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1-Deoxynojirimycin (DNJ) from mulberry: A multifunctional bioactive compound for pharmaceutical applications

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Abstract

Polyhydroxylated piperidines and their derivatives are widely recognized for their diverse biological activities. Among these, 1-deoxynojirimycin (DNJ), also referred to as an azasugar, is a naturally occurring bioactive compound present in mulberry leaves. Chemically identified as $C_6H_{13}NO_4$, DNJ is also known by the name moranoline. In addition to plant sources, it can be synthesized by certain microorganisms, including species of *Streptomyces* and *Bacillus*. Within mulberry plants, DNJ is distributed in different parts such as leaves, roots, and stems, although its concentration is highest in the leaves. Various analytical techniques are available to determine DNJ levels, with High-Performance Liquid Chromatography (HPLC) coupled with fluorescence detection being one of the most reliable methods. DNJ has attracted considerable attention due to its wide range of biological and therapeutic properties. It functions as a potent α-glucosidase inhibitor, thereby helping to regulate postprandial blood glucose levels by interfering with carbohydrate digestion. For optimal benefits in humans, regular intake of DNJ is generally recommended. Beyond its role in glucose metabolism, DNJ has been associated with multiple pharmacological effects, including reduction of oxidative stress, and potential benefits in managing conditions such as diabetes, obesity, cancer, and aging. Among different mulberry species, the leaves of white mulberry (*Morus Alba*) are particularly rich in DNJ. The concentration is reported to be around 0.1% on a dry weight basis, equivalent to approximately 100 mg per 100 g. The estimated effective intake for humans is about 10 mg per 60 kg body weight. Due to its relatively low natural abundance, developing efficient extraction methods is important for its use in food and pharmaceutical applications. This review therefore emphasizes the physiological actions and bioavailability of DNJ.

Keywords: 1-Deoxynojirimycin (DNJ), mulberry (*Morus Alba*), DNJ biosynthesis, pharmacological activity and physiological function

Introduction

Plants have long served as a valuable source of medicinal compounds, and many modern drugs have been derived either directly or indirectly from plant materials. Among the plants in the *Morus* genus, mulberry is considered one of the most important due to its wide range of therapeutic uses. Mulberry trees can grow up to 10–12 meters in height and may be either monoecious or dioecious. They are widely distributed across regions such as Southern Europe, North Africa, the Arabian Peninsula, China, and Japan. Mulberry has been traditionally used in the management of several chronic conditions, including atherosclerosis, diabetes, hyperlipidemia, and hypertension. The genus *Morus* comprises around a dozen species, and these plants can be cultivated under both tropical and temperate conditions. They adapt well to irrigated as well as rainfed environments, with optimal growth occurring at temperatures between 24–29°C and relative humidity levels of 65–80%. While mulberry leaves are primarily used as feed for silkworms, they are also consumed in various forms such as herbal teas, owing to their medicinal value (Venkatesh Kumar, 2008) [25]. Over time, medicinal plants have played a significant role in managing a wide range of health conditions. Their ability to produce diverse bioactive compounds makes them an important source for drug development. In traditional Indian systems like Ayurveda, plant-based remedies are widely used, and many active constituents have been isolated and developed into therapeutic agents. Mulberry, in particular, has been used for centuries due to its rich chemical composition and pharmacological properties. Studies have shown that compounds derived from medicinal plants can influence human health and possess antimicrobial activity against bacteria and fungi (Singh *et al*., 2008) [19]. Mulberry leaves contain several bioactive constituents, including nitrogen-containing sugars, flavonoids such as rutin and quercetin, volatile oils, amino acids, vitamins, and trace elements. These compounds contribute to various health benefits, such as lowering blood glucose and lipid levels, regulating blood pressure, and exhibiting antimicrobial and antiviral effects. Azasugars are a class of alkaloids that structurally resemble monosaccharides, with a nitrogen atom replacing the oxygen atom in the sugar ring. The first azasugar, nojirimycin, was discovered in 1966 from *Streptomyces* species. Since then, more than a hundred azasugars have been identified from both microbial and plant sources. One such compound, 1-deoxynojirimycin (DNJ), is a glucose analogue known chemically as 5-amino-1,5-dideoxy-D-glucopyranose. DNJ was initially synthesized through the reduction of nojirimycin, and later it was isolated from mulberry roots and named moranoline (Yagi *et al*., 1976) [31]. It is also produced by certain bacteria, including *Bacillus* and *Streptomyces*. Mulberry leaves are particularly rich in azasugars such as DNJ, fagomine, N-methyl-DNJ, and 2-O-R-D-galactopyranosyl-DNJ, with DNJ being the most abundant, accounting for nearly half of the total azasugar content. These compounds exhibit their biological activity by mimicking natural carbohydrate substrates and competitively binding to the active sites of glycosidase enzymes. As a result, they effectively inhibit α-glucosidase activity. Many clinically used α-glucosidase inhibitors are derived from or inspired by naturally occurring azasugars. For example, miglitol was developed using DNJ as a lead compound due to its strong inhibitory potential. This work also highlights the biosynthetic pathways involved in DNJ formation, various extraction techniques, and its overall mechanism of action in disease management. Diabetes has emerged as a major global health concern, with the number of affected individuals projected to reach nearly 700 million by 2045 (Straube *et al*., 2023) [20]. Among the available therapeutic approaches, α-glucosidase inhibitors play an important role in controlling blood glucose levels. These compounds act by slowing down carbohydrate digestion, thereby reducing the rise in blood glucose levels after meals (Zhang *et al*., 2019) [21].

Mulberry plant acts as source for DNJ Production

Mulberry serves as the primary host plant for silkworms and is also rich in biologically active compounds with significant pharmacological potential. Studies have shown that extracts obtained from mulberry contain various bioactive constituents that contribute to the management of several health conditions, including diabetes, obesity, inflammatory disorders, neurological diseases, and allergic reactions. Among these compounds, a number of polyhydroxylated alkaloids such as piperidine, pyrrolidine, and indolizidine derivatives have been identified. These polyhydroxylated compounds are known for their antihyperglycemic effects, mainly due to their structural similarity to sugars, which allows them to inhibit glycosidase enzymes. Among them, 1-deoxynojirimycin (DNJ) and its related derivatives have been isolated from multiple plant and microbial sources; however, mulberry has been reported to contain the highest levels of this compound. In one study, four mulberry varieties-V1, S-34, S-13, and K-2 were obtained from CSRTI, Mysore, with the aim of determining their DNJ content. For analysis, 100 mg of powdered leaf material from each variety was mixed with 10 mL of 0.05 M hydrochloric acid and subjected to ultrasonication for 30 minutes to enhance extraction efficiency. The samples were then centrifuged at 10,000 rpm for 20 minutes, and the resulting supernatant was collected. This extract was further processed through derivatization using FMOC-OSu (9-fluorenylmethyl succinimidyl carbonate). Finally, the derivatized samples were analyzed using High-Performance Liquid Chromatography (HPLC) to quantify the DNJ content in each mulberry variety (Saurabh Bajpai & Vijaya Bhaskara Rao, 2014) [2].

Table 1: DNJ determination in different varieties of mulberry

S. No.	Name of varieties	Retention Time	Area	Height	Area %	Height%	DNJ (mg/gm)
1	V-1	22.088	1963699	116678	9.501	12.808	0.67±0.03
2	S-34	22.073	2240418	160685	12.119	16.389	0.73±0.16
3	S-13	22.044	4179044	247384	8.133	11.862	1.32±0.03
4	K-2	22.091	8548625	561712	12.288	14.958	2.79±0.07

The analysis carried out using the HPLC-PDA system revealed noticeable differences in DNJ levels among the studied Indian mulberry varieties shown in table 1. The results indicated a clear variation in concentration, with the varieties arranged in the following order based on DNJ content: K-2 > S-13 > S-34 > V-1. The measured concentrations were approximately 2.79 ± 0.07 mg/g, 1.32 ± 0.03 mg/g, 0.73 ± 0.16 mg/g, and 0.67 ± 0.03 mg/g of dry leaf weight, respectively. These findings highlight the significant variability in DNJ accumulation among different mulberry genotypes. Interestingly, the V-1 variety, which was developed through breeding techniques, exhibited a lower DNJ content compared to the K-2 variety, which originated through natural selection. This suggests that genetic improvement for agronomic traits does not necessarily correspond to higher levels of bioactive compounds. Since the K-2 variety demonstrated the highest DNJ concentration, it may serve as a suitable candidate for large-scale extraction of this compound for pharmaceutical applications. DNJ is a naturally occurring compound synthesized by a wide range of organisms, including plants, insects, and microorganisms. It can also be produced through chemical synthesis. Among plant sources, mulberry (*Morus Alba* L.) is considered one of the most prominent reservoirs of DNJ (Wang *et al*., 2014) [29]. The concentration of DNJ within the mulberry plant varies depending on the plant part and developmental stage. Studies have reported DNJ levels ranging from 2.24 to 3.08 mg/g in young shoots, 0.62 to 1.61 mg/g in tender leaves, and 0.47 to 0.96 mg/g in fully matured leaves (Zhang *et al*., 2019) [21]. In addition to leaves, mulberry fruits also contain DNJ, making them a valuable source of this bioactive alkaloid. Due to its strong α-glucosidase inhibitory activity, DNJ has gained attention for its potential health benefits, including anti-diabetic, anti-inflammatory, and anti-obesity effects (Shreelakshmi *et al*., 2021) [18].

Extraction, purification and determination of DNJ

Water extraction is one of the traditional approaches used for isolating DNJ. In this method, the plant material is first dried and then boiled in distilled water. The resulting mixture is filtered, and the filtrate is treated with methanol, followed by centrifugation to obtain DNJ from the supernatant. Although this technique is simple and easy to perform, it has certain limitations. Prolonged heating can lead to degradation of DNJ, and extraction efficiency may be reduced when DNJ is bound to other biomolecules such as proteins, sugars, or lipids. Given that DNJ is an alkaloid, acid-based extraction methods can also be employed, where the compound is converted into a soluble salt form. While this approach is relatively convenient, it often results in low concentration of the final extract. Organic solvents such as methanol and ethanol are commonly used for DNJ extraction because of their ability to penetrate plant cell walls effectively. Among these, ethanol is generally preferred due to its lower toxicity. In addition, modern techniques like microwave-assisted extraction have been introduced to improve efficiency. This method enhances cell wall disruption and facilitates rapid release of DNJ, making it increasingly popular due to its speed and operational simplicity (Wang *et al*., 2017) [27]. For purification, several techniques are available. Macroporous resin chromatography is widely used, where porous polymeric materials selectively adsorb target compounds from aqueous solutions. This method offers advantages such as high adsorption capacity, ease of desorption, and good mechanical stability. Using this approach, the DNJ content can be significantly enriched, increasing from about 0.23% in crude extracts to nearly 4.9% in the purified fraction, with a recovery rate of around 98%. However, the efficiency of this process depends on the type of resin used, as different resins exhibit varying adsorption and desorption properties. Another purification strategy involves solvent extraction, which relies on differences in solubility of compounds. DNJ can be separated from mulberry extracts using solvents such as diethyl ether, ethyl acetate, and 1-butanol, followed by analysis using HPLC. Ion-exchange chromatography provides a more refined separation technique, utilizing charge interactions between the target compound and the resin. This method can further increase the DNJ concentration from 4.9% to approximately 16.7%. However, it may generate chemical waste, such as ammonium hydroxide, which requires careful handling and disposal. Quantification of DNJ presents a challenge because the molecule lacks a chromophore group, making direct detection difficult. To overcome this, several advanced analytical methods have been developed. These include reversed-phase HPLC coupled with fluorescence detection, HPLC with evaporative light scattering detection, hydrophilic interaction chromatography (HILIC) combined with mass spectrometry, HPLC-MS/MS, high-performance anion-exchange chromatography with pulsed amperometric detection, and direct analysis in real-time mass spectrometry. These techniques provide reliable and sensitive detection of DNJ in various samples.

Biosynthesis of DNJ

Due to the wide therapeutic potential of 1-deoxynojirimycin (DNJ) in managing various lifestyle-related disorders, there is a growing need for its production to be both cost-effective and scalable. However, the chemical synthesis of DNJ is challenging and expensive because of its complex molecular structure. As a result, biological production, particularly through microorganisms, has emerged as a promising alternative to plant-based extraction. Traditionally, DNJ was primarily obtained from higher plants such as *Morus Alba* (GAO *Et al*., 2016) [7]. In recent years, however, certain microbial species, including Bacillus and Streptomyces, have been identified as efficient producers of DNJ, making large-scale production more feasible. DNJ has also been detected in the lepidopteran insect Bombyx mori. Studies using HPLC analysis have shown that DNJ distribution varies across different tissues and developmental stages of the insect. Notably, male larvae tend to accumulate higher levels of DNJ compared to females. The compound has been detected in the haemolymph, digestive system, and gut fluid, but it is absent in the silk glands. Interestingly, DNJ is not synthesized internally by silkworms. This was confirmed by experiments in which silkworms fed on an artificial diet lacking mulberry leaves showed no detectable DNJ content. This indicates that DNJ is acquired through feeding rather than endogenous synthesis (Shi *et al*., 2010) [35]. The pattern of DNJ accumulation in silkworm larvae is also stage-dependent. Newly hatched larvae do not contain DNJ, while accumulation occurs mainly during the early and middle instars. In the later stages, much of the accumulated DNJ is excreted, leading to fluctuations in its levels throughout development. Although glucose has long been recognized as a precursor in DNJ biosynthesis, the microbial pathway has been more clearly understood in recent years, particularly in bacteria such as Bacillus amyloliquefaciens. The biosynthetic process involves several key genes, including gabT1, yktc1, and gutB1. Initially, D-glucose enters the glycolytic pathway and is converted into fructose-6-phosphate. The enzyme GabT1 catalyzes a transamination reaction at the C2 position, followed by dephosphorylation by Yktc1 to form 2-amino-2-deoxy-D-mannitol (ADM), an important intermediate. Subsequently, the enzyme GutB1 facilitates oxidation at the C6 position of ADM, leading to the formation of mannojirimycin through cyclization of the intermediate compound. This is then converted into nojirimycin via epimerization at the C2 position. Finally, dehydration and reduction steps transform nojirimycin into 1-deoxynojirimycin. Overall, microbial biosynthesis offers a promising and efficient approach for DNJ production, overcoming the limitations associated with plant extraction and chemical synthesis. Advanced transcriptomic studies have helped identify the genes responsible for DNJ biosynthesis in mulberry leaves. These analyses revealed several important transcripts, particularly those associated with lysine decarboxylase and primary amine oxidase enzymes, which play key roles in the formation of DNJ (Wang *et al*., 2018) [26]. The biosynthetic pathway is believed to begin with aspartic acid, which is converted through a sequence of enzymatic reactions involving aspartate kinase and aspartate semialdehyde dehydrogenase. This process ultimately leads to the formation of a piperidine intermediate, which is further modified by enzymes such as cytochrome P450 and methyltransferases to produce DNJ. More recently, specific genes involved in piperidine formation have been identified in *Morus Alba*. Two such genes, Δ^1-piperideine reductase 1 (MaSDR1) and Δ^1-piperideine reductase 2 (MaSDR2), have been shown to participate in the DNJ biosynthetic pathway originating from lysine (Liu *et al*., 2020) [12]. In addition to the lysine-derived pathway, evidence suggests that DNJ in mulberry may also be synthesized through a route starting from D-glucose. In this pathway, intermediates such as 2-amino-2-deoxy-D-mannitol (ADM) and nojirimycin (NJ) are formed. The enzyme MnGUTB1, an amino-polyol dehydrogenase, catalyzes the conversion of ADM to NJ, which is a critical step in the production of DNJ, a compound known for its antihyperglycemic properties (Yang *et al*., 2023) [33]. Comprehensive gene expression studies have identified a total of 38 potential genes associated with DNJ biosynthesis in mulberry, among which nine genes showed significant variation in expression levels. The accumulation of DNJ in mulberry plants is not solely governed by genetic factors but is also influenced by environmental conditions. Factors such as mulberry variety, geographic location, soil characteristics, climatic conditions, and harvesting time all play an important role in determining DNJ content (Bharathi *et al*., 2020) [4]. Figure 1 shows the DNJ biosynthesis pathway in mulberry plant (Yang *et al*., 2023) [33].

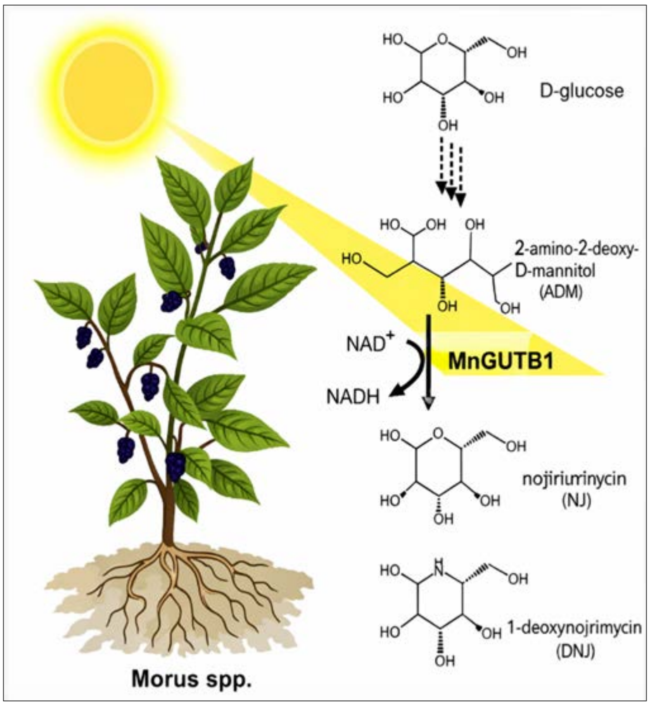

Fig 1: Biosynthesis pathway of DNJ in mulberry plant.

Physiological functions of DNJ

Mulberry plants are rich in a diverse group of polyhydroxylated piperidine alkaloids, with more than twenty such compounds identified. Among these, 1-deoxynojirimycin (DNJ) is the most prominent, along with related compounds such as 2-O-α-D-galactopyranosyl-1-deoxynojirimycin and 1-N-methyl-1-deoxynojirimycin. DNJ is widely recognized for its strong inhibitory effect on α-glucosidase (Asano *et al*., 2000) [1]. The enzyme α-glucosidase is located in the small intestine and plays a key role in carbohydrate digestion by converting dietary oligosaccharides into simple sugars like glucose. These glucose molecules are then absorbed into the bloodstream, leading to a rise in blood sugar levels. DNJ exhibits a high affinity for α-glucosidase, often binding more effectively than natural substrates such as sucrose and maltose. By occupying the enzyme's active site, DNJ limits the breakdown of complex carbohydrates, thereby reducing glucose production and slowing its absorption into the bloodstream. This action helps in controlling post-meal blood glucose spikes. In addition to its inhibitory role, DNJ has been reported to influence glucose handling in the intestine, contributing to better regulation of blood sugar levels. It may also help maintain glucose balance during fasting by reducing glycogen breakdown through inhibition of enzymes involved in glycogen metabolism. Furthermore, DNJ has been associated with improved insulin sensitivity, which is particularly beneficial in individuals with diabetes, as insulin resistance is a major factor contributing to disease progression. The presence of DNJ in mulberry leaves gives them significant pharmacological importance, particularly in managing hyperglycemia. Beyond its anti-diabetic role, DNJ has shown potential benefits in cardiovascular conditions. For instance, it has been reported to improve symptoms in patients with stable angina and coronary heart disease by enhancing antioxidant status and reducing inflammation (Sarkhel *et al*., 2020) [17]. Additionally, DNJ has demonstrated the ability to lower oxidative stress and reduce levels of inflammatory markers such as C-reactive protein in individuals with mild lipid disorders, suggesting its role in controlling inflammation (Cho *et al*., 2025) [5]. Recent findings also indicate that DNJ can modulate multiple signaling pathways across various organs including the heart, liver, kidneys, pancreas, and skeletal muscles by interacting with different molecular targets. Through these mechanisms, it contributes to the overall management of diabetes and its associated complications (Mehmood *et al*., 2025) [13].

Anti-diabetic effect

A clinical study was conducted on twenty-four healthy individuals to evaluate the effective dose of DNJ-enriched powder. After fasting for 12 hours, the participants were randomly assigned to four groups, each consisting of six subjects. These groups received either a placebo (0 g) or DNJ-enriched powder at doses of 0.4 g, 0.8 g, and 1.2 g, corresponding to 0, 6, 12, and 18 mg of DNJ, respectively. Following administration, each participant consumed 50 g of sucrose dissolved in 100 mL of water. Blood samples (10 mL) were collected at baseline and at intervals of 30, 60, 90, 120, 150, and 180 minutes after ingestion to monitor changes in glucose levels. For evaluating longer-term effects, an additional study involving daily intake of DNJ-enriched powder was performed. The collected blood samples were centrifuged at 4 °C for 10 minutes at 1000 rpm to obtain plasma. Plasma glucose levels were measured using the glucose oxidase method with a commercial assay kit. The results indicated that consumption of DNJ-enriched powder significantly reduced the rise in plasma glucose levels following sucrose intake. A reduction in insulin secretion was also observed in treated groups compared to the placebo group. This dual effect lowering both glucose and insulin responses—is characteristic of α-glucosidase inhibitors, suggesting that DNJ present in mulberry powder acts by inhibiting intestinal carbohydrate digestion. The most effective responses were observed at doses of 0.8 g and 1.2 g of DNJ-enriched powder, equivalent to 12 mg and 18 mg of DNJ (Kimura *et al*., 2007) [10]. A large body of research supports the antidiabetic potential of plant-derived phytochemicals. Mulberry leaf extracts, in particular, have been widely used in traditional medicine systems across Asia, especially in China, where they have a long history of use in diabetes management. Experimental studies have confirmed their beneficial effects on glucose regulation. Comparative studies have shown that silkworm powder contains a higher concentration of DNJ (approximately 0.39%–0.58%) than mulberry leaf powder (around 0.08%–0.12%). Correspondingly, silkworm powder exhibits stronger α-glucosidase inhibitory activity compared to mulberry leaves and even green tea. These findings suggest that both mulberry-derived and silkworm-derived DNJ can play a role in improving glucose metabolism (Yatsunami *et al*., 2011) [34].

Anti-lipid effect

Individuals with diabetes are more susceptible to complications such as fatty liver disease and cardiovascular disorders compared to healthy individuals. Research has shown that 1-deoxynojirimycin (DNJ) plays a role in reducing lipid accumulation by stimulating fatty acid β-oxidation in the liver (Do *et al*., 2015). Both DNJ and mulberry extracts enriched with DNJ have been reported to lower hepatic triglyceride levels. This effect is associated with increased activity of key enzymes involved in fatty acid β-oxidation, including acyl-CoA oxidase and carnitine transferase. Enhanced expression of these enzymes suggests that DNJ promotes the breakdown of fatty acids, thereby limiting lipid deposition in the liver. The regulation of fatty acid β-oxidation is largely controlled by peroxisome proliferator-activated receptor alpha (PPARα) and AMP-activated protein kinase (AMPK), which functions as a cellular energy sensor. DNJ treatment has been linked to elevated levels of adiponectin, an anti-obesity hormone, in both plasma and white adipose tissue. Increased adiponectin levels contribute to the activation of AMPK, which in turn stimulates fatty acid oxidation pathways. Previous findings have shown that higher adiponectin expression leads to enhanced AMPK activity, thereby promoting fatty acid breakdown and reducing lipid accumulation in the liver (Yamauchi *et al*., 2005). Through these mechanisms, DNJ demonstrates potential in managing metabolic disorders associated with lipid imbalance.

Anti-cancer effect

Cancer remains one of the leading causes of mortality worldwide and continues to pose a major public health challenge. Dietary approaches, such as calorie restriction, have been explored as preventive strategies; however, they often impose physiological stress, limiting their long-term effectiveness. Although 1-deoxynojirimycin (DNJ), a structural analogue of D-glucose, has not been conclusively proven to directly prevent cancer, it may indirectly influence cancer progression by reducing glucose availability in the body. Since cancer cells have a higher demand for glucose than normal cells, limiting its availability can potentially slow their growth. In addition to its effects on glucose metabolism, DNJ may contribute to cancer prevention by reducing oxidative stress, which plays a role in the initiation and progression of tumor formation. Studies have also demonstrated that DNJ can inhibit key processes involved in metastasis, such as cell adhesion, migration, and invasion (Wang *et al*., 2010) [28]. These processes are essential for tumor cells to spread to other tissues. Metastasis involves the breakdown of the extracellular matrix surrounding tumor cells, a process largely mediated by matrix metalloproteinases (MMPs) and regulated by their inhibitors, known as tissue inhibitors of metalloproteinases (TIMPs). DNJ has been reported to interfere with these mechanisms, thereby limiting tumor progression. Furthermore, its antioxidant and anti-inflammatory properties have been linked to protective effects in disease models, including the prevention of gastric ulcer formation through modulation of pathways such as NF-κB. Because of its structural similarity to glucose, DNJ has attracted attention for its potential role in cancer research. It may also disrupt interactions at the cell surface that are necessary for cancer cell attachment. Although DNJ is not considered a direct anticancer agent, its ability to reduce glucose bioavailability and interfere with key cellular processes suggests a supportive role in inhibiting cancer cell growth and spread (Bharathi *et al*., 2020) [4].

Anti-obesity action

Obesity is associated with an increase in adipose tissue, which alters the secretion of various adipokines and regulatory proteins. Among these, adiponectin plays a crucial role, as it is positively linked to fatty acid oxidation, insulin sensitivity, and glucose metabolism. Studies have shown that 1-deoxynojirimycin (DNJ) can help counteract diet-induced obesity by elevating adiponectin levels. In experimental models, prolonged administration of DNJ for 12 weeks in obese mice resulted in a significant reduction in body fat, adipocyte size, liver lipid accumulation, and plasma triglyceride levels. At the same time, DNJ treatment led to increased circulating adiponectin levels and enhanced activation of the fatty acid β-oxidation pathway (Tsuduki *et al*., 2013) [23]. Further research has explored the central mechanisms underlying DNJ's anti-obesity effects. In studies involving high-fat diet–induced obese mice, DNJ administration was found to reduce endoplasmic reticulum (ER) stress in the hypothalamus. This reduction in ER stress improved leptin signaling through the activation of STAT pathways, which contributed to decreased food intake (Kim *et al*., 2017) [9]. These findings suggest that DNJ exerts anti-obesity effects through both peripheral and central mechanisms. By enhancing adiponectin levels, DNJ promotes improved lipid and glucose metabolism, while its action on the hypothalamus helps regulate appetite and energy balance. Together, these effects contribute to the prevention and management of diet-induced obesity.

Antiviral Activity

1-Deoxynojirimycin (DNJ) has demonstrated antiviral potential by reducing the infectivity and cytopathic effects of HIV-1, as well as inhibiting virus-induced syncytium formation. Early investigations into its antiviral activity against dengue virus (DENV), a member of the *Flaviviridae* family, began around 2000. However, derivatives of DNJ, particularly N-butyldeoxynojirimycin, were found to exhibit stronger antiviral activity than DNJ itself (Tricase *et al*., 2025) [22]. Subsequent research has identified several DNJ-derived iminosugars with effectiveness against DENV (Perera *et al*., 2022) [16]. In addition, these compounds have shown activity against other viruses of public health concern, including the Crimean-Congo hemorrhagic fever virus (CCHFV), which causes a severe and often fatal disease (Tyrrell *et al*., 2023) [24]. Overall, these findings highlight the potential of DNJ and its derivatives as antiviral agents, particularly through their ability to interfere with viral replication and spread.

Function in anti-aging

Advancing age is often associated with a gradual decline in cognitive function and an increased risk of neurological disorders. Many chronic conditions, including cardiovascular and metabolic diseases, are closely linked with aging and tend to worsen over time. These conditions are commonly referred to as age-related disorders due to their progressive nature. Research has indicated that 1-deoxynojirimycin (DNJ), derived from mulberry, may help delay cellular aging by influencing metabolic balance and maintaining proper glucose and insulin regulation (Thakur *et al*., 2019) [21]. Experimental studies using human umbilical vein endothelial cells (HUVECs) have provided insight into this effect. In these studies, cells were cultured under different conditions, including normal glucose levels, normal glucose with DNJ, high glucose conditions, and high glucose combined with DNJ treatment. Under high glucose conditions, cells showed reduced proliferation, increased cellular aging markers, and elevated expression of senescence-associated genes such as PAI-1 and p21. There was also a significant rise in senescence-associated β-galactosidase activity, indicating accelerated aging at the cellular level. However, when DNJ was introduced, these effects were significantly reduced. DNJ helped restore cell growth rates and decreased the number of senescent cells. Additionally, high glucose conditions were associated with increased production of reactive oxygen species, activation of NF-κB signaling, and enhanced monocyte adhesion all of which contribute to cellular aging and inflammation. DNJ treatment effectively suppressed these changes, suggesting its protective role against oxidative stress and inflammatory responses. Overall, these findings demonstrate that DNJ can counteract the harmful effects of high glucose on endothelial cells and delay the onset of cellular senescence. This protective action highlights its potential significance in the prevention and management of age-related disorders.

Conclusion

In summary, 1-deoxynojirimycin (DNJ) derived from mulberry has emerged as a promising bioactive compound with wide-ranging pharmaceutical potential. Its applications span multiple therapeutic areas, including the management of diabetes, support in cancer-related research, and antiviral interventions. The distinctive biochemical characteristics of DNJ make it an important candidate for future drug development and innovation. Despite its advantages, several limitations still need to be addressed before DNJ can be widely adopted in clinical practice. Challenges such as limited bioavailability, target specificity, and cost-effective large-scale production remain areas of concern and require further investigation. Nevertheless, ongoing progress in pharmaceutical technologies such as advanced drug delivery systems, combination therapies, and personalized treatment approaches offers opportunities to overcome these barriers. With continued research and interdisciplinary collaboration, DNJ holds significant potential to contribute to the development of novel therapeutic strategies. Overall, sustained efforts from scientists, industry stakeholders, and regulatory authorities will be crucial in translating the benefits of DNJ into practical medical applications, thereby addressing complex health challenges and improving patient outcomes.

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Conflict of interest

There is no conflict of interest regarding the publication of this manuscript.

References

1. Asano N, Ishii S, Kizu H, Ikeda K, Yasuda K, Kato A, *et al*. *In vitro* inhibition and intracellular enhancement of lysosomal α-galactosidase A activity in Fabry lymphoblasts by 1-deoxygalactonojirimycin and its derivatives. European Journal of Biochemistry,2000:267(13):4179-4186.
2. Bajpai S, Rao AVB. Quantitative determination of 1-deoxynojirimycin in different mulberry varieties of India. J. Pharmacogn. Phytochem,2014:3(3):17-22.
3. Bajpai S, Rao AVB. Quantitative determination of 1-deoxynojirimycin in different mulberry varieties of India. Journal of Pharmacognosy and Phytochemistry,2014:3(3):17–22.
4. Bharathi VP. Natural alkaloid DNJ in mulberry and its application: An overview. Journal of Pharmacognosy and Phytochemistry,2020:9(4):1646-1654.
5. Cho IH, Cheng R, Jung CW, Won TH, Wang D, Jang HH, *et al*. Effects of 1-Deoxynojirimycin on glycemic control: A systematic review and meta-analysis. NFS Journal,2025:38:100210.
6. Do HJ, Chung JH, Hwang JW, Kim OY, Lee JY, Shin MJ. 1-Deoxynojirimycin isolated from *Bacillus subtilis* improves hepatic lipid metabolism and mitochondrial function in high-fat–fed mice. Food and Chemical Toxicology,2015:75:1–7.
7. Gao K, Zheng C, Wang T, Zhao H, Wang J, Wang Z, *et al*. 1-Deoxynojirimycin: occurrence, extraction, chemistry, oral pharmacokinetics, biological activities and in silico target fishing. Molecules,2016:21(11):1600.
8. Kim JW, Kim SU, Lee HS, Kim I, Ahn MY, Ryu KS. Determination of 1-deoxynojirimycin in *Morus Alba* L. leaves by derivatization with 9-fluorenylmethyl chloroformate followed by reversed-phase high-performance liquid chromatography. Journal of Chromatography A,2003:1002(1-2):93-99.
9. Kim J, Yun EY, Quan FS, Park SW, Goo TW. Central administration of 1-deoxynojirimycin attenuates hypothalamic endoplasmic reticulum stress and regulates food intake and body weight in mice with high-fat diet-induced obesity. Evidence-Based Complementary and Alternative Medicine, 2017, 3607089.
10. Kimura T, Nakagawa K, Kubota H, Kojima Y, Goto Y, Yamagishi K, *et al*. Food-grade mulberry powder enriched with 1-deoxynojirimycin suppresses the elevation of postprandial blood glucose in humans. Journal of Agricultural and Food Chemistry,2007:55(14):5869–5874.
11. Kimura T, Nakagawa K, Saito Y, Yamagishi K, Suzuki M, Yamaki K, *et al*. Determination of 1-deoxynojirimycin in mulberry leaves using hydrophilic interaction chromatography with evaporative light scattering detection. Journal of Agricultural and Food Chemistry,2004:52(6):1415-1418.
12. Liu J, Wan J, Wang D, Wen C, Wei Y, Ouyang Z. Comparative transcriptome analysis of key reductase genes involved in the 1-deoxynojirimycin biosynthetic pathway in mulberry leaves and cloning, prokaryotic expression, and functional analysis of MaSDR 1 and MaSDR 2. Journal of agricultural and food chemistry,2020:68(44):12345-12357.
13. Mehmood A, Battino M, Chen X. 1-Deoxynojirimycin: a comprehensive review of sources, biosynthesis pathways, strategies to enhance its production, and anti-diabetic activities. Food & Function,2025:16(12):4673-4701.
14. Nakagawa K, Kubota H, Kimura T, Yamashita S, Tsuzuki T, Oikawa S, *et al*. Occurrence of orally administered mulberry 1-deoxynojirimycin in rat plasma. Journal of agricultural and food chemistry,2007:55(22):8928-8933.
15. Nuengchamnong N, Ingkaninan K, Kaewruang W, Wongareonwanakij S, Hongthongdaeng B. Quantitative determination of 1-deoxynojirimycin in mulberry leaves using liquid chromatography–tandem mass spectrometry. Journal of pharmaceutical and biomedical analysis,2007:44(4):853-858.
16. Perera N, Brun J, Alonzi DS, Tyrrell BE, Miller JL, Zitzmann N. Antiviral effects of deoxynojirimycin (DNJ)-based iminosugars in dengue virus-infected primary dendritic cells. Antiviral Research,2022:199:105269.

17. Sarkhel S, Manvi D, Ramachandra CT. Nutrition importance and health benefits of mulberry leaf extract: A review. Journal of Pharmacognosy and Phytochemistry,2020:9(5):689-695.
18. Shreelakshmi SV, Nazareth MS, Kumar SS, Giridhar P, Prashanth KH, Shetty NP. Physicochemical composition and characterization of bioactive compounds of mulberry (*Morus indica* L.) fruit during ontogeny. Plant Foods for Human Nutrition,2021:76(3):304-310.
19. Singh DK, Singh VK. Pharmacological Effects of *Allium Sativum* L.(Garlic). Annual Review of Biomedical Sciences,2008:10:6-26.
20. Straube H. Am-aza-ing antidiabetic: Mulberry dehydrogenase MnGUTB1 contributes to the biosynthesis of 1-deoxynojirimycin. Plant Physiology,2023:192(2):700.
21. Thakur K, Zhang YY, Mocan A, Zhang F, Zhang JG, Wei ZJ. 1-Deoxynojirimycin, its potential for management of non-communicable metabolic diseases. Trends in Food Science & Technology,2019:89:88–99.
22. Tricase AF, Cavalluzzi MM, Catalano A, De Bellis M, De Palma A, Basile G, *et al*. Insights into the activities and usefulness of deoxynojirimycin and *Morus Alba*: a comprehensive review. Molecules,2025:30(15):3213.
23. Tsuduki T, Kikuchi I, Kimura T, Nakagawa K, Miyazawa T. Intake of mulberry 1-deoxynojirimycin prevents diet-induced obesity through increases in adiponectin in mice. Food Chemistry,2013:139(1–4):16–23.
24. Tyrrell BE, Kumar A, Gangadharan B, Alonzi D, Brun J, Hill M, *et al*. Exploring the potential of Iminosugars as antivirals for Crimean-Congo Haemorrhagic Fever Virus, using the Surrogate Hazara Virus: liquid-chromatography-based mapping of viral N-Glycosylation and *in vitro* Antiviral assays. Pathogens,2023:12(3):399.
25. Venkatesh Kumar R, Chauhan S. Mulberry: life enhancer. Journal of Medicinal Plants Research,2008:2(10):271-278.
26. Wang D, Zhao L, Wang D, Liu J, Yu X, Wei Y, *et al*. Transcriptome analysis and identification of key genes involved in 1-deoxynojirimycin biosynthesis of mulberry (*Morus Alba* L.). PeerJ,2018:6:e5443.
27. Wang N, Zhu F, Chen K. 1-Deoxynojirimycin: Sources, extraction, analysis and biological functions. Natural Product Communications,2017:12(9):1521–1526.
28. Wang RJ, Yang CH, Hu ML. 1-Deoxynojirimycin inhibits metastasis of B16F10 melanoma cells by attenuating the activity and expression of matrix metalloproteinases-2 and -9 and altering cell surface glycosylation. Journal of Agricultural and Food Chemistry,2010:58(16):8988–8993.
29. Wang T, Li CQ, Zhang H, Li JW. Response surface optimized extraction of 1-deoxynojirimycin from mulberry leaves (*Morus Alba* L.) and preparative separation with resins. Molecules,2014:19(6):7040-7056.
30. Xu B, Zhang DY, Liu ZY, Zhang Y, Liu L, Li L, *et al*. Rapid determination of 1-deoxynojirimycin in *Morus Alba* L. leaves by direct analysis in real time (DART) mass spectrometry. Journal of Pharmaceutical and Biomedical Analysis,2015:114:447-454.
31. Yagi M, Kouno T, Aoyagi Y, Murai H. The structure of moranoline, a piperidine alkaloid from *Morus* species. Bulletin of the Agricultural Chemical Society of Japan,1976:50:571–572.
32. Yamauchi T, Kamon J, Minokoshi Y, Ito Y, Waki H, Uchida S, *et al*. Adiponectin stimulates glucose utilization and fatty-acid oxidation by activating AMP-activated protein kinase. Nature Medicine,2002:8(11):1288–1295.
33. Yang Z, Luo Y, Xia X, He J, Zhang J, Zeng Q, *et al*. Dehydrogenase MnGutB1 catalyzes 1-deoxynojirimycin biosynthesis in mulberry. Plant Physiology,2023:192(2):1307-1320.
34. Yatsunami K, Murata K, Kamei T. 1-Deoxynojirimycin content and α-glucosidase inhibitory activity and heat stability of 1-deoxynojirimycin in silkworm powder. Food and Nutrition Sciences,2011:2(2).
35. Yin H, Shi XQ, Sun B, Ye JJ, Duan ZA, Zhou XL, *et al*. Accumulation of 1-deoxynojirimycin in silkworm, *Bombyx mori* L. Journal of Zhejiang University Science B,2010:11(4):286–291.
36. Yoshihashi T, Do HTT, Tungtrakul P, Boonbumrung S, Yamaki K. Simple, selective, and rapid quantification of 1-deoxynojirimycin in mulberry leaf products by high-performance anion-exchange chromatography with pulsed amperometric detection. Journal of food science,2010:75(3):C246-C250.
37. Zhang W, Mu W, Wu H, Liang Z. An overview of the biological production of 1-deoxynojirimycin: current status and future perspective. Applied microbiology and biotechnology,2019:103(23):9335-9344.
38. Zhang W, Mu W, Wu H, Liang Z. An overview of the biological production of 1-deoxynojirimycin: current status and future perspective. Applied microbiology and biotechnology,2019:103(23):9335-9344.