



MULBERRIES AS FUNCTIONAL FOODS: NUTRITIONAL AND THERAPEUTIC POTENTIAL

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Introduction

Mulberry fruits are highly nutritious and traditionally valued berries obtained from trees belonging to the genus *Morus*, family Moraceae. The most widely cultivated species include *Morus alba*, *Morus nigra* and *Morus rubra*. Although mulberry is primarily known for its leaves, which serve as the sole food source for the silkworm (*Bombyx mori*) in sericulture, its fruits have gained increasing recognition for their nutritional, medicinal, and functional food value.

Mulberry fruits are succulent, multiple fruits formed from clustered flowers, resembling elongated berries. They vary in color from white and pink to deep purple and black, depending on the species and stage of ripening. The fruits are rich in carbohydrates, dietary fiber, vitamins (especially vitamin C and vitamin K), minerals such as iron, potassium, and calcium, and a wide range of bioactive compounds including anthocyanins, flavonoids, and phenolic acids. These phytochemicals contribute to strong antioxidant, anti-inflammatory, and immune-supporting properties.

Mulberries have attracted attention as a functional food due to their potential role in managing lifestyle-related disorders such as diabetes, cardiovascular diseases, and anemia. The presence of natural antioxidants helps reduce oxidative stress.

Fresh fruits, dried mulberries, juices, jams, syrups and nutraceutical products are increasingly incorporated into modern diets.



Chemical composition

Macronutrients

Mulberry fruits contain carbohydrates, making up 7.8–9% of their composition. These include neutral sugars such as glucose, arabinose, galactose, rhamnose, xylose, and mannose, along with uronic acids like galacturonic and glucouronic acid. The protein content ranges from 0.5–1.4 to 5.54%, with glutamate being the primary amino acid, making up around 20%, and others like glycine, aspartate, and leucine are also present in higher amounts in white mulberry. The fat content is relatively low, ranging from 1.23–2.23%, primarily consisting of fatty acids such as linoleic (26.40–74.77%), palmitic (9.29–22.26%), oleic, stearic, and behenic acids.

Vitamins and Organic Acids

Important vitamins found in mulberries include vitamin C (ascorbic acid, up to 31.22 mg per 100g), vitamin A, vitamin E (0.98 mg per

100g), and various B-group vitamins. Organic acids present include succinic, acetic, malic, citric, and tartaric acids, contributing to the titratable acidity (0.20–2.65%), with higher levels found in black mulberry.

Minerals

Important minerals in mulberries include potassium, which is the highest among fruits in black mulberry, calcium (138.35 mg per 100g), magnesium (179.25 mg per 100g), phosphorus (323.12 mg per 100g), iron (6.02 mg per 100g), zinc (2.17 mg per 100g), along with sodium, copper, and selenium.

Phytochemicals

Phenolic compounds are the main phytochemicals present in mulberries. These include total phenols (104.78–215.53 mg GAE per 100g or up to 1375 mg GAE per 100g), flavonoids (64.55–211.01 mg or 278.32 mg QE per 100g), and anthocyanins (55.21 mg per 100g). Specific phenolic substances include chlorogenic acid, caffeic acid, gallic acid, rutin, catechin, quercetin glycosides, and hydroxycinnamates. The soluble solids in mulberries, ranging from 6.2–25.8%, affect the taste by contributing to the levels of sugars, acids, and minerals.

Health Benefits

Antimicrobial Activity

The water extracts from mulberries can inhibit bacterial growth and prevent pathogenic intestinal bacteria from attaching to intestinal cells. This antimicrobial activity helps fight bacteria that cause digestive tract infections.

Anticancer

Mulberries may help stop the spread of cancer cells, making them potential anticancer agents. The active components in mulberries can stop cancer progression by influencing apoptosis and matrix metalloproteinases. Polyphenolic compounds can suppress the NF- κ B pathway in

cancer cells, leading to cell death through apoptosis and preventing cancer cell growth, movement, and invasion. Morusin may help slow the growth of human colorectal cells by affecting the NF- κ B signaling pathway.

Hepatoprotection

The liver is one of the most metabolically active organs in the body, involved in metabolism, detoxification, storing glycogen, and producing and releasing proteins. Bioactive compounds in mulberry water extracts have been shown to reduce liver damage. Preliminary studies suggest they may reduce liver fibrosis. This protective effect might be linked to the regulation of fatty liver disease and lipid metabolism, as well as the suppression of oxidative stress and inflammation. MicroRNAs (miRNAs) that control gene expression and translation efficiency are involved in liver function. Mulberry extracts can reduce liver damage by regulating miR-155, which is differentially expressed in obese individuals, and PPAR α , which plays a role in lipid metabolism. Mulberry water extracts may protect against liver fibrosis induced by CC4 by reducing oxidative stress, ferroptosis, and inflammation through the activation of the Nrf2 signaling pathway. White mulberry extracts can protect against iron-induced cell death by increasing the levels of Bax, caspase-3, and PARP.

Blood Sugar Reduction

High blood sugar levels can disrupt the body's internal balance, leading to harmful biochemical and physiological effects. Mulberry extracts have been shown to help manage high blood sugar. They can reduce insulin resistance in diabetic mice by stimulating the AMP-activated protein kinase (AMPK) pathway and regulating the activity of GLUT4, acetyl-CoA carboxylase (ACC), and peroxisome proliferator-activated receptor gamma (PPAR γ).

This regulation lowers blood sugar levels and improves issues related to lipid metabolism. The phosphorylation of AKT and glycogen synthase kinase 3 β (GSK3 β) increases glycogen production. Anthocyanins in mulberries activate phosphorylated AKT, increasing the levels of GSK3 β , which raises glycogen synthase 1 (GYS1). Studies using LY294002 to pre-treat cells show that the effect on insulin resistance is dependent on the PI3K pathway. Anthocyanins may also help improve diabetes-related impairments and reduce insulin resistance in HepG2 cells by activating the PI3K/AKT pathway, resulting in lower blood sugar levels.

Antioxidant

Mulberries contain natural substances that can neutralize various free radicals, such as superoxide anions, hydroxyl radicals, hydrogen peroxide, and alkyl radicals. Research on aged mice has shown that mulberry extract increases moisture, hyaluronic acid, and hydroxyproline levels in the skin, lowers advanced glycation end-products (AGEs), and improves damage caused by oxidative stress. These findings suggest that mulberries may help delay aging and offer valuable cosmetic benefits.

Resveratrol and resveratrol glucoside, in particular, are effective antioxidants that boost the activity of enzymes like catalase (CAT), superoxide dismutase (SOD), and glutathione (GSH), while decreasing reactive oxygen species (ROS), lactate dehydrogenase (LDH), levels, and malondialdehyde (MDA) content. Mulberries offer a sweet and tart flavor that is perfect for summer dishes, including desserts, drinks, and salads.

Beverages

Mulberry lemonade combines pureed fresh mulberries with lemon juice, sugar, and ice to create a refreshing slushie. Mulberry mojitos are a twist on the classic cocktail, made by

muddling the berries with mint, lime, rum, and soda for a vibrant, fruity drink.

Mulberry juice or syrup maintains the fruit's tanginess and is great for drizzling over pancakes, yogurt, or ice cream.



Desserts

Mulberry pie features juicy berries enclosed in a flaky crust and is best enjoyed warm with vanilla ice cream. Fresh mulberry cobbler pairs the fruit with a cake-like topping, which can be enhanced with whipped cream. Crumb bars and scones incorporate mulberries with a cornstarch-based filling and a lemon glaze, making them easy to bake.



Savories

Mulberry jam is mixed with cherries for use on toast or pastries. Fruit leather is made by drying mulberries into chewy snacks, sometimes with the addition of lavender.

Mulberry Fruit Dishes with Nutritional Value

Key nutrients found in 100g of raw mulberries include 43 calories, 10g of carbohydrates, 1.4g of protein, 0.4g of fat, 194mg of potassium, 10mg of sodium, along with vitamin C (36mg), iron, and magnesium.

Conclusion

Mulberry fruits are highly nutritious and medicinally valuable berries that contribute significantly to human health. Rich in natural antioxidants such as anthocyanins, resveratrol, and vitamin C, mulberries help combat oxidative stress and reduce the risk of chronic diseases. Their high iron content supports the prevention of anemia, while dietary fiber aids digestion and promotes gut health. Regular consumption of mulberries may assist in regulating blood sugar levels, improving cardiovascular health, and enhancing immunity. The presence of bioactive compounds also contributes to anti-inflammatory, anti-aging, and antimicrobial properties.

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