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Therapeutic potential of an edible macro-fungus: *Ganoderma lucidum* (Curtis) P. Karst

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A range of dietary products has been used in Asia as a common remedy to prevent or cure various diseases. The extracts from medicinal mushrooms (stem, butt and root rot) are utilized for the treatment of multiple diseases. As we know that mushroom is an abundant source of various minerals such as vitamins, fiber and different type of amino acids along with low in fat, cholesterol and calories. Carbohydrates and protein of proteoglycans are in 11.5:1 ratio. In addition, major 03 monosaccharides were present in carbohydrates i.e., D-glucose, D-galactose and D-mannose in the molar concentration of 3:1:1. The edible mushroom fungus, *Ganoderma lucidum* reportedly introduces many compounds as well as triterpenoids, polysaccharides, proteoglycans or glycopeptides, sterols, steroids and fatty acids with a role in prevention or cure for various diseases like that immunomodulation, anti-atherosclerotic, anti-inflammatory, analgesic, chemo-preventive, antitumor, antimicrobial, anti-HIV, anti-diabetic, anti-fibrotic, hepatoprotective, anti-androgenic, anti-herpetic, anti-angiogenic, antioxidative, free radical-scavenging, anti-aging, hypoglycemic along with estrogenic activity properties. This review summarizes the cultivation and biologically active compounds of *G. lucidum* with various therapeutic applications.

Keywords: Amino acids, Bioactive compounds, *G. lucidum*, Therapeutic activity
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G. lucidum is a basidiomycete belongs to the family of Polyporaceae. It is also known as '*Lingzhi'* in China, *'Reishi'* in Japan**,**'*Yeong Ji'* or '*Yung Gee'*or 'Seon-cho' in Korea, '*Linh chi'* in Vietnam and '*Lingzhi'* or '*ling chih' in* English[1,2]. It was commonly used as a traditional medicine in the orient for more than 2000 years[3]. The first mention of this mushroom dates from the period of the first emperor of China, Shih-Huang (221–227 BC) of the Ch'in Dynasty[4]. Members of the Ganodermataceae family are defined by distinctive double-walled basidiospores. The shape and size of basidiospores and the pileus surfaces are significant features that differentiate family members. The macro and micro-morphological characters are widely variable with more than 250 species being described[5]. Therefore, it is the most challenging genus among the polypores to be classified[6,7]. The variability of *Ganoderma* morphological features resulted in many taxonomists to investigate chemical and molecular techniques for discriminating between *Ganoderma* species.

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Mushrooms are known to be rich in high-quality protein, contain a high proportion of unsaturated fatty acid and have a nucleic acid content low sufficient to allow daily use as a vegetable. These fungi are used for medicinal purpose. Several studies have shown that *Ganoderma* parts have multiple medicinal impacts including inhibition of Ras-dependent cell transformation, anti-fibrotic activity, immune modulating activity and free-radical scavenging activities[8-11].

ATTRIBUTES OF *G. LUCIDUM* GENOME

The whole-genome sequence assembly of *G. lucidum* consists of 82 scaffolds, which contains 13 chromosomes with a complete length of genome assembly was 43.3 Mb. A total of 16,113 genes were predicted with an average length of sequence 1556bp. Percentage (%) of GC content is 55.9 and protein-coding gene GC content is 59.3. An average amount of exons per gene 4.7, while the average length of exons, introns, intergenic regions and coding sequence is 268bp, 87bp, 1206bp and 1188 respectively[12,13].

HISTORY

Names for the *lingzhi* mushroom have a two thousand year history. The Chinese term *lingzhi* was first used record maintains during the Eastern Han dynasty (25–220 CE). Karsten proposed the name of the genus *Ganoderma*[14]. Lingzhi is the Chinese name for *G. lucidum*. It means the *Spiritual Herb* that Energizes the *Chi* or Life force. The first Chinese Emperor Chin Shi Huang Ti even called it the *Herb of Deathlessness*. In the Emperors of the ancient period, the mushroom was considered so important that they have given it names like *The Elixir of Immortality*, *Herb of Spiritual Potency* and *Soup of the Emperor with a Thousand Mistresses*. The mushroom did not exist in China as medicine alone but also as a symbol of prosperity, immortality and energy as can be judged from the inscription carved on various parts of the royal palaces. English botanist William Curtis coined the term *Boletus lucidus,* for the *G. lucidum* in 1781. The term lingzhi botanical names have comes from Greek and Latin roots[15].

HABITAT & HABIT

It was reported to grow in the Northern Eastern Hemlock forests. Bracket fungus species have a global distribution in each of these tropical and temperate geographical areas as well as discovered in Amazon. It is native to Asian region[16,17]. Lingzhi arises on deciduous trees at base and stumps, particularly on maple[18]. Nowadays, Lingzhi is effectively grown indoor and outdoor on logs or woodchip beds under sterile conditions. It is a heterotrophic fungus. However, it often is also saprophytic and feeds on the organic tissue of a dead organism. In the case of *G. lucidum,* the dead tissue is usually from a few trees, which can diverge with the locality. However, it should be noted that in a few cases it is truly a parasite that attacks living trees. A parasite is a symbiotic relationship where one organism benefits and other organism have a loss. The hyphae enter into the plant at an injured or weakened area of the plant[19].

TYPES: *G. lucidum* (Reishi) has a different color such as Red, White, Black, Yellow, Purple and Blue/green. It was classified by color into 06 types (Table 1).

CULTURE AND CULTIVATION

CULTURE MEDIA: *G. lucidum* species were cultured on PDA media. The media were sterilized by autoclaving at 121-6°C (15 lbs psi) for 20 min.PDA was prepared accordingly[20] and included 200 gm Lit^{-1} potato extract, 20 g Lit^{-1} dextrose and 20 gm Lit^{-1} Agar.

Preparation of Mushroom culture from Mushroom Tissues: Young and vigorously growing mycelial tissue are used for culturing of mushrooms. Young tissues can be obtained after removal of the surface layers of tissues from the fruiting body. Firstly, fresh fruiting body of the mushroom is selected and washes with running tap water to remove dust/soil particles adhering to its surface. The outer layer of the fruiting body is removed by razor and with fresh tissue from the inner position of the fruiting body is taken out and excised into small pieces (2-4 mm), Surface sterilize with 0.1% mercuric chloride for few seconds. The cut pieces are then washed in sterilized distilled water three times aseptically and then finally inoculated into media slants in culture tubes or media in Petri plates. Cultures are incubated at 26˚C for the attainment of growth of the mushroom mycelium[21].

Spawn Preparation: The spawn was prepared on wheat grains in half-liter capacity glass bottles. For this, the grains were cleaned to remove the dust particle. After that, the grains were dipped into fresh water and washed. Then boiled (wheat grain and water 1:25 w/v) in water for 20-25 min, taking care not to break the grains during cooking. The boiled grained were spread over wired net for the removal of excess water and put for overnight for cooling at 20-25^{0}C. The cooled grain mixed with 1.2% of gypsum ($CaSO_4$) for prevention of stickiness between the wheat grain and 0.3% calcium carbonate ($CaCO_3$) maintained the pH 5.5-7.5. The grains were packed upto 2/3 of their ability in smooth glass bottles. The bottles were logged in non-absorbent cotton as well as coated with aluminum foil. Packed bottles were sterilized for 90 min at 121^{0}C and 15psi; sterilized bottles were removed from autoclave while still hot and shaken to prevent clumping of grains, followed by bottles were inoculated with bits of the aggressively growing culture of the different strains. Inoculated bottles were inoculated at 30±1˚C and shaking is done after 7 days[21]. The spawn was ready when the whole grain was surrounded with thin mycelial growth (Fig. 1). This spawn is known as mother or master spawn.

Substrate Preparation: Wheat straw used as a substrate and soaked in water with treated using Babustin 7.0 g + formalin 100 mL/100 L. for 18 h. The mouth of the tank was wrapped with polythene sheet to

avoid formalin evaporation. Moreover, straw was removed from the tank and retained for 2.3 h to drain out the water and spread for two hours on smooth cemented ground pre-treated with 2% formalin[21].

CULTIVATION: To cultivate the macro fungi the agricultural waste/straw of wheat was dipped in clean water for about 12 to 18 h and excess water was removed (waste material should contain the moisture to about 50 to 55%). The required material (waste material of wheat and rice @ 10%, magnesium sulphate @ 1%, calcium sulphate 0.5%) was taken in polypropylene bag of capacity 2 kg autoclaved at

Table 1 — *G. lucidum* (Reishi) was classified by color into six types

S.No.	Colour	Japan name	Taste	Medicinal Uses	Visibility	Reference
1.	Red	Akashiba	Bitter	Aids internal organs and improves memory		97
2.	White	Shiroshiba	Hot	Protects kidney		97
3.	Black	Kuroshiba	Salty	Improves lung function		97
4.	Yellow	Kishiba	Sweet	Strengthen spleen function		97
5.	Purple	Murosakishiba	Sweet	Enhances the function of eyes joints, helps complexion.		97
6.	Blue/ Green	Aoshiba	Sour	Improves eye sight and liver function.		97

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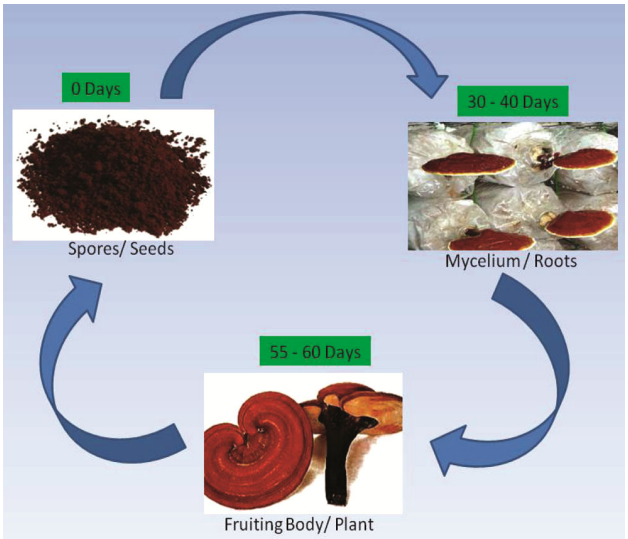

Fig.1 — Cultivation of *G. lucidum*

22 psi for 1.5 h. The seed (mother spawn) which is 5% of the straw material was shown on the above and keeping it at 25 to 28^{0}C. After 30 to 40 days network of fungi is done. After developing the network of fungi remove these bags and sprinkling with water 2 to 3 times in a day and maintaining the moisture about 85 to 90%. After 14 to 15 days harvesting of fruiting body and production is near about 150 to 220 g/kg of dry straw weight[21](Fig.1).

COMPOSITION: Total 90% of water content is present in mushroom. After removal of water mushroom powder consist of protein (10-40%), fiber (3-32%), carbohydrate (3-28%) along with less amount of vitamins and minerals[22] Apart from that *G. lucidum* has many distinctive bioactive molecules[23].

Amino Acid Analysis of *G. lucidum* Extract: The crude extract of *G. lucidum* consists of 15.6% proteins and various amino acid abundance is listed in Table 2 in decreasing order of relative abundance. Glutamic acid and methionine occur with maximum and minimum relative abundance respectively[24].

Biologically Active Compounds in *G. lucidum*: A numerous number of biologically active compounds have been reported in *G. lucidum* (Table 3). These compounds are associated with a variety of functions and effects. These include inhibition of sarcoma, neutrophils, apoptosis and phagocytosis. Many tumor and growth inhibitors, stimulation of interleukins and immune response, β-lymphocytes as antioxidants. The most important bioactive of *G. lucidum* include the triterpenoids (Ganoderic acids, Ganoderic Alcohols, Lucidenic Acids) and the polysaccharides[25]. The chemical structures of some bioactive compound are given in Fig. 2.

Table 2 — Relative abundance of amino acid in *G. lucidum*

S.No.	Amino Acid	Relative abundance
1	Glutamic acid	120
2	Aspartic acid	117
3	Glycine	108
4	Alanine	100
5	Threonine	66
6	Valine	61
7	Proline	60
8	Leucine	55
9	Serine	54
10	Isoleucine	36
11	Phenylalanine	28
12	Arginine	22
13	Lysine	21
14	Tyrosine	16
15	Histidine	12
16	Methionine	06

MAJOR THERAPEUTIC APPLICATIONS OF *G. lucidum*

Various number of clinical impact has been reported such as immunomodulating, anti-atherosclerotic, anti-inflammatory, chemo-preventive, analgesic, anti-tumor, sleep-promoting, anti-bacterial, anti-viral (including anti-HIV), hypo-lipidemic, radio-protective, anti-fibrotic, hepato-protective, anti-diabetic, antioxidative and anti-aging, free radical-scavenging, hypoglycemic and antiulcer effects in *G. lucidum*[20,26-28]. It is also identified as alternative medicine in the therapy of leukemia, hepatitis, carcinoma and diabetes[29-32]. Role of *G. lucidum* in a different therapeutic applications (Fig. 3) in detailed below.

Anti-Human Immunodeficiency Virus (HIV) effect: AIDS induced through HIV infection has become a significant social and medical issue with *in vitro* research of various *G. lucidum* triterpenoids have an efficient inhibitory activity toward HIV[33]. Likewise, Lucidenic acid and Lucidenic lactones that suppress the fuction of DNA polymerase in calf and rat, these two compound extracted from *G. lucidum*, along with inhibits HIV-1 RT[34]. McKenna et al. isolated Ganoderiol F and ganodermanontriol from its fruiting part are inhibit growth of HIV-1 with an IC_{100} of 7.8 μg/mL[26]. Additionally, some compounds like that, ganodermanondiol, ganolucidic acid A, ganoderic acid, ganodermanontriol and lucidumol B showed significantly anti-HIV-1 protease activity. It states that there is a structural activity connection for triterpenoids demonstrating against protease activity

Table 3 — List of Biological active compound present in *G. lucidum*

S.No.	Compound	Detection method	Function/ Nature	References
1.	Polysaccharides			
i	(1→3)-β-D-glucans	Chromatography	Inhibition of growth of sarcoma S 180 tumor in mice	80
ii	PS-G, protein-bound polysaccharides (95% polysaccharides and 5% peptides)	Biochemical	Activation of immune response, stimulation of the IL-1β, IL-6, TNF-α, and IFN-γ production by macrophages and T lymphocytes	40
iii			Inhibition of neutrophil apoptosis	81
iv			Induction of neutrophil phagocytosis	82
v			Induction of GST	83
vi	G009, aminopolysaccharides	Chromatography	Antioxidant	84
vii	Glycoproteins (with fructose)	Chromatography	Stimulation of IL-1, IL-2 and IFN-γ expression in spleen cells	85
viii	GLIS, proteoglycans	Chromatography	Activation of B-lymphocytes	86
ix	Cerebrosides	Chromatography	Inhibition of DNA-polymerase	87
2.	Triterpenes			
i	Ganoderic acid (U, V, W, X, Y)	Chromatography	Cytotoxic for hepatoma cells	88
ii	Ganoderic acid (A, C)	Chromatography	Inhibition of farnesyl protein transferase	43
iii	Lucidimol (A, B), ganodermanondiol, Ganoderiol F, ganodermanontriol	Chromatography	Cytotoxic for sarcoma and lung carcinoma cells	35,89,90
iv	Ganoderic acid F	Chromatography	Inhibition of angiogenesis	91
	Ganodermic acid G	Chromatography	Direct lethal effect on Meth-A cancer cell	89
	Ganoderic acid B	Chromatography	oxidization and hydroxylation were the common metabolic pathways for GAB in rats	92
	Ganoderic acid T	Chromatography	inhibit tumour invasion by inhibiting Matrix Metalloproteinase (MMP)-9 expression	17
	Ganoderic acid D	Chromatography	contribute to the apoptosis observed in HeLa cell	93
	Ganoderic acid 24	Chromatography	fungal apoptosis and enhancing Secondary metabolite production in fungi.	94
v	Phenols	Biochemical	Antioxidant	95
vi	Lipids	Chromatography	Growth inhibition of hepatoma, sarcoma S-180 and reticulocyte sarcoma L-II in vivo	96

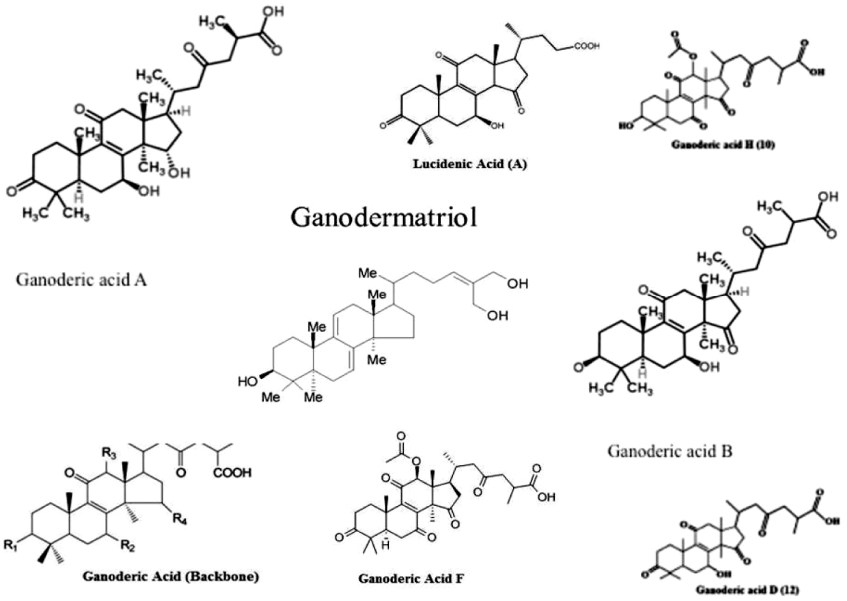

Fig.2 — Chemical structure of different terpenoids extracted from *G. lucidum*

of HIV with specially C3, C24 or C25 atoms of triterpenoids[35].

Immunological effects*:* *G. lucidum* comprises protein (LZ-8), polysaccharides (D-glucan) and

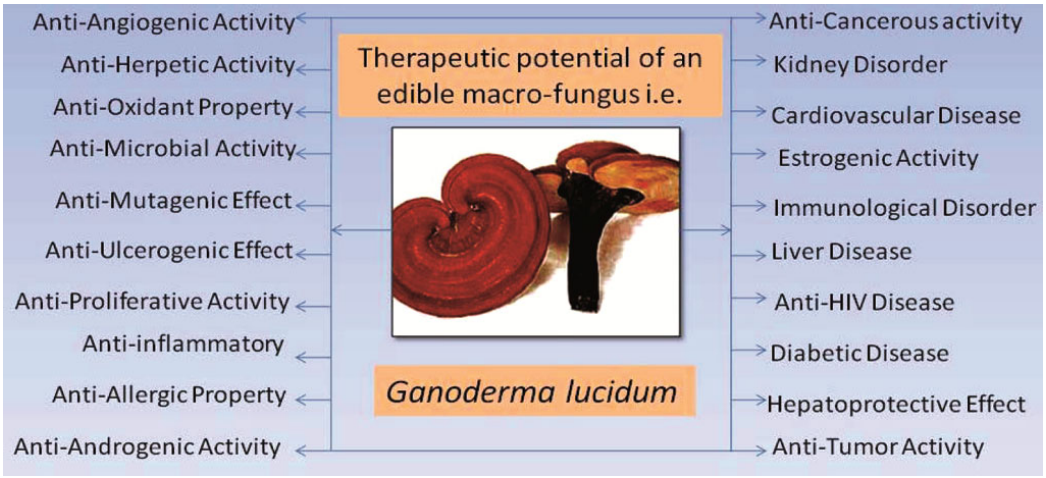

Fig.3 — Major therapeutic application of *G. lucidum*

triterpenoids, which showed the significant immunomodulating activity. The significant immunomodulating impacts of such active components include mitogenicity and activation of immune effectors cells i.e., T-cells, macrophages and NK cells, resulting in cytokine manufacturing, including IL, tumor necrosis factor (TNF-) and interferons. Different types of extracts of *G. lucidum* apotent activator of T cells, which produces a various number of cytokines specially IL-2[36]. Crude water extract of *G. lucidum* triggered the expression of different kind of cytokines such as IL-10, TNF-, IL-1, IL-6 and IL-2 in human PBMC (mainly T cells)[37]. A polysaccharide fraction (GL-B) facilitated development of IL-2 and significantly increased the effect of cytotoxicity in cytotoxic T lymphocytes[38]. In another study, a polysaccharide extracted using water increased the cytotoxicity of splenic NK cells in tumor bearing mice[39]. In our body, macrophages are the primary line of protection and its processing starts using the substance by *G. lucidum* resulting in cytokine-free, nitric oxide (NO) and other facilitators[40].

Effects on Complement System: Both classical and alternative pathways of complement system are activated by alkaline extraction of different compounds from mycelium of *G. lucidum*[41]. Fraction of it also stimulates mice reticuloendothelial system in carbon consent as well as improved hemolytic sign for development of spleen cells. The extract of alkali contains mainly 49% protein along with 10% carbohydrate. Another medical study reported that old patients with insomnia palpitation showed that *G. lucidum* essentially improved their C3 concentration for 4-6 weeks[42].

Antitumor Activity: Among the various compounds, polysaccharides (D-glucans, heteropolysaccharides and glycoproteins) and extracts of *G. lucidum* performed function against sarcoma 180 in mice[29], While, in case of triterpenoids, such as, ganoderic acids T-Z significantly showed activity in hepatoma cells *in vitro*[43]. A lanostanoid, 3-hydroxyl-26-oxo-5-lanosta-8,24-dien-11-one and a steroid, ergosta-7,22-diene-3,3,9–triol extracted from *G. lucidum* fruiting bodies showed potential suppressive effects on KB cells and human PLC/PRF/5 *in vitro*[44]. Among cases polysaccharide induces the immune function through foremost mechanism of antitumor action by *G. lucidum*. Between various polysaccharide only one of the significant substance (D-glucans) showed antitumor effects[45].

Anti-Diabetic Effects (Diabetes Mellitus): The aqueous extract of *G. lucidum* have a potential of hypoglycemic and hypolipidemic action for normalization of glucose concentrations in blood during alloxan-induced diabetes Wistar rats. This extract slows down the enhanced blood glucose level concentration within rats for glucose testing. Concerning adrenaline (iv) or oral glucose in rats, mushroom inhibited enhanced blood glucose without increasing blood insulin concentrations[46]. Glycans (ganoderans B, D) also showed important hypoglycemic action in mice, in which Ganoderan B was revealed to boost and reduce plasma insulin and hepatic glycogen quantity using a mouse model and alters the activity of glucose metabolizing enzymes in liver[47]. Clinical research was conducted to evaluate the anti-diabetic effectiveness of polysaccharide fractions obtained with *G. lucidum* (Ganopoly) by a patented method in 71 patients with reported Type II

diabetes mellitus[48]. Triterpenoids of *G. lucidum* were showed inhibitory activity on aldose reductase and α-glucosidase that can repress postprandial hyperglycemia[49].

Hepatoprotective Effect: Ganoderic acids R, S and ganosporeric acid A manifest the *in vitro* antihepatotoxic activity against hepatocytes cells in rat[50]. In another study the ethanolic extract of triterpenoids of *G. lucidum* can protect mice towards the disease of hepatic necrosis initiated by chloroform and d-galactosamine[24].

Anti-Inflammatory Property: The water extract of *G. Lucidum* was found to have important activity toward carrageenan in caused paw oedema when it applied intravenously to rats[51].Moreover, 100 distinct strongly oxygenated lanostanoid triterpenes were present in Reishi mushroom. Ganoderic acids A-Z are significant triterpenes. In addition the extraction of ganoderic acid C using non-polar solvent of *G. lucidum*. It has contained most anti-inflammatory activity using histamine release from mast cells detected through *in vitro* tests. Another group of scientists later discovered the rich content of ganoderic acids in ethyl acetate to show countable anti-inflammatory activity in conventional animal models, including the croton oil-induced mouse ear inflammation test[52].

Anti-Allergic Property: The *G. lucidum* fruiting portion was generally used as an anti-inflammatory agent to heal allergy or asthma. These two (allergy and asthma) are two significant examples of histamine-mediated allergic reactions[53]. The present strategy to anti-allergic studies is specific to a target, further another study; it is a potential cause in patients with a histamine-mediated allergic reaction to repair the balance among TH1 and TH2 cytokines[52].

Anti-Androgenic Activity: The Androgen-mediated diseases i.e. prostate cancer, hirsutism, acne androgenic alopecia and Benign Prostatic Hyperplasia (BPH) are considered as a massive issues[53]. The fundamental hormone behind prostatic androgen is dihydrotestosterone (DHT), that is produced from its substrate testosterone by the steroid enzyme 5-reductase (Type 1 & 2 isozymes)[54]. Further in another case, its ethanolic extract indicates inhibitory activity on 5-reductase (isozymes) and down-regulation of androgen receptor (AR) signaling via extracted ganoderol B from the fruiting part of it and gives the mechanism to ganoderol B binding with AR can reduce cell growth of androgen-induced LNcaP and ventral prostrate regrowth due to testosterone in rat[55]. TLC analysis recommended that *G. lucidum* triterpenoids may be a helpful substance in cure of BPH. Another research showed that extract of *G. lucidum* has the more significant 5-reductase inhibitory activity of BPH[56,57].

Anti-Angiogenic Activity: The Angiogenesis is a physiological method related to the development of new blood cells from previous blood cells. It is a common method in growth and development as well as tissue repair. This effect can significant factor to the treatment for cancer victims. The extract of *G. lucidum* performed the this activity and reduce the production of inducible free radical component such as nitric oxide (NO). In addition, 70% eththanolic extract of fruiting bodies (*G. lucidum*) showed these type of activity. Hence, It can be used as an admirable agent for controlling angiogenesis[58].

Anti-Herpetic Activity: Herpes simplex virus (HSV) caused the viral disease i.e. herpes simplex. It is of two types such as HSV-1 and HSV-2. *G. lucidum* has been showing the significant inhibitor of both HSV-1 and HSV-2. Acidic protein bound polysaccharide (APBP) extracted from the *G. lucidum.* which showed the anti-herpetic actions[59]. APBP was efficient toward viral activity in conjuction with HSV-1 and HSV-2 in vitro cells at an efficient quantity of 50% of 300 and 440 µg/mL. Protein bound polysaccharide like that GLhw, GLhw-01, GLhw-02 and GLhw-3 isolated from the *G. lucidum* and these polysaccharides showed the anti-hepatic activities[60]. Between APBP and GLhw-02, GLhw-02 contains the future prospective development of new antihepatic agent. Therefore, *G. lucidum* acts as a powerful inhibitor of both HSV-1 and HSV-2.

Anti-Oxidant Property: As we know that fungus has very less capacity for anti-oxidant activity, in contrast *G. lucidum* has been significant property of scavenging of free radicals as we as it contains lipid by oxidation reduction property[61]. The methanol and chloroform extracts of *G. lucidum* showed the antioxidant properties. Its chloroform extract does not show superoxide scavenging activity and it is of forthcoming understanding as major sources of ordinary antioxidants in the different food and cosmetic company[62].

Anti-Microbial Activity: So many research have shown that *G. lucidum* contains antimicrobial components that inhibit bacteria, viruses and fungi[32,63]. The aqueous extract of *G. lucidum* with combination of

four antibiotics (chloramphenicol, cefazolin, ampicillin and oxytetracycline) show the effects in main cases: Synergism in two situations while combined with cefazolin toward *Bacillus subtilis*, *Klebsiella oxytoca* and antagonism in two context, but in another research it was observed that some antifungal compounds were extracted from *G. lucidum* such as *Ganoderma* (antifungal protein)[63,64]. *Ganoderma* has inhibited the growth of mycelial in *Botrytis cinerea*, *Physalospora piricola* as well as *Fusarium oxysporum*. Five compounds extracted from *G. lucidum* carpophores in case of anti-viral activity such as GLhw, GLMe-1,-2,-4, and -7 noticeably inhibited the cytopathological impact of Vesicular Stomatitis Virus (VSV) and Herpes Simplex Virus (HSV)[65]. Polysaccharides of *G. lucidum* act as prebiotics composition has been also reported to decrease mice obesity by modulating gut microbiota structure and potentially contribute to the good health[66,67].

Estrogenic Activity: Osteoporosis, a bone deformity that results in an increased likelihood of fracture, is significantly affected by hormonal influences such as absence of estrogen (e.g. due to menopause), improves bone resorption and decreases the deposition of fresh bone that generally occurs in weight-bearing bones and has shown the preventive impact of osteoporosis by *G. lucidum*. According to the Song et al., the ethanolic extract of *G. lucidum* had significant impact on breast cancer in human being through proliferation of MCF-7 cells. This proliferation activity was inhibited by the addition of anti-estrogenic compound[57]. *G. lucidum* ethanol extract suppressed ovariectomy induced bone defeat and reduced the amount of osteocalcin in blood serum, comparable to 17-estradiol intervention. The research has given proof that ethanolic extract of *G. lucidum* has significant property against bone resorption that was induced by estrogen deficiency devoid of a significant impact on the uterus. There results indicated that *G. lucidum* may be a useful component for osteoporosis treatment.

Anti-Mutagenic Effect: Methanolic extract of *G. lucidum* showed the anti-mutagenic effect on hepatic infection caused by benzo[a]pyrene[68] and also reported significant inhibition ($p<0.001$). Dose-reliant His+ revertants were caused by invitro sodium azide (NaN_3), N-methyl-N-nitro-N-nitrosoguanidine (MNNG) & 4-nitro-phenylenediamine (NPD) and benzo[a]pyrene (B[a]P), as well as B[a]P function on hepatic enzyme i.e., serum glutamate oxaloacetate transaminase (GOT), glutamate pyruvate transaminase (GPT) and alkaline phosphatase (ALP). The methanolic extract as well prevented the amplify the SGOT, SGPT and ALP activities resulting to B[*a*]P challenge and enhanced the levels of different reduced glutathione (GSH) and activities of glutathione peroxidase (GPx), glutathione-*S*-transferase (GST), superoxide dismutase (SOD) and catalase (CAT) enzyme. The finding indicated that *G. lucidum* extracts revived antioxidant protection and avoided hepatic harm resulting in B[*a*]P challenge.

Anti-Ulcerogenic Effect: There are different types of ulcers detected such as oral, peptic, corneal, venous, genital. *G. lucidum* seems to be one of the curative ulcers. Polysaccharides of *G. lucidum* had a specific mucosal effect on the rat infected with indomethacin. The potential pathways associated were explored by determining the activity of the gastric mucosal mRNA and protein concentrations of TNF and ornithine decarboxylase (ODC). The study also examined the effects of GLPS on cell proliferation, ODC and c-Myc protein expression and mucus synthesis in the gastric cell culture (RGM-1). In addition, GLPS improved expression of c-Myc protein at a fixed concentration. These finding indicates the GLPS produced a mucosal healing effect in the rat, potentially primarlily owing to the removal of TNF, c-MYc and ODC gene induction. It may also be apparent that *G. lucidum* has an anti-ulcerogenic impact[25].

Anti-Proliferative Activity: *G. lucidum* causes apoptosis in leukemia, lymphoma along with numerous myeloma cells[63]. Using a number of human cancer lines, six hematologic cell lines together with leukemia, lymphoma and numerous myeloma cells were found to be most sensitive when *G. lucidum* extract was evaluated for its anti-proliferative activity. These finding show that *G. lucidum* extract might be a narrative adjuvant treatment for the cure for hematological malignancies. Ganoderic acid T (GA-T), a lanostane triterpenoid purified from the methanol extract of *G. lucidum* mycelia, has been found to be cytotoxicity on various cell lines of human carcinoma[69].

Cardiovascular: Introduction of 5% of the powdered mycelium of *G. lucidum* in diet of a rat for 4 weeks significantly decreased the total plasma cholesterol (by 18.6%) compared to controls. In the reishi-fed group, complete liver triglyceride and complete liver cholesterol concentrations were also considerably smaller[70,71].

Anti-inflammatory: *G. lucidum* extracts are an efficient anti-inflammatory agent. The fruiting body's water extract was effective orally against both carrageenan-induced infection and croton oil-induced infection. The extract of ethyl acetate was an anti-inflammatory agent both orally and topically. The active compound has been separated and recognized. This compound is similar to hydrocortisone in anti-inflammatory activity. This compound is similar to hydrocortisone in anti-inflammatory activity. It has not shown any typical side effects of steroids i.e. thymic involution, that does not appear to cause gastropathy, which is a significant side effect of non-steroidal anti-inflammatory drugs like that aspirin[72].

Industrial application of *G. lucidum*

The worldwide production of *G. lucidum* was 5000-6000 MT approximately, out of this more than fifty percentage production from only China[73,74]. As we know that, many of the products are available in the market, in which some are discussed here. Such as, CV Skinlabs Body Repair Lotion, USA and Skin relief face mask is a useful product for the wound healing and anti-inflammatory properties[75]. In addition, for the current of skin anti-aging and anti-wrinkle different product are present in the market like that, moisturizing body cream[76]. Guangzhou Bocaly Bio-tec and Guangzhou Ocean Cosmetic Beauty (www.vegamebeljepara.com), MAVEX (www.dazzlingroup.com) and Pureology Nano Words Shineluxe[77].

Conclusion

The *G. lucidum* is a traditionally medicinal macro-fungus that has been used since many thousands of years for its different biological activity. Most important components of *G. lucidum* are triterpenoids and polysaccharides. Triterpenoids have been exposed to reduce the toxicity of the liver, decrease the development of cancerous tumors, lower cholesterol and ameliorate complications linked to diabetes mellitus. *G. lucidum* polysaccharides also have cancer-fighting characteristics mainly owing to the modulation of the immune system and the cellular defense against free radicals. *G. lucidum* might have beneficial in the cure of anti-diabetic diabetes mellitus II. The fungus eliminates the toxicity caused by other therapies such as cancer radiotherapy. The elucidation of the *G. lucidum* genome allows this organism for further studying of secondary metabolites.

Future scope

Since last 40 years, the genus *G. lucidum* has been broadly researched in order to find new therapeutic metabolites. This review article has summarized to its various bioactive compounds with their therapeutic value, the majority of them being either lanosterol derivatives or polysaccharides. Some bioactive compounds with cytotoxicity against various cancer cell lines, anti-inflammatory, antiviral and hepatoprotective activity, along with the polysaccharides boost the immune system and exert free-radical scavenging activity. However, since this genus is one of the largest member belonging to the family ganodermataceae; there is still an abundance of room for further research. Mushrooms can also be utilized as bioreactors in the industry for the combination of proteins and pharmaceutical compounds[78]. Cultivation of new mushroom cultivars with narrative and enhanced characteristics will provide to a company with alternatives to solve food issues[79]and increase the efficiency of manufacturing.

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