Phytochemical and pharmacological review of *Solanum melongena* L.

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Abstract:
The eggplant (*Solanum melongena* L.) is a herbaceous, vegetable crop with coarsely lobed leaves, white to purple flowers, fruit is berry and are grown around the world mainly for food representing one of the best dietary sources of biologically active polyphenolic compounds, vitamins, antioxidants and medicinal requirements. The plant contains flavonoids, tropane, glycol-alkaloids, arginine, lanosterol, gramisterol, aspartic acid as important constituents. Metabolomics and metabolic profiling are important platforms for assessing the chemical composition of plants and breeders are increasingly concerned about the nutritional and health benefits of crops. The plant is reported to have analgesic, antipyretic, antioxidant, anti-inflammatory, anti-asthmatic, hypo-lipidemic, hypotensive, antiplatelet, intraocular pressure reducing, and CNS depressant and anaphylactic reaction inhibitory activities. In this review, an overview mainly on the historical background, phyto-chemistry and pharmacology with hepato-protective potential of Nasunin extracted from purple peels are discussed.

***Index Terms* – anthocyanin, brinjal, Carbon Tetrachloride, chromatography, Eggplant, hepato-protection, Nasunin, Paracetamol *Solanum melongena* L.**

I. INTRODUCTION

Eggplant, scientifically known as *Solanum melongena* L., is called as **aubergine** or **Guinea squash**, is a tender plant of the Solanaceae family commonly known as nightshade family, too. It is cultivated for its edible fruits. It requires a warm climate and has been primarily cultivated in South East Asia since ancient times. It is a staple food in the Mediterranean food. It is also national food of japan. It is consumed in various forms like baked, grilled, fried or boiled. It is closely related to potato (*S. tuberosum*) and tomato (*Solanum lycopersicum)* family as they all three belong from Solanaceae family.

Eggplant is an annually growing shrub featuring erect bushy stem often with spines and protrusions. They bear large ovate leaves which are slightly lobed. The flowers are pendant like violet in colour that are single bearing range of upto 5 cm (2 inches) across. The fruit is large purple coloured egg shaped glossy ranging from dark purple to red, pink, yellowish, or white and is sometimes striped. The common name is based on the fruit colour they bear.

S. melongena has been reported to possess extensive therapeutic properties as well as nutritional values, which might be owing to the presence of a myriad of bioactive constituents. These constituents can be categorized as flavonoids, saponins, phenolic acids, anthocyanins, alkaloids. Based on ethnobotanical claims and ancient literature, eggplant has been indicated in the treatment of several diseases, including asthma, bronchitis diabetes, and arthritis.

Phenolics are class of compounds that are basically secondary metabolites and are synthesized by the plant during basic metabolic and life cycle process like growth, reproduction and also as a protective agent against environment stress conditions, defense against infection by pathogens and UV radiation. (Karakaya, 2004, Naczk and Shahidi, 2004). These phenolic compounds have been categorized on the basis of phenolic rings and moieties attached to the rings. Commonly available phenolics in plant and vegetables are flavonoids and phenolic acids (Manach et al., 2004). Eggplant is regarded for its high phenolic content with strong anti-oxidant properties Cao et al. (1996) In the list of vegetables with highest anti-oxidant activity, eggplant tops in the list of 10 to be ranked at 2. In addition purple peeled eggplant is characterized for its highest content of purple colored anthocyanin pigment in peels (Wu et al., 2006, Koponen et al., 2007). It also contains high levels of phenolic acids in the flesh, especially chlorogenic acid (Winter and Herrmann, 1986, Whitaker and Stommel, 2003). Few studies have been performed to demonstrate the anti-oxidant efficacy of the fruit especially peels. These are systemically well absorbed and metabolized too (Noda et al., 2000, Hanson et al., 2006, Sarkar et al, 2019). It has also potential hypolipidemic activity and inturn hepato-protective activity which has been proved in animal experiment too (Sarkar et al, 2020).). The chemical structures and levels of phenolics in eggplant are the topics of the present review.

Solanum melongena Linn. belonging to the family Solanaceae, is considered as an important vegetable crop of tropical, subtropical as well warm temperate areas and is the most widely known edible fruits. [423] *S. melongena* is commonly known as eggplant, brinjal or aubergine, melanzane or berenjena. *S. melongena* L. has been cultivated for more than 2000 years ago in Southeast Asia, particularly in Northeast India and southeast China. [424] *S. melongena* fruits are popular and useful vegetables, and the colour of their peels is noted for its beautiful dark purple which is taken as a standard in dying from the olden time in Japan, being called as 'Nasu blue'. *S. melongena* L. is a rich source of vitamins and minerals which makes its value comparable with tomato which is economically the most important vegetable worldwide. Eggplant is an important food component of the human diet, and it has been extensively used as traditional medicine for treatment of many diseases. [425, 426]

Botanical description: [429, 430, 431, 432, 433, 434, 435, 436, 437]

Table 1: Scientific classification of *S. melongena* L.:

Scientific classification	
Kingdom	Plantae
Order	Solanales
Family	Solanaceae
Subfamily	Solanoidae
Tribe	Solaneae
Genus	*Solanum* L.
Species	*Solanum melongena* L.

Vernacular Names

- Sanskrit: Vartaku English: Brinjal
- Assamese: Bengena Hindi: Baingan
- Marathi: Vangi
- Bengali: Begun
- Malayalam: Kathrikka
- Kannada: Badane
- Telugu: Vankaya
- Tamil: Kathirikkai.

In the present review, light was thrown on phytochemical screening, anthocyanins and flavanols, their pharmacological properties with especial emphasis on hepato-protection are analysed. The potential of this plant to be developed as standalone drug of choice for hepato-protection is also discussed.

Abbreviations and Acronyms

Solanum melongena L.: *S. melongena*
2,2 Diphenyl 1 picrylhydrazyl: DPPH
Acetylcholinesterase: AChE
Polymorphonuclear NeutrophiL: PMN
agent tert-butyl hydroperoxide: tBOOH
2,2-azinobis-(3-ethylbenzothiazoline-6-sulfonate: ABTS
Paracetamol: PCM
Carbon Tetrachloride: CCl_4

I.1 TRADITIONAL USES OF *Solanum melongena* L.

S. melongena is one of the common vegetable with low calorie feature in the Mediterranean diet. It provides fibre and a variety of nutrients. *S. melongena* flowers and leaves have been extensively utilized as culinary ingredients in multiple parts of the world. Besides its use in cooking, it is also well recognized in medicinal systems of different civilizations. It is noteworthy that all parts of this plant have been utilized as traditional remedies for the treatment of various disorders. The conventional uses of *S. melongena* in Ayurveda and traditional medicinal systems of several countries such as Pakistan, Iran, Saudi Arabia, Jordan, Morocco, and Persian are reported for arthritis, weight loss, anaemia, antihypertensive etc.

I.2 PLANT PARTS AND THERAPEUTIC USAGE

Table 1

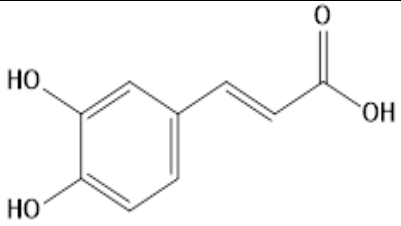
Plant part	Extract	Method followed	Inference
Fruit Peel	Acetone	• Trolox equivalent antioxidant capacity • Ferric reducing capacity antioxidant • power	Antioxidant activity
Whole Fruit	Methanol	• Total antioxidant capacity • Superoxide radical scavenging • Total reducing power assay • DPPH radical scavenging	Antioxidants activity
Fruit pulp	Aqueous	• Human Polymorphonuclear Neutrophil (PMN) Collection • Measurement of Oxidative Burst Responses	Antioxidant capacity and inhibitory effect on Neutrophil Burst
Fruit pulp	Aqueous	• Superoxide radical scavenging • Total reducing power assay • DPPH radical scavenging	Antioxidants activity
		• Ellmann's method	Acetylcholinesterase (AChE) Inhibitory Activity
Whole fruit	Methanol	• DPPH radical scavenging	Antioxidants activity
	Ethyl acetate	• Agar diffusion assay against *Escherichia coli, Burkholderia sp., Haemopilus somnus, Haemopilus parasuis, Clostridium perfringens, and Pantoea agglomerans.*	Antibacterial activity
Whole fruit	Aqueous	• Paw edema was induced by injection of trypsin or trans-cinnamoyl-LIGRLO-NH2 (tc-NH_2)	Anti-inflammatory activity
Fruit peel	Ethanolic	• Oxidative injury induced by the known oxidative agent tert-butyl hydroperoxide (tBOOH) in Caco2 cells	Antioxidative capacity against oxidative stress induced cell damage
		• DPPH and ABTS assays	Antioxidant effects
Whole fruit	Aqueous	• Triphenyltetrazolium in phosphate buffer infusion to isolated heart	Cardioprotective properties
Nasunin isolated from fruit peel	-	• Radical scavenging assay	Antioxidant capacity
Whole fruit	Aqueous Ethanol	• Total phenol content • DPPH radical scavenging • Superoxide anions scavenging • Lipid hydroperoxide levels in the plasma of a healthy donor	Antioxidant activity

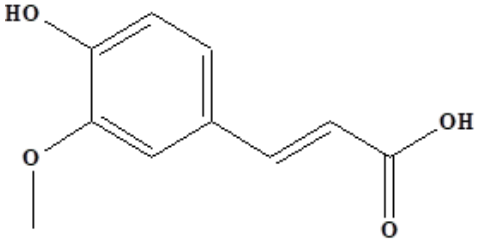
I.3 REPORTED PHYTOCHEMICALS OF *S. melongena* L.

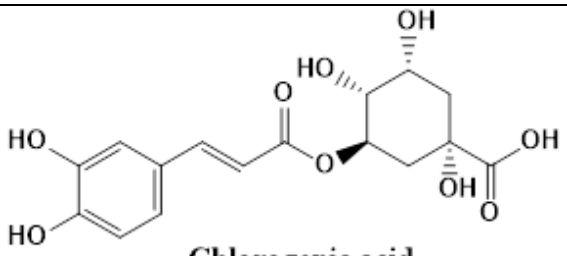
Table 2

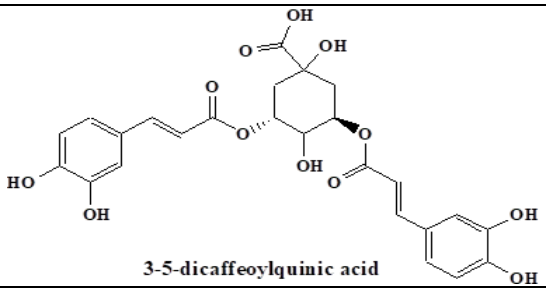
Class	Reported phyto-constituents
Phenolic acids	Caffeic acid, ferulic acid, sinapic acid, cinnamic acid, chlorogenic acid, 5-caffeoylquinic acid, cryptochlorogenic acid, 4-caffeoylquinic acid, 4-caffeoylquinic acid, 3-O-acetyl-5-caffeoylquinic acid, 3-O-acetyl-4-caffeoylquinic acid, 3-5-dicaffeoylquinic acid and 4-5-dicaffeoylquinic acid
Anthocyanins	Delphinidin-3-(p-coumaroylrutinoside)-5-glucoside (Nasunin), delphinidin-3-glucoside, delphinidin-3-rutinoside-5-galactoside, delphinidin-3-rutinosyl-glucoside, delphinidin-3-(caffeoylrutinoside)-5-glucoside, petunidin-3-(p-coumaroylrutinoside)-5-glucoside
Flavonoids	Kaempferol, quercetin, apigenin, isorhamnetin
Caroteinoids	Leutin, Zeaxanthin

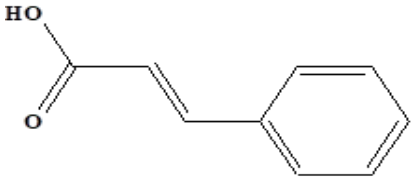
Phenolic acids

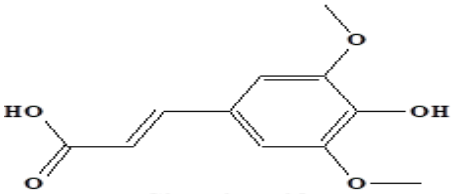

Caffeic acid

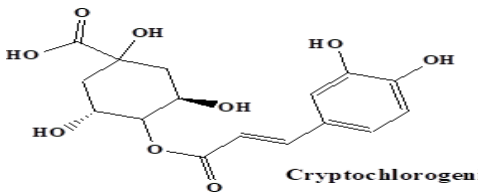

Ferulic acid

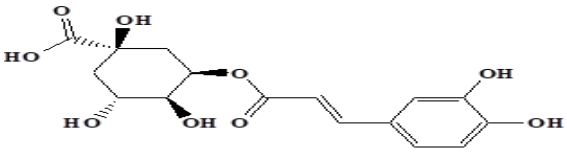

Chlorogenic acid


3-5-dicaffeoylquinic acid

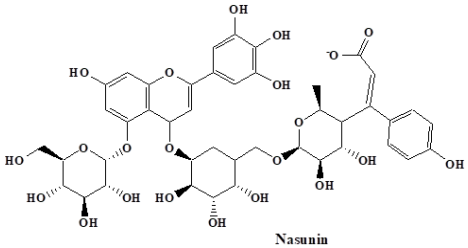

Cinnamic acid

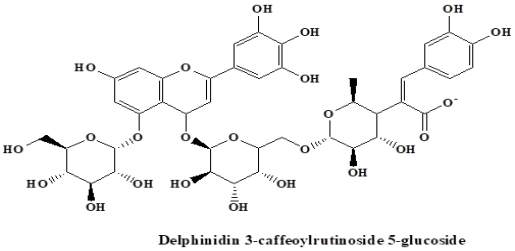

Sinapic acid


Cryptochlorogenic acid


5-caffeoylquinic acid

Anthocyanins


Nasunin


Delphinidin 3-caffeoylrutinoside 5-glucoside

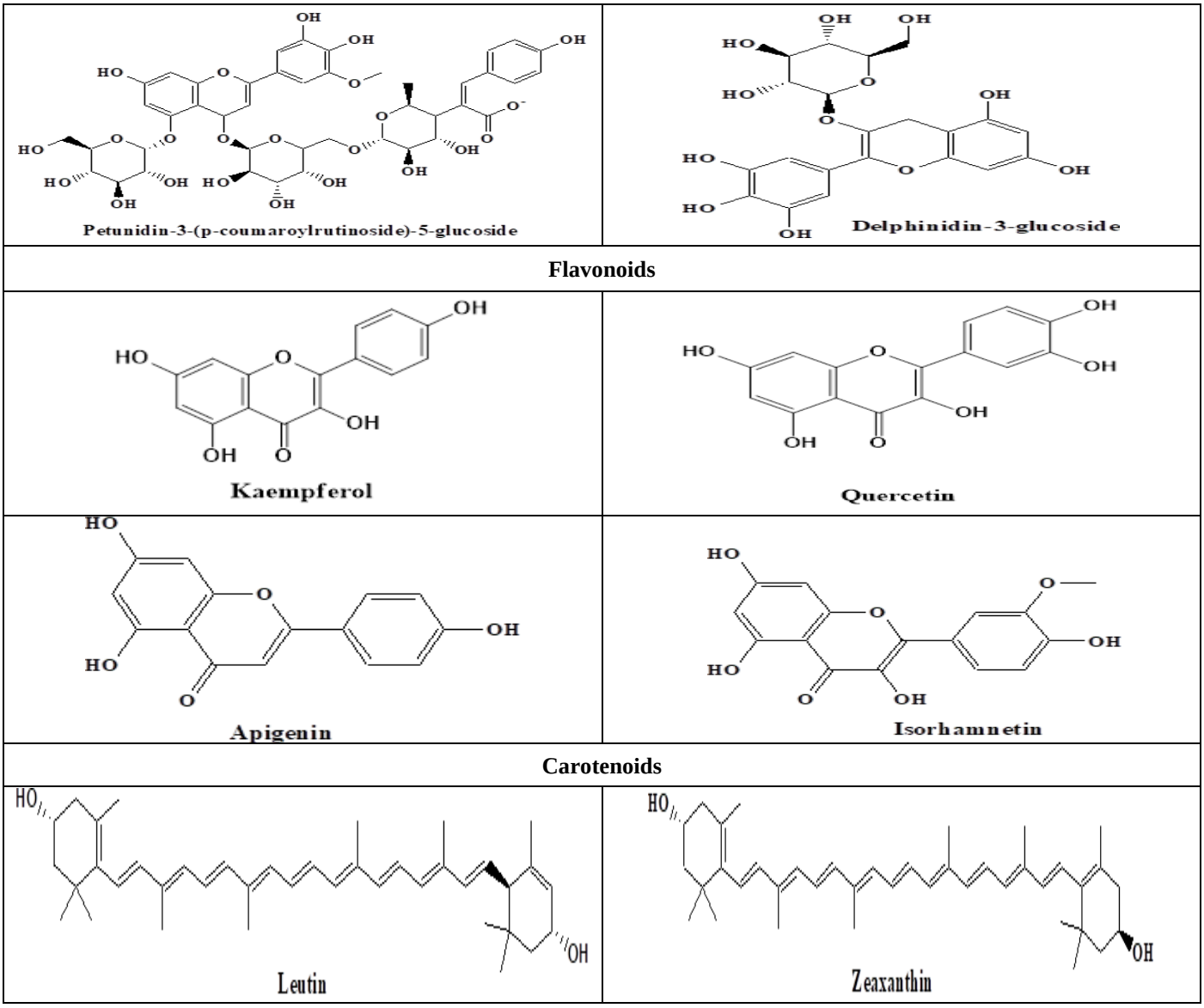


Figure 1: Phytochemicals of *S. melongena* L.

II. INDIVIDUAL ANTHOCYANINS AND FLAVANOLS IN EGGPLANT

S. melongena has been reported to possess extensive therapeutic properties as well as nutritional values, which might be owing to the presence of a myriad of bioactive constituents. These constituents can be categorized as flavonoids, saponins, phenolic acids, anthocyanins, alkaloids.

Anthocyanins (from the Greek *anthos* = flower and *kyano* = blue) are type of flavonoids. They are the largest group of water-soluble pigments in the plant kingdom. The basic carbon structure of anthocyanins are C_6-C_3-C_6 skeleton with the structural basis in the anthocyanidins. If a sugar moiety gets bound to anthocyanidins, the resultant chemical structure is of anthocyanins (Clifford, 2000b, Castañeda-Ovando et al., 2009). In nature 20 different types of anthocyanins have been isolated and identified, but only 6 are commonly available in fruits and vegetables. Anthocyanins in eggplant peel consist mainly in delphinidin (**1**) derivatives, of which nasunin is reported as the main in peels of Japanese eggplant cultivars (Fig. 2). Nasunin was isolated for the first time in 1933 by Kuroda and Wada, they found moieties of delphinidin, glucose, and *p*-coumaric acid and at that time structure was named delphinidin-3-diglucoside acylated with *p*-coumaric acid (Noda et al., 2000). Watanabe et al. (1966), identified nasunin as delphinidin-3-(*p*-coumaroylrutinoside)-5-glucoside and Ichiyanagi et al. (2005) reported that nasunin occurs as *cis* (**2**) and *trans* (**3**) stereoisomers, being *trans* the more stable form and because of that it is present mainly in major quantity.

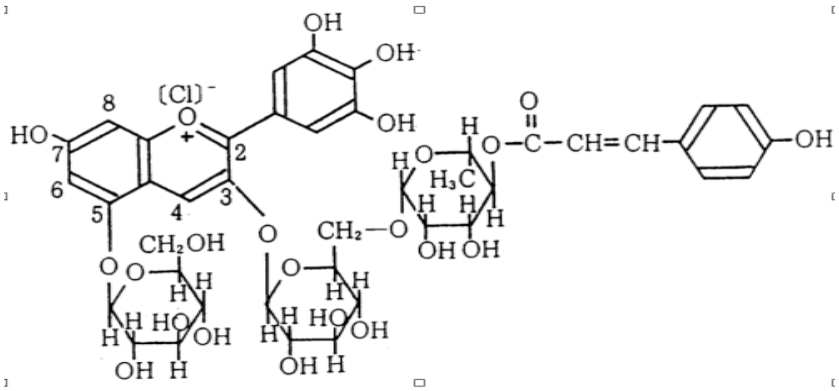


Figure. 2: delphinidin-3-(p-coumaroylrutinoside)-5-glucoside.

➢ Effect of agricultural practices in eggplant phenolics

The amount of phytochemicals gets modified on the basis of Environmental conditions and physiological Variation in agronomic conditions.

III. PHARMACOLOGICAL STUDIES

The medicinal properties of the plant are derived from its chemical constituents. The plant's antioxidant property is due to the flavonoids. The terpenes (steroids) make it useful for bronchitis. Analgesic property is because of the alkaloids. They have been categorized as:

1) Antioxidant activity (Guohua Cao, *et al.*, 1996)

In terms of oxygen radical scavenging capacity, Eggplant is ranked as one of the top ten vegetables because of phenolic constituents in the fruit's (Cao *et al.*, 1996). The antioxidant property is because of flavonoids. (Kwon *et al.*, 2007) Antioxidant Activity was proved on rat liver by using peel extracts of purple coloured brinjal (Sarkar et al., 2019).

2) Analgesic Property

Alkaloids impart analgesic property (Kwon *et al.*, 2007) The effect of crude alkaloidal fraction as tested on central nervous system from the leaves. It exhibited significant analgesic effect (Vohora *et al.*, 1984).

3) Lungs

The terpenes (steroids) content impart a significant bronchial anti-inflammatory effect for treating asthma (Kwon *et al.*, 2007). Decoction of roots when taken internally, as a general stimulant and also for treating asthma (Kwon *et al.*, 2007).

4) Diabetes

Eggplant traditionally is also known to have antidiabetic action. The high fiber and low soluble carbohydrate content of fruits impart this capacity.

5) Cardiac Activity

In a study, cardiovascular action of *S. melongena* extract (SME) was evaluated in-vivo and in-vitro. There was a dose dependent hypotensive responses in normotensive albino rats Shum and Chiu, 1991.

6) Nervous system

To treat neuralgias, various plant parts are useful. Vohora *et al.*, 1984

7) Antipyretic Activity

S. melongena leaves *was evaluated for its* antipyretic effect at 100 mg, 250 mg and 500 mg/kg body weight. There was reported a significant antipyretic effect in a dose-dependent manner (Mutalik S *et al.*, 2003).

8) Hypolipidemic Action

the hypolipidaemic effect of flavonoids was tested in-vivo. Extract extracted from the fruits of *S. melongena*, was orally administered at 1 mg/100 g body weight/day in normal and cholesterol-fed rats. Significant hypolipidaemic action was reported (Sudheesh *et al.*, 1997)

9) Spasmogenic Activity

Spasmogenic activity of methanolic extract of *S. melongena* leaves were tested on guinea pig tracheal chain using serial dilutions between 0.0025 and 2.5 mg/ml. There was observed dose dependent increase in the force of muscle contraction and concomitant use of histamine Man's *et al.*, 2004

10) Action on the Eye

In a clinical study, visually active male volunteer's bolus consumption of 10 gm of *S. melongena* on to determine its ocular complications. There was observed intraocular pressure by 25%. and miosis

11) Hepatoactivity

for liver complaints it has been recommended as an excellent remedy (Kwon *et al.*, 2007). Also in-vivo animal activity has been performed to demonstrate the same (Sarkar et al., 2021).

12) Miscellaneous

For various other ailments too, brinjal has been proven like ulcer of nose, cholera, otitis, toothaches, and dysuria (Kwon *et al.*, 2007). Leaves are used for piles.

IV. MATERIALS AND METHODS:

Phytochemical and pharmacological evaluation of peel extract was also done at our level. Nasunin as its been reported to be most potent anthocyanin to possess anti-oxidant activity, both ethnobotanically and also at lab level.

The plant material of *S. melongena* was procured from the local market of Gurgaon, Haryana, India. Authentication was carried out by Dr. K. Madhava Chetty, Department of Botany, Sri Venkateshwara University, Tirupati, India. Plant specimen voucher no. 1894 is available with the institute's herbarium for future reference.

IV.1 CHEMICALS AND DIAGNOSTIC KITS

Table 3: List of chemicals, solvents and diagnostic kits

Chemical	Source
5,5-dithio-bis-(2-nitrobenzoic acid (DTNB)	Molychem, India
Ascorbic acid	Sigma-Aldrich, Milwaukee, USA
Butanol	Molychem, India
Carbon tetrachloride	Sigma-Aldrich, Milwaukee, USA
Diethyl ether	Molychem, India
DPPH	Molychem, India
Ethanol, Methanol, Petroleum ether, Chloroform, Ethyl acetate, Acetic acid, and trifluoroacetic acid	Molychem, India
Ferric chloride	Molychem, India
Folin-Ciocalteau reagent	Molychem, India
Formalin	Thomas Baker (Chemicals)
Gallic acid	Molychem, India
Gelatin	Molychem, India
Hydrogen peroxide	Molychem, India
Liver enzymes (AST, ALT, ALP and Bilirubin)	Reckon Diagnostics Pvt. Ltd
Napthylethylenediamine dihydrochloride	Molychem, India
Nitro blue tetrazolium (NBT)	Molychem, India
Paracetamol	Sigma-Aldrich, Milwaukee, USA
Picric acid	Molychem, India
Reduced glutathione (GSH)	Molychem, India
Sodium carbonate	Molychem, India
Sodium chloride	Molychem, India
Sodium nitrate	Molychem, India
Sodium nitroprusside	Thomas Baker (Chemicals)
Sulphanilamide	Molychem, India
Sulphuric acid	Molychem, India
TBA	Sigma-Aldrich, Milwaukee, USA
Total cholesterol, Triglycerides, HDL	Reckon Diagnostics Pvt. Ltd
Tri-chloroacetic acid	Molychem, India

IV.2 PREPARATION OF THE EXTRACTS

The whole fruit of *S. melongena* was peeled off and peels were dried in the shade. Shade-dried peels were coarsely powdered and subjected to the Soxhlet extraction procedure using hydro-alcohol (50%; v/v). The powdered peels were also subjected to maceration procedure at 50 ^{o}C to obtain aqueous extract. The extracts so obtained were filtered, distilled off and concentrated under reduced pressure using rotary evaporator at a temperature of 40 ^{o}C. These crude extracts were used for further study.

IV.3 QUALITATIVE ANALYSIS

The phytochemicals present in the extracts were screened by the qualitative assays described by Trease and Evans (1979) [438]. Assays for alkaloids, terpenoids, steroids, fats and fixed oils, saponins, glycosides, flavonoids, and tannins were performed. The methods followed for phytochemical screening are described below:

1. **Carbohydrates:**
   - *Fehling's test:* 50 mg extract + distilled water and filtered; 1 ml filtrate + 1 ml Fehling's solution (1 ml); heated up to the boiling; red coloured precipitates.
   - *Molisch's test*: 2 ml of extract + few drops of Molisch's reagent (Mixture1); add mixture 1 to 2 ml of conc. H_2SO_4; development of red or purple-coloured layer compound.
2. **Alkaloids:**
   - *Dragendroff's Reagent test*: 1 ml of plant extract + Dragendroff's Reagent; Development of orange-red colour.
   - *Mayer's test*: 1 ml plant extract + Mayer's reagent: Development of cream coloured precipitates.
3. **Flavonoids:**
   - Ferric *chloride test*: 1 ml of plant extract + ferric chloride (0.5 ml) solution; blue to greenish violet colour.
   - *Alkaline reagent test*: 1 ml of plant extract + few drops of lead acetate solution; intense yellow colour.
4. **Glycosides:**
   - *Keller-Killiani's test:* 1 Extract + 1 ml glacial acetic acid; Stirred followed by addition of a few drops of ferric chloride solution; added 1ml of concentrated sulphuric acid; Bluish green layer on standing.
   - Borntrager's test: 3 ml extract + dil. H2SO4 follwed by boiling and filtration; Add chloroform and shake; separate organic layer; add ammonia; ammonia layer turns pink/red.
5. **Fixed Oils and Fats:**
   - *Stain test:* Small amount of extract applied and pressed between the layers of two filter papers; Oily stain on filter paper.
6. **Tannins:**
   - *Gelatin test:* Extract dissolved in 5 ml of distilled water + added 1 % gelatin solution and 10 % sodium chloride; formation of precipitates.
7. **Saponins:**
   - *Froth test:* Plant extract + 5 ml of water; Shaken vigorously; stable froth formed.
8. **Terpenoids:**
   - Salkowaski *test:* Small amount of extract + 2 ml chloroform + 3 ml concentrated sulphuric acid; A reddish- brown ring formed at the junction of two layers.
   - Liebermann *Burchard Reagent:* 1 ml of extract + few drops of Liebermann Burchard Reagent; development of green colour.
9. **Volatile oils:**
   - *Sudan III test:* Few ml of extract + few drops of Sudan III; development of red colour.

IV.4 QUANTITATIVE ANALYSIS

A. Estimation of total flavonoids

Coarsely powdered plant material (10 gm) extracted with 100 ml of 80% methanol at least thrice at room temperature. All solutions were mixed & filtered through Whatman filter paper (no. 42). Filtrate was kept aside in a crucible and evaporated to dryness. Dried content weighed; total flavonoids calculated as percent weight (% w/w).

B. Estimation of total saponins

Coarsely powdered plant material (10 gm) in conical flask added with 100 ml of 20% ethanol and heated no more than 55°C for at least 4 hours on a hot water bath; stirred continuously; filtered. Residue added with 100 ml of 20% ethanol for re-extraction; filtrates combined; reduced up to 40 ml. Concentrated filtrate transferred to a separating funnel added with 20 ml of diethyl ether; shaken vigorously; ethereal layer discarded. Aqueous layer purified with another 20 ml of diethyl ether. Concentrate fractionated with 60 ml n-butanol; three times. Butanol fractions combined; washed twice with 10 ml of 5% aqueous sodium chloride. Purified butanol fractions evaporated to dryness; saponin content calculated as percent weight (% w/w).

V. RESULTS AND DISCUSSION

V.1 Extraction of plant material

The whole fruit of *S. melongena* was peeled off and peels were dried in the shade. Shade-dried peels were coarsely powdered and subjected to the sequential Soxhlet extraction procedure using petroleum ether, chloroform, hydro-alcohol (50%; v/v) and maceration using water. The extracts so obtained were filtered, distilled off and concentrated under reduced pressure using rotary evaporator at a temperature of 40 ºC. Hydro-alcohol (SMHA) and water extract (SMAQ) were used for further study. The extractive yield of plant materials from the respective solvents was calculated and is given in **Table 17.**

Table 4: Extractive yield of *S. melongena* with respective solvents

S. No.	**Extract**	**% w/w extractive yield of *S. melongena* L.**
1.	Petroleum ether	0.24
2.	Chloroform	1.23
3.	Hydroalcohol	10.23
4.	Aqueous	12.18

V.2 Qualitative phytochemical analysis

The qualitative phytochemical analysis exhibited the presence of different phytochemicals in the extracts. The results so obtained are given in Table 18.

V.3 Quantitative phytochemical analysis

Quantitative phytochemical analysis was carried for estimating the amount of flavonoids, and saponins in *S. melongena* peels. The results are expressed as % w/w and are given below:

Table 5

Flavonoids (% w/w)	**Saponins (% w/w)**
1.87	**0.31**

Table 6: Qualitative analysis of *S. melongena* extracts

Qualitative analysis				
Phytochemicals	**Name of test**	**Indication**	**Result**	
			Hydro-alcohol	**Aqueous**
Carbohydrates	Molisch	Red or purple-coloured layer	Present	Present
	Fehling	Red precipitate	Present	Present
Alkaloid	Mayer	Cream color precipitates	Traces	Traces
	Dragendroff	Reddish brown precipitates	Traces	Traces
Glycosides	Keller-Killiani	Blue color	Present	Present
	Borntrager	Layer of red color	Present	Present
Flavonoids	Ferric chloride	Light to dark green color	Present	Present
	Alkaline reagent	Intense yellow color; disappears on addition of dilute acid	Present	Present
Tannins	Gelatin	Precipitation	Present	Present
Saponins	Froth test	Froth formation	Present	Present
Terpenoids	Libermann Burchard	Deep red color	Absent	Absent
	Salkowaski	Layer of yellow color	Absent	Absent
Fats and Fixed oil	Stain test	Oil spot	Absent	Absent
Volatile oil	Sudan III	Red colour	Absent	Absent

V.4 Chromatography

The concentration of identified compound was calculated as mg/g of extract. The concentration of identified compound was found to be 0.927 and 1.48 mg/g of the methanol and aqueous extracts, respectively. The results so obtained (retention time) were found to be in accordance with study published Hayashi et al., 1998 and evidenced the presence of Nasunin in *S. melongena*. The blank chromatogram and chromatogram of sample extract depicting retention time of identified compound are given below; respectively.

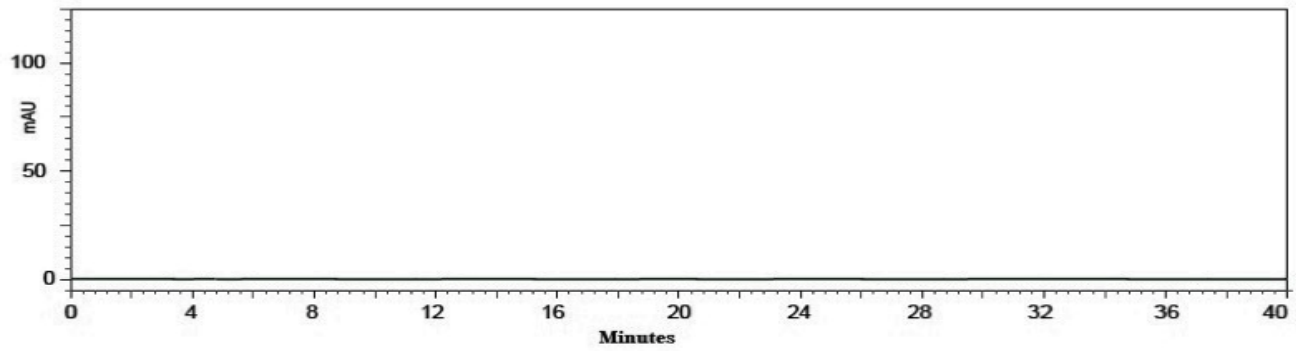


Figure 3. Blank HPLC chromatogram

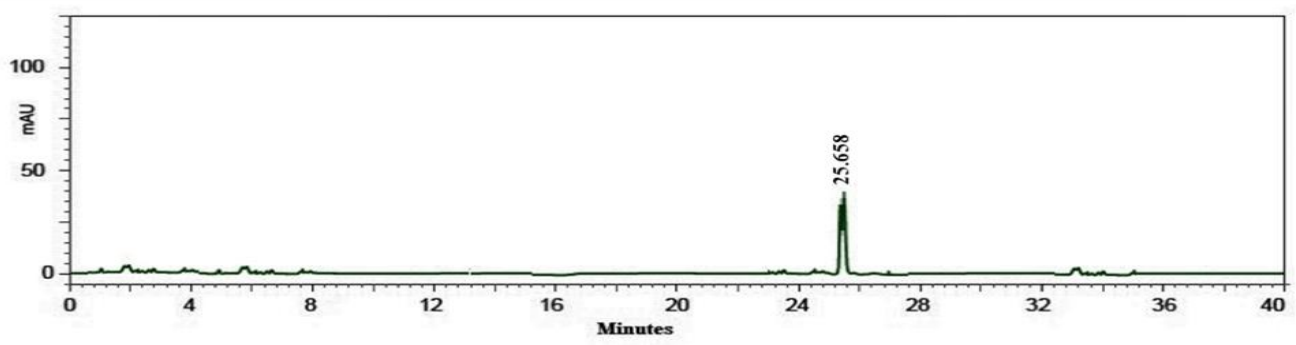


Figure 4. HPLC chromatogram of methanol extract of *S. melongena* for identification of Nasunin

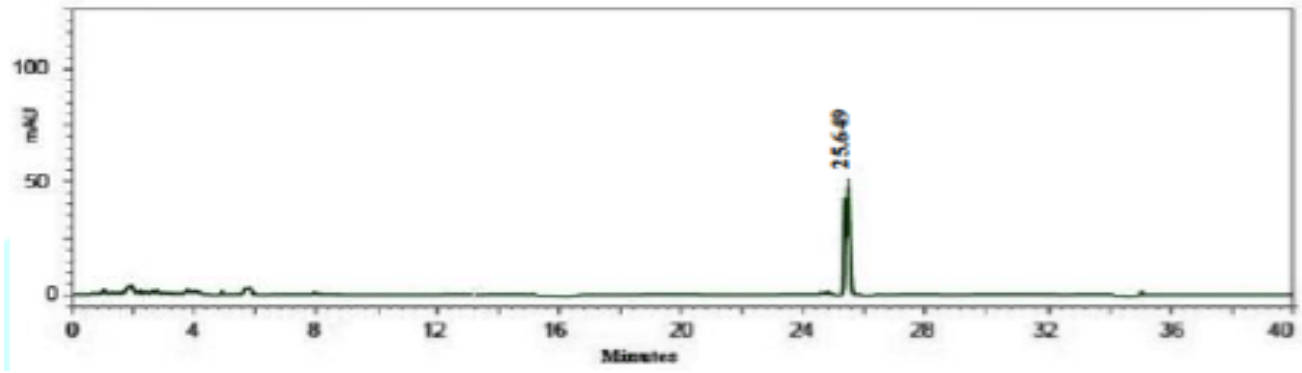


Figure 5. HPLC chromatogram of aqueous extract of *S. melongena* for identification of Nasunin

V.5 Animal study:

- **Ethics:** The experimental animal protocol was approved by the Institutional Animal's Ethics Committee of K. R. Mangalam University, School of Medical and Allied Sciences, Dept. of Pharmacy, Sohna Road, Gurgaon, Pin. - 122103, Haryana, India; on 27th October, 2018 with protocol no. KRMU/CPCSEA/RES/IAEC-2018(1) and was in accordance with guidelines of the regulatory body of the government. Animals were kept as per the guidelines of the Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA), Ministry of Environment and Forest, Government of India
- **Acute toxicity study** of the SMHA and SMAQ was carried out in albino mice using varying doses of the extract at 75, 150, 250, 500, 1000, 2000 mg/kg body weight (BW) following OECD test guideline 423. Therefore, SMHA and SMAQ extracts of *S. melongena* were considered safe and non-toxic up to 2000 mg/kg and the LD_{50} was considered more than 2000 mg/kg. On the basis of acute toxicity study, different doses *i.e.* 100, 200 and 400 mg/kg of SMHA and SMAQ were selected for the *in-vivo* study.
- **Two hepato-toxic models** were selected based on their prevalence and mechanism through which they exhibit hepato-toxicity *in-vivo*.

i. **Carbon tetrachloride (CCl4), and**
ii. **Paracetamol (PCM) induced hepato-toxicity**

Holistically liver weight can be considered as a representative of health condition of animal. So a comparative liver weight based on biochemistry has been plotted and shown here:

Effect of SMHA and SMAQ extracts of *S. melongena* L. on liver weight

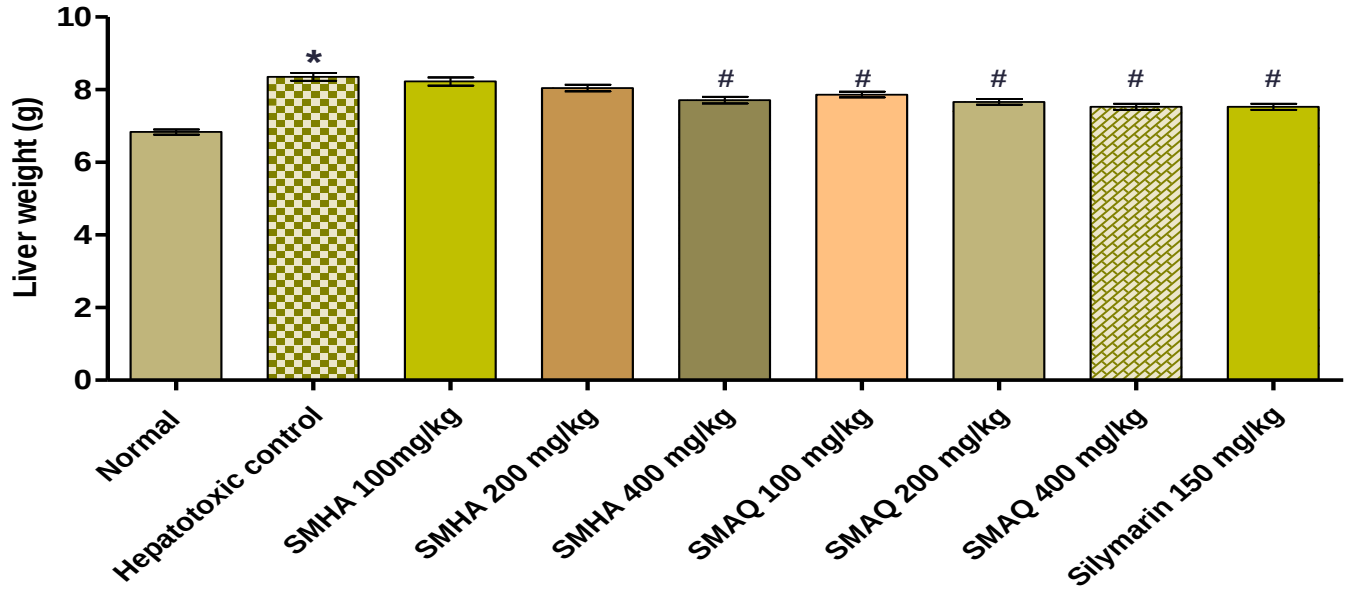


Figure 6. CCL_4 model

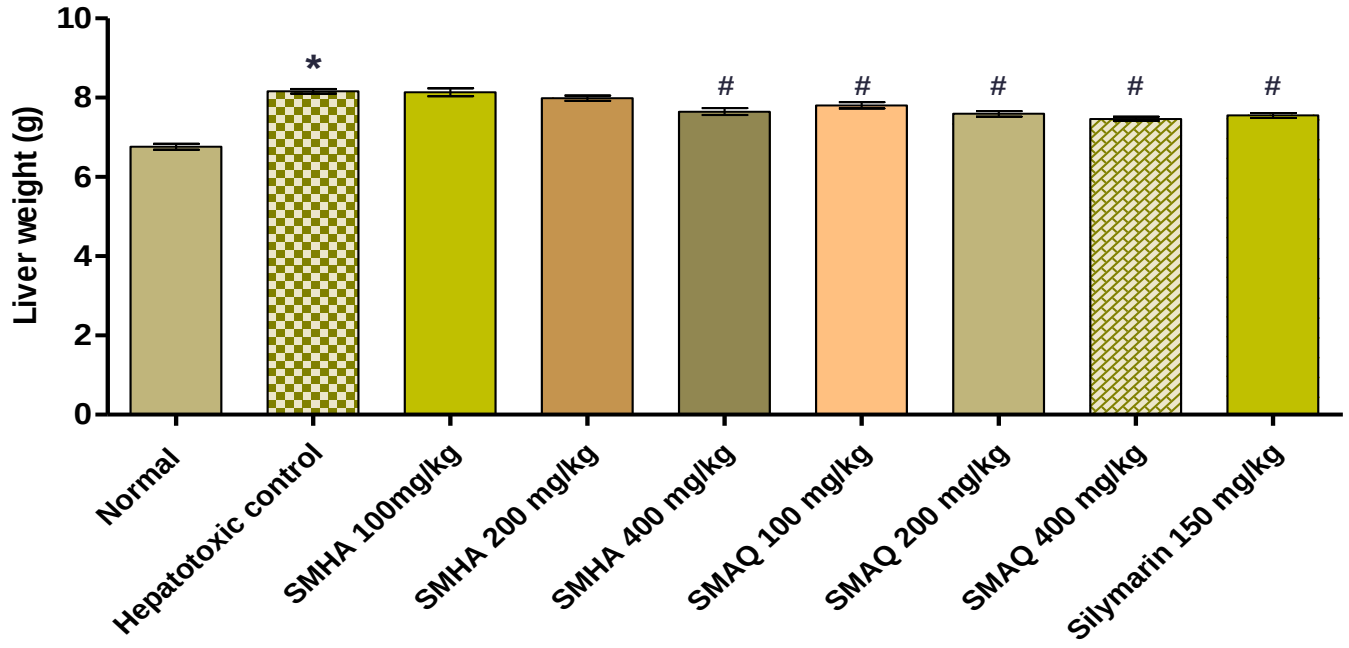


Figure 7. PCM model

Histopathology was performed on liver of animals of all dose group. A representative of both models have been shown her to provide a solid background for Nasunin as a hepato-protective agent.

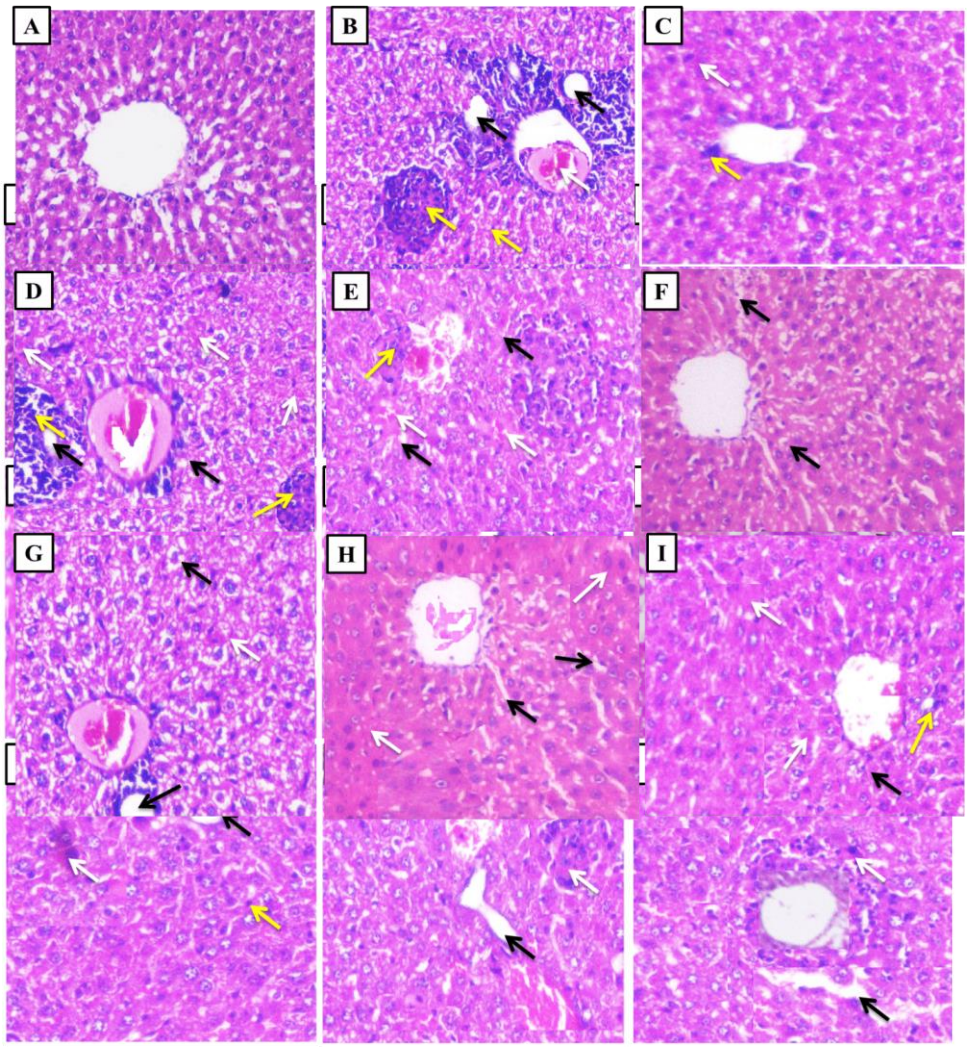
Microscopical illustration: Liver of normal rats, normal central vein with radiating sinusoid cords were present. There was no sinusoid congestion, swelling and necrotic cells. Hepatotoxic control rats demonstrated perivenular inflammatory collection and

hyperplasia of Kupffer cell with condensed nuclei and fatty infiltration. These pathological changes were alleviated by different doses of *S. melongena* L. extracts

A. Normal,
B. Hepatotoxic control CCl_4
C. Silymarin 150 mg/kg,
D. SMHA 100 mg/kg,
E. SMHA 200 mg/kg,
F. SMHA 400 mg/kg,
G. SMAQ 100 mg/kg,
H. SMAQ 200 mg/kg and
I. SMAQ 400 mg/kg

(H&E × 100)

Figure 8. CCL_4 model



A. Normal,
B. Hepatotoxic control PCM,
C. Silymarin 150 mg/kg,
D. SMHA 100 mg/kg,
E. SMHA 200 mg/kg,
F. SMHA 400 mg/kg,
G. SMAQ 100 mg/kg,
H. SMAQ 200 mg/kg and
I. SMAQ 400 mg/kg

(H&E × 100)

Figure 9. PCM model

Legends:

- ✓ **White arrows indicate inflammation;**
- ✓ **Yellow arrows indicate condensed nuclei of cells;**
- ✓ **Black arrows indicate fat infiltration**

DISCUSSION

This review article is a comprehensive piece of literature on *S. melongena* L. Peels of fruits contain Nasunin as major anthocyanin pigment in addition to numerous alkaloids, glycosides, saponin, chlorogenic, hydrocaffeic and protocatechuric acids. The whole plant contains numerous pharmacological and therapeutic benefits like antioxidant, analgesic, anti-diabetic, bronchitis, asthma, liver complaints, Cardiac activity, neuralgias, CNS depressant activity, Antipyretic Activity, Hypolipidemic Action, Spasmogenic Activity, glaucoma, otitis, toothaches, cholera, dysuria, ulcer of nose etc. Nasunin was worked upon to pinpoint its anti-oxidant activity and retrospectively hepato-protective action was also proven in animals.

From the literature, Nasunin extracted from purple peels of eggplant can be further worked upon to develop it as a standalone drug of choice for hepato-protection.

VI. ACKNOWLEDGMENT

None

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