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Review Article

NUTRITIONAL POTENTIAL, HEALTH EFFECTS AND STRUCTURAL DIVERSITY OF BIOACTIVE POLYSACCHARIDES FROM *LAGENARIA SICERARIA*: A REVIEW

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ABSTRACT

Lagenaria siceraria (family cucurbitaceae, herbaceous climbing plant) commonly known as bottle gourd, is a medicinal plant, various parts of which have been recognized for their pharmacological potential. The fruiting body of the plant is very popular for its palatability and high nutritive values comprising almost all essential constituents for normal and sound human health. The plant is a potential source of biologically active polysaccharides. The past three decades witnessed increasing investigation of the polysaccharides isolated from different parts of the plant, and the polysaccharides were reported to show immune-enhancing, anti-tumor, antihyperlipidemic, cardioprotective, analgesic, anti-inflammatory anti-diabetic, antioxidant and hepatoprotective effects. A diversity of structures has been proposed for several polysaccharides isolated from various parts of *L. siceraria*. Apart from other bio active properties, this plant through the process of bioremediation can potentially detoxify soil from heavy metals. This paper reviews the nutritional composition, different health beneficial effects as well as structural variations of the polysaccharides of *L. siceraria* and its environmental potential.

Keywords: *Lagenaria siceraria,* Polysaccharides, Pharmacological, Immune-enhancing, Antioxidant

1. INTRODUCTION

With the advancement of medicinal and nutritional science, herbal products and health promoting foods have drawn enormous attention of nutritionists and chemists. Being inspired by one of the laws of nature "Thy food be thy medicine" [1] human beings realized that, proper nutrition from plants can give healthy life. Out of this thought, plant medicines have been widely used as therapeutics for treatment of various diseases and found to be safer and less toxic than many synthetic drugs [2]. Now a days polysaccharides, isolated from vegetables and different parts of plants are found to show significant anti-tumor, immuno-modulatory, anti-inflammatory and antioxidant properties [3-9].

Lagenaria siceraria, commonly known as Lau (regional Bengali language) and bottle gourd (English), is a medicinal plant. This climbing or trailing herbs, with bottle or dumb-bell shaped fruits plant, is one of the earliest plants on the earth. Both its aerial parts and fruits are commonly consumed as vegetables. Since ancient age, its fruit has been used as vegetable and traditional medicine [10]. Probability of Colon cancer is reported to be increased by dietary fat through tumor promoters as bile acids and diacylglycerol [11]. *L. siceraria*, a good source of dietary prebiotics and non-digestible food ingredients, can improve the probiotic populations that affect enteric microbial metabolisms [12, 13] and suppress progression of colon cancer through reducing colon pH and bile acid concentration. The edible portion of its fruits is a very rich source of Soluble Dietary Fibers (SDF). Pectin is a major component of SDF that can lower serum cholesterol [14]. The fruit pulp is used as an antidote to certain poisons apart from showing antibilious and cooling effect [15, 16]. The anti-stress and adaptogenic activity of *L. siceraria* have been reported due to alteration in plasma cortisol, triglyceride, glucose, cholesterol and blood urea nitrogen that can stimulate or inhibit the sympathetic nervous system [17]. *L. siceraria*, through microwave assisted extraction release mucilage, that is used as a binding, thickening, emulsifying and stabilizing agent in food, cosmetics and pharmaceutical industries due to their capability of absorbing water, nontoxicity, biocompatibility and low price relative to synthetic polymers[18].

L. siceraria leaves have long been used for the treatment of headache and baldness. The juice of its leaves has been reported to effectively treat Jaundice and used as a very good laxative [19]. Flowers show effectiveness against certain poisons. Stem bark is diuretic in nature [20] and the roots are used for the treatment of dropsy. *L. siceraria* plants can absorb heavy metals and other toxins directly into their tissues.

In the present review, attempts have been made to compile different aspects that include but not limited to nutritional composition, traditional medicinal use and structural variations of different polysaccharides derived from *L. siceraria*.

2. NUTRITIONAL COMPOSITION

The edible portion of the fruit [21] has a fairly high proportion of carbohydrates, proteins, fibers and minerals like calcium, phosphorous, sodium etc (Table 1, Table 3) and is a rich source of ascorbic acid, vitamin B-complex, β-carotene, pectin dietary soluble fibers and amino acids [19-23] (Table 2). It contains high proportion of choline (1.6% on dry wt. basis), a precursor to acetyl choline, used to transfer nerve impulses and hence, it is reported to show valuable neurological effects [24]. Equal proportion of glucose and fructose with trace amount of sucrose and unidentified mono and di-caffeoylquinic acid derivatives were detected in the fruit bodies [25]. Sweet and bitter fruits are used as vegetable and medicine respectively. Bitter fruits contain triterepeniode cucurbitacins B, D, G, H and 22-deoxy cucurbitacin [16, 26]. Two steroids, fucosterol and campesterol were isolated from petroleum ether extract of the fruit [27].

Table 1: Nutritional Composition of fruits [28, 29] seeds [22] and leaves [30] of *L. siceraria* shown in percentage

Nutrients	*Lagenaria siceraria*		
	Fruits	**Seeds**	**Leaves**
Moisture	96.3	2.47	87.9
Carbohydrate	2.9	8.3	6.1
Protein	0.2	30.72	2.3
Fat	0.1	-	0.7
Minerals	0.5	-	1.7
Fiber	-	1.58	1.3
Ash	-	4.43	-
Oil	-	52.54	-

The fruit contains alkaloids, flavonoids, steroids, saponins and poly phenolic materials [31, 32]. Fruit juice contains β-glycosidase (elasterase enzyme) as ingredient [16]. Volatile profile of bottle gourd consists of aliphatic aldehydes such as octanal, nonanal and decanal with fruity, floral and citrus odours. Glycosidic precursors like 1, 4-benzenediol (12.51%), 2-pentadecyn-1-ol (17.87%), 9,12-octadecadienal and fatty acids such as palmitic acid and stearic acid are present in volatile aroma profile [33]. With peel, fruits have more amounts of minerals like iron, magnesium, zinc, phosphorous and less amount of sodium, potassium, manganese, copper than without peel [21]. The flowering plant extract of *L. siceraria* upon HPLC analysis shows the presence of flavones-C glycosides [34].

The seeds contain alkaloids, steroids, carbohydrates, fats, proteins, potassium, sodium, calcium, zinc and iron [35] (Table 1, Table 3). The oil from seed kernals is clear and pale yellow. Kernals from ripe seeds contain 45% of oil [36] with 0.54%free fatty acids and 0.67% unsaponified matter [23]. Seed oil having cooling effect can be effectively used in migraine type headache.

Table 2: Essential amino acid (EAA) composition [22, 37] of fruits and seeds of *L. siceraria*

Amino acids (gm/100gm dry wt.)	*Lagenaria siceraria*	
	Fruits	**Seeds**
Tryptophan	0.003	0.431
Threonin	0.018	0.903
Isolucine	0.033	1.264
Leucin	0.036	2.079
Lysine	0.021	1.833
Methionin	0.004	0.551
Cystine	--	0.301
Phenylalanine	0.015	1.222
Tyrosine	--	1.019
Valine	0.027	1.972
Arginine	0.014	4.033
Histidine	0.004	0.681
Alanine	--	1.158
Aspartic acid	--	2.477
Glutamic acid	--	4.315
Glycine	--	1.796
Proline	--	1.000
Serine	--	1.148

The free fatty acids are linoleic acids (64%), oleic acid (18.2%) and saturated fatty acids (17.8%) [38]. Glutamic acid (139-168mg/g protein) and aspartic acid (89-116mg/g protein) are the most abundant amino acids present in both the seed flours and protein fractions. The predicted biological value range and protein efficiency ratio [39] are 8.7 to 44.0 and 2.4 to 2.9 respectively. The amount of lysine present in the seed flours and their protein fractions of *L. siceraria* (37.5-60.1 mg/g protein) are comparable to that of egg protein [40]. The percentage of total essential amino acids (Table 2) present is (45.8% -51.5%) much higher than that required (36 %) for being considered as an ideal protein [41].

Table 3: Comparative Vitamin and Mineral composition [22, 37] (dry weight basis) of fruits and seeds of *L.siceraria*

Parameter (mg/100gm dry wt.)	***Lagenaria siceraria*** Fruits	Seeds
Vitamin C	10.000	1.900
Thiamin	0.029	0.210
Riboflavin	0.022	0.320
Niacin	0.320	1.745
Vitamin B6	0.040	0.224
Pantothenic acid	0.152	0.339
Vitamin E	16.02/g	1.000
Calcium	26	43
Iron	0.20	14.97
Magnesium	11	535
Phosphorous	13	1174
Potassium	150	807
Sodium	2	18
Zinc	0.70	7046
Copper	0.026	1.387
Manganese	0.066	3.02

The seeds are also reported to contain adequate amount of dietary proteins [42]. Being a rich source of good quality proteins, the seed flours and their protein fraction of *L. siceraria* might be used as pretty good food supplement. Cucumber green mottle mosaic virus (CGMMV) is present in *L. siceraria* cv. FR-King II seeds [43]. Leaves contain cucurbitacin B, D, E (trace), carbohydrates (Table 1) phytosterols, saphonins, phenolic compounds, tannins, amino acids and flavonoids [30]. Flavonoids, isolated from plant, are 4-C-glycosylflavone: 7-O-glucosyl-6-C-glucoside apigenin, 6-C-glucoside apigenin, C-glucosideluteolin and 7, 4-O-diglucosyl-6-C-glucoside apigenin [44]. Cucurbitacin B, D, E and triterpenebryonolic acid are constituents of root extract.

3. POLYSACCHARIDES AND BIOLOGICAL ACTIVITY

A water soluble heteropolysaccharide, methyl galacturonosylmethoxyxylan was isolated from the aqueous extract of the stem [45] of *L. siceraria* and found to be constituted of D-methyl galacturonate, 2-O-methyl D-xylose and D-xylose in a ratio of 1:1:1 (Table 4).

Another water-soluble polysaccharide, molecular weight ~78,000Da, isolated from fruits [46] of *L. siceraria*, showed cytotoxic activity on adenocarcinoma cell line MCF-7, and the IC_{50} value was 1.0μg mL^{-1}. This polysaccharide contains methyl-α-D-galacturonate, 3-O-acetyl methyl α-D-galacturonate and β-D-galactose residue in equal proportions (Table 4).

Table 4: Structural features of polysaccharides [45-47] from different parts of *L. siceraria*

Source (*L. siceraria*)	Extraction/Purification	Molecular Weight	Structural features (Linkages)
Stem	Hot water extraction Ethanol(1.5v/v) precipitation& Purification through Sepharose-6B	*1.67 X 10^5 Da*	(1→4)-α-D-Gal*p*A6Me,(1→3)-2-*O*-Me-β-D-Xyl*p* and (1→2)-β-D-Xyl*p* *(1:1:1)*
Fruits	Water extraction Ethanol(1.5v/v) precipitation& Purification through Sepharose-6B	*78,000 Da*	(1→4)-α-D-Gal*p*A6Me, (1→2)-3-*O*-Ac α-D-Gal*p*A6Me and (1→4)-β-D-Gal*p* (1:1:1)
Seeds	Hot water extraction Ethanol (1.5v/v) precipitation, 1% acetic acid &Purification through Sepharose-6B	*70,000 Da*	(1→4)-β-D-Gal*p*, (1→4)-α-D-Gal*p*A6Me and (1→2)-α-D-Gal*p* (1:1:1)

Similarly, a water-soluble polysaccharide, isolated from seeds [47] of *L. siceraria* is found to be composed of methyl-α-D-galacturonate, α-D-galactose and β-D-galactose in a 1:1:1 ratio (Table 4). At 10μg mL^{-1} of polysaccharide, splenocytes and thymocytes proliferation index were found maximum. Hence 10μg mL^{-1} concentration of polysaccharide has been considered as efficient splenocyte and thymocyte stimulator. 25μg mL^{-1}

was effective dose of polysaccharide for macrophage activation. It exhibited antioxidant activity also. Structural studies of these polysaccharides were carried out using chemical (total acid hydrolysis, methylation analysis and periodate oxidation studies etc.), 1D & 2D NMR spectral (^{1}H, ^{13}C, 2D-COSY, TOCSY, NOESY, HSQC, and HMBC NMR spectroscopy), and MALDI-TOF analysis.

L. siceraria polysaccharides can effect on immune function of red blood cells and cytokines in mice [48]. Fruits of *L. siceraria* are a source of polysaccharide that may be converted to reducing sugar. The non-edible portion (Peel) of the fruit was hydrolyzed using sulphuric acid at 75ºC.

Degradated materials turned to sugar [49]; yield is around 40-50%. Carboxymethylated starch, isolated from seeds of *L. siceraria* was studied for physicochemical and drug release properties by FT-IR, XRD and SEM. Modified starch with high degree of substitution has been used as a drug release retardant in sustained release formulations due to higher drug dissolution rate of this starch than native starch [50]. Pectinase is the enzyme responsible for degradation of pectins, the acid polysaccharides that is the main component of plant cell wall (21% dry weight basis). Peel and seed of bottle gourd exhibited maximum pectinase activity (4.8x10^{-3} U^{-1} min^{-1} gm) than pulp (2.8 x 10^{-3} U^{-1} min^{-1} gm) [51].

4. TRADITIONAL HEALTH EFFECTS

Traditionally, the fruit, leaves, stem, seeds and even whole plant of *L. siceraria* have been used as herbal medicine for the treatment of pain, fever, ulcer, piles, and jaundice, colitis, hypertension and skin diseases. Fruit juice has been used to relief from acidity and indigestion. Fruit pulp has been considered as purgative, cool, diuretic, antibilious [15, 20] and useful for the treatment of asthma, cough, other bronchial disorders and specific antidote to certain poisons [15, 20, 52]. In the Northern Telangana zone, the tribal communities (Koyas, Gutti Koyas and Lambadas) use the dry hard shells of bottle gourd fruits for different purposes. Bottle gourd is commonly known to the tribal people as anamgapkaya, burrakaya, anapakaya, sorakaya, and tumri. Several types of containers, bottle, bowl, milkpot, and spoon etc., made of dried shells are used for domestic purpose. Tribals, especially ethnic group of khammam district use the dry shells for carrying mahua drink, toddy (country liquor), honey and water. In few places, it is being used for making wind musical instruments and pipes. It has nutritionally low calorific value but the local people like the vegetable for cooking palatable dishes and pickles [53-55]. The Koya community uses wild bottle gourd as purgative. The Guttikoya tribals use it for treatment of headache by mixing seed oil with castor oil. It is also used to make glaze for cakes and sweets [56]. Kofta is the most famous vegetable curry among the people in India. Leaves of *L. siceraria* are very useful in the form of juice or decoction by adding sugar for treatment of jaundice. Crushed leaves are also used for treatment of headache and baldness. Seeds are used to treat toothache and gum infections. Health effects of different parts of *L. siceraria* are given in Table 5.

Table 5: Health effects of different parts of *L.siceraria*

Different parts of *L. siceraria*	Constituents present	Health effects of these constituents	Reference
Juice powder	Isolated compound	Serum cholesterol, triglycerides, LDL and HDL	57
Juice	Choline	Neurotransmitter acetyl choline	58
	Ellagitannins	Cardiac atherosclerosis	59
Seed	Lignin	Antitumor, antiviral, antiproliferative and anti-HIV	60
Seed extract	Pectic polysaccharide	Immuno enhancing and antioxidant activity	47
Fruit extract	Polysaccharide	Cytotoxic activity	46
Epicarp/Peel	Phenolic compounds	Antioxidant	61

5. HEALTH EFFECTS OF DIFFERENT PARTS OF L. SICERARIA

5.1. Fruit

The fruits of *L. siceraria* exhibited antithrombotic potential due to inhibition of ADP-induced platelet aggregation and non-cellular blood chemical mediators' involvement [62]. *Lagenaria siceraria* endornavirus-Hubei (LsEV-HuB), an RNA virus, was isolated from *L. siceraria* var. hispida. LsEV-CA (*Lagenaria siceraria* endornavirus California) is closest relative of LsEV-HuB, having

72.96% and 77.95% nucleotide and amino acid sequence identities respectively [63]. The latex sap of the dietary *L. siceraria* exhibited proliferation of lymphocytes and showed strong cytotoxic activity against cancer both *in vivo* and *in vitro*. Reduction of tumor with drastic decrease in tumeral neovasculature parallely occurred and detected from angiogenic parameters and abrogated related gene expression [64]. Bottle gourd juice shows chemopreventive effect against 7,12-dimethylbenz(a) anthracene (DMBA) plus croton oil induced skin papillomagenesis in swiss albino mice [65]. Heperlipidemia is storage of excess lipids, mainly cholesterol and triglycerides in blood. It may be called hyperlipoproteinemia as excess fats attached to protein in blood. *L. siceraria* fruit juice with cow urine and hydroalcoholic extract of the fruit with cow urine exhibited significant anti-hyperlipidemia effects in obese and hyperlipidemic rats [66]. The ethanolic extract of fruits reduces the risk of atherosclerosis by decreasing cholesterol, triglycerides, VLDL-c, LDL-c and increasing HDL-c levels in blood of rats [67].

Crude peel extract of bottle gourd showed highest anti-oxidant and reducing properties due to the presence of phenolic compounds such as methyl apigenin, acacetin, thymol, dicaffeoylquinic acid, phloridzin, isorhamnetin-3-O-hexoside and rosmarinic acid, identified from LCMS/MS analysis of EAF. Gold nanoparticles (size range 40-50 nm) were synthesized using bottle gourd peel extract and showed good anti-cancer activity against A431 skin carcinoma cells. The preparation of nanoparticles using bio-waste (peel) indicates alternative eco-friendly physical and chemical methods of biological applications [61]. The DPPH radical scavenging activity [51] of its peel, pulp and seed was found to be 70.58 %, 50.73 % and 41.92 % respectively at a concentration of 30 $\mu g\ mL^{-1}$.

Although the methanol extract of dried pulps of *L. siceraria* contains caffeic acid as the major constituent, isoquercetin is the key component responsible for showing antioxidant and α-glucosidase activities [68]. Dried bottle gourd pulp powder and whole bottle gourd pulp powder (fiber) can lower levels of plasma glucose after consumption [69]. *L. siceraria* fruit powder showed cardio protective effect against doxorubicin (Dox)-induced cardio toxicity in male wistar albino rats [70]. The oral application of powder prevents acute Dox-induced cardiotoxicity. Markers of cardiotoxicity i.e. CK-MB (creatine kinase) and LDH (Lactate dehydrogenase) were reduced significantly.

L. siceraria fruit juice contains sterol ester that may reduce serum cholesterol levels and risk factor of coronary artery diseases [71, 72]. Fresh fruit juice exhibited antihyperlipidemic activity by decreasing the blood cholesterol level of atherogenic diet rat [73]. Four constituents (LSN-1, LSN-2, LSN-3 and LSN-4) from *L. siceraria* fruit juice extract were isolated and tested for antihyperlipidemic activity against triton X-induced hyperlipidemia [57]. Antihyperlipidemic effect was studied with four different extracts viz. petroleum ether, chloroform, alcoholic and aqueous from bottle gourd in triton-induced hyperlipidemic rats. Oral administration of 200mg/kg and 400mg/kg of chloroform and alcoholic extract respectively exhibited significant affect in lowering total cholesterol, triglyceride and LDL along with an increase in HDL levels [74].

L. siceraria fruit was evaluated for its diuretic activity by Ghule et al. [75]. The activity was identified by measuring total urine volume, urine concentration of Na^+, K^+ and Cl^- ions. An oral dose of 100-200mg/kg showed maximum activity. Ethanolic extract of *L. siceraria* epicarp showed hepatoprotective activity in rats at doses of 100mg/kg and 200mg/kg and exhibited significant prevention of elevated levels of serum glutamate oxaloacetate, serum glutamate pyruvate transaminase, alkaline phosphatase and bilirubin [76].

Successive methanol extract of *L. siceraria* from n-butanol and ethyl acetate-soluble fractions indicated the presence of sterols and flavonoids mixers as oleanolic acid (1), sitosterol (2), campesterol (3), isoquercitrin (4) and kaempeferol (5). Compounds 1 and 4 inhibited delayed type hypersensitivity response in rats and increased phagocytosis through increasing the clearance rate of carbon from blood of mice [72]. Both specific and non-specific immune modulating activities are found in fruit extracts [77].

5.2. Stems

Four new D:C-friedooleanane-type triterpenes, isolated from *L. siceraria* stems exhibited cytotoxic activity against the SK-Hep1cell line. These are 3β-O-(E)-feruloyl- D:C-friedooleana-7,9(11)-dien-29-ol (1), 3β-O-(E)-coum-aroyl- D:C-friedooleana-7,9(11)-dien-29-ol(2), 3β-O-(E)-coum-aroyl- D:C-friedooleana-7,9(11)-dien-29-oic acid(3) and methyl 2β ,3β-dihydroxy- D:C-friedoolean-8-en-29-oate(6). Five known triterpenes with same skeleton, 3-epikarounidiol (4), 3-oxo- D:C-friedooleana-7,9(11)-dien-29-oic acid(5), bryonolol (7),bryononic acid (8) and 20-epibryonolic acid (9)were obtained.

Triterpenes 3 and 9 showed cytotoxic activity against the SK-Hep1cell line with IC_{50} values of 4.8 and 2.1 $mg.mL^{-1}$ respectively [78].

5.3. Seeds

Proteomic analysis of *L. siceraria* seed using phenol extraction method for protein isolation was done. Protein spots were identified by MALDI-TOF/MS analysis. These proteins have been found to be associated with various functions such as biosynthesis of plant cell wall polysaccharides and glycoproteins, serine/threonine kinase activity, plant disease resistance, transferase activity against insects, antimicrobial, anti-HIV and antihelmintic properties [79].

De-oiled bottle gourd seed is very nutritious material for edible oil industries. For the improvement of the quality of commercial biscuit, de-oiled bottle guard seed cake powder is added instead of traditional wheat flour [80]. Crude extract of seed exhibits antihelmintic potential in vitro using test worms, *Pheretima posthuma* [81]. *L. siceraria* seed extract [82] shows antimicrobial activities against *Staphylococcus aureus, Pseudomonas aeruginosa* and *Streptococcus pyogenes*. Lagenin, a novel ribosome-inactivating protein with ribonucleolytic activity, shows immunosuppressive, antiviral, antitumor, antiproliferative and anti-HIV activities [60]. A peptide having molecular weight of 678.9 Da, isolated from *L. siceraria* seed shows anti microbial and trypsin inhibitory activities [83]. The RLsAP1 and RLsAP2, two acid phosphatases exhibit enzymatic potential in energy transfer, releasing of inorganic phosphate and reducing the rate of phytate (anti nutrient) [84]. *L. siceraria* seed extract shows therapeutic antihelmintic potential in various worm infections. Pulverized seed kernels are used to expel intestinal worms [58, 76, 85-87].Oil was extracted from *L. siceraria* seed using a green process. Amount of oil yield depends on pressure, temperature and supercritical fluid's flow rate.

This seed oil is used in cosmetics, skin therapy and treatment of benign prostatic hyperplasia. Oil is added to make medicines for the treatment of acne, hyper-seborrhea, alopecia and hirsutism [88]. Three enzymatic activities *e.g.* phosphatase (0.71 ± 0.2Ul/mg), β-galactosidase (0.31 ± 0.03Ul/mg) and α-mannosidase (0.21 ± 0.02Ul/mg) were identified from the seed extract of *L.siceraria*. These enzymatics activities were found to be acidic (pH-4.6-5.6), mesophilic (55°C), stable in most cationic, non-ionic and anionic detergents [89]. Several bioactive proteins were isolated from bottle gourd plant. Protein fractions from seeds of bottle gourd showed strong anti oxidative and dehalogenase potential [90].

6. BIOREMEDIATION AND ENVIRONMENTAL POTENTIAL

Toxic heavy metal contamination of agricultural industrial soil and water is one of the major environmental problems. Conventional detoxification processes are expensive and create toxic by-products that affect the environment. So it is necessary to motivate our interest towards biological process. Bioremediation is a low cost simple technique that involves the living organisms (algae, bacteria, fungi and plants) for polluted waste water and soil detoxification. Mobility and toxicity of heavy metals [91, 92] in soil depend on their binding condition, specific forms and soil texture. Vegetable plants can accumulate heavy metals depending on the type of soil, plant species and its growth, environment and presence of other ions [93, 94]. Two processes namely, adsorption and absorption are mainly responsible for the process of metal uptaking. Under experimental conditions *L. siceraria* can uptake two toxic heavy metals [95], Ni (Nickel) and Pb (Lead) in concentration of 137.0 $mgKg^{-1}$ and 144.0 $mgKg^{-1}$ respectively. High metal concentrations in edible parts of vegetable can affect human nutrition and interfere metabolic process and growth [96].

7. CONCLUSION

L. siceraria is a well known medicinal plant with the global importance and is widely used in the Indian system of medicine. These plants also play an important role for people of remote area of developing countries for health purpose. The proximate and mineral compositions suggest that the fruit and seeds are good sources of carbohydrate, fats, protein and micro& macro minerals. These are natural foods having potential in maintaining good health and are known to be rich sources of various bioactive components having antibacterial, antioxidant, anticancer, antitumor, cytotoxic, anti-HIV and hypocholesterolemic effects. This plant is potential source of polysaccharides that boost immune system of the human body. One of the very important aspects of *L. siceraria* lies in the fact that, sufficient amount of many of the essential amino acids required for well-being and overall development of both preschool children and school going children are present in its seed flours and their protein fractions. From the point of view of pharmacological research and drug development, this plant is very important. Different parts of the plant are directly used as therapeutic agents as well as starting materials for the synthesis of drugs or as models for pharmacological compounds. Since these are non-narcotic elements, have very little or no side effects. Bioactive polysaccharides isolated from different plant constituents can be used to synthesize nanoparticles for therapeutic use.

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9. REFERENCES

1. McGuire M, Beerman K.A. Nutritional Sciences: from fundamentals to Food. Thomson Learning Inc., Belmont: CA; 2007.
2. Dubey NK, Kumar R, Tripathi, P. *Curr Sci,* 2004; **86(1)**:37-41.
3. Li HF, Ma FI, Hu MH, Ma CW, et.al. *Rejuvenation Res,* 2014; **17**:201-204.
4. Zou YF, Chen XF, Malterud KE, Rise F, et al. *Carbohydr Polym*, 2014; **113**:420-429.
5. Mandal EK, Mandal S, Maity S, Behera B,et al. *Carbohydr Polym*, 2013; **92**:704-711.
6. Das D, Maiti S, Maity TK, Islam SS, *Carbohydr Polym*, 2013; **92**:1243-1248.
7. Tong HB, Jiang GQ, Qi DK, Bi JF, et al. *Carbohydr Polym*, 2017; **156**:244-252.
8. Zhu Q, Jiang Y, Lin S, Wen L, et al. *Biomacromol,* 2013;**14(6)**:1999-2003.
9. Pan LH, Li XF, Wang MN, Zha XQ, et al. *Int J Biol Macromol*, 2014; **64**:420-427.
10. Sirohi PS, Sivakami N, *Ind Hort,* 1991; **36**:44-45.
11. Morotomi M, Guillem JG, LoGerfo P, Weinstein IB. *Cancer Res,* 1990; **50**:3595-3599.
12. Furukawa K, Yamamoto I, Tanida N, Taujia T, et al. Sixth annual meeting Japanese Research Society for Gastroenterological Carcinogenesis, Kobe: Japan; 1994, 1-2Sept.
13. Gibson GR, Roberfroid MB. *J Nutr*, 1995; **125**:1401-1412.
14. Chang SC, Lee MS, Li CH, Chen ML. *Asian Pracific J Clin Nutr,* 1995; **4**:204-210.
15. Van-Wyk BE, Gericke N. Peoples plants: a guide to useful plants of southern Africa. Briza Publications: Pretoria; 2000.
16. Duke JA. Handbook of phytochemical and constituents of GRAS herbs and economic plants, CRC Press: Boca Raton, Fla; 1999.
17. Lakshmi BVS, Sudhakar M. *J Pharmacol Toxicol,* 2009; **4(8)**:300-306.
18. Shah BN, Seth AK, Nayak BS. *Der Pharmacia Lett,* 2010; **2(2)**:202-205.
19. Chopra RN, Chopra IC, Verma BS. *Supplement to glossary of Indian medicinal plants, CSIR: New Delhi, India; 1992.*
20. Duke JA. Handbook of Biologically active Phytochemicals and their activities, CRC Press: Boca Raton, FL; 1992.
21. Modgil M, Modgl R, Kumar R. *J Human Ecol,* 2004; **15**:157-159.
22. Gopalan C, Sastri BVR, Balsubramanian SC. Nutritive value of Indian foods, National Institute of Nutrition: Hyderabad, India; 1996.
23. Habibur-Rahman AS. *Nat Prod Radiance,* 2003; **2**:249-256.
24. Thomas SC. Nutritional and therapeutic values of vegetables in: vegetable and fruits: Nutritional and therapeutic values, chap1, CRC Press: London; 2008.
25. Calabrese N, Venere D, Linsalata V. *ISHS Acta Hort,* 1999; **492**:179-186.
26. Evans WC. Trease and Evan's pharmacognosy, 14th ed, W.B.Saunders: London;1996.
27. Shirwaikar A, Sreenivasan KK. *Ind J Pharm Sci,* 1996; **58**:197-202.
28. CSIR, New Delhi. The Wealth of India- *A Dictionary of Indian raw materials & industrial products:* 1962; Vol.-VI, p.16-19.
29. Giri K. *Proc Ind Acad Sci B*, 1949; **29**:155-167.
30. Basu TK, Som MG, Kabir J. Vegetable Crops of India, revised ed, Prokash: Calcutta; 1993.
31. Ghule BV, Ghante MH, Saoji AN, Yeole PG. *Ind J Exp Biol,* 2006; **44**:905-909.
32. Irshad M, Ahmad I, Goel HC, Rizvi MMA. *Res J Phytochem*, 2010; **4(4)**:242-247.
33. Chatterjee S, Sharma J, Variyar PS, Sharma A. Elec *J Environ Agric Food Chem,* 2009; **8**:613-620.
34. Baoranoswka KM, Cisowski W. J Chromatogram A, 1994; **675**: 240-243.
35. Ojiako OA, Igwe CU. *J Med Food,* 2007; **10** : 735-738.
36. Warrier PK, Nambiar VPK, Ramankutty C. *Indian medicinal plants, Orient Longman Limited: Madras, India;* 1995.

37. USDA Nutrient Database Sr-15,NBD No.11218,1206
38. CSIR, New Delhi. The Wealth of India- *A Dictionary of Indian raw materials & industrial products:* 2004; Vol.-III, p.16-19.
39. Ogunbusola ME, Fagbemi TN, Osundahunsi OF. *J Food Sci Technol,* 2010; **47**:656-661.
40. FAO/WHO/UNU, Energy and protein requirements. Report of a Joint FAO/WHO/ UNU Expect consultation. WHO Technical Report series 742, WHO, Geneva; 1985.
41. FAO/WHO, Energy and protein requirements. Report of FAO Nutritional meeting series, No 52. Rome, Italy; 1973.
42. Fokou E, Achu MB, Techounguel FM. *Afr J Food Agric Nut Dev Rural Outr Prog,* 2004; **4(1)**:1-7.
43. *DuHyun K, JungMyung L. J Korean Society Hortic Sci, 2000;* **41(1)**:*1-6.*
44. Miroslawa KB, Cisowski W. *L LD Res, 1995;* **52**:137-139.
45. Ghosh K, Chandra K, Roy SK, Mondal S, et al. *Carbohydr Res*, 2008; **343**:341-349.
46. Ghosh K, Chandra K, Ojha AK, Sarkar S, et al. *Carbohydr Res*, 2009; **344**:693-698.
47. Ghosh K. *J Physical Sci,* 2015; **20**:225-238.
48. Abuiizi A, Maihemuti S, Abula S, Aini M. Heilongjiang Animal Science and Veterinary Medicine, *CNKI J,* 2015; **9**:179-181.
49. *Chandraju S, Venkatesh R, Chidan Kumar CS. Int J Curr Res Chem Pharm Sci,* 2014; **1(4)**:37-43.
50. Kulkarni SD, Sinha BN, Jayaram Kumar K. *Int J Biol Macromol,* 2013; **61**:396-403.
51. Shirsati SD, Kadam AS. *Int J Appl Biol Pharm Technol*, 2015; **6(2)**:58-67.
52. Nadkarni KM, Nadkarni AK. Indian Materica Medica, Vol-I, Popular Prakashan: Bombay; 1992. p.722-723.
53. Rood B. Kosuit die veldkombuis: Tafelberg, Cape Town; 1994.
54. Chittendon F. RHS Dictionary of plants plus Supplements, (1956) Oxford University Press: UK; 1951.
55. Summit G, Widess J. Making gourd musical instruments: over 60 string, wind and percussion instruments, and how to play them, Sterling Publication: New York; 1999.
56. Robinson RW, Decker-Walters DS. Major and minor crops, Cucurbits, CABI Publishing: USA; 2004, p.88-92.
57. Mohale DS, Dewani AP, Saoji AN, Khads CD. *Int J Green Pharm,* 2008; **2(2)**:104-107.
58. Milind P, Kaur S. *Int Res J Pharm,* 2011; **2(6)**:13-17.
59. Deshpande JR, Mishra MR, Meghre VS, Wadodkar SG,et al. *Nat Prod Radiance,* 2007; **6(2)**:127-130.
60. Wang HX, Ng TB. *Life Sci,* 2000; **67**:2631-2638.
61. Kumar V, Hussain PR, Chatterjee S, Variyar PS. *Int J Food Nutri Safety,* 2015; **6(3)**:125-149.
62. Rajput MS, Balekar N, Jain DK. *Chinese J Natural Med,* 2014; **12(8)**:0599-0606.
63. *Peng X, Pan H, Muhammad A, An H, et al. Archives of Virology,* 2017 doi: https://doi.org/10.1007/s00705-017-3664-y.
64. *Vigneshwaran V, Thirusangu P, Madhusudana, S., Krishna, V, et al. Int Immunopharmacol,* 2016; **39**:158-171.
65. Kumar N, Kale RK, Tiku AB. *Nutr Cancer*, 2013; **65(7)**:991-1001.
66. Kumar P, Sharma S, Patil HC. *Pharmacophore,* 2016; **7(6)**:295-321.
67. Rajput MS, Balekar N, Jain DK. *J Acute Dis,* 2014; doi: 10.1016/S2221-6189(14)60004-4
68. Sulaiman SF, Ooi KL, Supriatno. *J Agric Food Chem,* 2013; **61**:10080-10090.
69. Sharma **S,** Katare C, Prasad GBKS. *J Complement Med Alt Healthcare,* 2017; **2(4):**001-006.
70. Fard MH, Bodhankar SL, Dikshit M. *Int J Pharmacol*, 2008; **4:**466-471.
71. Amundsen AL, Ose L, Nenseter MS, Ntanios FY. *Amer J Clin Nutr,* 2002; **76:**338-344.
72. Gangwal A, Parmar SK, Sheth NR. *Pharm Commun,* 2009; **2**:46-50.
73. Nainwal P. *Int J Res Pharm Biomed Sci,* 2011; **2**:110-114.
74. Ghule BV, Ghante MH, Saoji AN, Yeole PG. *Ind J Exp Biol,* 2006; **44:**905-909.
75. Ghule BV, Ghante MH, Saoji AN, Yeole PG. *Int J Pharm Sci,* 2007; **69(6)**:817-819.
76. Deshpande JR, Choudhry AA, Mishra MR, .Meghre VS, et al. *Ind J Expt Biol,* 2008; **46**:234-242.
77. Mehta VB, Sharma VJ, Shaikh MF, Amin PD, et al. *Int J Res Pharm Sci,*2011; **2**:393-398.
78. Chiy-Rong C, Hung-Wei C, Chi-I C. *Chem Pharm Bull,* 2008; **56**:385-388.
79. Kumari N, Tajmul Md, Yadav S. *Appl Biochem Biotechnol,* 2015; **175**:3643-3656.
80. Patel AS, Pradhan RC, Kar A, Mohapatra D. *Curr Res Nutri Food Sci,* 2018; **6(3)**:720-733.

81. Gorasiya HJ, Paranjape A, Murti K. *Pharmacol Online,* 2011; **3**:317-324.
82. Gautam SS, Navneet KS. *Ind J Biotechnol Pharm Res,* 2013; **1**:23-26.
83. Shee C, Agarwal S, Gahloth D, Meena K, et al. *J. Plant Biochem. Biotechnol.,* 2009;**18**:101-104.
84. Koff, DM, Faulet BM, Gonnety JT, Bédikou ME, et al. *Philipp Agric Sci,* 2012; **95**:14-21.
85. Prajapati RP, Kalariya M, Parmar SK, Sheth NR. *J Ayurveda Integr Med,* 2010; **1**:266-272.
86. Gill N S, Singh S, Arora R, Bali M. *J Med Sci,* 2012; **12**: 78-84.
87. Chimonyo VGP, Modi AT. *Amer J Expt Agric,* 2013; **3**:740-766.
88. Said PP, Pradhan RC, Rai BN. *Ind crops prod,* 2014; **52**:796-800.
89. Koffi DM, Gonnety JT, Faulet BM, Bedikou ME. *J Appl Biosci,* 2010; **29**:1793-1808.
90. Choudhury RR, Verma HN, Sharma NK. *J Plant Sci Res,*2013; **29(2)**:145-158.
91. Rieuwerts JS, Ashnore MR, Farago ME, Thornton I. *Sci Total Environ,* 2006; **366(2-3)**:864-875.
92. Kashem MA, Singh BR, Shigenao K. *Nutr Cycl Agroeco-sys,* 2007; **77(2)**:187-198.
93. Rattan RK, Datta SP, Chhonkar PK, Suribabu K, et al. *Agric Ecosyst Environ,* 2005; **109(3-4)**:310-322.
94. Lokeshwari H. *Asian J Environ Sci,* 2006; **6(12)** :167-170.
95. Seshabala P, Chandra Sekhar Reddy P, Azeem Unnisa S, Mukkanti K. *Curr World Environ,*2007; **2(2)**:229-232.
96. Geldmacher VM. *Anal Chem,* 1984; **3(17)**:427-432.