



# An In-Depth Examination of Phytochemicals and Medicinal Uses on *Morus alba*

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## Abstract

*Morus alba*, commonly known as white mulberry, is a plant renowned for its diverse range of bioactive compounds that confer numerous health benefits. This review explores the plant's antioxidant, anti-inflammatory, anticancer, cardiovascular, neuroprotective, hepatoprotective, and antimicrobial properties. The antioxidant effects, primarily attributed to flavonoids, phenolic acids, and terpenoids, help mitigate oxidative stress and protect against various diseases. The anti-inflammatory properties reduce chronic inflammation, while the anticancer compounds induce apoptosis and inhibit tumor growth. *Morus alba*'s cardiovascular benefits include improved endothelial function and lipid metabolism. Its neuroprotective effects protect the brain from oxidative damage and neuroinflammation, supporting cognitive function. The hepatoprotective activity enhances liver health and prevents damage from toxins. Additionally, the plant's antimicrobial properties make it effective against a broad spectrum of pathogens. Overall, *Morus alba* holds significant potential as a natural therapeutic agent, with applications in both traditional and modern medicines.

## Keywords

- ▶ *Morus alba*
- ▶ white mulberry
- ▶ antioxidant properties
- ▶ anti-inflammatory effects
- ▶ anticancer potential
- ▶ cardiovascular health

## Introduction

*Morus alba*, commonly known as the white mulberry, is a deciduous tree native to northern China. *The Grand Compendium of Materia Medica* says: "Morus alba is the divine tree in China. It can relieve consumptive thirst." Morus alba leaves are sweet, bitter, and cold in nature, and the meridian tropism of Morus alba leaves are lung and liver meridians. They have the effects of dispersing wind-heat, suppressing hyperactive liver for improving eyesight, clearing lung-heat and moistening dryness. The leaves of *Morus alba* contain flavonoids, alkaloids, and other compounds with potential health benefits. The fruit is rich in vitamins, especially vitamin C, minerals, and antioxidants, including resveratrol, which is associated with cardiovascular health. In traditional Chinese medicine, *Morus alba* is used to treat fever and

cough, and as a diuretic, with the root bark specifically used for its antihypertensive properties.<sup>1</sup>

*Morus alba* thrives in temperate to tropical climates and is highly adaptable to different soil types, although it prefers well-drained soil. Originally from northern China, it has been widely cultivated and naturalized across Asia, Europe, Africa, and the Americas.<sup>2</sup> Its ability to tolerate drought and poor soil conditions has contributed to its widespread distribution (▶ Fig. 1).

The white mulberry is integral to sericulture, as its leaves are the primary food source for silkworms (*Bombyx mori*), essential for silk production. Beyond its role in sericulture, the fruits of *Morus alba* are consumed fresh or dried and used in various culinary applications such as jams, jellies, and wines.<sup>3</sup> The plant also holds a significant place in traditional medicine, with different parts used to treat various ailments.

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**Fig. 1** A systematic view of the plant *Morus alba* (white mulberry).

The leaves, fruits, and bark are believed to have medicinal properties, purportedly beneficial for conditions like diabetes, hypertension, and inflammation. Despite its beneficial uses,<sup>4</sup> *Morus alba* has invasive potential, particularly in North America, where it can outcompete native vegetation and hybridize with native mulberry species like *Morus rubra*. This has raised concerns about its impact on local ecosystems. However, it also contributes to biodiversity by providing food and habitat for various bird species and insects.<sup>5</sup>

Nutritionally, the leaves of *Morus alba* are high in protein, making them ideal for silkworm consumption.<sup>6</sup>

In ayurvedic medicine, the plant is valued for its cooling properties and is used to treat heat-related conditions and inflammation.

### Phytochemicals in *Morus Alba*

The phytochemical constituents of *Morus alba* are presented in **Table 1**.

*Morus alba* is rich in various phytochemicals distributed throughout its leaves, fruits, bark, and roots, each contributing significantly to its medicinal and nutritional value. The leaves of *Morus alba* are abundant in flavonoids such as quercetin, kaempferol, and rutin, which exhibit anti-inflammatory, antioxidant, antihypertensive, and blood vessel-strengthening properties. Alkaloids 1-deoxynojirimycin (DNJ) found in the leaves provide anticancer, antioxidant, and anti-inflammatory effects, and help control blood sugar levels.<sup>7</sup> Additionally, coumarins such as scopoletin offer anti-inflammatory, antimicrobial, and anticoagulant benefits,<sup>8</sup> while phenolic acids like chlorogenic acid and terpenoids

like betulinic acid enhance the leaves' antioxidant, neuroprotective, and antiviral properties.

The fruits of *Morus alba* are particularly rich in anthocyanins, including cyanidin-3-glucoside and pelargonidin-3-glucoside, which are powerful antioxidants that may reduce the risk of chronic diseases and possess anti-inflammatory properties.<sup>9</sup> Flavonoids such as quercetin and rutin further contribute to the fruits' anti-inflammatory, antioxidant, and cardiovascular health benefits. The fruits also contain essential vitamins and minerals, including vitamin C, which boosts immune function and improves skin health; vitamin K, crucial for blood clotting and bone health; and iron, necessary for red blood cell formation and oxygen transport. Organic acids like malic acid and citric acid enhance energy production, muscle performance, mineral absorption, and offer antioxidant benefits.<sup>10</sup>

The bark and roots of *Morus alba* contain stilbenoids like resveratrol, known for their cardioprotective, anticancer, and antiaging effects. Flavonoids such as morusin and kuwanon G present in the bark and roots exhibit anti-inflammatory, anticancer, and antibacterial activities. Alkaloids like calyptegine in the bark and roots inhibit glycosidase enzymes, which is beneficial for diabetes management. Additionally, phenolic compounds in the bark and roots provide antioxidant and anti-inflammatory effects.

### Medicinal Uses

#### Antidiabetic Properties

*Morus alba* is recognized for its significant antidiabetic properties, primarily due to various bioactive compounds in its leaves, fruits, and roots. One of the key compounds is DNJ, an

**Table 1** Phytochemicals constituents in the plant *Morus alba*<sup>2-6</sup>

Part of plant	Phytochemicals	Health benefits
Leaves	<b>Flavonoids</b>	
	Quercetin	Anti-inflammatory, antioxidant, antihypertensive
	Kaempferol	Anticancer, anti-inflammatory, antioxidant
	Rutin	Strengthens blood vessels, anti-inflammatory, antioxidant
	<b>Alkaloids</b>	
	Morusin	Anticancer, antioxidant, anti-inflammatory
	1-Deoxynojirimycin (DNJ)	Controls blood sugar levels
	<b>Coumarins</b>	
	Scopoletin	Anti-inflammatory, antimicrobial, anticoagulant
	<b>Phenolic acids</b>	
	Chlorogenic acid	Antioxidant, anti-inflammatory, neuroprotective
	<b>Terpenoids</b>	
	Betulinic acid	Anticancer, anti-inflammatory, antiviral
Fruits	<b>Anthocyanins</b>	
	Cyanidin-3-glucoside	Antioxidant, reduces risk of chronic diseases
	Pelargonidin-3-glucoside	Antioxidant, anti-inflammatory
	<b>Flavonoids</b>	
	Quercetin	Anti-inflammatory, antioxidant
	Rutin	Supports cardiovascular health, anti-inflammatory
	<b>Vitamins and minerals</b>	
	Vitamin C	Antioxidant, boosts immune function, improves skin health
	Vitamin K	Essential for blood clotting, bone health
	Iron	Red blood cell formation, oxygen transport
	<b>Organic acids</b>	
	Malic acid	Enhances energy production, muscle performance
	Citric acid	Improves mineral absorption, antioxidant
Bark and roots	<b>Stilbenoids</b>	
	Resveratrol	Cardioprotective, anti-cancer, anti-aging
	<b>Flavonoids</b>	
	Morusin	Anti-inflammatory, anticancer
	Kuwanon G	Antibacterial, anti-inflammatory
	<b>Alkaloids</b>	
	Calystegine	Inhibits glycosidase enzymes, beneficial for diabetes management
	<b>Phenolic compounds</b>	
Phenolic acids	Antioxidant, anti-inflammatory	

$\alpha$ -glucosidase inhibitor that slows the digestion and absorption of carbohydrates, thereby reducing postprandial blood glucose levels. This mechanism is crucial for managing type 2 diabetes as it helps prevent spikes in blood sugar after meals.<sup>11</sup> The leaves of *Morus alba* are rich in flavonoids such as quercetin, kaempferol, and rutin, which possess strong antioxidant properties that protect pancreatic  $\beta$  cells from oxidative stress, enhance insulin secretion, and improve insulin sensitivity. These flavonoids also have anti-inflammatory effects, reducing chronic inflammation linked to insulin resistance.

Additionally, phenolic compounds like chlorogenic acid and rutin in *Morus alba* play a significant role in antidiabetic activity. Chlorogenic acid reduces glucose production in the liver, slows glucose absorption in the intestines, and improves insulin sensitivity, while rutin enhances insulin secretion and protects pancreatic cells from oxidative damage. Betulinic acid, a terpenoid found in the bark and roots, further contributes to enhancing insulin sensitivity and lowering blood glucose levels, thanks to its anti-inflammatory properties.<sup>12</sup>

Numerous studies support these effects. Studies have shown that diabetic mice treated with *M. alba* leaf extracts exhibit reduced blood glucose levels, improved glucose tolerance, and increased insulin secretion.<sup>13</sup> Clinical trials have also demonstrated significant reductions in fasting and postprandial blood glucose levels, as well as HbA1c, in patients with type 2 diabetes who consumed *M. alba* leaf extract. These improvements are attributed to the inhibitory effects of DNJ on carbohydrate digestion and absorption, alongside the antioxidant and anti-inflammatory properties of the plant's other bioactive compounds. In vitro studies further confirm that *Morus alba* extracts enhance insulin secretion, reduce glucose production, and protect against oxidative stress and inflammation.<sup>14</sup>

In addition to its direct antidiabetic effects, *Morus alba* helps manage weight, a critical factor in diabetes control, by reducing fat accumulation and improving lipid metabolism. Its antioxidant and anti-inflammatory properties also benefit cardiovascular health by improving lipid profiles, reducing blood pressure, and preventing low-density lipoprotein (LDL) cholesterol oxidation, thereby lowering the risk of cardiovascular complications associated with diabetes. Overall, *Morus alba* multifaceted bioactive compounds provide a robust complementary approach to diabetes management and prevention of its complications.<sup>15</sup>

### Antioxidant Effects

*Morus alba*, commonly known as white mulberry, is notable for its significant antioxidant properties, which arise from various bioactive compounds present in its leaves, fruits, bark, and roots. Among these compounds, flavonoids such as quercetin, kaempferol, and rutin stand out for their potent antioxidant activity. These flavonoids help neutralize free radicals, inhibit lipid peroxidation, and upregulate antioxidant enzymes like superoxide dismutase and catalase, thereby protecting cells from oxidative damage and reducing oxidative stress. Phenolic acids like chlorogenic acid and gallic acid also contribute significantly by scavenging free radicals and enhancing the body's antioxidant defense system.<sup>16</sup> In the fruits, anthocyanins such as cyanidin-3-glucoside and pelargonidin-3-glucoside provide powerful antioxidant effects, protecting against oxidative damage to cells and tissues.

Additionally, alkaloids like morusin and terpenoids such as betulinic acid exhibit strong antioxidant properties, further bolstering *Morus alba*'s capacity to combat oxidative stress. The combined antioxidant effects of these compounds confer numerous health benefits. For cardiovascular health, they prevent the oxidation of LDL cholesterol, improve endothelial function, and reduce inflammation, thus protecting against atherosclerosis. In terms of neuroprotection, these antioxidants safeguard neurons from oxidative damage, reduce neuroinflammation, and enhance cognitive function, thereby helping prevent neurodegenerative diseases like Alzheimer's and Parkinson's diseases.<sup>17</sup>

*Morus alba*'s antioxidants also play a crucial role in its anticancer properties by reducing oxidative stress and preventing DNA damage, which inhibits cancer initiation and progression. Compounds such as quercetin and morusin have

been shown to induce apoptosis in cancer cells and reduce tumor growth. Moreover, the antiaging effects of these antioxidants are significant, as they protect skin cells from oxidative damage, enhance collagen production, and improve skin elasticity, thereby reducing wrinkles and improving skin hydration. In diabetes management, the antioxidants in *M. alba* protect pancreatic  $\beta$  cells from oxidative damage, enhance insulin sensitivity,<sup>18</sup> and mitigate complications associated with diabetes, with rutin and chlorogenic acid playing particularly important roles in improving glucose metabolism and reducing oxidative stress-induced damage.

Overall, *Morus alba* rich array of antioxidant compounds makes it a valuable plant for protecting against oxidative stress-related diseases, including cardiovascular diseases, neurodegenerative disorders, cancer, aging, and diabetes, underscoring its importance in both traditional and modern medicines.

### Anti-Inflammatory Benefits

*Morus alba*, or white mulberry, is known for its substantial anti-inflammatory benefits, largely due to the bioactive compounds found in its leaves, fruits, bark, and roots. Flavonoids such as quercetin, kaempferol, and rutin play crucial roles in modulating the inflammatory response. Quercetin is a potent anti-inflammatory agent that inhibits the production of proinflammatory cytokines like TNF- $\alpha$ , IL-1 $\beta$ , and IL-6, and reduces the activity of inflammatory enzymes such as cyclooxygenase (COX) and lipoxygenase (LOX), which in turn decreases the synthesis of inflammatory mediators like prostaglandins and leukotrienes. Kaempferol exhibits strong anti-inflammatory effects by downregulating the expression of inflammatory genes and inhibiting the nuclear factor-kappa B (NF- $\kappa$ B) pathway, a key regulator of inflammation, leading to reduced production of proinflammatory cytokines and enzymes.<sup>19</sup> Rutin also contributes by scavenging free radicals, inhibiting the release of proinflammatory cytokines, and reducing the infiltration of inflammatory cells into tissues.

Phenolic compounds like chlorogenic acid further enhance *Morus alba*'s anti-inflammatory properties. Chlorogenic acid reduces inflammation by inhibiting the production of proinflammatory cytokines and enzymes and blocking the NF- $\kappa$ B pathway, thereby reducing the expression of inflammatory genes. Additionally, the alkaloid morusin and terpenoids like betulinic acid exhibit significant anti-inflammatory activities, contributing to the overall anti-inflammatory effects of *Morus alba*. These bioactive compounds collectively help in modulating the inflammatory response, reducing chronic inflammation, and providing protection against various inflammatory diseases, making *Morus alba* a valuable plant for managing inflammation and its associated conditions.<sup>20</sup>

### Anticancer Potential

*Morus alba*, commonly known as white mulberry, exhibits significant anticancer potential due to a variety of bioactive compounds found in its leaves, fruits, bark, and roots. Among these, flavonoids such as quercetin, kaempferol, and rutin play a pivotal role. Quercetin, for example, induces apoptosis

(programmed cell death) in cancer cells, inhibits cell proliferation, and disrupts various signaling pathways crucial for cancer growth. Kaempferol also promotes apoptosis, inhibits angiogenesis (the formation of new blood vessels that feed tumors), and hampers the metastatic spread of cancer cells. Rutin contributes by enhancing the antioxidant defense system, which helps protect against DNA damage and the subsequent development of cancer.<sup>21</sup>

Phenolic compounds like chlorogenic acid and gallic acid add to the anticancer effects of *Morus alba*. Chlorogenic acid inhibits the proliferation of cancer cells and induces apoptosis, while gallic acid has been shown to disrupt cancer cell cycles and promote cell death. Additionally, the stilbenoid resveratrol, found in the roots and bark, is known for its ability to inhibit cancer cell growth, induce apoptosis, and prevent metastasis. Resveratrol's multifaceted mechanisms include modulating various molecular pathways, such as the NF- $\kappa$ B pathway, which is involved in cell survival and inflammation.<sup>22</sup>

Furthermore, alkaloids such as morusin exhibit strong anticancer properties by inducing apoptosis, inhibiting cell migration, and reducing tumor growth. Terpenoids like betulinic acid also contribute by promoting cancer cell death and inhibiting tumor development. Collectively, these compounds in *Morus alba* not only inhibit cancer cell growth and proliferation but also enhance the body's natural defenses against cancer progression. The diverse and potent anticancer properties of *M. alba* make it a promising candidate for further research and potential therapeutic use in cancer prevention and treatment.

### Cardiovascular Health

*Morus alba*, or white mulberry, offers significant benefits for cardiovascular health, thanks to the various bioactive compounds present in its leaves, fruits, bark, and roots. Flavonoids such as quercetin, kaempferol, and rutin are particularly beneficial for heart health. Quercetin helps reduce blood pressure by improving endothelial function and relaxing blood vessels. It also inhibits the oxidation of LDL cholesterol, a key step in the development of atherosclerosis. Kaempferol contributes by reducing inflammation and preventing the formation of blood clots, thereby lowering the risk of heart attacks and strokes. Rutin enhances capillary strength and improves blood circulation, further supporting cardiovascular health.<sup>23</sup>

Phenolic acids, including chlorogenic acid and gallic acid, also play crucial roles in maintaining heart health. Chlorogenic acid reduces blood pressure and improves lipid metabolism, thereby decreasing the risk of cardiovascular diseases. Gallic acid exhibits strong antioxidant properties, protecting the heart from oxidative stress and reducing inflammation. Additionally, stilbenoids like resveratrol, found in the roots and bark, are known for their cardioprotective effects. Resveratrol improves endothelial function, reduces oxidative stress, and has anti-inflammatory properties, all of which contribute to better heart health.<sup>24</sup>

Alkaloids such as morusin and terpenoids like betulinic acid further enhance the cardiovascular benefits of *M. alba*. Morusin helps lower blood pressure and cholesterol levels, while betulinic acid has anti-inflammatory and lipid-lowering effects. Collectively, these compounds in *M. alba* work

synergistically to improve endothelial function, reduce oxidative stress and inflammation, lower blood pressure and cholesterol levels, and prevent the formation of atherosclerotic plaques. These combined actions make *M. alba* a valuable natural remedy for supporting and maintaining cardiovascular health.

### Neuroprotective Effects

*Morus alba*, or white mulberry, demonstrates significant neuroprotective effects due to its rich array of bioactive compounds, which include flavonoids, phenolic acids, alkaloids, and terpenoids. Flavonoids such as quercetin, kaempferol, and rutin are particularly effective in protecting the nervous system. Quercetin has been shown to cross the blood-brain barrier, where it acts as a potent antioxidant, scavenging free radicals and reducing oxidative stress, a key factor in neurodegenerative diseases like Alzheimer's and Parkinson's diseases.<sup>25</sup> Kaempferol also exhibits strong antioxidant properties and has been found to inhibit neuroinflammation by downregulating proinflammatory pathways, thus protecting neurons from damage.

Phenolic acids, including chlorogenic acid and gallic acid, contribute significantly to the neuroprotective benefits of *Morus alba*. Chlorogenic acid enhances cognitive function by improving cerebral blood flow and reducing inflammation in the brain. Gallic acid protects against neurotoxicity and oxidative stress, further safeguarding neuronal health. Additionally, alkaloids such as morusin have demonstrated neuroprotective properties by reducing neuroinflammation and preventing neuronal apoptosis.

Terpenoids like betulinic acid add another layer of protection. Betulinic acid has been shown to exert neuroprotective effects through its anti-inflammatory and antioxidant activities, which help maintain the integrity of neurons and support brain function. Collectively, these compounds in *Morus alba* protect against oxidative damage, reduce neuroinflammation, enhance cognitive function, and prevent neuronal cell death.<sup>26</sup> These effects make *Morus alba* a promising natural agent for the prevention and management of neurodegenerative diseases, as well as for the overall maintenance of brain health.

### Hepatoprotective Activity

*Morus alba*, commonly known as white mulberry, exhibits significant hepatoprotective activity due to its rich content of bioactive compounds, including flavonoids, phenolic acids, alkaloids, and terpenoids. Flavonoids such as quercetin, kaempferol, and rutin play a critical role in protecting the liver. Quercetin's antioxidant properties help neutralize free radicals, reducing oxidative stress and preventing liver cell damage. Kaempferol enhances this protective effect by inhibiting inflammation and promoting the regeneration of hepatocytes, the functional cells of the liver. Rutin also contributes by strengthening the liver's antioxidant defense system and reducing lipid peroxidation, which can damage liver cells.

Phenolic acids, such as chlorogenic acid and gallic acid, further enhance the hepatoprotective effects of *Morus alba*. Chlorogenic acid helps by inhibiting fat accumulation in the liver and improving lipid metabolism, thereby preventing nonalcoholic fatty liver disease (NAFLD). Gallic acid offers

strong antioxidant and anti-inflammatory properties, protecting the liver from toxins and supporting its detoxification processes. Alkaloids like morusin also play a crucial role in liver protection by reducing liver inflammation and preventing hepatocyte apoptosis (cell death).<sup>27</sup>

Terpenoids such as betulinic acid add an additional layer of liver protection. Betulinic acid has been shown to possess potent anti-inflammatory and antioxidant properties, which help in protecting liver cells from damage caused by toxins, drugs, and other harmful substances. Collectively, these compounds in *Morus alba* work synergistically to enhance liver function, reduce oxidative stress and inflammation, and prevent liver cell damage.<sup>28</sup> These protective effects make *M. alba* a valuable natural remedy for maintaining liver health and preventing liver diseases.

### Antimicrobial Properties

*Morus alba*, commonly known as white mulberry, possesses notable antimicrobial properties, attributed to a diverse array of bioactive compounds in its leaves, fruits, bark, and roots. Flavonoids such as quercetin, kaempferol, and rutin play a pivotal role in these antimicrobial activities. Quercetin, for instance, disrupts the cell walls of bacteria and inhibits their growth, while kaempferol exhibits broad-spectrum antimicrobial effects against various bacterial and fungal strains by interfering with their cellular processes. Rutin enhances these effects by damaging microbial cell membranes and inhibiting their ability to replicate.<sup>28</sup>

Phenolic acids, such as chlorogenic acid and gallic acid, also contribute significantly to the antimicrobial properties of *Morus alba*. Chlorogenic acid disrupts microbial cell walls

and inhibits the synthesis of essential proteins and nucleic acids, thereby preventing microbial growth. Gallic acid, known for its strong antibacterial and antifungal activities, targets multiple microbial pathways, making it difficult for pathogens to develop resistance.

Alkaloids like morusin add another layer of antimicrobial defense. Morusin has been shown to possess potent antibacterial and antifungal properties, disrupting microbial membranes and inhibiting their metabolic activities. Terpenoids such as betulinic acid further enhance the antimicrobial potential of *M. alba*. Betulinic acid has been found to exert strong effects against a variety of pathogens by disrupting their cell membranes and interfering with their energy production processes.<sup>29</sup>

Collectively, these bioactive compounds in *Morus alba* work synergistically to inhibit the growth and proliferation of a wide range of bacteria, fungi, and other pathogens.<sup>30</sup> The plant's antimicrobial properties make it a valuable natural remedy for treating infections and promoting overall health. These effects also highlight the potential of *Morus alba* as a source of new antimicrobial agents for use in both traditional and modern medicine.<sup>31</sup> In **Table 2**, the authors list the marketed products that contain parts of the *Morus alba*.

### Conclusion

*Morus alba*, or white mulberry, stands out as a plant with multifaceted health benefits, supported by its rich composition of bioactive compounds. Its antioxidant properties, derived from flavonoids, phenolic acids, and terpenoids, help combat oxidative stress and protect against various diseases. The plant's anti-inflammatory effects further enhance its therapeutic

**Table 2** Market product containing plant parts *Morus alba*

Product category	Description	Details
Nutritional supplements	White mulberry leaves, fruits, and bark are used in dietary supplements for their potential health benefits	Uses: blood sugar regulation, antioxidant properties, weight management, cardiovascular health Forms: capsules, powders, extracts
Herbal teas	Dried white mulberry leaves are used to make herbal teas	Benefits: may improve digestion, reduce blood sugar levels, support weight loss Preparation: leaves are dried, then steeped in hot water
Mulberry fruit products	The fruits are consumed fresh or used in various products for their sweet taste and nutritional value	Products: jams, jellies, wines, dried fruits, smoothies, syrups Nutritional value: high in vitamins (C, K), fiber, antioxidants
Silk production	The leaves are the primary food source for silkworms, making the plant essential for silk production	Process: leaves are harvested and fed to silkworms, which produce silk fibers Regions: major in China, India, Thailand, and Brazil
Traditional medicine	Various parts of the white mulberry plant are used in traditional medicine, especially in Chinese medicine	Conditions treated: diabetes, high blood pressure, high cholesterol, joint pain, respiratory issues Forms: decoctions, powders, extracts
Cosmetic products	Extracts from the white mulberry plant are used in skincare and cosmetic products	Effects: Antiaging, skin brightening, anti-inflammatory, moisturizing Products: creams, serums, lotions, masks
Animal feed	The leaves are used as fodder for livestock, particularly in regions where the plant is cultivated	Benefits: high nutritional content for livestock (proteins, vitamins, minerals) Usage: fed directly or mixed with other feed

potential, offering relief from chronic inflammation and related conditions. *Morus alba's* anticancer properties, highlighted by its ability to induce apoptosis and inhibit tumor growth, position it as a promising candidate for cancer prevention and treatment. Its cardiovascular benefits, through improved endothelial function and lipid metabolism, contribute to overall heart health. Additionally, the neuroprotective effects of *M. alba* safeguard the brain from oxidative damage and neuroinflammation, supporting cognitive function and protecting against neurodegenerative diseases. The plant also exhibits hepatoprotective activity, enhancing liver health and preventing damage from toxins and oxidative stress. Finally, the antimicrobial properties of *M. alba* make it an effective natural remedy against a wide range of pathogens. Collectively, these diverse health benefits underscore the importance of *M. alba* in both traditional and modern medicine, highlighting its potential as a valuable natural therapeutic agent.

At present, there are still many shortcomings in the research on the chemical composition and medicinal value of *Morus alba*, including the need for further improvement of their mechanism of action, and the need for further verification of their safety and effectiveness in clinical applications. Future research should delve into the chemical composition and medicinal value of *Morus alba*, and evaluate their safety and effectiveness in clinical applications; At the same time, it is necessary to have a precise understanding of the synthesis and regulation pathways of active ingredients, and cultivate variety resources rich in active substances in various parts, explore more effective and efficient extraction methods, and provide more reliable theoretical basis for the development and application of medicinal active substances in *Morus alba*.

#### CRediT Authorship Contribution Statement

**Roshan Kumar Dubey, Satyam Shukla, and Prashant Shukla:** data curation and writing-review & editing.

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#### Conflict of Interest

The authors declare no conflict of interest.

#### References

- Jeong JY, Liu Q, Kim SB, et al. Characterization of melanogenesis inhibitory constituents of *Morus alba* leaves and optimization of extraction conditions using response surface methodology. *Molecules* 2015;20(05):8730–8741
- Lee SH, Choi SY, Kim H, et al. Mulberroside F isolated from the leaves of *Morus alba* inhibits melanin biosynthesis. *Biol Pharm Bull* 2002;25(08):1045–1048
- Lee S, Kim DH, Lee JH, et al. Involvement of histaminergic system in the anxiolytic-like activities of *Morus alba* leaves in mice. *Biol Pharm Bull* 2013;36(11):1692–1699
- Lee MR, Kim JE, Choi JY, et al. Anti-obesity effect in high-fat-diet-induced obese C57BL/6 mice: study of a novel extract from mulberry (*Morus alba*) leaves fermented with *Cordyceps militaris*. *Exp Ther Med* 2019;17(03):2185–2193
- Lee YJ, Choi DH, Kim EJ, et al. Hypotensive, hypolipidemic, and vascular protective effects of *Morus alba* L. in rats fed an atherogenic diet. *Am J Chin Med* 2011;39(01):39–52
- Lim HJ, Jin HG, Woo ER, et al. The root barks of *Morus alba* and the flavonoid constituents inhibit airway inflammation. *J Ethnopharmacol* 2013;149(01):169–175
- Lim HS, Ha H, Lee H, et al. *Morus alba* L. suppresses the development of atopic dermatitis induced by the house dust mite in NC/Nga mice. *BMC Complement Altern Med* 2014;14:139
- Kim ES, Park SJ, Lee EJ, et al. Purification and characterization of Moran 20K from *Morus alba*. *Arch Pharm Res* 1999;22(01):9–12
- Łochyńska M, Oleszak G. Multi-use of the white mulberry (*Morus alba* L.). *Ecol Quest* 2013;15(01):91
- Lu HP, Jia YN, Peng YL, et al. Oxyresveratrol, a stilbene compound from *Morus alba* L. twig extract active against *Trichophyton rubrum*. *Phytother Res* 2017;31(12):1842–1848
- Ma X, Iwanaka N, Masuda S, et al. *Morus alba* leaf extract stimulates 5'-AMP-activated protein kinase in isolated rat skeletal muscle. *J Ethnopharmacol* 2009;122(01):54–59
- Mahmoud MY. Natural antioxidants effect of mulberry fruits (*Morus nigra* and *Morus alba* L.) on lipids profile and oxidative stress in hypercholesterolemic rats. *Pak J Nutr* 2013;12(07):665–672
- Hong Y, Kim MY, Yoon M. The anti-angiogenic herbal extracts Ob-X from *Morus alba*, *Melissa officinalis*, and *Artemisia capillaris* suppresses adipogenesis in 3T3-L1 adipocytes. *Pharm Biol* 2011;49(08):775–783
- Habeeb N. Fractionation and screening of *Morus alba* L. leaf extracts and bioassay for antidiabetic activity in the selected animal model. Mysuru, Karnataka, India: University of Mysore; 2014
- Mahmoud AM, Abd El-Twab SM, Abdel-Reheim ES. Consumption of polyphenol-rich *Morus alba* leaves extract attenuates early diabetic retinopathy: the underlying mechanism. *Eur J Nutr* 2017;56(04):1671–1684
- Marx TK, Glávits R, Endres JR, et al. A 28-day repeated dose toxicological study of an aqueous extract of *Morus alba* L. *Int J Toxicol* 2016;35(06):683–691
- Ali Memon A, Memon N, Luthria DL, et al. Phenolic acids profiling and antioxidant potential of mulberry (*Morus laevigata* W., *Morus nigra* L., *Morus alba* L.) leaves and fruits grown in Pakistan. *Pol J Food Nutr Sci* 2010;60(01):25–32
- Metwally FM, Rashad H, Mahmoud AA. *Morus alba* L. diminishes visceral adiposity, insulin resistance, behavioral alterations via regulation of gene expression of leptin, resistin and adiponectin in rats fed a high-cholesterol diet. *Physiol Behav* 2019;201:1–11
- Nematbakhsh M, Hajhashemi V, Ghannadi A, et al. Protective effects of the *Morus alba* L. leaf extracts on cisplatin-induced nephrotoxicity in rat. *Res Pharm Sci* 2013;8(02):71–77
- Niidome T, Takahashi K, Goto Y, et al. Mulberry leaf extract prevents amyloid beta-peptide fibril formation and neurotoxicity. *Neuroreport* 2007;18(08):813–816
- Nomura T, Fukai T, Katayanagi M. Studies on the constituents of the cultivated mulberry tree. III. Isolation of four new flavones, kuwanon A, B, C and oxydihydromorusin from the root bark of *Morus alba* L. *Chem Pharm Bull (Tokyo)* 1978;26(05):1453–1458
- Nomura T, Fukai T, Hano Y, et al. Constituents of cultivated mulberry tree. *Planta Med* 1983;47(03):151–156
- Mohamed NE, Ashour SE. Role of ethanolic extract of *Morus alba* leaves on some biochemical and hematological alterations in irradiated male rats. *Int J Radiat Biol* 2018;94(04):374–384
- Mohammadi J, Naik PR. The histopathologic effects of *Morus alba* leaf extract on the pancreas of diabetic rats. *Turk J Biol* 2012;36:211–216

- 25 Mucimapura S, Wattanathorn J, Thongrong S, et al. *Morus alba* enhanced functional recovery after sciatic nerve crush injury. *Am J Agric Biol Sci* 2010;5(03):294–300
- 26 Nade VS, Kawale LA, Yadav AV. Protective effect of *Morus alba* leaves on haloperidol-induced orofacial dyskinesia and oxidative stress. *Pharm Biol* 2010;48(01):17–22
- 27 Nade V, Kawale L, Bhargale S, et al. Cardioprotective and antihypertensive potential of *Morus alba* L. in isoproterenol-induced myocardial infarction and renal artery ligation-induced hypertension. *J Nat Rem* 2013;13:54–67
- 28 Naowaboot J, Pannangpetch P, Kukongviriyapan V, et al. Mulberry leaf extract restores arterial pressure in streptozotocin-induced chronic diabetic rats. *Nutr Res* 2009;29(08):602–608
- 29 Naowaratwattana W, De-Eknamkul W, De Meija EG. Phenolic-containing organic extracts of mulberry (*Morus alba* L.) leaves inhibit HepG2 hepatoma cells through G2/M phase arrest, induction of apoptosis, and inhibition of topoisomerase II $\alpha$  activity. *J Med Food* 2010;13(05):1045–1056
- 30 Natić MM, Dabić DČ, Papetti A, et al. Analysis and characterisation of phytochemicals in mulberry (*Morus alba* L.) fruits grown in Vojvodina, North Serbia. *Food Chem* 2015; 171:128–136
- 31 Nazari M, Hajizadeh MR, Mahmoodi M, et al. The regulatory impacts of *Morus alba* leaf extract on some enzymes involved in glucose metabolism pathways in diabetic rat liver. *Clin Lab* 2013;59(5–6):497–504