Available online at www.sciencedirect.com
ScienceDirect
Chinese Journal of Natural Medicines 2016, **14**(1): 0017–0030
doi: 10.3724/SP.J.1009.2016.00017
Chinese Journal of Natural Medicines

·Review·

Phytochemistry, pharmacology, and clinical trials of *Morus alba*

Eric Wei-Chiang CHAN [1*], Phui-Yan LYE [1], Siu-Kuin WONG [2]

[1]*Faculty of Applied Sciences, UCSI University, 56000 Cheras, Kuala Lumpur, Malaysia;*

[2]*School of Science, Monash University Sunway, 46150 Petaling Jaya, Selangor, Malaysia*

Available online 20 Jan., 2016

[ABSTRACT] The present review is aimed at providing a comprehensive summary on the botany, utility, phytochemistry, pharmacology, and clinical trials of *Morus alba* (mulberry or *sang shu*). The mulberry foliage has remained the primary food for silkworms for centuries. Its leaves have also been used as animal feed for livestock and its fruits have been made into a variety of food products. With flavonoids as major constituents, mulberry leaves possess various biological activities, including antioxidant, antimicrobial, skin-whitening, cytotoxic, anti-diabetic, glucosidase inhibition, anti-hyperlipidemic, anti-atherosclerotic, anti-obesity, cardioprotective, and cognitive enhancement activities. Rich in anthocyanins and alkaloids, mulberry fruits have pharmacological properties, such as antioxidant, anti-diabetic, anti-atherosclerotic, anti-obesity, and hepatoprotective activities. The root bark of mulberry, containing flavonoids, alkaloids and stilbenoids, has antimicrobial, skin-whitening, cytotoxic, anti-inflammatory, and anti-hyperlipidemic properties. Other pharmacological properties of *M. alba* include anti-platelet, anxiolytic, anti-asthmatic, anthelmintic, antidepressant, cardioprotective, and immunomodulatory activities. Clinical trials on the efficiency of *M. alba* extracts in reducing blood glucose and cholesterol levels and enhancing cognitive ability have been conducted. The phytochemistry and pharmacology of the different parts of the mulberry tree confer its traditional and current uses as fodder, food, cosmetics, and medicine. Overall, *M. alba* is a multi-functional plant with promising medicinal properties.

[KEY WORDS] Mulberry; Multi-purpose; Medicinal properties; *Morus alba*

[CLC Number] Q5 **[Document code]** A **[Article ID]** 2095-6975(2016)01-0017-14

Introduction

Morus alba L. (mulberry or sang shu) has long been used as fodder and traditional medicine. There has been much research work that has been done since several published reviews on the species [1-4]. Herein, we attempted to provide a comprehensive update on its botany, applications, phytochemistry, medicinal properties, and clinical trials. *Morus alba* L. of the family Moraceae is native to Chinaand is also widely cultivated in Japan and Korea [5-6]. The species is a fast-growing tree, which can reach up to 20 meters in height. Under cultivation with regular harvesting, pruning, and pollarding, the trees are reduced to a low-growing bush to facilitate the harvesting of leaves or fruits. The bark is dark grey-brown with horizontal lenticels. The leaves are glossy green, alternate, cordate at the base, and acuminate at the apex, the margins are serrated, and the petioles are long and slender. Varying from 5.0−7.5 cm in length, the leaves are very variable in form. Even on the same tree, some are unlobed while others may be almost palmate. In the temperate and sub-tropical areas, the trees are commonly dioecious (separate male and female plants), but may be monoecious (male and female flowers on the same plants), and sometimes can change from one sex to another. The flowers comprising male and female catkins are inconspicuous, pendulous, and greenish. The fruit consists of many drupes formed by individual flowers to form a sorosis, the characteristic mulberry fruit. The fruit color is green when young, turning orange to red and finally to purplish black when fully ripened. Fig. 1 shows the leaves and fruits of *M. alba*.

Mulberry foliage is valued as the primary food for silkworms, supporting the silk industry for centuries [7-9]. The silkworm eats only mulberry leaves to make its cocoon, which produces the silk, and there is a high correlation between the content of leaf protein and the efficiency of cocoon production [9]. The amino acids (threonine, valine, methionine,

[Received on] 04-Feb.-2015
[*Corresponding author] E-mail: chanwc@ucsiuniversity.edu.my.
These authors have no conflict of interest to declare.

Fig. 1 Leaves and fruits of *Morus alba*

leucine, phenylalanine, lysine, histidine, and arginine) found in mulberry leaves are needed for silkworm growth. It is well established that the growth of silkworms as well as the cocoon and raw silk quality depend on the quality of mulberry leaves, which in turn is closely related to the plant varieties, environmental conditions, and cultivation practice [10]. In China, 15−18 kg of mulberry leaves is needed to produce 1 kg of cocoon at the farm level [7].

Mulberry leaves are also used as fodder for livestock. They are nutritious, palatable, and non-toxic and can improve milk production when fed to dairy animals [11]. The high crude protein content and organic matter digestibility of mulberry leaves are superior to most tropical grasses commonly used as cattle feed [12].

In traditional Chinese medicine (TCM), leaves, fruits, and bark of *M. alba* have long been used to treat fever, protect liver damage, improve eyesight, strengthen joints, facilitate discharge of urine, and lower blood pressure [13]. In Korea and Japan, patients with diabetes consume mulberry leaves as an anti-hyperglycemic supplement [14]. Mulberry leaves are effective against high blood pressure and hangover from alcohol and in lowering blood sugar level related to diabetes [9]. In East and Southeast Asia, the drinking of mulberry tea is gaining popularity. The tea is rich in γ-aminobutyric acid (2.7 mg·g^{-1} dry weight) which is 10 times higher than that of green tea [6]. The compound is known to lower blood pressure.

In Turkey and Greece, trees of *M. alba* are grown for fruits rather than foliage [15]. The fruits are used to produce mulberry juice, jam, liquor, and canned mulberries. In China, the leaves of *M. alba* are processed into tea while fruit juice is consumed as a health beverage [7]. Other uses of mulberry include paper and mushroom production [9]. Woodchips of mulberry trees have been used as pulp for paper production and as media for mushroom culture. In India, mulberry wood is made into sports equipment, furniture, household utensils, and agricultural implements [8].

Phytochemistry

Photochemical studies have identified terpenoids, alkaloids, flavonoids (including chalcones and anthocyanins), phenolic acids, stilbenoids, and coumarins in *Morus alba*. Compounds isolated from the leaf, fruit, root, bark, root bark, twig, and stem of the plant are listed in Table 1. Mulberry fruits yield the most number of compounds.

Leaf

Three flavonol glycosides, quercetin 3-(6-malonylglucoside), rutin, and isoquercitrin, are identified as the major antioxidant compounds in the ethanol leaf extract of *M. alba* [14]. Their contents are 9.0, 5.7, and 1.9 mg·g^{-1} dry weight, respectively. From the ethanol leaf extract of mulberry, four new 2-arylbenzofuran derivatives (moracins V−Y), together with two known compounds (moracins N and P) are isolated [37]. From the butanol leaf extract, two novel prenylflavanes and a glycoside, along with six known compounds, isoquercitrin, astragalin, scopolin, skimmin, roseoside II, and benzyl D-glucopyranoside, are isolated [23]. From the methanol leaf extract, a new and ten known flavonoids are isolated [21] (Fig. 2).

From the ethanol leaf extract of *M. alba,* morachalcones B and C have been isolated [19]. They are unusual chalcones having a five-membered furan ring with an oxygen molecule. Further bioassay-guided fractionation of the extract leads to the isolation of 15 flavonoids, including five new compounds [24].

Fruit

Extraction of fresh fruits of *M. alba* has yielded five anthocyanins [33]. From the ethanol fruit extract of *M. alba*, bioactivity-guided fractionation has led to the isolation of 25 phenolic compounds, all of which are isolated from the mulberry fruit for the first time [20]. Some of the phyto-chemicals and their molecular structures are shown in Fig. 3.