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Entomophagy to Entomotherapy: Emerging Biomedical Applications of the Silkworm *Bombyx mori* L.

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Abstract

Insects have played an important role in traditional medicine for thousands of years, serving as sources of nutritive, pharmacological and therapeutic materials. Although entomophagy has a long history in many cultures, modern biomedical research has only recently begun recognizing insects as promising reservoirs of novel bioactive compounds. Among the various medicinal insects, the domesticated silkworm, *Bombyx mori* L., is of particular interest. Traditionally valued for its silk, the silkworm larva contains a diverse spectrum of biologically active molecules, including proteins, polyphenols, amino acids, fatty acids, antimicrobial peptides and compounds such as 1-deoxynojirimycin (1-DNJ), all of which contribute to significant medicinal properties. Recent experimental studies demonstrate that silkworm powders prepared through freeze-drying, steaming or boiling can act as antidiabetic, hepatoprotective, anti-inflammatory, antioxidant and immunomodulatory agents. These powders have shown meaningful protection against chemical and alcohol-induced liver injury, improvement in lipid metabolism, reduction of fibrosis and modulation of glucose homeostasis. This review integrates historical perspectives, nutritional insights, pharmacological findings and modern biotechnological developments to highlight the therapeutic promise of *Bombyx mori* and its emerging role within entomotherapy and functional sericulture.

Keywords: Entomophagy, Entomotherapy, *Bombyx mori*, Silkworm, Nutritional profile

1. Introduction

Throughout human history, a wide variety of animals have been used in medicine, either directly as remedies or indirectly as materials incorporated into medicinal formulations. Folk practices across continents - particularly in Asia, Africa and the Mediterranean - have long included insect-derived products as curative agents. These traditional systems relied on dried insects, larvae, pupae, cocoons, excretions and nests to treat conditions ranging from infections and inflammation to digestive and metabolic disorders. Despite the long-standing use of insects in ethno medicine, modern pharmacology and drug discovery have largely overlooked these organisms. It is emphasized that insects possess a considerable diversity of therapeutic properties, including immunological, analgesic, antibacterial, diuretic, anti-rheumatic and metabolic activities. These characteristics, combined with their extraordinary biodiversity make insects valuable yet underexploited candidates for drug development. With nearly one million described species and many more yet undiscovered, insects represent approximately eighty percent of all known animal life on Earth. Their chemical diversity is immense, containing compounds that have evolved through millions of years of ecological interactions. For this reason, Metcalf of the University of California described insects as a new frontier for natural products chemistry, highlighting their potential to contribute to pharmaceutical innovation.

Within this context, the silkworm occupies a unique position. Domesticated for more than five millennia for silk production, it has become indispensable to global sericulture. Over time, however, a transformation has taken place. Traditional sericulture has expanded beyond cocoon production into functional sericulture, encompassing nutritional applications, therapeutic uses, biotechnology and the manufacture of bioengineered materials. As a result, the silkworm has shifted from a textile-focused organism to a versatile bio-industrial resource. Silkworms have also been used in Chinese traditional medicine for more than 3000 years particularly as dried, processed larvae used to treat seizures, skin disorders, circulatory disturbances, and inflammatory

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ailments. As scientific interest in entomotherapy grows, *Bombyx mori* has emerged as one of the most thoroughly studied insects for medicinal applications.

2. Nutritional and Biochemical Profile of *Bombyx mori*

The nutritional composition of silkworm larvae contributes significantly to their therapeutic value. Silkworms contain a high percentage of proteins, especially fibroin and sericin, which are the primary components of silk. These proteins possess unique physicochemical and biological properties, such as

biocompatibility, antioxidant activity and the ability to modulate inflammation, all of which make them useful in both medicine and biotechnology. The larvae also contain a complete range of essential amino acids, along with vitamins such as vitamin A, several B-complex vitamins and trace amounts of other micronutrients. Fatty acids, including omega-3 and omega-6, are present in quantities that support cardiovascular and metabolic health. Polyphenols and flavonoids further contribute to antioxidant potential, helping neutralize free radicals and reduce oxidative damage (Table 1).

Table 1: Nutrient content of silkworm (*Bombyx mori* L.)

Parameters (%)	Larvae	Pupa
Crude protein content	20.79±2.22	21.59±2.91
Ash content	6.34±0.84	5.50±0.51
Moisture content	7.92±0.98	8.26±0.66
Fat content	17.57±1.51	19.90±1.80
Crude fibre content	6.46±0.21	6.30±0.12
Carbohydrate content	40.93±3.20	38.47±4.24
Parameter smg/100g		
Na	10.52±1.31	11.66±1.22
Ca	20.31±2.78	26.65±3.49
Mg	31.24±3.61	27.53±3.76
Zn	35.63±4.98	37.50±4.64
Fe	5.31±0.72	6.33±0.81

Among the most important bioactive compounds in silkworm is 1-deoxynojirimycin (1-DNJ), an alkaloid that naturally occurs in mulberry plants and becomes concentrated within the silkworm after consumption of mulberry leaves. This compound is responsible for notable antidiabetic properties due to its inhibitory effects on enzymes involved in carbohydrate digestion (Table

2). Additionally, the silkworm immune system generates antimicrobial peptides such as cecropins, moricins and defensins, which contribute to its ability to resist pathogens and offer potential as natural antibiotic agents. Taken together, these nutritional and biochemical components make *Bombyx mori* a rich source of therapeutic substances.

Table 2: Functional Importance of Nutrients in Silkworm Larva

Sl. No.	Nutrients	Components	Functional Importance
1	Protein	Fibroin, Sericin	Antioxidant, tissue repair, immunomodulation, biomaterial source
2	Essential amino acid	Lysine, Methionine, Leucine, Isoleucine, Valine, Threonine	Support metabolic function, muscle development, and enzyme synthesis
3	Vitamins	Vitamin A, Vitamin B1, B2, B6, Niacin	Vision, metabolism, nervous system health
4	Fatty Acids	Omega-3, Omega-6, Unsaturated lipids	Cardiovascular protection, anti-inflammatory effects
5	Polyphenols & Flavonoids	Catechins, Quercetin-like compounds	Antioxidant, anti-inflammatory properties
6	Bioactive Compounds	1-Deoxynojirimycin (1-DNJ), antimicrobial peptides	Antidiabetic activity, immune defense
7	Minerals	Calcium, Iron, Phosphorus, Magnesium	Bone health, enzymatic reactions

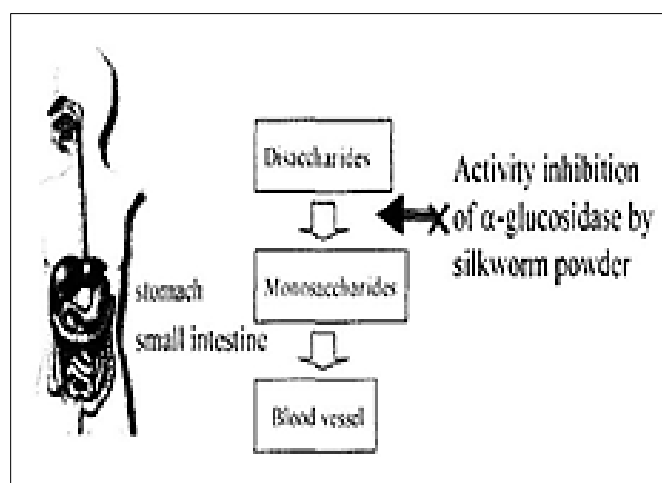


Fig 1: Pharmacological mechanism of Silkworm Powder

3. Transition from Traditional Medicine to Functional Sericulture

The evolution of sericulture practices has led to a broader understanding of the potential applications of silkworm. Traditionally, silkworm was primarily used to produce silk, prized for their texture and strength. Today, the industry has expanded into the realm of functional sericulture, which applies modern biological, nutritionaland technological knowledge to utilize silkworm for a variety of new purposes. Functional sericulture includes the production of silkworm powders and extracts for use in dietary supplements, natural health products and pharmaceuticals. Silkworm are also integrated into food

production systems, particularly in East and Southeast Asia, where roasted or powdered larvae serve as protein-rich food sources. Moreover, *Bombyx mori* has become an important biotechnological organism used for producing recombinant proteins, expressing therapeutic molecules and generating materials for tissue engineering. This shift reflects a growing global interest in sustainable, cost-effective and natural sources of biologically active compounds. Because silkworm is easy to rear, require relatively low resources, and produce a high biomass yield, they have become an appealing platform for drug discovery and nutraceutical development.

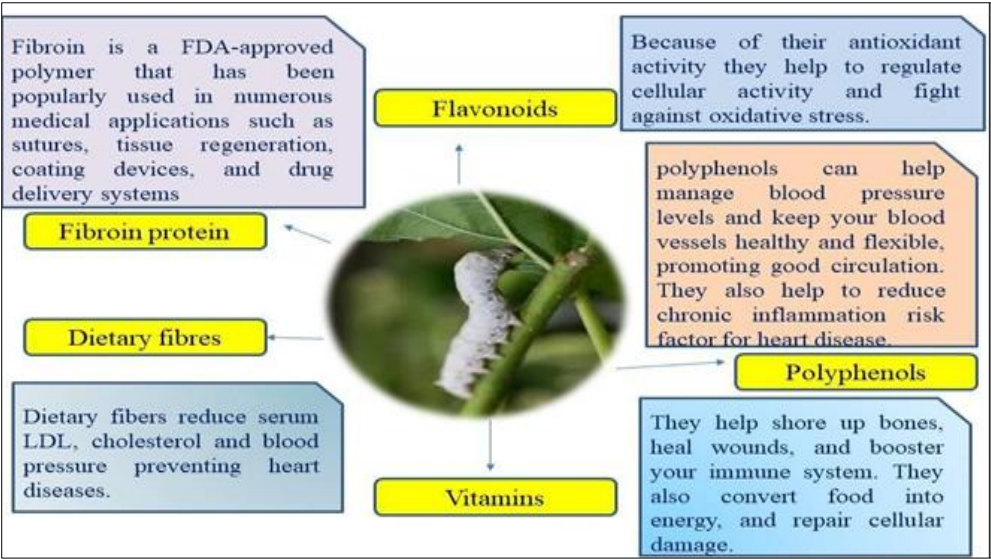


Fig 2: Bioactive compounds of *Bombyx mori*

4. Antidiabetic Potential of Silkworm Powder

One of the most thoroughly researched medicinal properties of *Bombyx mori* is its ability to regulate blood glucose levels. This effect is primarily attributed to the presence of 1-deoxynojirimycin, a compound known to inhibit alpha-glucosidase enzymes in the small intestine. By preventing the rapid breakdown of complex carbohydrates into glucose, 1-DNJ slows glucose absorption, thereby reducing postprandial glucose spikes.

4.1 Concentration of 1-DNJ in Silkworm Powder

It is found that silkworm powder contains between 0.39 and 0.58 percent 1-DNJ. In contrast, mulberry leaf powder contains only 0.08 to 0.12 percent. This difference arises from the silkworm ability to concentrate mulberry-derived DNJ in its body through feeding. When mulberry leaves are damaged by insects, they release a milky sap rich in DNJ, which the silkworm ingests and accumulates (Table 3).

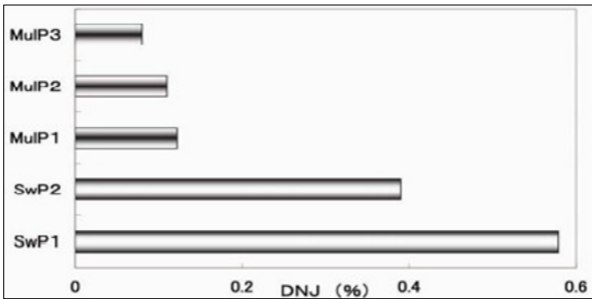


Fig 3: 1- deoxynojirimycin (DNJ) content in silkworm powder (SwP) and mulberry powder (MulP)

Table 3: Pharmacological Activities of Silkworm-Derived Compounds

Sl No.	Bioactive Component	Source	Known Activities
1	1-DNJ	Silkworm larva, mulberry sap	α -glucosidase inhibitor; reduces postprandial glucose
2	Fibroin Protein	Silk gland	Antioxidant, tissue regeneration, biomaterial scaffold
3	Sericin Protein	Silk gland	Anti-inflammatory, moisturizing, antioxidant
4	Polyphenols & Flavonoids	Larval tissue	Anti-inflammatory, free radical scavenging
5	Antimicrobial Peptides	Hemolymph	Antibacterial, antifungal
6	Fatty Acids	Larval body	Hypolipidemic, hepatoprotective

4.2 Comparison of α -Glucosidase Inhibition

The same study demonstrated the superior alpha-glucosidase inhibitory activity of silkworm powder compared to other natural substances. Silkworm powder achieved approximately ninety

percent inhibition, whereas mulberry leaf powder reached 50 percent and green tea powder only twenty-five percent. This highlights the potential for silkworm powder to serve as a natural antidiabetic supplement (Table 4).

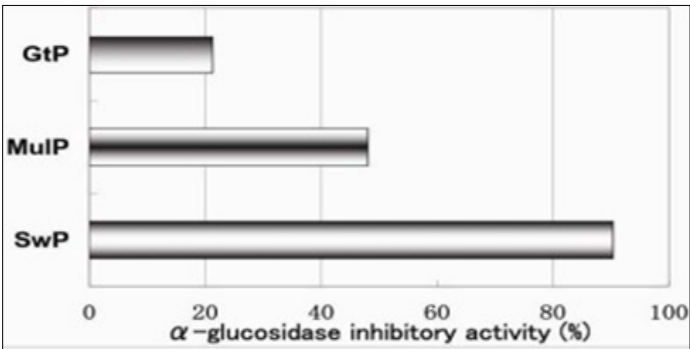


Fig 4: α -Glucosidase inhibitory activity in silkworm powder (SwP), mulberry powder (MuIP) and Green tea powder (GtP)

Table 4: Comparison of α -Glucosidase inhibition among natural powders

Sl. No.	Powder Type	α -Glucosidase Inhibitory Activity (%)	Key Notes
1	Silkworm Powder	~90%	Highest inhibition; bio-concentration of DNJ
2	Mulberry Leaf Powder	~50%	Natural DNJ source
3	Green Tea Powder	~25%	Contains catechins but lower DNJ

4.3 Mechanisms of Glucose Regulation

The influence of silkworm powder on glucose regulation is multifaceted. In addition to enzyme inhibition, the powder enhances adiponectin secretion, increases insulin levels, promotes

glycolysis and glycogenesis and reduces gluconeogenesis in the liver. It also suppresses glucose absorption in the intestine and improves glucose transport by increasing the expression of GLUT2 and GLUT4 proteins.

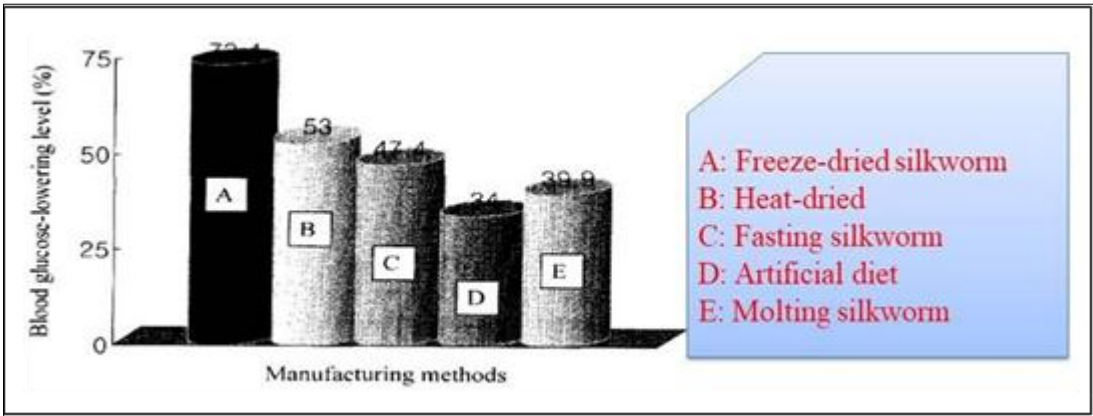


Fig 5: Effect of silkworm powder prepared by different methods on blood glucose lowering level

4.4 Importance of Processing Methods

It is evaluated different methods of preparing silkworm powder and found that freeze-drying preserved the highest level of antidiabetic activity. Heat-based methods, such as boiling or roasting, caused oxidation and degradation of bioactive

components due to the sensitivity of digestive enzymes and hemolymph. Freeze-dried silkworm powder demonstrated a significant reduction of blood glucose levels, reaching up to seventy-three percent, outperforming other methods (Table 5).

Table 5: Processing Methods and Effectiveness of Silkworm Powder

Sl. No.	Preparation Method	Description	Advantages	Disadvantages	Bioactivity Retention
1	Freeze-drying	Rapid dehydration at low temperatures	Preserves enzymes, polyphenols, DNJ	Higher cost	Very high
2	Steaming + freeze-drying	Heat treatment before drying	Reduces microbial load, stabilizes tissues	Some heat-sensitive compounds lost	High
3	Boiling + freeze-drying	Mild cooking followed by drying	Safe for consumption, reduces toxins	Loss of some bioactives	Moderate
4	Hot air drying	High temperature drying	Economical	Causes oxidation, degrades enzymes	Low

5. Hepatoprotective Effects of Silkworm Powder

Recent studies have revealed that silkworm powders can protect the liver from chemical-induced damage. Boiled and freeze-dried

mature silkworm powder, referred to as BMSP, was tested against hepatotoxicity induced by diethylnitrosamine (DEN), a known carcinogenic agent (Table 6).

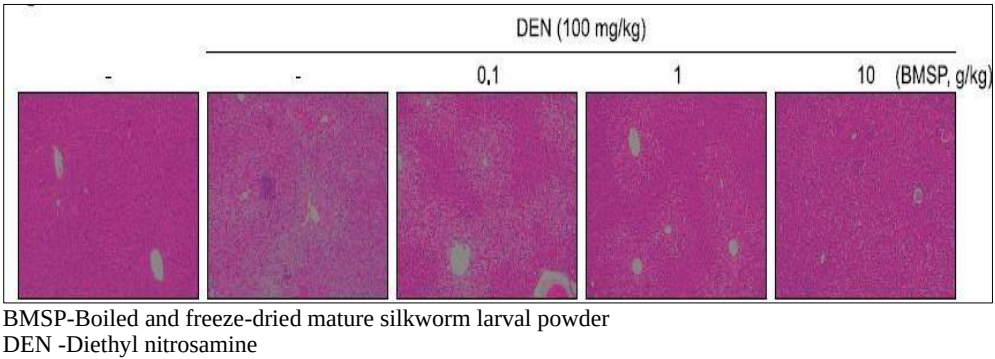


Fig 6: Histological sections from the livers of DEN-treated mice with BMSP

Table 6: Hepatoprotective Effects of Silkworm Powders

Sl. No.	Model Used	Treatment	Major Outcomes
1	DEN-induced toxicity in mice	Boiled & freeze-dried silkworm powder (BMSP)	Reduced necrosis, lowered ALT/AST/ALP, decreased macrophage infiltration, reduced cytokine levels
2	Alcoholic fatty liver disease in rats	Steamed & freeze-dried silkworm powder (SMSP)	Reduced steatosis, improved lipid profile, reversed fibrosis, normalized albumin

Cho *et al.* (2016) & Hong *et al.* (2018)

5.1 Restoration of Liver Weight and Structure

Mice treated with DEN experienced a significant reduction in liver weight, indicating tissue damage. However, pretreatment with BMSP restored liver weight in a dose-dependent manner. Histological analysis showed that DEN exposure caused widespread necrosis, inflammatory cell infiltration, and edema, particularly around the central vein and portal regions. BMSP administration mitigated these changes, preserving the integrity of hepatocytes and reducing necrotic patches.

5.2 Reduction of Liver Enzymes

Levels of alkaline phosphatase, alanine amino-transferase and aspartate amino-transferase were elevated in DEN-treated groups, reflecting liver injury. BMSP significantly reduced these enzyme levels, indicating its protective action against hepatotoxicity.

5.3 Anti-inflammatory Gene Regulation

Further analysis demonstrated that BMSP reduced macrophage infiltration, as seen through decreased F4/80 and CD31 markers. It also downregulated inflammatory chemokines and cytokines, including CXCL11, CCL17 and CCR2. These findings confirm the compound anti-inflammatory and immunomodulatory properties.

6. Silkworm Powder as Therapy for Alcoholic Fatty Liver Disease

The effects of steamed and freeze-dried mature silkworm powder, referred to as SMSP, on alcoholic fatty liver disease in rats. Alcohol consumption induces steatosis, inflammation, and

fibrosis, ultimately impairing liver function.

6.1 Reduction of Steatosis

Histological observations revealed severe lipid accumulation in the livers of ethanol-treated rats. Rats fed diets supplemented with SMSP exhibited markedly reduced steatosis, even at varying doses. The treatment did not affect food intake, suggesting that the powder does not interfere with appetite or general metabolism.

6.2 Improvement in Liver Function Markers

Serum levels of alanine aminotransferase and aspartate aminotransferase, which typically rise during liver injury, were significantly reduced in SMSP-treated groups. Additionally, SMSP restored albumin levels, which are often decreased in alcoholic liver disease.

6.3 Regulation of Lipid Metabolism

SMSP supplementation improved several lipid parameters. Total cholesterol and the ratio of low-density lipoprotein to high-density lipoprotein were both reduced. Serum triacylglycerol levels were also lowered, indicating a broad improvement in lipid homeostasis.

6.4 Reduction of Fibrosis

Alcohol consumption led to increased deposition of collagen fibers, visible as blue staining in fibrosis assays. SMSP significantly reduced collagen accumulation and downregulated fibrosis-related genes, including Col1a1 and Acta2. Protein analysis showed lower levels of pro-collagen type I and alpha-smooth muscle actin, suggesting reduced fibrogenic activity.

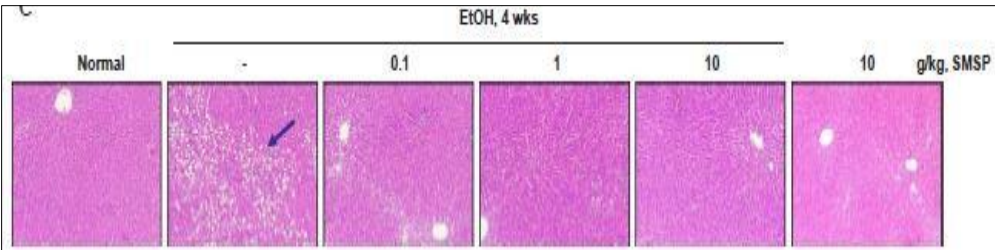


Fig 7: Effect of SMSP on the ethanol-induced injury in rats.

(Histopathological sections of the liver)

EtoH- Ethanol treated group

SMSP- Steamed and freeze dried mature silkworm larval powder
AIN-76A- it is a rodent diet

7. Additional Biomedical Applications of *Bombyx mori*

Beyond its antidiabetic and hepatoprotective properties, Silkworm possesses several other medicinal applications.

7.1 Antimicrobial Activity

Antimicrobial peptides produced by the silkworm immune system show promising activity against bacterial and fungal pathogens. These peptides function by disrupting microbial cell membranes and may serve as alternatives to conventional antibiotics.

7.2 Anti-inflammatory Effects

Silkworm proteins and polyphenols regulate inflammatory pathways by modulating cytokine expression, which may support their use in chronic inflammatory disorders.

7.3 Antioxidant Properties

Silkworm extracts help neutralize free radicals, reduce lipid peroxidation and enhance endogenous antioxidant enzymes. These effects contribute to protection against oxidative stress-related diseases.

7.4 Functional Food Applications

Silkworm powders are increasingly incorporated into functional foods, protein supplements, and health beverages. Their nutrient-rich composition makes them suitable as dietary ingredients in both human and animal nutrition.

7.5 Biotechnological Uses

Bombyx mori plays an important role in biotechnology, including the production of recombinant proteins, vaccine components and silk-based scaffolds for tissue regeneration. Its silk fibroin is widely used for developing biomedical implants, drug delivery systems and wound dressings.

Conclusion

Bombyx mori has undergone a remarkable transformation from a textile-oriented organism to a multifaceted biological resource with significant therapeutic potential. Extensive research highlights the ability of silkworm powders and extracts to regulate glucose levels, protect the liver from chemical and alcohol-induced injury, reduce inflammation, and improve lipid metabolism. These effects are made possible by the rich composition of proteins, amino acids, polyphenols, fatty acids, antimicrobial peptides, and bioactive compounds such as 1-deoxynojirimycin. Studies conducted using DEN models and ethanol-induced liver disorders consistently demonstrate the hepatoprotective and metabolic benefits of silkworm powders. Moreover, the broad range of additional activities, including antimicrobial, antioxidant, and anti-inflammatory effects, further support their potential for pharmaceutical and nutritional applications. As global demand increases for safe, sustainable, and natural therapeutic agents, entomotherapy is emerging as a promising field. *Bombyx mori* stands at the forefront of this movement, offering cost-effective and environmentally friendly alternatives to conventional medicinal resources. Continued scientific investigation, coupled with rigorous clinical evaluation, will be crucial in unlocking the full potential of silkworm-based therapeutics and establishing their place in modern medicine.

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