols, Punicallin, Castalagin, Casuariin, Punicalagin, Terchebulin, Terflavin C. Tannins are speculated to have astringent, hypotensive, wound- healing, antioxidant as well as antimicrobial effects [24][25]. They have multiple biological effects and also act as antioxidants by preventing the oxidation of Low-Density Lipoproteins (LDL), platelet aggregation and damage of red blood cells. Some of these substances have anti-fungal, anti-bacterial, antioxidant, anti-cancer, wound healing and hepato-protective effects [26, 27, 28, 29, 30].

4.4 Minerals and amino acids

The bark of *T. arjuna* contains large amount of various minerals and trace elements such as magnesium (4000 mg/g), calcium (3133 mg/g), zinc (119 mg/g) and copper (19 mg/g). It contains some amino acids such as tryptophan, tyrosine, histidine and cysteine [31].

Table 1: Phytochemical constituents of various parts of *T.arjuna* (Roxb.) wight and Arn.

Parts	Major chemical constituent	References
Stem bark	Triterpenoids	
	Arjunin	[23, 32]
	Arjunic acid	[15, 30, 33]
	Arjunenin	[31, 33, 37]
	Terminic acid	[33]
	Terminoltin	[19]
	Arjunolic acid	[33, 34, 35, 36, 37]
	Glycosides	
	Arjunetin	[23, 30, 32, 33, 34, 37]
	Arjunoside I, II	[18, 23, 30, 33]
	Arjunolone	[23, 30]
	Arjunolitin	[23, 37]
	Arjunaphthanolside	[38]
	Arjunglucoside IV and V, Arjunasides A-E	[20, 21]
	Olean-3b, 22b-diol-12-en-28 b-D-glucopyranosie-oic acid	[39]
	Terminarjunoside I and II	[21]
	Terminoside A	[40]
Termionic acid		
	Flavonoids and phenolics	
	Arjunone	[23, 37]
	Luteolin	[41]
	Baicalin	[42]
	Ethyl gallate	[1]
	Gallic acid	[41]
	Kempferol	[41]
	Oligomeric proanthocyanidins	[1]
	Pelargonidin	[1]
	Quercetin	[1]
	(p)-catechin, (p)-gallocatechin and (-)-epigallocatechin	[23]
	Gallic acid, ellagic acid and its derivatives such as 3-O-methyl-ellagic acid 4-O-b-D-xylopyranoside,	[1]
	3-O-methyl ellagic acid 3-O-rhamnoside	[1]
	3-O-methyl ellagic acid 4-O-a-L-rhamnophranoside	[22]
	(-)-epicatechin	[1]
	Tannin	
	Pyrocatechols	[43]
	Punicallin	[44]
	Castalagin	[45]
	Casuariin	[1]
	Casuarinin	[1]
	Punicalagin	[1]
	Terchebulin	[1]
Terflavin C	[1]	
	Minerals and trace elements	
	Calcium, magnesium, aluminum, zinc, copper, silica	[46]

	Other compounds b-Sitosterol	[19]
Roots	Triterpenoids Arjunoside I-IV Arjunolic acid Oleanolic acid Terminic acid 2a,19a-Dihydroxy-3Oxo-Olean-12-En28-Olic acid 28-O-b-D-glucopyranoside Arjunic acid Glycosides Arjunetosie (3-O-b-D-glucopyranosyl-2a, 3b, 19a-trihydroxyolean-12-en-28-oic acid 28-O-b-D-glucopyranoside)	[19] [19, 47] [1] [1] [48] [33, 34] [1] [49]
Fruit	Triterpenoids and flavonoids Arjunic acid, Arjunone, Arachidic stearate, Cerasidin, Ellagic acid Fridelin, Gallic acid, Hentriacontane, Methyl oleolate, Myristyloleate, b-Sitosterol	[50]
Leaves and seeds	Flavonoids and glycosides Luteolin, 14,16-dianhydrodigitoxigenin 3-b-D-xylopyranosyl-(1 > 2)-O-b-D-galactopyranoside	[41] [51]

The phytochemical screening of various extract of *T. arjuna* was performed. The presence of alkaloids, flavonoids, glycosides, terpenoids and saponins were performed. For the confirmation of these phytoconstituent in the plant extract, various numbers of tests were performed. Test for phytosterol was confirmed by salkowski’s reaction. Formation of brown color upon addition of few drops of conc. H₂SO₄ in the solution of chloroform with extract. Triterpenoids were confirmed by formation of reddish violet color upon addition of 1ml of chloroform and acetic anhydride to the extract. Saponins were considered to be present when the extract showed 1 cm layer of foam after giving a shake on addition of distilled water. Test for alkaloid was confirmed by Dragendroff’s test. On addition of few drops of Dragendroff’s reagent formation of orange brown precipitate indicates the presence of alkaloids. When extract is treated with few drops of alcoholic alpha- naphthol. Appearance of violet ring at interphase on addition of conc. H₂SO₄ along the side of test tube confirmed the presence of carbohydrate. Ninhydrin test was conducted to indicate the presence of protein. When the Keller- kiliani tests were conducted to indicate the presence of glycosides. Reddish brown color appears at junction of the two liquid layers and upper layer appears bluish green indicates the presence of glycosides. The standard methods for phytochemical screening are mentioned in Table 2.

Table 2: Preliminary phytochemical analysis of *T. arjuna* bark extract [8].

Phytoconstituents	Test
Phytosterol	Salkowski reaction
Triterpenoid	liebermann- Burchard’s test
Saponin	Foam test
Alkaloid	Dragendroff’s test
Carbohydrate	Molisch’s test
Proteins	Ninhydrin test
Glycosides	Keller- Killiani test.

5. Pharmacological studies

5.1 Antimicrobial Property

The antimicrobial screening of free and bound flavonoid from the bark of *T. arjuna* was analyzed. The study confined to explore the bark of *T. arjuna* for some bioactive compounds. Both bound and free flavonoid showed activity against all the selected pathogens but the maximum inhibition zone was observed against *Agrobacterium tumifaciens* (IZ= 19mm, AI=1.461±0.010) & *Bacillus subtilis* (IZ= 16mm, AI= 1.230±0.098) by the bound and free flavonoid extract of the

plant respectively [52].

The antimicrobial potential of *T. 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. 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 [53].

5.2 Antioxidant property

1) The protective effect of ethanolic extract of *T. arjuna* bark (TAA) was studied and its fractions, including dichloromethane (TAD), ethyl acetate (TAE), butanol (TAB) and water (TAW) against free radicals, protein oxidation and DNA damage. The maximum inhibition of DPPH, hydroxyl, ABTS, nitric oxide radicals and metal chelation was observed in TAE fraction (IC₅₀ values: 270 ± 2 mg/ml, 175 ±11 mg/ml, 25 ±1.2 mg/ml, 405 ±9 mg/ml, 310 ±11 mg/ ml, 82 ±4 mg/ml, respectively). According to this study the *T.* bark extracts ameliorate various impairments associated with DNA damage and free radical formation [54].

1) The hypolipidaemic and anti-oxidative properties of encapsulated herb (*T. arjuna*, 1.8%) added vanilla chocolate dairy drink was evaluated in high cholesterol fed Wistar rats for 60 days. The results demonstrated that the bioactive components (phytosterols, flavanoids, saponins and tannins etc.) which were present in the encapsulated *T. arjuna* not only withstand the processing conditions but also are effectively released in the intestine and show their effects, such as hypolipidaemic and antioxidant activities, for better treating cardiovascular disease [55].

2) The alcoholic extract of stem bark of *T.arjuna* (ALTA) was screened for antioxidant and antimutagenic (anticlastogenic) activity. The ALTA has shown potent antioxidant activity with EC₅₀ of 2.491±0.160, 50.110±0.150 & 71.00±0.250 in DPPH assay, Superoxide radical scavenging activity and lipid peroxidation assay, which is comparable with ascorbic acid with EC₅₀ of 2.471±0.140, 40.500±0.390 & 63.00±0.360 respectively. In micronucleus test, ALTA (100 & 200 mg/ kg, p.o) showed significant reduction in percentage of micronucleus in both polychromatic erythrocytes (PCE) and normochromatic erythrocytes (NCE) and also shown significant reduction in P/N ratio. The results suggested

that ALTA possess significant antioxidant and antimutagenic activity^[56].

- 3) The antioxidant activity and free radical scavenging capacity was determined. The extraction yields of extracts were ranged from 6.66-19.09g/100g (w/w) on dry weight basis. It was observed that *T. arjuna* extracts contained appreciable amount of TPC (6.02-11.00 g/100g, as gallic acid equivalent). The range of TFC was (1.75- 5.96 g/100g, as catechin equivalent) and DPPH radical scavenging activity was (IC₅₀ 2.71-7.68 µg/ mL), inhibition of peroxidation was (64.79-71.43%) and reducing power was (0.001-1.584 mg/mL). It can be concluded from the results that *T. arjuna* extracts were good source of natural antioxidants^[57].
- 4) Cu²⁺ ascorbate induced oxidative stress in goat red blood cell- an established model of oxidative stress *in vitro* was used for the investigation. Aqueous *T. arjuna* bark extract decreased the level of lipid peroxidation, increased the reduced glutathione content and decreased the protein carbonyl content in Cu²⁺-ascorbate treated RBCs. The activities of antioxidant enzymes, catalase and superoxide dismutase (SOD), were also found to be protected by this aqueous bark extract. Aqueous bark extract of *T. arjuna* was found to scavenge hydroxyl radical in a chemically defined system. It also exhibited superoxide anion radical scavenging activity^[58].
- 5) The antioxidant and anthelmintic activity of *T. arjuna* bark extracts were studied. The analysis for inorganic component in the sample indicated the presence of Cd, Mn, Cu, Ni, Pb, Zn, K and Na. The crude extracts were prepared from the *T. arjuna* stem bark and the preliminary phytochemical screening of crude extract indicates the presence of flavonoids, glycosides, triterpenoids, saponins and tannins in the crude ethanolic extract. From the observation, it was found that the phenolic and flavonoid contents were high in TAEE compared to other extracts^[31].

5.3 Anti-inflammatory Effects

The Arjun ksheera paka was prepared in cow milk (as per standard Ayurvedic procedure) and compared with standard hydroalcoholic extract of *T. arjuna*. The extracts were analyzed for gross phytoconstituents levels and their antioxidant activity was assayed by DPPH free radical scavenging activity and inhibition of lipid peroxidation. The percentage extraction yield of Arjun ksheera paka was two folds higher than hydroalcoholic extract implying that the phytoconstituents in Arjun ksheera paka were diluted by a factor of 0.5. The total polyphenol content of hydroalcoholic extract was (3.8 times) higher than Arjun ksheera paka and the antioxidant activity of hydroalcoholic extract was also higher compared to Arjun ksheera paka^[59].

5.4 Repellent and antifeedant activities

The repellent and antifeedant activities of *Saraca asoca* and *T. arjuna* bark extract to control *Sitophilus oryzae* were studied. The repellent activity against *S. oryzae* adults was more pronounced in methanol extract of *T. arjuna* bark as compared with *Saraca asoca* bark extract. The antifeedant activity against *S. oryzae* adults was greater in methanol extract of *T. arjuna* bark as compared with *S. asoca* bark extract. The potential insecticidal, repellent and antifeedant activity of *S. asoca* and *T. arjuna* bark extracts might be present in bioactive compounds. Therefore, *S. asoca* and *T.*

arjuna could be considered an ideal grain (Rice) protectant from the point of view of seed viability and safety to mammals^[60].

5.5 Cardiovascular activity

The research was investigated to know the effect of different schedules of administration of *T. arjuna* bark powder serum biochemistry of broilers chicks. A total of 72 (Arbor-Acres) day old chicks were used in this study. Four levels of Arjuna bark powder at the rate of .00%, 0.50%, 0.75%, and 1% were incorporated into the basal diet for five weeks. Feeding period for all groups was lasted for 35 days. Significant decreased total cholesterol, triglycerides and LDL was observed in Treatment T4 (1%). It is concluded that schedule on the basis receiving infusion three days in a week is more potent than other schedule of research study^[61].

5.6 Antihyperglycemic and Lipid Lowering Effect

The study performed on Type 2 model rats, which were made diabetic by the single intraperitoneal injection of Streptozotocin (STZ). The STZ has been shown to induce free radical production and cause tissue injury. The ethanol extract of *T. arjuna* was evaluated recently for its potent antioxidant potential against OH•, O₂•⁻ and lipid peroxidation. It has been shown that, due to high degree of some derivatives of arjunic acid like arjunoglycoside (I, II, III and IV), arjungenin, arjunolone, arjunetin, tanins, ellagic acid and it significantly decreased free radical damage and hepatic lipid peroxidation. After 21 days the antidiabetic effect of ethanolic extract of *T. arjuna* was found^[62].

5.6.1 Lipid lowering effect

Apart from the blood sugar lowering effect, beneficial changes in lipid profile have also been observed by *T. arjuna* extract. According to this study, ethanol extract of *T. arjuna* significantly decreased serum total cholesterol (p<0.05) and triglyceride (p<0.001). Considering triglyceride level, it was found that ethanol extract of *T. arjuna* decreased TG level more significantly (p<0.001) than glibenclamide treated group (p<0.05). The observed results suggesting that arjunic acid as well as its derivatives when undergo biotransformation by hepatic drug metabolism, produce common active metabolites, which probably responsible for lipid lowering activity. This demonstrates that *T. arjuna* ethanol extract have potential anti hyperlipidemic effect in type 2 diabetic model rats.

The anti-diabetic and haemolytic activity of aqueous stem bark extract of *T. arjuna* was investigated. Antidiabetic bioassay was done through estimation of blood counts, total cellular (i.e. proteins) and free haemoglobin content in diabetic blood plasma and also determined its haemolytic activity in human whole blood. The results suggest that aqueous stem bark extract of *Terminalia arjuna* showed anti-diabetic activity with respect to enhancement of granulocytes count and decrease in free haemoglobin content including total cellular content in diabetic human whole blood and plasma samples. *T. arjuna* aqueous stem bark extract revealed the presence of bio-active constituents which are known to exhibit anti-diabetic activities^[63].

5.7 Anti-cancer activity

The anti-cancer activity of *T. arjuna* was reported. An endophytic fungus, *Pestalotiopsis terminaliae* was isolated from *T. arjuna* leaves and was screened for the production of

taxol (anticancer drug). Sufficient amount of taxol 211.1 µg/litre was produced by fungus. The fungal taxol extracted from an organic extract of the fungal culture had strong cytotoxic activity towards BT220, H116, Int 407, HL 251 and HLK 210 human cancer cells *in vitro* when tested by apoptosis assay [64].

6. Incorporation of arjuna in food products

- 1) In India, about 39% of the total milk produced is converted into ghee and butter. The clarified milk fat, particularly ghee, has the characteristics to absorb all the medicinal properties of the herbs with which it is fortified, without losing its own qualities. Presently, the herbal ghee being marketed in the global market is mostly sold as medicine (medicinal ghee). These products possess a typical flavour, a bitter or pungent taste and a dark colour. Such therapeutic preparations are therefore not acceptable for regular consumption. Arjuna ghee has been developed for providing beneficial effects against CVD and the product was more stable to oxidative deterioration as compared to conventional ghee. The consumer acceptability of this product is also very good [65]. Unlike in case of medicated ghee preparations, in daily diet Arjuna ghee can be replaced with regular ghee. Also the antioxidant properties of herbs led their use into fat rich dairy products for retarding auto-oxidation there by prolonging the shelf-life [65, 66].
- 2) The study was performed on development of buffalo meat rolls by incorporating extracts from *T. arjuna* at 2, 4 and 6% level (each) for selecting optimum level of incorporation and their effect on the texture profile of the developed products. On the basis of sensory scores, 2% level of arjun tree bark extract were found suitable for incorporation and selected for further studies. The hardness, springiness and cohesiveness of the developed products were comparable to control samples. The buffalo male calf meat rolls with good sensory and textural properties can be developed by incorporating 2% arjun tree bark extracts [67].
- 3) Systematic comparison of high-performance liquid chromatograms of a standardized the *Arjuna churna* formulation and marketed formulations of *Arjuna churna* revealed eight common peaks at retention times of 1.5, 4.0, 22.0, 24.8, 31.8, 37.7, 39.3, and 44.2 min in an acetonitrile–water gradient program, which can serve as a fingerprint for *Arjuna churna* formulations. High-performance liquid chromatograms of isolated saponin and formulations of *Arjuna churna* showed the presence of six common peaks at retention times of 1.5, 4.0, 22.0, 24.8, 31.8, and 39.3 min in acetonitrile - water gradient eluted solvent system [68].
- 4) Herbal green tea was developed using *T. arjuna*. The nutritional, phytochemical, antioxidant and antibacterial activity showed that *Withania somnifera* stem, Cinnamon bark, *Tinospora cordifolia* stems, *T. arjuna* bark, Green tea and the formulation mixture of these herbs showed that they can be proven to be an excellent source of nutraceuticals and flavoring agents. Multiple health benefits featured in the blended formulation make it a perfect physical and psychological health rejuvenator. As sensory appeal matters the most to consumers more than health or nutritional benefits, so the above infusion will provide them with new alternatives to traditional flavored teas which can impart health benefits too [69].

- 5) The hypolipidaemic and anti-oxidative properties of encapsulated herb (*Terminalia arjuna*, 1.8%) added vanilla chocolate dairy drink was evaluated in high cholesterol fed Wistar rats for 60 days. Moreover, a significant decrease in serum lipids such as triglycerides, total cholesterol, low-density lipoprotein cholesterol, very-low-density lipoprotein cholesterol and atherogenic index was observed with encapsulated. The results demonstrated that the bioactive components (phytosterols, flavanoids, saponins and tannins etc.) which are present in the encapsulated *T. arjuna* not only withstand the processing conditions but also are effectively released in the intestine and show their effects, such as hypolipidaemic and antioxidant activities for better treating cardiovascular disease [55].

7. Toxicity/ Side Effects

T. arjuna has been used in the dose between 1 to 2 g per day and found that this is an optimum dose in the patients particularly CAD. These doses have lesser side effect like headache, mild gastritis and constipation. There were no reports in the regards of hematological, hepatic, metabolic and renal toxicity after more than two years of its administration. No haematological, metabolic, renal and hepatic toxicity has been reported even more than 24 months of its administration [70, 71, 72].

8. Conclusion

Herbs and their extracts have long been used for curing health related components and metabolic disorders as natural remedies. *T. arjuna*, the versatile traditional medicinal plant of India, is the rich source of bioactive compounds with diverse chemical structure. Functional components present in them aids in performing a wide range of biological functionalities. A considerable portion's functional food market consists of herbal supplemented functional foods. Research should be focused in development of food products enriched with medicinal plant. Scientific community must apply modern techniques to assure the efficacy and safety of herbs and their bioactive components for their use in food formulations.

A vast scope exists for undertaking well planned multi-disciplinary studies in this field in which at most importance should be given to the concepts behind Ayurvedic formulations.

Conflict of interest statement

We declare that we have no conflict of interest.

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