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COMPREHENSIVE REVIEW OF PHYTOCHEMICALS AND PHARMACOLOGICAL ACTIVITIES OF WHITE MULBERRY (*MORUS ALBA* L.) FOR MEDICINAL USE

Actuality. *White mulberry (Morus alba L.) is a promising subject of phytochemical and pharmacological research due to its wide range of bioactive compounds, including flavonoids, alkaloids, polysaccharides, and phenolic substances. Current studies confirm its antioxidant, anti-inflammatory, hypoglycemic, and neuroprotective effects, highlighting its potential as a source for new medicines and dietary supplements. Considering the increasing prevalence of chronic diseases associated with metabolic disorders and oxidative stress, the search for safe and effective plant-based remedies is of high importance. Therefore, summarizing data on the phytochemical composition and pharmacological activity of morus alba L. is scientifically and practically significant for pharmaceutical and medical applications.*

The article is devoted to studying the phytochemical composition and pharmacological activity of morus alba L. The main bioactive substances, including flavonoids, alkaloids, polysaccharides, and phenolic acids, were analyzed. Their antioxidant, anti-inflammatory, hypoglycemic, and antibacterial properties were examined. Particular attention was given to the potential of white mulberry extract as a medicinal product.

Objective of the study. *Determining the potential medical applications of morus alba L.*

Materials and methods. *This structured review synthesized data from 70 peer-reviewed publications (2017–2025) identified via PubMed, Scopus and Web of Science. The search focused on the pharmacological activity and major bioactive compounds of morus alba (leaves, fruits, and root bark). The final qualitative synthesis categorized the findings according to biological activity types, molecular mechanisms of action, and potential therapeutic applications of white mulberry.*

Research results. *The main phytochemical components of morus alba L. were identified. The total phenol content ranged from 104.78 to 213.53 mg GAE/100 g, while flavonoid content varied between 69.58 and 211.01 mg CE/100 g. The plant is rich in calcium, potassium, magnesium, phosphorus, and iron. Its active compounds (alkaloids, flavonoids, phenolic acids, anthocyanins, coumarins) exhibit antioxidant, neuroprotective, immunomodulatory, anticancer, and hypoglycemic properties. These findings highlight the potential of white mulberry in medicine.*

Conclusion. *Based on the analysis of published experimental studies, the pharmacological activities of white mulberry were systematized according to plant parts and profiles of bioactive compounds. Extracts from leaves, fruits, bark, and roots demonstrate hypoglycemic, anti-inflammatory, antioxidant, immunomodulatory, antimicrobial, and hepatoprotective effects in in vitro and in vivo models. The level of experimental and clinical evidence varies among the reported effects, indicating the need for further clinical validation of selected pharmacological activities.*

Key words: *Morus alba L., white mulberry, phytochemistry, pharmacological activity, therapeutic use.*

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КОМПЛЕКСНИЙ ОГЛЯД ФІТОХІМІЧНИХ РЕЧОВИН І ФАРМАКОЛОГІЧНОЇ АКТИВНОСТІ БІЛОЇ ШОВКОВИЦІ (*MORUS ALBA* L.) ДЛЯ МЕДИЧНОГО ВИКОРИСТАННЯ

Актуальність. *Біла шовковиця (Morus alba L.) є перспективним об'єктом фітохімічних і фармакологічних досліджень завдяки широкому спектру біоактивних сполук, до яких належать флавоноїди, алкалоїди, полісахариди та фенольні речовини. Сучасні дослідження підтверджують її антиоксидантну, протизапальну, гіпоглікемічну та нейропротекторну дію, що підкреслює її потенціал як джерела для створення нових лікарських засобів і дієтичних добавок. З огляду на зростання поширеності хронічних захворювань, пов'язаних із метаболічними порушеннями та оксидативним стресом, пошук безпечних і ефективних рослинних засобів є надзвичайно актуальним. Тому узагальнення даних щодо фітохімічного складу та фармакологічної активності Morus alba L. має велике наукове й практичне значення для фармацевтичної та медичної галузей.*

Статтю присвячено вивченню фітохімічного складу та фармакологічної активності Morus alba L. Проаналізовано основні біоактивні речовини, зокрема флавоноїди, алкалоїди, полісахариди та фенольні кислоти. Досліджено їхні антиоксидантні, протизапальні, гіпоглікемічні та антибактеріальні властивості. Особливу увагу приділено потенційному використанню екстракту різних частин білої шовковиці як лікарських засобів.

***Мета дослідження** – визначення потенційних медичних застосувань morus alba L.*

Матеріал і методи. *Дослідження базується на наукових публікаціях і даних міжнародних баз (PubMed, Web of Science, MDPI, Nature Springer, Elsevier). Проаналізовано експериментальні, клінічні та оглядові роботи для оцінки фармакологічного потенціалу білої шовковиці.*

Результати дослідження. *Визначено основні фітохімічні компоненти morus alba L. Загальний уміст фенолів становив від 104,78 до 213,53 мг ГЕК/100 г, а флавоноїдів – від 69,58 до 211,01 мг КЕК/100 г. Рослина багата на кальцій, калій, магній,*

фосфор і залізо. Її активні сполуки (алкалоїди, флавоноїди, фенольні кислоти, антоціани, кумарини) проявляють антиоксидантну, нейропротекторну, імуномодулюючу, протипухлинну та гіпоглікемічну дію. Отримані дані свідчать про значний фармакологічний потенціал білої шовковиці.

Висновок. *Дослідження показали, що екстракти різних частин білої шовковиці завдяки своїм гіпоглікемічним, протизапальним, антиоксидантним імуномодулюючим властивостям є перспективним засобом для лікування цукрового діабету, серцево-судинних захворювань, запальних процесів і порушень нервової системи. Окрім того, науково доведено її антимікробну та гепатопротекторну дію. Зібрані дані свідчать, що біла шовковиця має високий фармакологічний потенціал. Однак подальші глибокі дослідження та клінічні випробування її біологічно активних сполук дадуть змогу широко застосовувати цю рослину в медицині. Продовження вивчення фітохімічного складу цієї рослини є важливим напрямом для розроблення нових лікарських засобів.*

Ключові слова: *Morus alba L., біла шовковиця, фітохімія, фармакологічна активність, лікувальне застосування.*

Introduction. Relevance. Plant sources of biologically active compounds are of great interest in medicine and pharmacology. Among them, the white mulberry (*Morus alba* L.) occupies a special place due to its rich phytochemical composition and various pharmacological properties. In traditional medicine of different countries, it is used for the treatment of diabetes, inflammatory diseases, cardiovascular pathologies, as well as as an antioxidant and neuroprotective agent.

Morus alba L. – a member of the mulberry family (*Moraceae*), commonly known as white mulberry. Grows in tropical, subtropical and temperate regions of Asia, Europe and North America. The fact that white mulberry is rich in biologically active compounds increases its potential in the treatment of various diseases (Zhumabaev et al., 2023, pp. 227–232).

As a result of phytochemical studies, phenolic compounds, flavonoids, alkaloids, anthocyanins, coumarins and other bioactive substances have been identified from various parts of white mulberry. These compounds provide antioxidant (Yu et al., 2021; Ganzon et al., 2018), anti-inflammatory (Baek et al., 2021; Shi et al., 2023), hypoglycemic (Liu et al., 2022; Jan et al., 2022), neuroprotective (Wang et al., 2023) and antimicrobial (Lee et al., 2020) activity of the plant. While numerous studies have shown that the leaves of white mulberry have an antidiabetic effect (Jiao, et al., 2017), the fruits have proven to be effective in supporting cardiovascular diseases and the immune system. In addition, the vascular shell contributes to the regulation of blood pressure and the protection of the liver.

Currently, the pharmacological effects of white mulberry are being studied in detail, however, additional scientific evidence is needed to fully reveal its potential for use in medicine. This review work is aimed at analyzing the phytochemical composition, pharmacological activity of white mulberry and the possibilities of its medical application.

Research purpose. Determination of the potential of white mulberry (*Morus alba* L.) in medicine.

Materials and methods. A structured literature review was conducted using international scientific databases, including PubMed, Scopus and Web of Science, as well as publisher platforms MDPI, Springer Nature, and Elsevier. The search covered publications published between 2017 and 2025. Boolean operators (AND/OR) were used to construct search queries. The main search combinations were: («morus alba L.» OR «white mulberry») AND («pharmacological activity» OR «bioactivity» OR «therapeutic potential»). Additional queries were applied using combinations of plant name + major bioactive compounds + biological activity. The search was conducted separately for different plant parts (leaves, fruits, root bark). Peer-reviewed *in vitro, in vivo* (animal), and clinical studies, as well as narrative and systematic reviews, were included in the analysis. Exclusion criteria comprised non-peer-reviewed sources, duplicated records, conference abstracts, and publications not available in full text. After screening and eligibility assessment, 70 publications were included in the final qualitative synthesis. The extracted data were systematized according to types of biological activity, major bioactive compounds, mechanisms of action, and potential therapeutic applications of white mulberry. The synthesis followed general principles of structured narrative review.

Results and discussion. White mulberry is a fast-growing shrub or medium-sized tree with a straight, cylindrical trunk 1.8 m long, belonging to the *Moraceae* family, widely distributed in eastern Asia. The bark is black, gray-brown in color with longitudinal cracks. The stem is lateral, scaly, coral-colored, two rows of Oval, the leaves are simple two to five-bladed, with serrated and finger-shaped leaves. The Leaf reaches 5–15 cm in length and 4–10 cm in width. The flowers are green, with four loose, scaly petals. The length of the buds reaches up to 6 mm, the shape is broadly ovoid. Blooms in April-May and bears fruit in May-June. The length of the fruit was on average 19.48 mm, and the mass was on average 1.59 g. White mulberry is widely distributed in various ecological and geographical regions – it is intensively grown in temperate, subtropical and tropical regions, and is also found in forests under natural conditions. This indicates its morphologically high adaptability to environmental changes (Orwa et al., 2009; Zhumabaev et al., 2023, pp. 227–232; Hashemi, Khadivi, 2020, pp. 109–117).

White mulberry has a wide geographical distribution due to its high adaptability and value as an agricultural and ornamental crop. White mulberry comes from the

eastern regions of China, at first it was grown as feed for silkworms for about four thousand years. From China, white mulberry has spread to Central Asia, Afghanistan, northern India, Pakistan, Iran. It was widely introduced from India, Afghanistan and Iran to Spain and Portugal.

Currently, the white mulberry (*Morus alba* L.) grown in a wide range of geographical, climatic and soil conditions, such as Europe, Asia, North America, South America and Africa (Muhammad et al., 2019).

The phytochemical composition of white mulberry is rich in biologically active substances (table 1). White mulberry contains alkaloids, coumarins, polysaccharides, phenolic compounds, flavonoids, anthocyanins, organic acids, amino acids, vitamins and minerals.

Table 1

Phytochemical composition of white mulberry (*Morus alba* L.)

№		Compound name	Quantity	Plant parts	Link
1	Alkaloids	Fagomin B	10 mkg/ml	Leaf	Hui et al., 2021
2		1-DNJ	40 mkg/ml	Leaf	
3		1,4-dideoxy-1,4-imino-D-arabinitol	10 mkg/ml	Leaf	
4		N-methyl-1-DNJ	5-6.2 mg/kg	Root, fruit	Fatima et al., 2024
5		2-O-α-D-galactopyranosyl-1-DNJ	16.6 mg/kg 140 mg/kg 305 mg/kg	Root, fruit, leaf	
6		2-O-α-D-glucopyranosyl-1-DNJ	1 mg/kg	Root	
7		3-O-β-D-glucopyranosyl-1-DNJ	8 mg/kg	Root	
8		4-O-β-D-glucopyranosyl-1-DNJ	1.1 mg/kg	Root	
9	Coumarins	Mulberroside A	9.38-600 mg/ml	Root bark	Kim et al., 2020
10		Skimmin	1.88-30 mg/ml	Leaf	
11		Skopoletin	9 mg/kg	Leaf	Firmansyah et al., 2021
12		5,7-Dihydroxycoumarin 7-O-β-D-apiofuranosyl-(1→6)-O-β-D-glucopyranoside	0.23 mg/g	Root bark	Huang et al., 2022
13		5,7-Dihydroxycoumarin 7-O-β-D-glucopyranoside	0.02 mg/g	Root bark	
14	Polysaccharides	Glucose	488.1 mg/g	Fruit	Huang et al., 2022
15		Galactose	227.9 mg/g	Fruit	
16		Mannose	182.0 mg/g	Fruit	
17		Ribose	4.3 mg/g	Fruit	
18		Ramnose	0.82 mg/g	Fruit	
19		Glucuronide	15.6 mg/g	Fruit	
20		Galacturonic acid	0.41 mg/g	Fruit	
21		Arabinosa	10.0 mg/g	Fruit	
22		Fucosa	2.2 mg/g	Fruit	
23	Phenolic compounds	Gallic acid	20-200 mkg/ml	Leaf (aqueous and hydrometanol extracts)	Polumackanycz et al., 2019
24		Vanilla acid	20-140 mkg/ml		
25		Coffee acid	20-140 mkg/ml		
26		Chlorogenic acid	20-200 mkg/ml		
27		Ferulic acid	20-200 mkg/ml		
28		p-coumaric acid	20-200 mkg/ml		
29		Rosemary acid	20-200 mkg/ml		
30		o-coumaric acid	0.015 mg/g	Fruit	Yuan, Zhao, 2017
31		p-hydroxybenzoic acid	0.028-0.154 mg/g	Fruit	
32		Protocatechinic acid	0.264-0.794 mg/100 g	Fruit	
33	Flavonoids	Rutin	20-200 mkg/ml	Leaf	Polumackanycz et al., 2019
34		Apigenin	20-200 mkg/ml		
35		Quercetin	20-140 mkg/ml		
36		Taxifolin	0.63-20 mg/ml	Root bark	Kim et al., 2020
37		Isoquercitrin	4.69-150 mg/ml	Leaf	
38		Astragalin	1.56-100 mg/ml	Leaf	
39		Quercitrin	0.78-50 mg/ml	Leaf	
40		Kuwanon G	3.13-200 mg/ml	Root bark	
41		Kaempferol-3-β-D-glucopyranoside	972.494 mg/100 g	Leaf	Hao et al., 2022
42		Kaempferol-7-O-glucoside	211.432 mg/100 g	Leaf	
43		Kaempferol-3-O-(6-malonyl)-glucoside	1332.91 mg/100 g	Leaf	
44		Kaempferol-3-O-glucopyranosyl-(1,6)-β-D-glucopyranoside	615.98 mg/100 g	Leaf	
45		Quercetin-3-O-glucoside	986 mg/100 g	Leaf	Hao et al., 2022; Lim et al., 2021; Polumackanycz et al., 2021
46		Quercetin-3-O-(6-malonyl)-β-D-glucoside	1258.58 mg/100 g	Leaf	Hao et al., 2022
47		Quercetin-3,7-D-O-β-D-glucopyranoside	137.949 mg/100 g	Leaf	
48		Quercetin 3-(6-malonylglucoside)	754 mg/100 g	Leaf	Hao et al., 2022; Lim et al., 2021; Polumackanycz et al., 2021
49		Quercetin-3-O-glucoside-7-O-rhamnoside	849.06 mg/100 g	Leaf	Hao et al., 2022
50		Quercetin-3-O-rhamnoside-7-O-glucoside	272.60 mg/100 g	Leaf	

Continuation of table 1

№		Compound name	Quantity	Plant parts	Link
51	Anthocyanins	Cyanidin-3-glucoside	301.75 mg/g (MAE)	Fruit	Yuan, Zhao, 2017
52		Cyanidin-3-rutinoside	108.79 mg/g (MAE)	Fruit	
53		Cyanidin 3-O-(6"-O-α-rhamnopyranosyl-β-D-glucopyranoside)	270 mg/g (SMA)	Fruit	
54		Cyanidin 3-O-(6"-O-α-rhamnopyranosyl-β-D-galactopyranoside)	57 mg/g (SMA)	Fruit	
55		Cyanidin 3-O-β-D-galactopyranoside	233 mg/g (SMA)	Fruit	
56		Cyanidin 7-O-β-D-glucopyranoside	33 mg/g (SMA)	Fruit	
57		Petunidine 3-O-β-glucopyranoside	5.1 mg/g (SEE)	Fruit	
58	Organic acids	Citric acid	0.687 ± 0.022 g/100 g	Fruit	Islamova et al., 2022
59		Malic acid	2.103 ± 0.028 g/100 g	Fruit	
60		Oxalic acid	0.437 ± 0.012 g/100 g	Fruit	
61		Tartaric acid	0.430 ± 0.006 g/100 g	Fruit	
62		Fumaric acid	0.123 ± 0.003 g/100 g	Fruit	
63	Amino acids	Aspartic acid	0.97 g/%	Leaf (aqueous-alcohol extracts)	Chen et al., 2018
64		Threonine	0.38 g/%		
65		Serine	0.19 g/%		
66		Glutamic acid	2.26 g/%		
67		Glycine	1.02 g/%		
68		Alanine	0.48 g/%		
69		Valine	0.54 g/%		
70		Methionine	1.34 g/%		
71		Isoleucine	0.26 g/%		
72		Leucine	0.57 g/%		
73		Tyrosine	0.96 g/%		
74		Phenylalanine	0.41 g/%		
75		Histidine	0.24 g/%		
76		Lysine	0.21 g/%		
77		Arginine	0.75 g/%		
78	Vitamins	Riboflavin (B_2)	0.088 mg/100 g	Fruit	Batiha et al., 2023
79		Ascorbic acid (C)	15.2 mg/100 g	Fruit	
80		Niacin (B_3)	3.10 mg/100 g	Fruit	
81		Vitamin E	0.87 mg/100 ml	Fruit	Kattil et al., 2024

The data presented in table 1 indicate that white mulberry is characterized by a high diversity and quantitative variability of biologically active compounds depending on the plant part. Leaves are predominantly rich in flavonoids and phenolic acids, with particularly high levels of flavonol glycosides (e.g., kaempferol and quercetin derivatives reaching up to approximately 1300 mg/100 g), which may explain the pronounced antioxidant and anti-inflammatory activity reported for leaf extracts.

Root bark is characterized by a high content of coumarins and prenylated flavonoids (e.g., mulberroside A up to 600 mg/ml; kuwanon G up to 200 mg/ml), compounds that are frequently associated with antimicrobial, anti-inflammatory, and enzyme-inhibitory effects.

Fruits contain substantial amounts of polysaccharides and organic acids, as well as high concentrations of anthocyanins (cyanidin derivatives reaching over 300 mg/g depending on the extraction method), which correlates with strong antioxidant potential and potential metabolic and cardioprotective effects.

In addition, alkaloids of the 1-deoxynojirimycin (1-DNJ) group are predominantly detected in leaves and roots, which is consistent with the hypoglycemic activity of white mulberry reported in experimental and clinical studies. Overall, the quantitative differences in major phytochemical groups among plant parts largely determine the spectrum and intensity of the observed pharmacological activities.

Based on the given phytochemical composition, one can observe the composition of white mulberry rich in fatty acids, amino acids, vitamins, minerals and biologically active substances, including anthocyanins, rutin, quercetin and polysaccharides. The flavonoids contained in white mulberry, in particular quercetin, kempferol and cyanidine, have antioxidant, anti-inflammatory and anticancerogenic activity. In addition, compounds such

as scopoletin and rutin can play an important role in regulating metabolic processes and strengthening the immune system.

The presence of sucrose, glucose, mannose and other carbohydrates indicates the importance of white mulberry as a source of carbohydrates, it can be used for dietary and medicinal purposes.

Each of these compounds has a certain pharmacological activity, which indicates that they can be used from white mulberry to treat various diseases, for example, to develop new drugs based on diabetes, hypertension, inflammatory diseases and cancer.

Chen et al. (Chen T., et al., 2022) according to studies on the phytochemical composition of 8 different varieties of white mulberry, the total content of phenols (TPC): 104.78 to 213.53 mg GAE/100 g, and the total content of flavonoids (TFC): 69.58 to 211.01 mg CE/100 g. In addition, the extracts and active components of white mulberry fruits show many biological activities, including antioxidant, neuroprotective, anti-atherosclerosis, immunomodulatory, antitumor, anti-hyperglycemic and hypolipidemic activity in in vitro and in vivo studies (Redha et al., 2023).

According to studies conducted by Lee et al. (Lee et al., 2016; Lee et al., 2018; Li et al., 2021), white mulberry fruits contain quercetin, pyrrole alkaloids, cyanide, epigallocatechin, epigallocatechin gallate, gallocatechin, gallocatechin gallate, isoramnetin glucuronate, isoramnetin hexoside, isoramnetin hexosylhexoside, kempferol, glucuronate, kempferol hexoside, kempferol ramnosylhexoside, maureen, odisolan and naringin, as well as phenols, flavonoids and anthocyanin compounds have been found.

Also, according to the studies carried out, a group of mineral elements useful for the human body was identified in the composition of white mulberry (*Morus alba* L.) (Figure 1). Including: Al (ppm) – 60.83; B (ppm) – 47.95; Ba (ppm) – 5.56; Ca (ppm) – 2421.65; Cr (ppm) – 1.62; Cu (ppm) – 27.09; Fe (ppm) - 28.2; K (ppm) – 14572.09; Li (ppm) – 1.12; Mg (ppm) – 1022.82; mn (ppm) – 7.11; na (ppm) – 264.98; ni (ppm) – 6.92; p (ppm) – 2213.41; s (ppm) – 574.64; sr (ppm) – 12.84; zn (ppm) – 13.41.

Compared to other fruit and berry fruits, the magnesium content in mulberry berries has been found to be very high.

The mineral composition of mulberry fruits in significant quantities is K, Ca, P, Mg, S, Na and Fe. The presence of antioxidants, multivitamins, magnesium, iron and other organic and mineral substances determines the healing properties of mulberry fruits (Cui et al., 2019; Paul et al., 2021; Yan et al., 2024).

Methanol extracts of white mulberry root bark have traditionally been used to lower blood pressure, stabilize blood sugar levels, and lower fever. The immune-boosting effect of polysaccharides isolated from water extracts from white mulberry root has been established, and the compounds kowanon G and cudraplavone B isolated from methanol extracts, on the contrary, have been shown to have immune-inhibiting properties. A number of studies have revealed the presence of various phytochemical compounds in the root membrane. In addition, ethanol extract from the dry root of Australian white mulberry has been found to reduce inflammation and necrosis of the liver caused by CCl_4 (Kavitha, Geetha, 2018; Tseng et al., 2018).

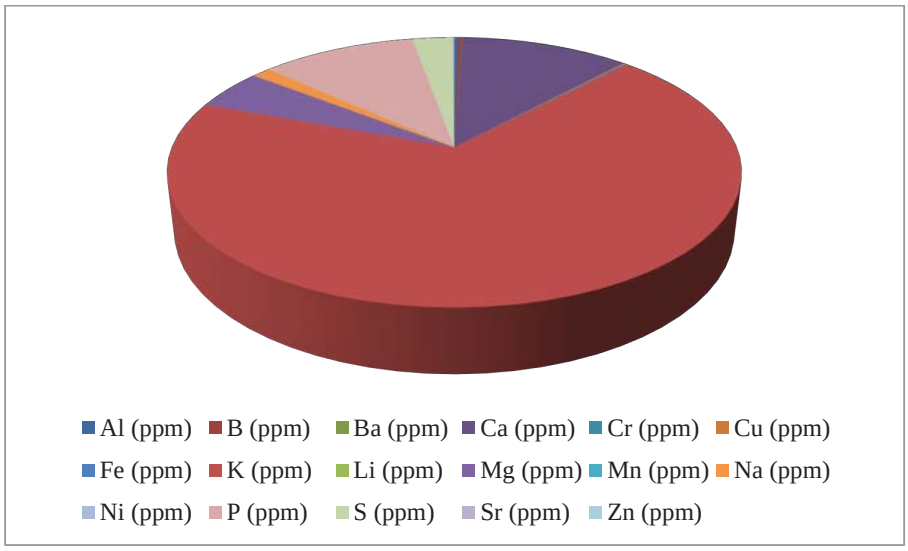

Fig. 1. Mineral composition of white mulberry (*Morus alba* L.)

White mulberry stem extracts have been shown to have anti-inflammatory (Soonthornsit et al., 2017; Yiemwattana et al., 2018) and anti-osteoarthritis (Khunakornvichaya et al., 2016) effects.

White mulberry (*Morus alba* L.) leaves are used to feed the silkworm. In addition, they are one of the most important medicinal plants in the treatment of hyperglycemia and are also used to treat diabetes (Gryn-Rynko et al., 2016; Mahmoud et al., 2016; Varghese, Thomas, 2019). Antimicrobial and liver-protecting properties of ethanol extracts of leaves (Lee et al., 2020) have been identified. In addition, ethanol extract (MLFE) of white mulberry leaf and fruit has been observed to activate the NLRP3 inflammatory complex in obese mice (Li et al., 2022). Chen et al. (Chen et al., 2019) isolated gamma-aminomaic acid (GABA) from the water extract of white mulberry leaves using biochemical methods.

Hypoglycemic activity. 1-deoxynoirimycin (1-DNJ) is one of the most important active components of white mulberry (*Morus alba* L.), which has a pronounced inhibitory effect on the enzyme α-glucosidase. Research has shown that 1-DNJ significantly reduces blood glucose levels after meals in people with prediabetes and mild diabetes (Hoogenraad et al., 2025). In addition, white mulberry shoot extract with the main active components-oxyzeratrol and kuwanone G showed hypoglycemic activity and effective inhibition of the enzymes PTP1B and α-glucosidase (Kwon et al., 2022). Compared to leaf and fruit extracts, the hypoglycemic effect of white mulberry shoots and bark extracts was more pronounced (Zhou et al., 2022).

Antioxidant activity. Research has shown that isoquercetin and 4-o-kaffeoylchinic acid, which are found in white mulberry leaves, have pronounced antioxidant activity. Concentrations that provide 50% absorption of radicals are 10.63 ± 0.96 mcg/ml for isoquercetin and 10.63 ± 0.96 mcg/ml for 4-o-kaffeoylchinic acid (Ganzon et al., 2018). In addition, in the study conducted, the antioxidant effect of biologically active substances of white mulberry was comprehensively evaluated using radical retention tests of DPPH and ABTS. White mulberry acetone extract has been found to have important antioxidant properties with SC50 values of 242.33 ± 15.78 and 129.28 ± 10.53 mcg/ml for DPPH and ABTS respectively (Hsu et al., 2022).

Anti-inflammatory activity. Studies have shown that white mulberry (*Morus alba* L.) and its active compounds are able to inhibit inflammation by inhibiting the chemotaxis of leukocytes. The mechanism of this effect includes the action of oxyzeratrol, which can inhibit leukocyte migration through the CXCR4 receptor by inactivating the MEK/ERK pathway (Dalla Costa et al., 2025). Methanol extract of white mulberry bark has been shown to promote anti-inflammatory effects on microglia (BV2) and macrophages (RAW264.7) by inhibiting the release of prostaglandin E2, interleukin-6 and α-factor of tumor necrosis and stimulating cyclooxygenase-2 expression (Ko et al., 2021).

Anti-cancer activity. Research has shown that some of the active compounds in white mulberry (*Morus alba* L.) affect cancer cells. Moracin D can inhibit the proliferation of breast cancer cells and induce apoptosis. This effect is achieved by inhibiting the transmission of the Wnt3a/FOXM1/β-catenin signal, as well as increasing the activity of caspase and GSK3β (Hwang et al., 2018).

Sanggenol L – a natural flavonoid of white mulberry-has been found to induce apoptosis in prostate cancer cells and interrupt their cell cycle through the activity of the p53 protein. In addition, Sanggenol L increases apoptosis in ovarian cancer cells and reduces cytotoxicity by inhibiting the NF-kB signaling pathway (Ko et al., 2021; Hwang et al., 2018; Won, Seo, 2020).

Moracin N – the active component in white mulberry has shown oncoprotective activity by inducing apoptosis and autophagy in lung cancer cells (Gao et al., 2020).

Morusin – a flavonoid secreted from the root of white mulberry inhibits the growth of prostate cancer cells and promotes their apoptosis. This is done by reducing the activity of STAT3, inhibiting its phosphorylation, nuclear accumulation and the ability to bind to DNA. In addition, morusin reduces the expression of the STAT1-regulated cyclin D2 gene and limits the growth of cancer cells (Halemani et al., 2017).

Thus, some of the bioactive compounds in white mulberry exhibit antitumor effects by regulating apoptosis and cell cycle in different types of cancer.

In addition, white mulberry extracts have been found to have a pronounced depigmentation effect. Ethanol extracts contain active components such as norluciferin, moracin B, moracin J, moracin M-3'-o-β-glucopyranoside and moracin m-6-o-β-d-glucopyranoside, which inhibit the production of melanin in a dose-dependent manner. These compounds inhibit tyrosinase activity in B10-F1 cells induced by α-melanocyte-stimulating hormone (Li et al., 2018).

In addition, white mulberry root has shown the ability to stimulate hair growth by increasing the secretion of extractive growth factors, accelerating the transition of hair follicles from the resting phase to the growth phase, as well as activating β-binding proteins that play a key role in a given process (Hyun et al., 2021).

Immunomodulatory properties. The methanol extract of white mulberry showed immunomodulatory activity. In the study aimed at this effect, various experimental

models were used, including a study of serum immunoglobulin levels, a cyclophosphamide-induced neutropenia test, a carbon clearance test, a neutrophil adhesion test, a death test in mice, and an indirect hemagglutination test. The results showed that administration of white mulberry extract promotes an increase in serum immunoglobulins and reduces mortality caused by *Pasteurella multocida* in mice. In addition, the use of methanol extract of white mulberry leaves significantly reduced neutropenia and increased the phagocytic index in the carbon clearance test. These data show that white mulberry has the ability to enhance cellular and humoral immune response (Hussain et al., 2017).

The pharmacological activity of white mulberry varies depending on its different parts. The leaves often show antioxidant and anti-inflammatory effects, while the fruits are distinguished by immunomodulatory and neuroprotective properties. The roots and bark of the plant are known for some anticancer and antiviral activity. In addition, the combination of various biologically active compounds enhances the hypoglycemic, cardioprotective and antibacterial effect of white mulberry. The following is a general overview of the pharmacological activity of white mulberry (table 2).

As can be seen from the table above, the various biologically active substances contained in white mulberry

Table 2

Overview of the pharmacological activity of white mulberry

№	Pharmacological properties	Mechanism of action	Biologically active substance	White mulberry part (extract)	Link
1	Hypoglycemic property	inhibits α-glucosidase	Chalcomoracin	Leaf	Liu et al., 2022
			1-DNJ	Leaf	Jan et al., 2022
2	Antioxidant activity	Inhibits active forms of oxygen	Astragalus, kaempferol, quercetin, taxifolin	Fruit	Yu et al., 2021
		Inhibits free radicals	4-O-caffeoylquinic acid	Leaf	Ganzon et al., 2018
3	Anti-inflammatory activity	Selectively inhibits the enzyme cyclooxygenase-2	kuwanon A	Bark, roots	Baek et al., 2021
		Inhibits the release of cytokines that cause inflammatory processes	Mulberroside A	Shoot	Shi et al., 2023
4	Anti-cancer activity	Blocks the Akt / mTOR signal path	Morucin	Leaf	Wu et al., 2023
		Regulates the expression of RNA molecules encoding the atg3l16 protein associated with autopagia	Cyanidin-3-glucoside	Fruit	Zabady et al., 2022
5	Immunomodulatory property	Stimulates serum immunoglobulins	Flavaonoidsanthocyans, saponins, alkaloids, glycosides and phenolic compounds	Leaf, bark, fruit, root	Hussain et al., 2017
6	Anti-virus activity	Inhibits proteases involved in the secretion of virus proteins necessary for replication and maturation of the COVID-19 virus	Sangenon C, sangenon G, sangenon O	Root bark	Wasilewicz et al. 2023
7	Antibacterial activity	Binding of radioactive methylated acetic acid to the lipids of the *Staphylococcus aureus* membrane	Chalcomoracin, moracin C	Leaf	Zhu et al., 2024
8	Neuroprotective property	Activates the AMPK-ULK1 signaling pathway, increasing mitophagy-regulating TFEB migration to the nucleus	Morin	Fruit	Wang et al. 2023
9	Cardioprotective property	In the case of a lack of oxygen (hypoxia), it enhances the process of destruction and recycling of damaged components of cells	Sangenon C	Leaf	Gu et al. 2017
10	Antihyperuricemic activity	Inhibits xanthine oxidase activity and reduces the expression of mURAT1, mGLUT9 and mABCG2	Polydatin	Bark	Ge et al. 2023
11	Antialheimer property	Reduction of cytotoxic effect caused by intracellular amyloid-β oligomer	Anthocyanins	Fruit	Ochiishi et al. 2021

(*Morus alba* L.) determine its wide range of pharmacological properties. The leaves, fruits, bark and roots are rich in a number of compounds that have a therapeutic effect against various diseases.

The Leaf has mainly hypoglycemic, antioxidant, anti-cancer, antibacterial and cardioprotective properties. The 1-DNJ, chalcomoracin, morucin, kempferol, quercetin and other flavonoids contained in it exhibit therapeutic effects by inhibiting enzymes and regulating signaling pathways.

The fruit stands out for its antioxidant, neuroprotective, anti-cancer and anti-Alzheimer properties. Cyanidine-3-glucoside, anthocyanins, morin and other polyphenolic compounds in its composition neutralize free radicals and regulate mitochondrial processes.

The bark and roots have mainly antiviral, anti-inflammatory, immunomodulatory and antihyperuricemic properties. These effects are carried out in the presence of sangenone C, G, O, mulberroside a, polydatin and other compounds.

In general, extracts from different parts of the white mulberry plant show high biological activity in the prevention and treatment of many diseases. The natural compounds contained in them have great research potential in modern pharmacology. In addition, according to research by scientists, white mulberry has several other pharmacological activities, in particular, Khawani et al. (Khawani et al. 2022) reported a significant decrease in the concentration of triglycerides, total cholesterol in serum and liver, and serum TTLP cholesterol in rats fed high-fat food supplemented with 5% or 10% powder of mulberry fruit. An increase in high serum density lipoprotein cholesterol (HTLP) was observed in rats fed high-fat foods supplemented with 5% or 10% mulberry fruit powder. The presence of dietary fiber in mulberry fruits inhibits liver lipogenesis and increases the activity of TTLP receptors. Accordingly, white mulberry can be used in medicine as a hyplipidemic agent. Jiao Y. et al. (Jiao et al., 2017), who found that fasting blood glucose levels decreased in diabetic rats fed white mulberry fruit polysaccharides for 2 weeks. Research by Alanazi, Anwar, Alam, and he (Alanazi et al., 2017) found that diabetic rats fed mulberry extract for 2 weeks showed a significant decrease in fasting blood glucose and glycosylated whey protein.

Huang et al. (Huang S., et al. 2023) found that the growth of atypical glandular cell tumor (AGS) xenotransplantate in mice slowed after male BALB/c nude mice were fed anthocyanin-rich white mulberry fruit extract for 7 weeks, allowing white mulberry fruit extract to be used to prevent gastric carcinoma. The protective effect of anthocyanins of white mulberry extract on liver fibrosis ($CC1_4$) caused by carbon tetrachloride has been established. In rats fed white mulberry extract, decreased levels of ALT, aspartataminotransferase, collagen type III hyaluronidase acid, and hydroxyproline were observed (Yu et al., 2022).

Thus, white mulberry (*Morus alba* L.) is a promising plant for use in medicine due to its rich phytochemical composition and extensive pharmacological properties. Biologically active compounds obtained from different parts of the plant show pronounced antioxidant, anti-inflammatory, hypoglycemic, neuroprotective, cardioprotective, immunomodulatory and anticancer activity.

One of the most important areas of study of white mulberry is its use in the treatment of metabolic diseases, including type 2 diabetes, hyperuricemia and their complications. Flavonoids and alkaloids contained in the leaves and bark can inhibit the main enzymes of carbohydrate metabolism and regulators of metabolic processes, which makes it possible to create new sugar-lowering drugs and nutriceutics based on them.

In addition, the use of white mulberry as a neuroprotective agent in neurodegenerative diseases, such as Parkinson's and Alzheimer's, is promising. The compounds found in fruits, bark and leaves regulate mitophagy and reduce oxidative stress and inflammation in neurons. This indicates the importance of their further study for the development of new neuroprotective drugs. The antimicrobial and antiviral activity of white mulberry is also of great interest. Research shows that compounds in the bark and roots can inhibit the replication of viruses, including SARS-CoV-2, as well as slow down the growth of pathogenic bacteria. This opens up the possibility of creating anti-infective drugs based on the plant.

Conclusion. This review systematically summarizes the pharmacological properties of white mulberry according to plant parts – leaves, fruits, bark, and roots and the corresponding groups of biologically active compounds. Studies indicate that white mulberry extracts exhibit hypoglycemic, anti-inflammatory, antioxidant, immunomodulatory, antimicrobial, and hepatoprotective effects, making them promising for the prevention and treatment of diabetes mellitus, cardiovascular diseases, inflammatory disorders, and nervous system dysfunctions.

The novelty of this review lies in the comprehensive systematization of existing data, highlighting both well-established pharmacological effects supported by multiple *in vitro* and *in vivo* studies and effects that are preliminary or require further clinical validation. This structured overview provides a clear understanding of the plant's pharmacological potential and identifies directions for future research, including detailed phytochemical profiling and clinical trials of specific bioactive compounds.

In conclusion, white mulberry represents a highly promising source of natural therapeutic agents, and continued research may contribute to the development of new drugs with clinically validated efficacy.

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