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PLANT REVIEW

Biological and Phytopharmacological Descriptions of *Litchi Chinensis*

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ABSTRACT

Plants remain a vital source of drugs and at present, much emphasis is given to nutraceuticals. Herbal medicines have been the basis of treatment and cure for various diseases and physiological conditions in the traditional methods practiced such as ayurveda and homeopathy. *Litchi chinensis* belongs to the Sapindaceae family and is well-known in the Indian traditional system for its traditional uses. The parts of the plant used are leaves, flowers, fruits, seed, pulp, and pericarp. All parts of the plant are rich sources of phytochemicals—epicatechin; procyanidin A2 and procyanidin B2; leucocyanidin; cyanidin glycoside, malvidin glycoside, and saponins; butylated hydroxytoluene; isolariciresinol; kaempferol; rutin; and stigmasterol. In the present review, we explore the lychee's description, traditional medicinal uses, and phytoconstituents, and investigate the pharmacological activities in various parts of the lychee to show its importance in ethanopharmacology. This is so that this review can serve as a ready-to-use material for further research on the plant.

Key words: *Litchi chinensis*, phytopharmacology, review

INTRODUCTION

Several phytochemicals possessing polyphenolic structures have been advocated as neutraceutical food supplements for better health care during recent years.[1] Ayurveda and the naturopathic system of medicine (indigenous to India) clearly state the use of medicinal plants for treating various disorders. India has a rich knowledge of phytotherapy from ayurveda and hundreds of potent drugs are yet to be evaluated scientifically. Keeping this in view, the lychee is one of the potential plants that has edible fruits and the other parts of which also have potent traditional application but it has not been studied much. So, this review will be a ready-to-use material for budding pharmacologists in the evaluation of the traditional uses of lychee, the botanical name of which is *Litchi chinensis*.[2,3]

TOXONOMICAL CLASSIFICATION

Kingdom: Plantae
Order: Sapindales
Family: Sapindaceae
Subfamily: Sapindaceae
Genes: Litchi
Species: *L. Chinensis*
Vernacular name: Nephelium litchi

GROWTH AND DISTRIBUTION

The lychee is cultivated in China, Sri Lanka, Taiwan, Thailand, Vietnam, Japan, India, Bangladesh, Pakistan, Nepal, Australia, Mexico, and parts of southern Africa. China is the main producer followed by India. The lychee has a history and cultivation going back as far as 2000 BC according to records in China. Cultivation began in southern China, Malaysia, and Vietnam. Wild trees still grow in parts of southern China and on Hainan Island. There are many stories of the fruit's use as a delicacy in the Chinese Imperial Court. It was first described and introduced to the West in 1782.

MORPHOLOGY

Litchi chinensis is an evergreen tree that is frequently less than 19 m (62 ft) tall, sometimes reaching more than 15 m (49 ft). The bark is grey-black and the branches brownish red. The leaves are 10–25 cm (3.9–9.8 in) or longer, with leaflets in two to four pairs. Lychee has similar foliage to the Lauraceae family, which is likely due to convergent evolution. The lychee plant adapts itself by developing leaves that repel water, which are called laurophyll or lauroid leaves. The flowers grow on a terminal inflorescence with many panicles on the particular season's growth. The panicles grow in clusters of

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Access this article online

Quick Response Code:

Website: www.phcogrev.com

DOI: 10.4103/0973-7847.176548

Cite this article as: Kilari EK, Putta S. Biological and phytopharmacological descriptions of *Litchi chinensis*. Phcog Rev 2016;10:60-5.

10 or more, reaching 10–40 cm (3.9 to 15.7 in) or longer, holding hundreds of small white, yellow, or green flowers that are distinctively fragrant.[4]

The fruits mature in 80–112 days, depending on the climate, location, and cultivar. Fruits vary in shape from round to ovoid to that of a heart. The thin, tough inedible skin is green when immature, ripening to red or pink-red, and is smooth or covered with small, sharp protuberances. The skin turns brown and dry when left out after harvesting. The fleshy, edible portion of the fruit is an aril, surrounding one dark brown inedible seed that is 1–3.3 cm long and 0.6–1.2 cm wide (0.39–1.30 in by 0.24–0.47 in). Some cultivars produce a high percentage of fruits with shriveled aborted seeds known as "chicken tongues." These fruits typically have a higher price as they have more edible flesh.[4]

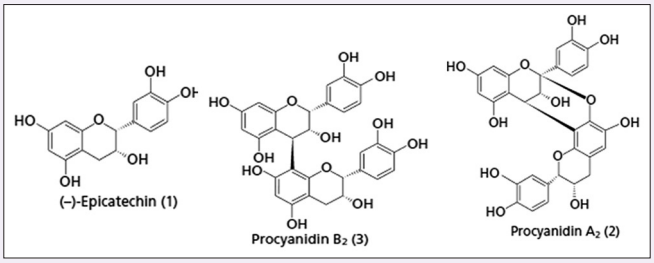
NUTRIENTS

Fresh whole lychee contains a total 72 mg of vitamin C per 100 g of fruit, an amount representing 86% of the daily value (DV). On an average, consuming nine peeled lychee fruits will meet an adult's daily vitamin C requirement but otherwise, the lychee supplies little nutrient content. A 100 g serving of raw lychee fruit provides, among other dietary minerals in minor amounts, 7% copper, 4% phosphorus, and 4% potassium (for DV in a 2,000-calorie diet). Lychees are low in saturated fat and sodium.

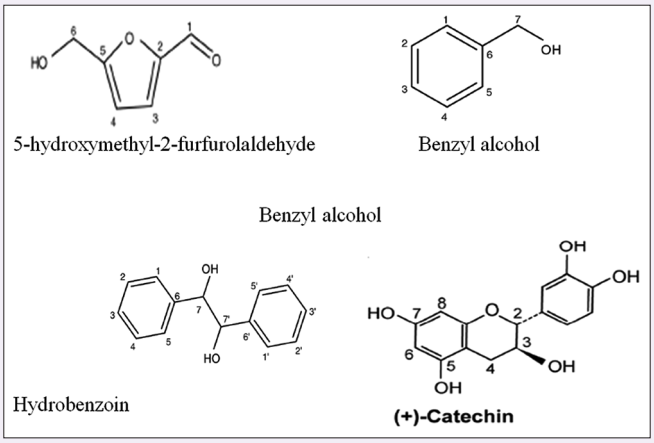
MEDICINAL USES

Phytochemicals

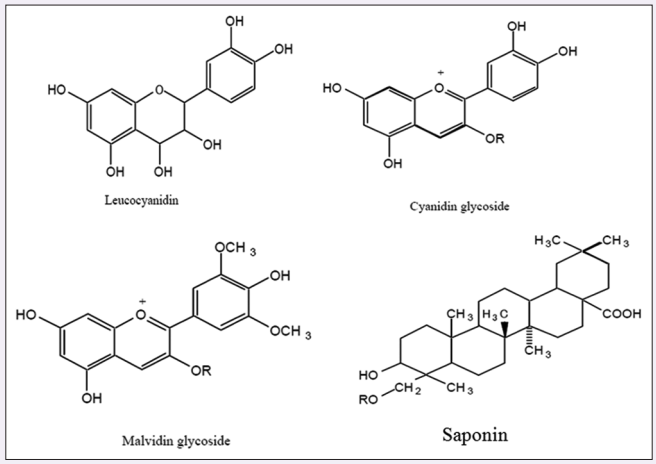
Leaves: (-)-Epicatechin, procyanidin A2, and procyanidin B2[5]



Fruit: 5-hydroxymethyl-2-furfurolaldehyde (5-HMF), benzyl alcohol, hydrobenzoin, and (+) – catechin[6]



Seed: Leucocyanidin, cyanidin glycoside and malvidin glycoside, and saponins



Pericarp: 5-2-(2-hydroxy-5- (methoxy carbonyl) phenoxy) benzoic acid, bis-(8-epicatochinyl) methane, butylated hydroxy toluene, epicatechin, dehydrodiepicatechin A, methyl shikimate, ethyl shikimate, isolariciresinol, kaempferol, methyl 3,4-dihydroxy benzoate, proanthocyanidin A1, A2, rutin, and stigmasterol[7]

PHARMACOLOGICAL ACTIVITIES

Leaves

Antioxidant activity

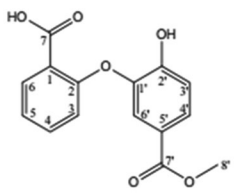
The antioxidant activity of the aqueous and organic extracts of leaves of *Litchi chinensis* was investigated using 2,2'-azinobis (3-ethylbenzothiazoline-6-sulpohonic acid) (ABTS) decolorization assay, the ferric reducing antioxidant power (FRAP) assay, 2.2'-diphenyl-1-picrylhydrazil (DPPH) assay, the total phenolic content (TPC) assay and the total antioxidant activity assay. Methanol, 1-butanol, aqueous, and ethyl acetate fractions of all the parts of *Litchi chinensis* showed strong DPPH and peroxyl radicals scavenging activity. The results obtained in the study demonstrated that all the parts studied were potential sources of natural antioxidants.[5]

Hepatoprotective activity

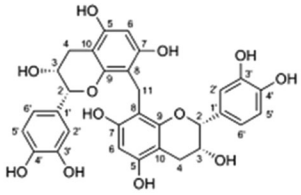
The chloroform and methanol leaf extracts from *Litchi chinensis* were studied for their protective effects on paracetamol-induced liver damage. The study evaluates the effect of *Litchi chinensis* on serum biochemical parameters serum glutamate-oxaloacetate transaminase (SGOT), serum glutamate-pyruvate transaminase (SGPT), serum alkaline phosphatase (SALP), total protein, bilirubin, cholesterol, and triglycerides and liver biochemical parameters such as lipid peroxidation, reduced glutathione (GSH) content, and catalase (CAT). The chloroform and methanol extracts of *Litchi chinensis* leaf offer potential hepatoprotection against paracetamol-induced hepatic damage, normalizing biochemical parameters in rats plausibly by augmenting endogenous antioxidant defense mechanisms.[8]

Anti-inflammatory and analgesic activity

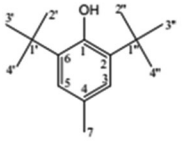
The potential of hydroalcohol extract of *Litchi chinensis* leaves (HLCL) was studied at three different dose levels for anti-inflammatory and analgesic activities. The preliminary phytochemical analysis of extracts indicated the presence of terpenoids, flavonoids, phenols, tannins, and saponins. The anti-inflammatory activity was evaluated by carrageenan-induced paw edema model in rats and analgesic activity was evaluated by acetic acid-induced writhing test and hot plate method in mice. Oral administration of HLCL exhibited a significant anti-inflammatory activity and maximum effect was observed after 4 h



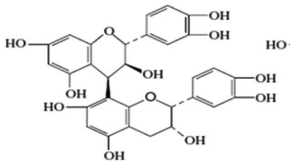
5-2-[2-hydroxy-5-(methoxy carbonyl)] phenoxy) benzoic acid



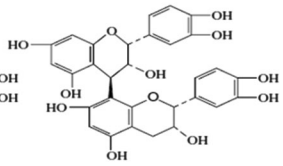
bis-(8-epicatochinyl) methane



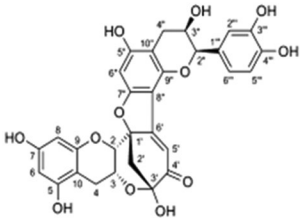
butylated hydroxy toluene



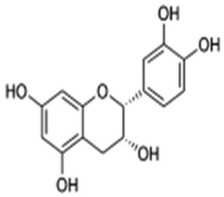
Proanthocyanidin B4



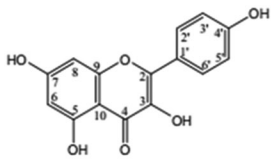
Proanthocyanidin B2



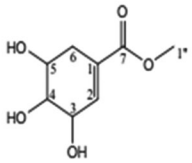
Dehydrodiepicatechin



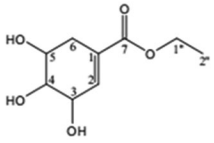
Epicatechin



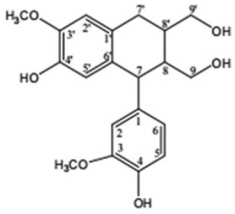
Kaempferol



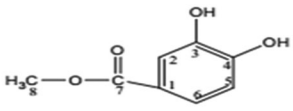
Ethyl shikimate



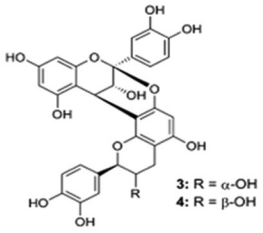
Mthyl shikimate



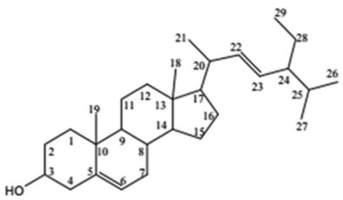
Isolariciresinol



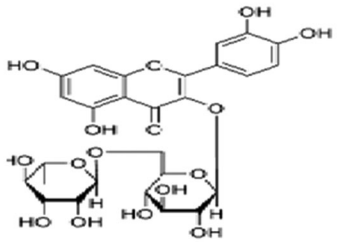
Methyl 3,4-dihydroxybenzoate



Proanthocyanidin A1, A2



Rutin



Stigmasterol

of carrageenan administration. Similar results were observed in the hot plate model indicating the analgesic activity.[9]

Flower

Cardiovascular activity

Lychee-flower-water extract (LFWE) contains phenols, flavonoids, and tannins. Ten male hamsters were assigned randomly to one of the following dietary groups: chow diet and normal distilled water (LFCD/NDW), high-fat/cholesterol diet, and normal distilled water. In gene expressions of lipid homeostasis in the high-fat/cholesterol-dietary hamsters, LFWE normalized the LDL receptor gene expression, downregulated FAS gene expression, and upregulated peroxisome proliferator-activated receptor alpha (PPAR-α) gene expression. LFWE enhanced the overall trolox equivalent antioxidant capacity (TEAC) of the serum, thus lowering serum lipid peroxidation [malonaldeyhde (MDA) content] in the high-fat/cholesterol-dietary hamsters.[10]

Anti-lipase activity

The water extract of *Litchi chinenesis* flower contains a wide range of phytochemicals–phenolic acids, flavonoids, condensed tannins, anthocyanins, and proanthocyanidins. The study was conducted to evaluate the anti-lipase effect of 2.5% and 5% of LFWE in hypercaloric diet-induced rats for 10 weeks. In the results, LFWEs showed inhibitory effect on *in vitro* lipase activities and were found to reduce the sizes of livers and perirenal and epididymal adipose tissues in 5% LFWE-treated groups. Hypercaloric-diet-fed rats increased serum cholesterol and liver lipid levels. However, drinking LFWEs also decreased these levels so that they were similar to that of the control rats. These results corresponded to the liver tumor necrosis factor alpha (TNF-α) and interleukin-1 beta (IL-1β) values, which were ameliorated in hypercaloric-diet-fed rats with LFWEs. The study concluded that the LFWE possesses a potential nutraceuticals for anti-obesity effects.[11]

Cytotoxicity

LFAE against cadmium (Cd)- and lead (Pb)-induced hepatocytotoxicity and transforming growth factor b1 (TGF-b1)-mediated activation of hepatic stellate cells (HSCs) were evaluated. Epicatechin, gentisic acid, and proanthocyanidin A2 are the major flavanoid, phenolic acid, and proanthocyanidin, respectively. LFAE addition could dose dependently decrease the Cd- and Pb-induced lipid peroxidation and DNA fragmentation, and increase the cell viabilities. LFAE can also suppress TGF- b1-induced activation of HSCs as concluded from the downregulating expression of smooth muscle a-actin (aSMA). These results finally demonstrated the effective antioxidant capacity of the lychee flower.[12]

Antioxidant activity

The acetone extract of *Litchi chinensis* flower extract showed DPPH radical scavenging activity and inhibiting low-density lipoprotein (LDL) oxidation due to the presence of phenolic components. The acetone extract of the flower with notable antioxidant capacities was suspended in water and sequentially partitioned with n-hexane, ethyl acetate (EA), and n-butanol. The EA partition with the highest phenolic levels and antioxidant capacities was subjected to silica gel column chromatography. (-)-Epicatechin and proanthocyanidin A2 were the two major compounds that could be isolated by semipreparative high-performance liquid chromatography (HPLC). Through mass spectroscopy (MS) and nuclear magnetic resonance (NMR) measurements. The study was the first attempt to reveal the efficacy of antioxidant components of lychee flower.[13]

Fruit

Aldose reductase activity

Litchi chinensis fruit extracts showed potent inhibitors of rat lens aldose reductase (RLAR) *in vitro* in both the methonolic and ethonolic organic fractions. From the active ethonolic fraction, four minor compounds with diverse structural moieties were isolated and identified as D-mannitol, 2,5-dihydroxybenzoic acid, delphinidin 3-*O*-β-galactopyranoside-39, 59-di-*O*-β-glucopyranoside, and delphinidin 3-*O*-β- galactopyranosid e-39-*O*-β-glucopyranoside. Among these, delphinidin 3-*O*-β- galacto pyranoside-39-*O*-β-glucopyranoside was found to be the most potent RLAR inhibitor and it may be useful in the prevention and/or treatment of diabetic complications.[14]

Prostaglandin E2 and nitric oxide production

Litchi chinensis fruit bears potent activities of induce prostaglandin E2 (PGE_2) and NO increase. The data of effects of hydrobenzoin, 5-hydroxymethyl (HMF), and benzyl alcohol on PGE_2 and NO production were coincident with cyclooxygenase-2 (COX-2) and inducible nitric oxide synthase (iNOS) messenger RNA (mRNA) expression and the NF-κB was the possible molecular mechanism. This study will provide the basic components' information supporting further well-controlled *in vivo* experiments and mechanisms of action; it also hopes to partially explain the "heating" in traditional Chinese medicine theory.[15]

Antiviral activity

The study was conducted to find out the inhibitory effect of Oligonol, a purified phenolic extract from *Litchi chinensis* fruit, on *Betanodavirus* infection in fish cells. *Betanodavirus*, a member of the family Nodaviridae, is the causal agent of viral nervous necrosis (VNN) in many species of marine farmed fish. Oligonol significantly inhibited the replication of *Betanodavirus*, as shown by the reduction of the virus-induced cytopathogenic effect (CPE) and the protection of cells in the crystal violet staining assay. The study concluded that the Oligonol partially inhibits attachment of the virion to the cell.[16]

Nootropic activity

Fruit of *Litchi chinensis* was evaluated in passive avoidance model (PAM) in mice, diazepam-induced amnesia model (DAM) in mice and sodium nitrite-induced hypoxia model (SHM) in mice for both the aqueous and alcoholic extracts. Piracetam was used as standard reference for the all the abovementioned models. Nootropic activity of the both extracts were tested at different dose levels and all the doses showed a significant nootropic effect by increased step-down latency (SDL), decreased time spent in the shock zone, and a number of errors in the passive avoidance paradigm. A significant increase in inflexion ratio was noted with all doses of extracts in the diazepam-induced amnesia model. In sodium nitrite intoxication model, both extracts showed a significant increase in cessation of respiration time in mice. Preliminary phytochemical investigation with both the extracts revealed a positive response regarding the presence of carbohydrates, flavonoids, tannins, triterpenes, Vitamin C, proteins, and amino acids.[17]

Anti-inflammatory effect

Flavanol (flavan-3-ol)-rich lychee fruit extract (FRLFE) is a mixture of oligomerized polyphenols primarily derived from the lychee fruit and is rich in flavanol monomers, dimers, and trimers. Supplementation with this functional food has been shown to suppress inflammation and tissue damage caused by high-intensity exercise training. The effects of FRLFE and its constituents on the expression of inflammatory genes in interleukin 1b (IL-1b)-treated rat hepatocytes were observed. FRLFE decreased the mRNA and protein expression

of the iNOS gene, leading to the suppression of IL-1b-induced NO production. FRLFE inhibited the phosphorylation of NF-kB inhibitor a (IkB-a) and reduced the mRNA levels of NF-kB target gene, TNF-a. The flavanols may have been responsible for the anti-inflammatory and hepatoprotective effects of FRLFE and may be used to treat inflammatory diseases.[18]

Pulp

Antioxidant activity of polysaccharide-enriched fractions

Antioxidant activities of four different polysaccharide fractions of *Litchi chinensis* were investigated using various *in vitro* assay systems. These four polysaccharide-enriched fractions exhibited a dose-dependent free radical scavenging activity as shown by their DPPH radical, superoxide anion, and hydroxyl radical inhibition, chelating ability, and reducing power. Among the different fractions, LFP-III showed the strongest scavenging activity against DPPH radicals, superoxide and hydroxyl radicals and chelating ability. This evaluation may shed the light on a better understanding on the potential of lychee fruit polysaccharides as a functional antioxidant for their high antioxidant activity.[19];

Hepatoprotective activity

Litchi chinensis fruit pulp extract was examined for vitamin C, phenolic contents, antilipid peroxidation activity, and hepatoprotective effect. In this study conducted on male Wistar albino rats, the rats were intraperitoneally injected (ip) with CCl (4) (2 ml/kg) and were then orally administered per os (PO) with silymarin (100 mg/kg), and *Lichi chinensis* (100 mg/kg and 500 mg/kg). After 10 days, the rats were sacrificed and their livers were examined histopathologically and immunohistochemically. Their serum glutamate-pyruvate transaminase, glutamate-oxalate transaminase, and alkaline phosphatase activities were analyzed. Apoptotic activity of the livers was assessed quantitatively. Antioxidant properties of *Litchi chinensis* were due to the presence of vitamin C and phenolic compounds; antilipid peroxidation and antiapoptosis can explain the hepatoprotective effects in CCl_4-induced hepatotoxicity.[20]

Hepatoprotective activity

The *Litchi chinensis* fruit pulp extract (alcoholic and aqueous) has shown hepatoprotective activity at the administered dose of 250 mg/kg body weight and 500 mg/kg body weight, orally. CCl4, a well-known hepatotoxin, produces liver toxicity due to generation of free radicals. Aqueous extract 500 mg/kg has shown protective activity that is comparable to the reference drug LIV-52. CCl_4-induced liver showed an increase in the liver weight due to the blocking of hepatic triglyceride secretion into the plasma; the extracts might have prevented this blockade, which might have been one of the reasons behind the decrease in liver weight. The protective activity shown may be due to their antioxidant activity of *Litchi chinensis*.[21]

Seed

Antimicrobial and antioxidant activities of the seed

Litchi chinensis seed extract was used for the antimicrobial test against all the selected bacterial strain gram-negative bacteria–*Klebsiella pneumoniae*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Proteus vulgaris* while the gram-positive bacteria used were *Staphylococcus aureus* and *Bacillus subtilis*. The extract showed a significant inhibitory effect; moreover, 1% of seed powder solution has shown higher antioxidant property than 1% ascorbic acid solution. So, the seed can be utilized as a therapeutic agent for the treatment of various types of diseases and as an antioxidant for preserving foods and neutralizing free radicals of the body.[22]

Pericarp

Antimicrobial activity

Aqueous pericarp extract of *Litchi chinensis* showed the presence of phenolic compounds, except for flavonoids. The antimicrobial activity of the aqueous pericarp extract of *Litchi chinensis* was studied by agar well diffusion method *in vitro*. The effect of the antimicrobial potential was examined by *Salmonella typhi, Vibrio cholerae, Shigella dysenteriae, Enterococcus faecalis*, *Escherichia coli*, *Klebsiella pneumoniae*, *Staphylococcus aureus*, and *Candida albicans*. The aqueous extract of the fruit pericarp showed consistently significant inhibitory activity on the different bacterial species tested and found the significance of antimicrobial activity of *Litchi chinensis*[23]

DNA protection effect of pericarp

Antioxidant activity was produced after fermentation of litchi pericarp extract (LPE) with *Aspergillus awamori*. Application of DNA cleavage assay further demonstrated the enhanced protection effect of the fermented phenolics on DNA damage. HPLC analysis showed that some new compounds such as catechin and quercetin appeared after *A. awamori* fermentation of LPE, which could account for the increased antioxidant activity and enhanced DNA protection capacity.[24]

Anticancer activity

Lychee fruit pericarp extract exhibited a strong inhibitory effect on the proliferation of both positive and negative breast cancer cells *in vitro* and inhibited the growth of estrogen receptor (ER) negative breast cancer *in vivo* in humans. The effect of Lychee fruit pericarp extract on proliferating inhibition and apoptosis induction of cancer cells through upregulation (CYP1A1 and ADPRTL1) and downregulation (BIRC3, ADAM9, and HMMR) of multiple genes, which are involved in the cell cycle regulation and cell proliferation, apoptosis, signal transduction and transcriptional regulation, motility, and invasiveness of cancer cells.[25]

Clinical trials

Lychee contains methylenecyclopropylglycine (MCPG) at lower level. The toxicant also called hypoglycin A. In animal experiments, MCPG has been found to induce encephalopathy and hypoglycemia. Encephalopathy is explained by the mitochondrial inhibition of fatty acid β-oxidation and accumulation of toxic metabolites.[26]

Litchi chinensis seed extract contains lectins. These lectins can agglutinate certain types of bacteria has been used for identification of certain antigenic types of organisms, so it could be made a possible to develop an identification procedure for clinical isolates.[27]

The oligomerized lychee fruit extract can induce endurance exercise performance more than vitamin C + vitamin E mixture or a placebo. Therefore, the study was designed as double-blind randomized controlled trial, with setting of the change of running time to exhaustion under submaximal treadmill test as the primary endpoint.[28]

Acute and short-term consumption of a lychee fruit extract, particularly rich in low molecular weight dietary flavanols, will improve vascular function and reduce platelet reactivity. So, a study was conducted regarding lychee fruit on vascular function and inflammation in postmenopausal women: A Double-Blind, Crossover Study.[29]

Interactions with drugs

Lychee may lower blood sugar levels. Caution is advised when taking insulin or drugs for diabetes: consumption by mouth should be monitored closely. Lychee may increase the risk of bleeding when taken with drugs including aspirin, anticoagulants such as warfarin or heparin, antiplatelet drugs such as clopidogrel, and nonsteroidal anti-inflammatory drugs such as ibuprofen or naproxen. It also

interacts with anticancer agents, anti-inflammatory agents, antivirals, cardiovascular agents, cholesterol- or lipid-lowering agents, immune modulating agents, or pain relievers.

Interactions with herbs and dietary supplements

Lychee may increase the risk of bleeding when taken with herbs and supplements that are believed to increase the risk of bleeding. Multiple cases of bleeding have been reported with the use of *Ginkgo biloba*, and fewer cases with garlic and saw palmetto.

Toxicological studies

Acute toxicity of lychee is a very low oral dosage of 20 g/kg, and there was no death were reported after 3 days of administration. There were no death reported after 3 days of Intragastric administration of 0.3 mL/10 g body weight of lychee seed extract three times a day. The mice were generally in a good condition and had no toxic manifestation; there was no death in the observation period of 14 days. Anatomical observation revealed that the heart, liver, spleen, lung, kidney, brain, and other organs had no abnormal changes. The maximum dose of lychee seed extract was 182 g/kg (crude drug) in mice in the oral acute toxicity test; the maximum dose of lychee seed extract was 87 g/kg (crude drug) in mice in the oral acute toxicity test.[30]

CONCLUSION

The chemical constituents of almost all parts of *Litchi chinenesis* have been investigated and a lot of bioactive and pharmacological *in vivo* and *in vitro* studies have been carried out as well. These results provided us a solid basis for the development and utilization of *Litchi chinenesis* as both a pharmaceutical and dietary supplement. The investigation in this area can lead us to thoroughly understand this plant and provide a foundation for safe and efficient use.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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