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REVIEW

Phytochemistry and Pharmacological Properties of *Morus alba* Linn. with Reference to its SARS-CoV-2 Inhibiting Potential

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Morus alba Linn. is a plant with varieties of phytochemicals and commonly known as Mulberry tree or Nuni (in Assamese). Mulberry is a perennial and woody plant, belongs to the family Moraceae consider as a native plant of China. In Assam, the leaves of mulberry tree are out most important in horticulture department for feeding purpose. A literature survey was done out by using key words such as *Morus alba*, or mulberry tree or phytoconstituents, or pharmacological activities, or ethnobotany on the search engine namely Scopus, Web of Science, Google Scholars, PubMed. The purpose of this article is to forward a solid review about the plant profile, method of extraction, phytochemicals constituents and pharmacological activities in reference to SARS-CoV-2. All the parts of *Morus alba* are phytochemically rich but highest number can be found in fruits and leaves. Fruits of *Morus alba* contains various class of phytochemicals such as alkaloids, anthocyanins, stillbenoids, flavones. Owing to presence of this compounds, it exhibits various pharmacological. Its leaves, fruits and root bark containing flavonoids, anthocyanins, alkaloids and stilbenoids, possess various pharmacological properties. Resveratrol is one of the most important compounds found in *M. alba* which possess SARS-CoV-2 inhibiting potential. Still there are some gaps remain in exploring whole plants parts and successive studies of toxicity.

Keywords: *Morus alba,* Mulberry tree, SARS-CoV-2, Ethnomedicines, Phytochemistry, Pharmacological activities.

INTRODUCTION

From the time immemorial, herbal medicine plays a vital role in our life. Ayurveda experts were used to collect various plants parts such as leaves, fruits, stems, barks, roots and used them to cure or in treatment of various ailments. India is rich in medicinal and herbal rich and hence India consider as the biggest reservoir of medicinal hub. Although, people use various herbal drug from ancient period without even knowing their way of uses, but due to exploration in the field of medicinal plants, people gathering enough knowledge regarding their extraction, isolation, phytochemical evaluation as well as their uses [1]. Medicinally important herbs can be included in regular diet to cure various ailments [2]. The plant which are used as herbal medicine as well as in various medical purpose are considered as the medicinal plant. The word 'herb' comes from Latin word *herba* which means any parts of plant such as bark, leaf, stigma, flower, twigs or roots. Traditional herbal medication includes in Homeopathy, Ayurveda, Yoga, Unani, Siddha and naturopathy except allopathy. As per some reports, most of the people in India are still choose allopathic medicine over the homeopathic or herbal medicine due to which they use to suffer different forms of drug interaction and side effects. Therefore, people should go for herbal medicine where they can add some medicinal plants or herbs in regular diet as per Indian Drugs Act. Various medicinal plants are prominent phytochemical source through which different kinds of phytochemicals such as alkaloids, tannins, saponins, flavonoid, terpenoids, *etc.* can be isolated [3].

Morus alba Linn. commonly known as mulberry belongs to the family *Moraceae* and genus *Morus* which are perennial

and woody plant. This plant having higher growth rate and short proliferation period, prefer to grow best under temperate climatic condition. At least 150 species are there under the genus *Morus* (Mulberry), among which *Morus alba* L. (white mulberry) is dominant species. Silkworm and ruminants are using this plant as their staple food [4]. The leaves, fruits which were taken by silkworm and ruminants are nutritious, non-toxic and can enhance the production of silk and milk in silkworm and ruminants, respectively [5]. Since time immemorial, due to its chemical composition and pharmacological function, most parts of mulberry plants are used as medicine in Chinese and Indian medicines [6]. They used to grow up to a height of 3-4 m having grey colour bark, shallowly furrowed. Stipules are lanceolate, 2.3-5 cm, highly covered with short pubescence and petioles are 1.5-5.5cm long. Ripe fruits of *M. alba* are sour in taste, which indicate presence of sufficient amount of vitamin C along with other important phytoconsti-tuents [3]. Overall picture of *Morus alba* plant has showed in Fig. 1.

Fig. 1. Whole *Morus alba* plant with fruiting bodies (photo taken by Shahnaz Alom on 15th January 2022)

Geographical source: About 12-16 species of genus *Morus* are found in warm, sub-tropical and temperate regions of Asia, Africa and North America and hilly areas of Himalayas at the height of 3300 m. *Morus alba* is native of India, China and Japan. These plants can also be found in various places of north-eastern region of India. Specially, Assam state is very famous for silk product and silkworm production [7].

Extraction of phytoconstituents: Since highest number of phytochemicals are present in fruits and leaves of *M. alba* Linn. For extraction from leaves, fresh leaves to be collected from plant and washed them with clean water at least for 3 times to remove any dirt particle or residue of insects excretes. Leaves are subjected to air dried and grinding done to convert into fine powder which them passed through sieve 40 to get some coarse powder. Powders are kept safely in air tight container. Powder are put into Soxhlet apparatus for extraction with range of solvent from non-polar to polar such as petroleum ether, hexane, ethyl acetate, methanol, ethanol, *etc.* Solvent are evaporated to get dry extract and perform phytochemical screening test by using spectroscopic methods. A general representation of extraction is being shown in Fig. 2. Animal experiment can also do to investigate their pharmacological effect and it can be done by using those extract solubilize in desired solvent.

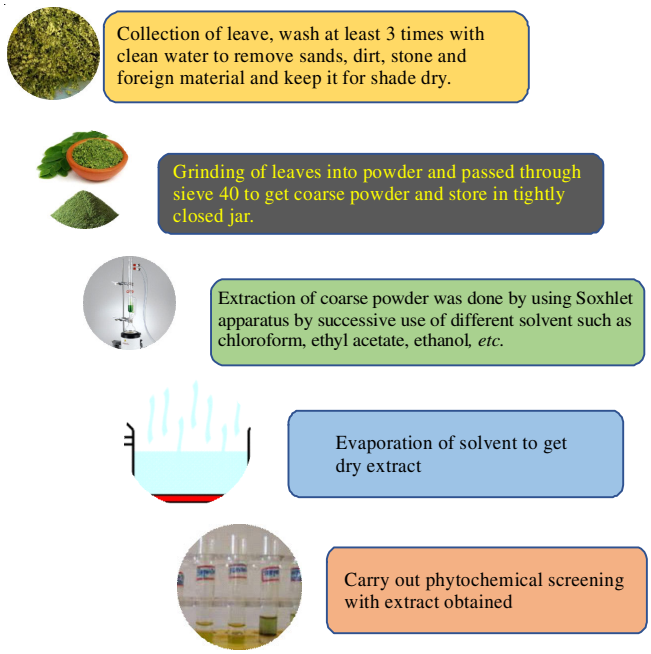

Fig. 2. Schematic representation for extraction of phytochemicals from *M. alba* leaves

Traditional uses: Traditionally, the leaves of this plant are mostly used as a feedstock for silkworm which mainly involved in the production of silk. In ancient period, tribal community of India have used this plant in treatment of cough, asthma, edema, wound healing, bronchitis, eye infection and nosebleeds. In ayurvedic formulation, the extract of this plant was used in purification of blood, treatment of weakness, fatigues, anemia, tinnitus, constipation and dizziness. In China, whole plant of white mulberry was used as medicine to treat different ailments like body pain, acne, microbial infection. This plant was prominent choices for different formulation in indigenous system of medicine as purgative, acrid, laxative, anti-helminthic, brain tonic, *etc.* [3].

Phytochemistry of *Morus alba* Linn.: Various parts of *M. alba* possess different type of pharmacological activities such as antioxidant, antidiabetic, anthelmintic, anticancer, hepatoprotective, due to presence of various chemical constituents. Phytochemical studies have found that the presence of different class of compound such as alkaloids, flavonoids, anthocyanins, stillbenoids, *etc.* Leaves, fruits and root exhibit highest number of phytochemicals that has been extracted with the help of different solvent system and their presence were being confirmed by carrying out phytochemical evaluation [8].

Alkaloids: Almost every parts of *M. alba* exhibit the presence of alkaloids. Kim *et al.* [9] carried out phytochemical test on the fruits of *M. alba* for the pyrrole containing alkaloids where they have confirmed the presence of compounds like 4-(2-formyl-5-(methoxymethyl)-1*H*-pyrrol-1-yl)butanoic acid (**1**), methyl 4-(2-formyl-5-(hydroxymethyl)-1*H*-pyrrol-1-yl)butanoate (**2**), methyl 4-(2-formyl-5-(methoxymethyl)-1*H*-

pyrrol-1-yl)butanoate (**3**), Morroles B (**4**), Morroles C (**5**), methyl 2-(2-formyl-5-(methoxymethyl)-1*H*-pyrrol-1-yl)-propanoate (**6**), Morroles D (**7**), methyl 2-(2-formyl-5-(methoxymethyl)-1*H*-pyrrol-1-yl)-3-(4-hydroxy phenyl)propanoate (**8**), 4-methyl-3-oxo-3,4-dihydro-1*H*-pyrrolo[2,1-*c*][1,4]oxazine-6-*c*arbaldehyde (**9**), 4-isopropyl-3-oxo-3,4-dihydro-1*H*-pyrrolo-[2,1-*c*][1,4]oxazine-6-*c*arbaldehyde (**10**), 4-isobutyl-3-oxo-3,4-dihydro-1*H*-pyrrolo[2,1-*c*][1,4]oxazine-6-*c*arbaldehyde (**11**), 4-(*sec*-butyl)-3-oxo-3,4-dihydro-1*H*-pyrrolo[2,1-*c*][1,4] oxazine-6-*c*arbaldehyde (**12**), 4-benzyl-3-oxo-3,4-dihydro-1*H*-pyrrolo[2,1-*c*][1,4]oxazine-6-*c*arbaldehyde (**13**), 4-(4-hydroxy benzyl)-3-oxo-3,4-dihydro-1*H*-pyrrolo[2,1-*c*][1,4]-oxazine-6-carbaldehyde (**14**), 1-(2,5-dioxo pyrroli din-3-yl)-5-(hydroxymethyl)-1*H*-pyrrole-2-*c*arbaldehyde (**15**), Morroles E (**16**) and Morroles F (**17**). Kusano *et al.* [10] identified and isolated five compounds belong to nortropane alkaloids such

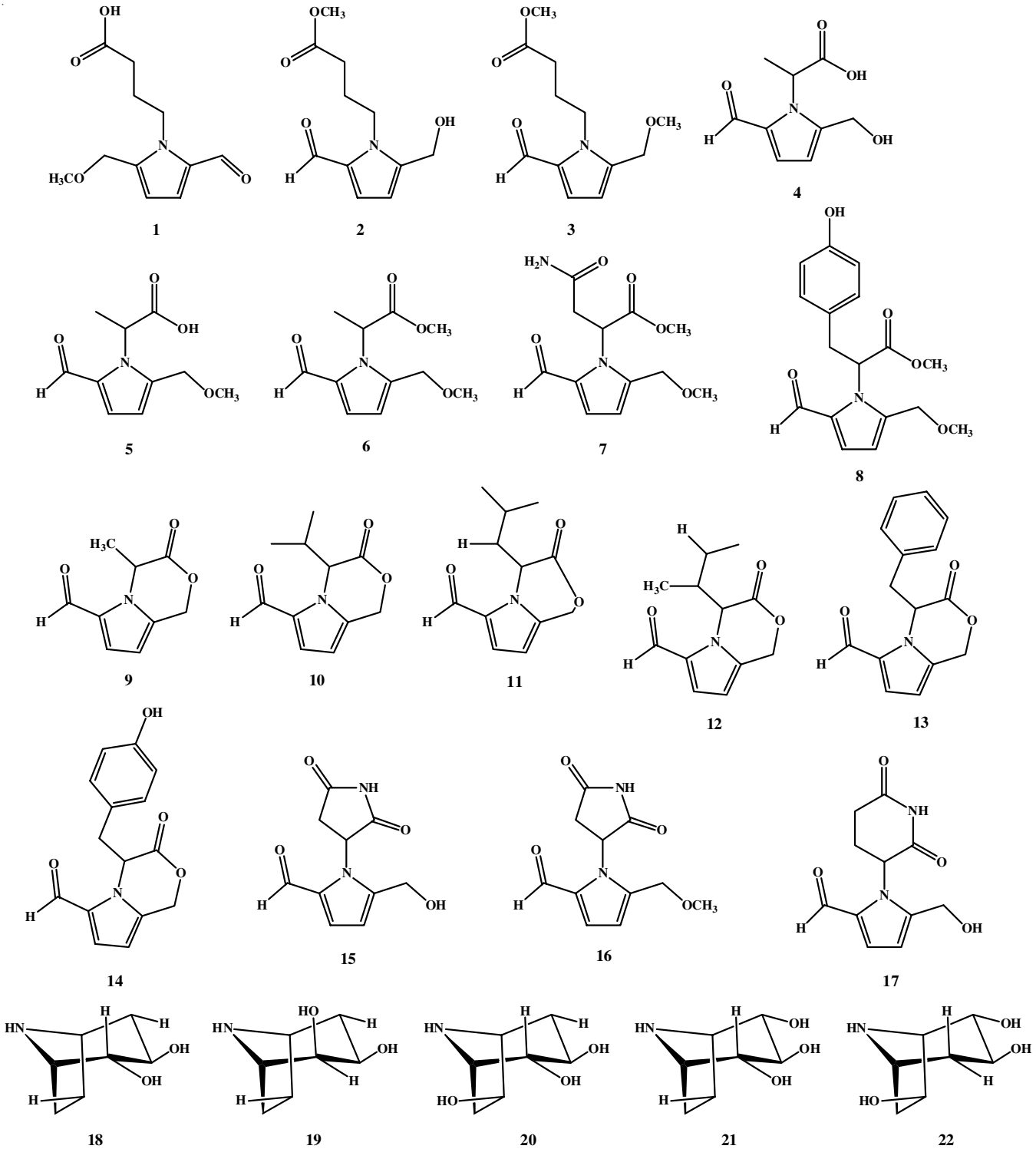

Fig. 3. Structures of alkaloidal compound present in *Morus alba* Linn.

as 2α,3β-dihydroxynortropane (**18**), 2β,3β-dihydroxynortropane (**19**), 2α,3β,6exo-trihydroxynortropane (**20**), 2α,3β,4a-trihydroxynortropane (**21**), 3β,6-*exo*-dihydroxynortropane (**22**). Structure of alkaloidal compounds has been shown in Fig. 3.

Flavonoids: *M. alba* is one of the richest sources of flavonol and flavanols due to which it exhibits various pharmacological activities like antioxidants, anticancer, anti-hyperglycaemia [8]. Fruits of *M. alba* containing flavonoidal compounds like quercetin (**23**), morin (**24**), kaempferol (**25**), kaempferol-3-O-hexoxyl-hexoside (**26**), quercetin-3-glucoside (**27**), epigallocatechin (**28**), epigallocatechin gallate (**29**), naringin (**30**), myricetin (**31**), rutin (**32**) [11-13]. Butkhup *et al.* [15] reported that the fruits of *M. alba* also contain procyanidin B1 (**33**), procyanidin B2 (**34**), catechin (**35**) [14]. Different derivatives of quercetin such as quercetin-3-O-β-D-glucopyranoside (**36**) are also present in mulberry fruits [15]. Structure of flavonoids has been shown in Fig. 4.

Anthocyanins: These are the subclass of flavonoids which directly contribute in the coloration of flowers and fruits of *M. alba*. The antioxidant properties are exhibited by this plant due to presence of anthocyanins. Two important anthocyanins such as cyanidin-3-glucoside (**37**) and cyanidin-3-rutinoside (**38**) are present in *M. alba* fruits and structure are shown in Fig. 5 [16,17].

Phenolic acid: Some of the important phenolic acid have been extracted from fruits of *M. alba* such as caffeic acid (**39**), chlorogenic acid (**40**), *o*-coumaric acid (**41**) and ferulic acid (**42**) [18-20]. Various derivatives of benzoic acid were also found in the fruits such as gallic acid (**43**), syringic acid (**44**), vanillic acid (**45**), protocatechuic acid (**46**) and *p*-hydroxy-benzoic acid (**47**) whose structures are shown in Fig. 6 [21,22].

Amino acids: Studies revealed that *M. alba* fruits contain essential amino acid such as lysine (**48**), methionine (**49**), leucine (**50**), isoleucine (**51**) and non-essential amino acid such as aspartate (**52**), glycine (**53**), glutamic acid (**54**), proline (**55**), serine (**56**), arginine (**57**), *etc.* Kusano *et al.* [10] detected few more amino acid with the help of spectroscopic analysis such as morusimic acid A (**58**), morusimic acid B (**59**), morusimic acid C (**60**), morusimic acid D (**61**) and structures are shown in Fig. 7 [10].

Stillbenoids: Mulberry plant contains two highly potent phytoconstituents such as resveratrol (**62**) and oxyresveratrol (**63**) (Fig. 8) due to which extract of mulberry plant exhibit various activities such as anticancer, antiviral, anti-inflammatory and cardioprotective effect [8].

Pharmacological effect of *M. alba* L.: Due to the presence of various class of chemical compound in *M. alba*, they have wide variety of pharmacological effect such as hypolipidimic effect, anticancer, antidiabetic, neuroprotective, nephroprotective, antimicrobial, hepatoprotective, antidopaminergic, anti-inflammatory properties, *etc.* Some of the important pharmacological effect are being discussed below:

Antioxidant properties: *M. alba* possesses significant antioxidant properties. According to Chan *et al.* [5] due to the presence of huge amount of anthocyanin, a strong antioxidant in mature fruits, the methanolic fruit extract shows significant antioxidant properties. Other than anthocyanin, some other flavonoidal compound such as rutin, isoquercetin, quercetin, quercetin 3-(6-malonylglucoside), astragalin, *etc.* are also present in methanolic extract of *M. alba*. According to Butt e*t al*. [2] due to the presence of significant amount of quercetin 3-(6-malonylglucoside) mulberry plant shows good amount of antioxidant potential. Iqbal *et al.* [23] determined the antioxidant properties of leaf extracts by using 2,2′-azino-*bis*-(3-ethylbenthiazoline-6-sulphonic acid ($ABTS^{\bullet+}$) radical cation scavenging capacity and ferric ion reducing power and 2,2-diphenylpicrylhydrazyl (DPPH) radical scavenging activity and the value ranges between 6.12-9.89, 0.56-0.97 and 1.89-2.12 mM Trolox equivalent/g of dried leaves, respectively.

Antidiabetic properties: Diabetes mellitus is characterized by high blood sugar levels which is basically a metabolic disorder, which is mainly occurs due to insufficient insulin secretion and release, insulin resistance and abnormal metabolism of fat, protein and carbohydrates. Studies revealed that methanolic extract of *M. alba* possesses good antidiabetic properties. The leaves and root bark extracts of *M. alba* shows prominent hypoglycemic effects in type 1 induced diabetes mellitus animal model [24]. *Morus alba* possesses prominent α-amylase inhibitory activity [25]. The 50% methanolic extract of *M. alba* showed acetylcholinesterase inhibitory activity in a concentration dose dependent manner which can correlate with anti-Alzheimer activity [26]. Jamshid *et al.* [24] stated that the *M. alba* extract may reduce blood glucose levels by regeneration of β cells and enhancing insulin production. *M. alba* reduce the intake of food and also reduce the absorption of blood glucose [27]. Owing to existence of polyhydroxylated piperidine and 1-deoxynojirimycin (DNJ), a potent α-glucosidase inhibitors, the leaves and bark of *M. alba* shows good antidiabetic properties [28]. *M. alba* have some insulinotropic properties due to which it can reduce the level of blood glucose by increasing insulin level [29].

Anthelmintic properties: The methanolic extract of *M. alba* possesses the prominent anthelmintic property against *Pheretima posthuman* when compared with standard drug, albendazole. Different extracts of *M. alba i.e.* petroleum ether, alcoholic and aqueous extract possesses significant anthelmintic property at higher dose when compared with standard drug [30].

Antimicrobial properties: Along with other activity *M. alba* extracts shows significant antimicrobial activity. Aditya Rao *et al.* [29] reported the antimicrobial activity of petroleum ether, chloroform and methanol extract of *M. alba* against different bacterial and viral strains such as *B. subtilis*, *E. coli*, *S. aureus*, *S. faecalis*, *M. smegmatis*, *etc*. and found that all the three extracts showed potent antimicrobial activity in a concentration dose dependant manner [31]. As extract of *M. alba* contain kuwanon C, albanol B, sanggenon B and D, mulberrofuran G and morusin, plant possess strong antioxidant potential [32,33].

Antiatherosclerosis properties: Atherosclerosis is prominent cause behind many cardiovascular disorders such as cerebral and myocardial infraction. *M. alba* possesses significant antiatherosclerosis properties. The phytoconstituents of *M. alba* such as glycoside, flavanol, quercetin 3-(6-malonylglucoside) are responsible for reduction of atherosclerotic lesion

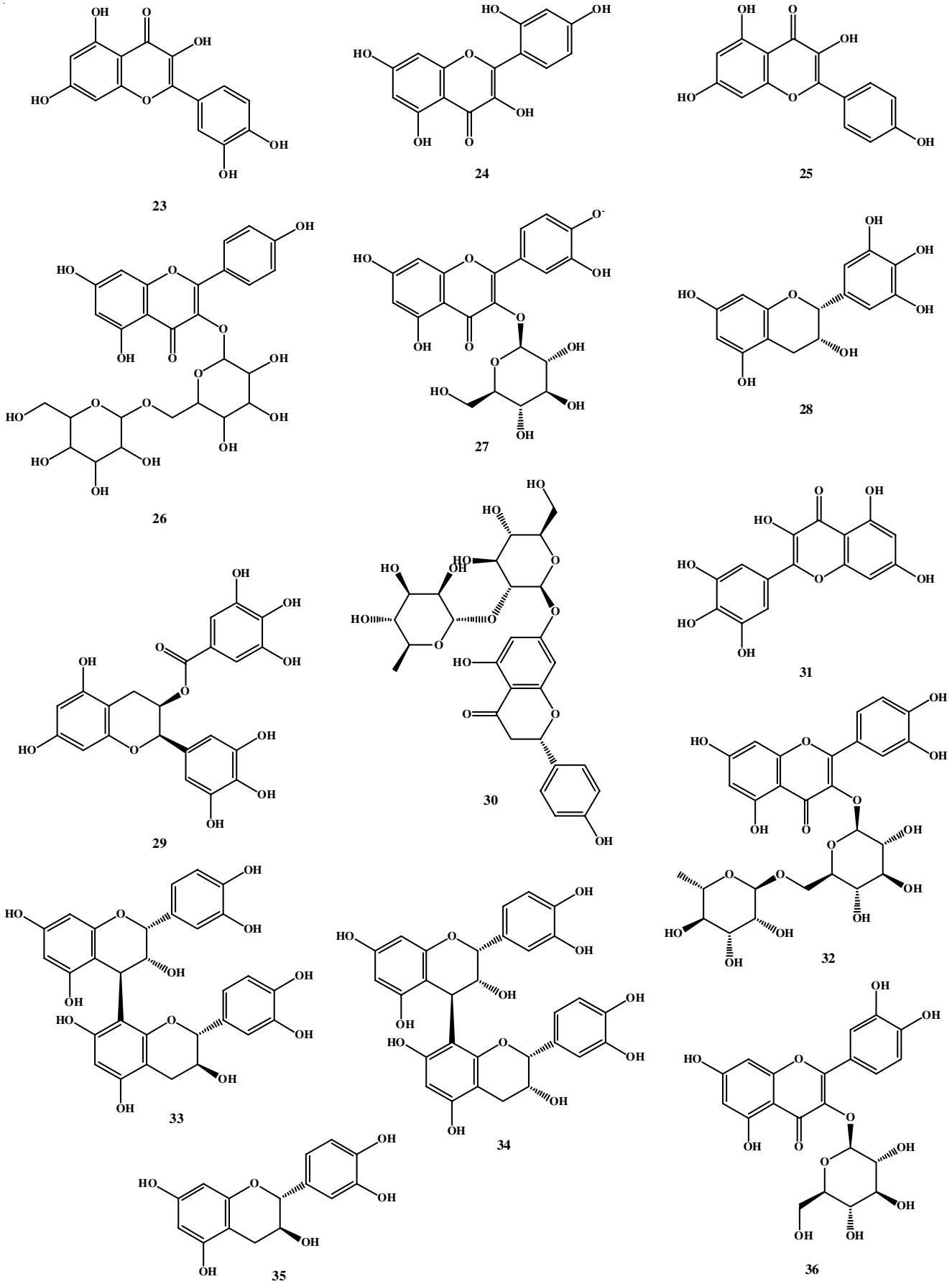

Fig. 4. Structures of flavonoids present in *Morus alba* Linn.

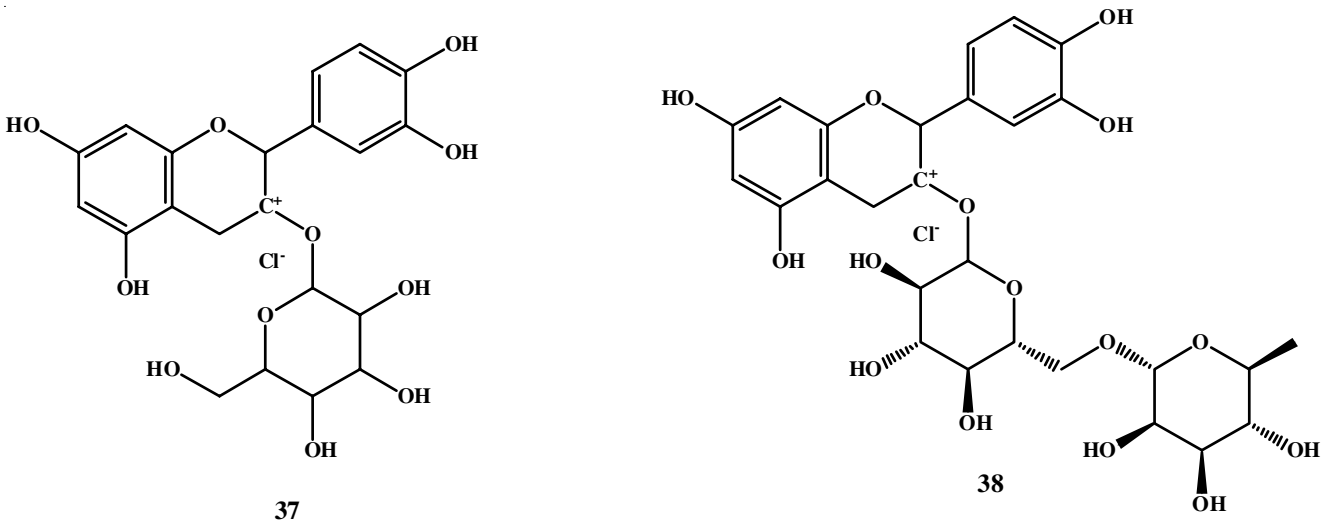

Fig. 5. Structures of anthocyanin compound present in *Morus alba* Linn.

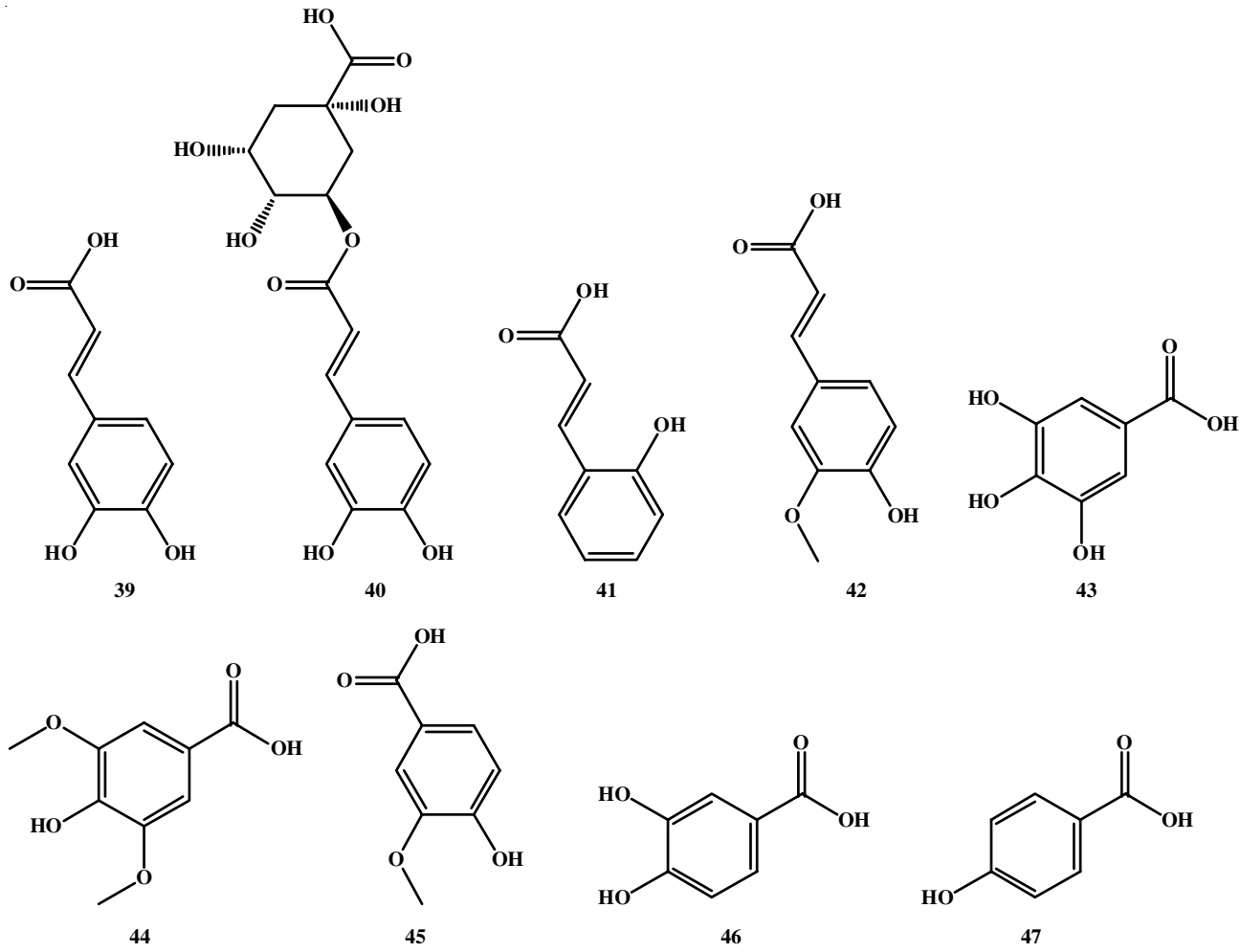

Fig. 6. Structures of phenolic acid compound present in *Morus alba* Linn.

by increasing low density lipoprotein (LDL) resistance to oxidative modification in LDL receptor [34]. Butanolic leaves extracts of *M. alba* have the DPPH radical scavenging properties and also inhibit the oxidative modification of human and rabbit LDL [35].

Anticancer properties: *M. alba* plant shows some strong antiproliferative and anticancer activities. Chung *et al.* [36] studied the methanolic extract of *M. alba* for anticancer properties by using different cell lines such as MCF-7 (human breast adenocarcinoma), HCT-116 (human colon carcinoma) and

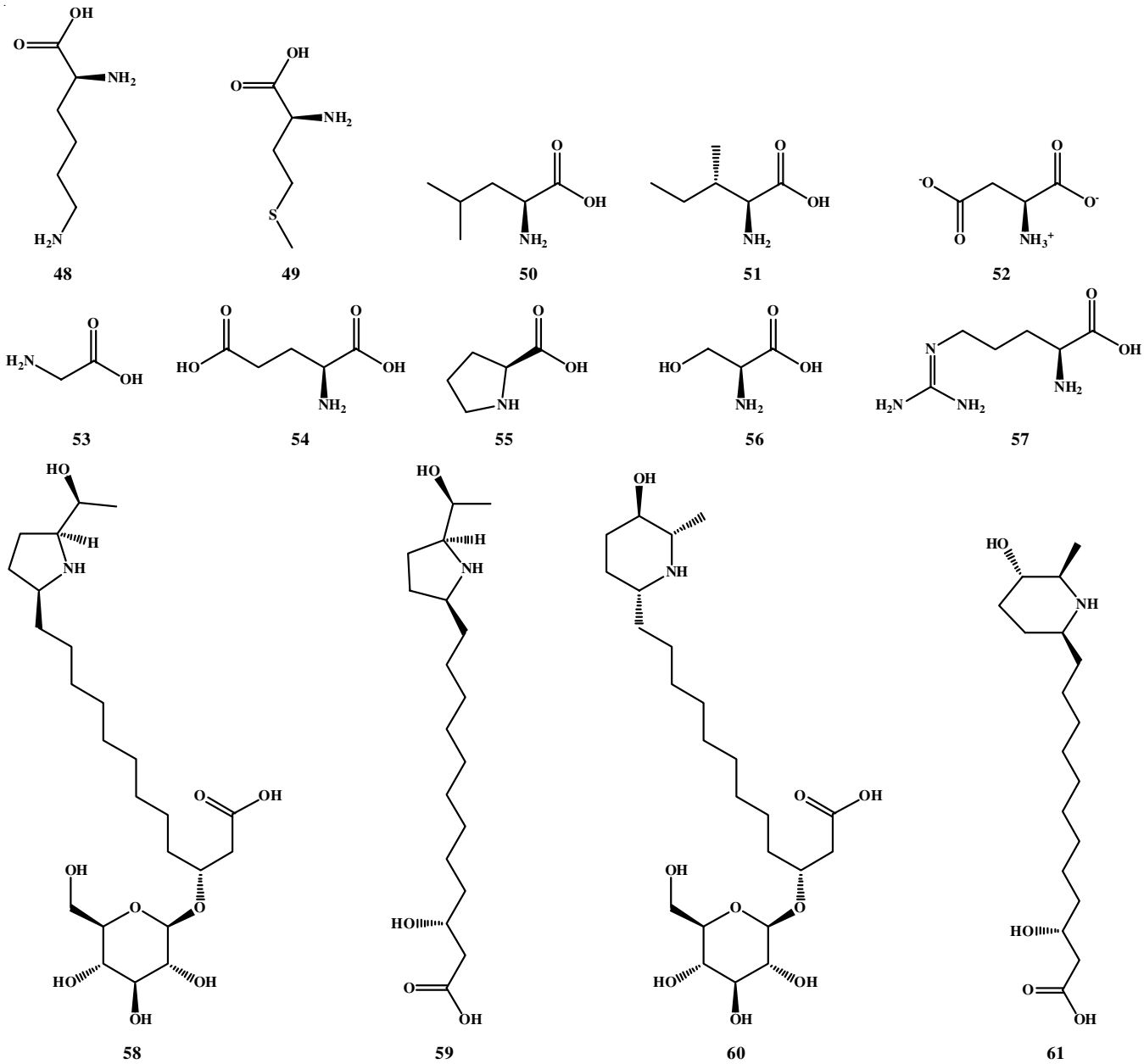

Fig. 7. Structures of alkaloidal compound present in *Morus alba* Linn.

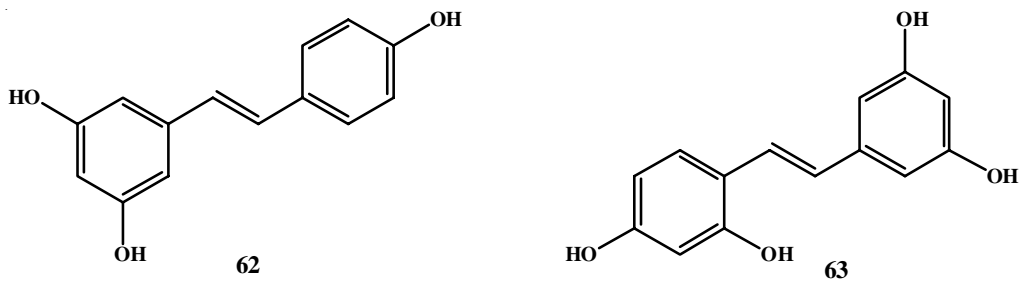

Fig. 8. Structures of stillbenoids present in *Morus alba* Linn.

Calu-6 (human pulmonary carcinoma) and found that the extract showed antiproliferative activity in a concentration dose dependent manner. They also observed that human gastric carcinoma (SNU-601) cell line show cell declining effect when they were treated against methanolic fermented leave extract.

7,2′,4′6′-Tetrahydroxy-6-geranylflavanone, a prenylated flavone found in ethyl acetate extract of *M. alba* possesses cytotoxic activity against hepatoma cells of rats. Another compound, oxyresveratrol have the inhibitory property of inducible nitric oxide and COX-2 activity [37]. The methanolic extract

of *M. alba* leaves have the NO inhibitory property and also it can prominently decrease the production of TNF-α [38]. Polysaccharide present in the root bark of *M. alba* have the potential to increase proliferation of lymphocyte and lower down the production of antibody in B cells, which is major reason for its anti-inflammatory activity [39,40].

Antihyperlipidemic and hypocholesterolaemic properties: The ethanolic root extract of *M. alba* possesses potent antihyperlipidemic activity due to the presence of mulberroside A and oxyresveratrol in it [39]. Mulberroside A and oxyresveratrol can significantly lower down the serum lipid level in hyperlipidemic rats. Among these, oxyresveratrol have more lipid lowering activity than mulberroside A. According to El-Beshbishy *et al.* [41], the alcoholic extract of *M. alba* showed strong hypocholesterolemic activity in hypercholesterolemic rat models.

Effects on central nervous system (CNS): Sattayasai *et al.* [42] reported that the leaves extract of *M. alba* and green tea possesses significant antidepressant activity. At high concentration, the extract may increase muscle strength, activity of animal in maze and also decreased pain response. The anxiolytic effect of methanolic leaves extract of *M. alba* was determined by using elevated plus maze paradigm, hole-board test, light and dark paradigm and open field test. *M. alba* extract at different doses found to increase the exploration of open arm in elevated plus maze, duration and frequency of head poking in hole-board test, exposure in the lighted box and rearing and number of squares crossed in open field. *M. alba* extract decrease the locomotor activity in the actophotometer, therefore have some remarkable sedative activity. Yadav *et al.* [43] stated that the *M. alba* extract showed some prominent apoptogenic properties, due to which it can be used as significant anti-stress agent. The leaves extract of *M. alba* possesses significant antidopaminergic activities due to which it can be used in many psychiatric disorders [44].

Neuroprotective properties: *M. alba* also possesses some significant protective effects against neurological disorders [45]. Due to the presence of cyanidin 3-O-β-glucopyranoside (C3 G), *M. alba* possesses prominent neuroprotective activity. C3 G is having free radical scavenging activity and inflammation inhibitory activity due to which it can protect brain from the endothelial dysfunction. The leaves extract of *M. alba* can inhibit the formation of amyloid fibril β-peptide and decreased amyloid β-peptide induced neurotoxicity, due to which it can be effective in the treatment of Alzheimer's disease [46].

Hepatoprotective and nephroprotective properties: The leaves extract of *M. alba* shows the hepatoprotective and nephroprotective effects. Kalantari *et al.* [47] stated that the aqueous and alcoholic extracts of *M. alba* can protect the damage of liver caused by the CCl_4. The *M. alba* extract protect the liver by decreasing the alanine aminotransferase (ALT), serum levels of aspartate aminotransferase (AST) and also by decreasing inflammation, sleeping time and prevent fibrosis. Nematbakhsh *et al.* [48] found that the flavonoid fraction of leaves of *M. alba* can protect the kidneys against cisplatin-induced nephrotoxicity in rats. Also, it can decrease the cisplatin-induced creatinine and blood urea nitrogen in kidney and inhibit nephrotoxicity [48,49].

Antiviral properties in reference to SARS-CoV-2: Few researches carried out the investigation of antiviral properties of *M. alba.* Kim & Chung [49] studied the antiviral properties of juice and seed extract of *M. alba* against strains of influenza virus such as BR59, KR01, BR10 and FL04 in a dose-dependent manner. Moreover, *M. alba* juice contain abundant polyphenol compound called cyanidin-3-rutinoside due to which juice exhibit weak inhibitory activity against FL04 strain in a dose-dependent manner [50]. Due to the present of some important phytoconstituents such as kuwanon G, 1-deaoxynojirimycin, mulberroside A in *M. alba,* it shows significant antiviral activities. *M. alba* shows prominent human corona virus (HCoV 229E) inhibiting activities, therefore it may also be effective in SARS-CoV-2 inhibition [51]. The water or methanolic extract of *M. alba* can inhibit HCoV 229E by decreasing its cytopathogenic effects and viral titer [52]. Thabti *et al.* [51] evaluated the antiviral activity of water and methanolic extract of kuwanon G, a phytoconstituents of *M. alba* against HCoV 229E and they found that the hydroalcoholic leave extract of *M. alba* can effectively inhibit the cytopathogenic effects and viral titer of this virus. From all these finding it is concluded that due to the presence of some active antiviral components *M. alba* may also be effective in SARS-CoV-2 inhibition. Shakya *et al.* [53] investigate some important inhibitors of transmembrane protease serine-2 (TMPRSS2) through pharmacoinformatic study. TMPRSS2 basically a surface protein, which involve in entry of SARS-CoV-2 into cell membrane. After molecular docking and simulation study, they have observed that all the five molecules effectively binding to active pocket inclusive of important amino acid such as Arg55, Asn451, Glu374 and Leu376 of TMPRSS2, which indicate that all the five molecules obtained from *M. alba* possess crucial anti-SARS-CoV-2 activity.

Conclusion

The beneficial effect of nutraceuticals from medicinal plants or herbs are so effective and potent that their utilization and consumption is being increasing abruptly. *Morus alba* Linn. commonly known as mulberry tree is one such emerging plant whose importance are being increasing day by day. This plant has got so many medicinally important values due to which it considers as a magical plant. Beside human usage, it also got one most important use in silk production as leaves of mulberry plant become primary food for silkworm. Every parts of this plant such as stem, root, leaves, fruits have its medicinal application because all the parts of this plant are rich in important phytochemicals such as alkaloids, flavonoids, amino acids, anthocyanin, stillbenoids, *etc*. Few potent phytochemicals are rutin, quercetin, isoquercetin, morins, epigallocatechin gallate, resveratrol, kaempferol, ferulic acid, morusimic acid, *etc*. Owing to presence of wide range of phytochemicals, extract of plant parts exhibits various pharmacological activities such as antioxidant, antimicrobial, skin-whitening, cytotoxic, anti-inflammatory, anti-diabetic, anti-hyperlipidemic, anti-atherosclerotic, anti-obesity, hepatoprotective and cardioprotective activities. Moreover, research has revealed other pharmacological properties such as antiplatelet, anti-asthmatic, anti-helminthic, anxiolytics, antidepressant, cardioprotective and

immunomodulatory activities. Regarding SARS-CoV-2 inhibiting potential, few researchers have found that juice of *M. alba* fruits exhibit antiviral activity against influenza, compound like kuwanon G or resveratrol can inhibit corona virus (HCoV 229E) and same results have been observed against SARS-CoV-2 through *in silico* experiment. It is concluded that fruit and leave extracts of *M. alba* may also exhibit SARS-CoV-2 inhibition in dose-dependent manner and it leave a scope of biological evaluation.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

REFERENCES

1. S.-Y. Pan, G. Litscher, S.-H. Gao, S.-F. Zhou, Z.-L. Yu, H.-Q. Chen, S.-F. Zhang, M.-K. Tang, J.-N. Sun and K.-M. Ko, *Evid. Based Complement Alternat. Med.*, **2014**, 525340 (2014); https://doi.org/10.1155/2014/525340
2. M.S. Butt, A. Nazir, M.T. Sultan and K. Schroën, *Trends Food Sci. Technol.*, **19**, 505 (2008); https://doi.org/10.1016/j.tifs.2008.06.002
3. A. Altemimi, N. Lakhssassi, A. Baharlouei, D.G. Watson and D.A. Lightfoot, *Plants*, 6, 42 (2017); https://doi.org/10.3390/plants6040042
4. S. Arabshahi-Delouee and A. Urooj, *Food Chem.*, **102**, 1233 (2007); https://doi.org/10.1016/j.foodchem.2006.07.013
5. E.W.C. Chan, P.Y. Lye and S.K. Wong, *Chin. J. Nat. Med.*, **14**, 17 (2016).
6. H.L. Ramesh, S. Venkataramegowda and V.N.Y. Murthy, *World J. Pharm. Res.*, **3**, 320 (2014).
7. M.S. Zafar, F. Muhammad, I. Javed, M. Akhtar, T. Khaliq, B. Aslam, A. Waheed, R. Yasmin and H. Zafar, *Int. J. Agric. Biol.*, **15**, 612 (2013).
8. V.K. Ramappa, D. Srivastava, P. Singh, U. Kumar, D. Kumar, S.B. Gosipatala, S. Saha, D. Kumar and R. Raj, *Int. J. Fruit Sci.*, **20(Suppl. 3)**, S1254 (2020); https://doi.org/10.1080/15538362.2020.1784075
9. S.B. Kim, B.Y. Chang, B.Y. Hwang, S.Y. Kim and M.K. Lee, *Bioorg. Med. Chem. Lett.*, **24**, 5656 (2014); https://doi.org/10.1016/j.bmcl.2014.10.073
10. G. Kusano, S. Orihara, D. Tsukamoto, M. Shibano, M. Coskun, A. Guvenc and C.S. Erdurak, *Chem. Pharm. Bull. (Tokyo)*, **50**, 185 (2002); https://doi.org/10.1248/cpb.50.185
11. M.M. Natic, D. Dabic, A. Papetti, M.M. Fotiric Akšic, V. Ognjanov, M. Ljubojevic and Z.L. Tešic, *Food Chem.*, **171**, 128 (2015); https://doi.org/10.1016/j.foodchem.2014.08.101
12. M.A. Minhas, A. Begum, S. Hamid, M. Babar, R. Ilyas, S. Ali, F. Latif and S. Andleeb, *Pak. J. Zool.*, **48**, 1381 (2016).
13. X. Yang, L. Yang and H. Zheng, *Food Chem. Toxicol.*, **48**, 2374 (2010); https://doi.org/10.1016/j.fct.2010.05.074
14. L. Butkhup, W. Samappito and S. Samappito, *Int. J. Food Sci. Technol.*, **48**, 934 (2013); https://doi.org/10.1111/ijfs.12044
15. Y. Wang, L. Xiang, C. Wang, C. Tang and X. He, *PLoS One*, **8**, e71144 (2013); https://doi.org/10.1371/journal.pone.0071144
16. P. Aramwit, N. Bang and T. Srichana, *Food Res. Int.*, **43**, 1093 (2010); https://doi.org/10.1016/j.foodres.2010.01.022
17. C. Qin, Y. Li, W. Niu, Y. Ding, R. Zhang and X. Shang, *Czech J. Food Sci.*, **28**, 117 (2010); https://doi.org/10.17221/228/2008-CJFS
18. M. Isabelle, B.L. Lee, C.N. Ong, X. Liu and D. Huang, *J. Agric. Food Chem.*, **56**, 9410 (2008); https://doi.org/10.1021/jf801527a
19. M. Gundogdu, F. Muradoglu, R.I.G. Sensoy and H. Yilmaz, *Sci. Hortic.*, **132**, 37 (2011); https://doi.org/10.1016/j.scienta.2011.09.035
20. A.A. Memon, N. Memon, D.L. Luthria, M.I. Bhanger and A.A. Pitafi, *Pol. J. Food Nutr. Sci.*, **60**, 25 (2010).
21. S.H. Bae and H.J. Suh, *Lebensm. Wiss. Technol.*, **40**, 955 (2007); https://doi.org/10.1016/j.lwt.2006.06.007
22. Q. Yuan and L. Zhao, *J. Agric. Food Chem.*, **65**, 10383 (2017); https://doi.org/10.1021/acs.jafc.7b03614
23. S. Iqbal, U. Younas, K.W. Sirajuddin, K.W. Chan, R.A. Sarfraz and M.K. Uddin, *Int. J. Mol. Sci.*, **13**, 6651 (2012); https://doi.org/10.3390/ijms13066651
24. B. Nickavar and G. Mosazadeh, *Iran. J. Pharm. Res.*, **8**, 115 (2009).
25. S. Priya, *J. Nat. Prod. Plant Resour.*, **2**, 440 (2012).
26. T. Oku, M. Yamada, M. Nakamura, N. Sadamori and S. Nakamura, *Br. J. Nutr.*, **95**, 933 (2006); https://doi.org/10.1079/BJN20061746
27. S.H. Lee, S.Y. Choi, H. Kim, J.S. Hwang, B.G. Lee, J.J. Gao and S.Y. Kim, *Biol. Pharm. Bull.*, **25**, 1045 (2002); https://doi.org/10.1248/bpb.25.1045
28. R. Singh, A. Bagachi, A. Semwell and S. Kaur, *J. Med. Plants Res.*, **7**, 461 (2013).
29. S.J. Aditya Rao, C.K. Ramesh, R. Mahmood and B.T. Prabhakar, *Int. J. Pharm. Pharm. Sci.*, **4**, 335 (2012).
30. A.C. Manjula, *Int. J. Curr. Pharm. Res.*, **3**, 13 (2011).
31. H.Y. Sohn, K.H. Son, C.S. Kwon, G.S. Kwon and S.S. Kang, *Phytomedicine*, **11**, 666 (2004); https://doi.org/10.1016/j.phymed.2003.09.005
32. T. Nomura, T. Fukai, Y. Hano, S. Yoshizawa, M. Suganuma and H. Fujiki, *Prog. Clin. Biol. Res.*, **280**, 267 (1988).
33. B. Enkhmaa, K. Shiwaku, T. Katsube, K. Kitajima, E. Anuurad, M. Yamasaki and Y. Yamane, *J. Nutr.*, **135**, 729 (2005); https://doi.org/10.1093/jn/135.4.729
34. K. Doi, T. Kojima and Y. Fujimoto, *Biol. Pharm. Bull.*, **23**, 1066 (2000); https://doi.org/10.1248/bpb.23.1066
35. S.U. Chon, Y.M. Kim, Y.J. Park, B.G. Heo, Y.S. Park and S. Gorinstein, *Eur. Food Res. Technol.*, **230**, 231 (2009); https://doi.org/10.1007/s00217-009-1165-2
36. K.-O. Chung, B.-Y. Kim, M.-H. Lee, Y.-R. Kim, H.-Y. Chung, J.-H. Park and J.-O. Moon, *J. Pharm. Pharmacol.*, **55**, 1695 (2010); https://doi.org/10.1211/0022357022313
37. E.M. Choi and J.K. Hwang, *Fitoterapia*, **76**, 608 (2005); https://doi.org/10.1016/j.fitote.2005.05.006
38. S.P. Jo, J.K. Kim and Y.H. Lim, *Food Chem. Toxicol.*, **65**, 213 (2014); https://doi.org/10.1016/j.fct.2013.12.040
39. H.M. Kim, S.B. Han, K.H. Lee, C.W. Lee, C.Y. Kim, E.J. Lee and H. Huh, *Arch. Pharm. Res.*, **23**, 240 (2000); https://doi.org/10.1007/BF02976452
40. A.L.B. Zeni and M. Dall'Molin, *Rev. Bras. Farmacogn.*, **20**, 130 (2010); https://doi.org/10.1590/S0102-695X2010000100025
41. H.A. El-Beshbishy, A.N.B. Singab, J. Sinkkonen and K. Pihlaja, *Life Sci.*, **78**, 2724 (2006); https://doi.org/10.1016/j.lfs.2005.10.010
42. J. Sattayasai, S. Tiamkao and P. Puapairoj, *Phytother. Res.*, **22**, 487 (2008); https://doi.org/10.1002/ptr.2346
43. J.P. Yadav, S. Saini, A.N. Kalia and A.S. Dangi, *Indian J. Pharmacol.*, **40**, 23 (2008); https://doi.org/10.4103/0253-7613.40485
44. N.P. Seeram, R.A. Momin, M.G. Nair and L.D. Bourquin, *Phytomedicine*, **8**, 362 (2001); https://doi.org/10.1078/0944-7113-00053
45. T. Niidome, K. Takahashi, Y. Goto, S. Goh, N. Tanaka, K. Kamei, M. Ichida, S. Hara, A. Akaike, T. Kihara and H. Sugimoto, *Neuroreport*, **18**, 813 (2007); https://doi.org/10.1097/WNR.0b013e3280dce5af

46. M.G. Hogade, K.S. Patil, G.H. Wadkar, S.S. Mathapati and P.B. Dhumal, *Afr. J. Pharm. Pharmacol.*, **4**, 731 (2010).
47. H. Kalantari, N. Aghel and M. Bayati, *Saudi Pharm. J.*, **17**, 90 (2009).
48. M. Nematbakhsh, V. Hajhashemi, A. Ghannadi, A. Talebi and M. Nikahd, *Res. Pharm. Sci.*, **8**, 71 (2013).
49. H. Kim and M.S. Chung, *Evidence-Based Complement. Altern. Med.*, **2018**, 2606583 (2018); https://doi.org/10.1155/2018/2606583
50. P.I. Manzano-Santana, J.P. Peñarreta-Tivillin, I.A. Chóez-Guaranda, A.D. Barragán-Lucas, A.K. Orellana-Manzano and L. Rastrelli, *Rev. Bionatura*, **6**, 1653 (2021); https://doi.org/10.21931/RB/2021.06.01.30
51. I. Thabti, Q. Albert, S. Philippot, F. Dupire, B. Westerhuis, S. Fontanay, A. Risler, T. Kassab, W. Elfalleh, A. Aferchichi and M. Varbanov, *Molecules*, **25**, 1876 (2020); https://doi.org/10.3390/molecules25081876
52. M. Omrani, M. Keshavarz, S.N. Ebrahimi, M. Mehrabi, L.J. McGaw, M.A. Abdalla and P. Mehrbod, *Front. Pharmacol.*, **11**, 586993 (2021); https://doi.org/10.3389/fphar.2020.586993
53. A. Shakya, R. V. Chikhale, H.R. Bhat, F.A. Alasmary, T.M. Almutairi, S.K. Ghosh, H.M. Alhajri, S.A. Alissa, S. Nagar and M.A. Islam, *Mol. Divers.*, **26**, 265 (2022); https://doi.org/10.1007/s11030-021-10209-3