Review Article

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"Role of chemical disinfectants in disease management and enhancing mulberry sericulture productivity: a review"

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Abstract

The sericulture industry, focused on producing silk from *Bombyx mori* silkworms, is highly vulnerable to pathogenic outbreaks due to the domestication of silkworms, which has diminished their natural immunity. Pathogens, including bacteria, fungi, and viruses, are common threats in silkworm rearing and significantly impact silk production. The use of chemical disinfectants in sericulture has proven to be an essential tool in mitigating these threats by maintaining hygienic rearing conditions. This paper reviews the importance, mechanisms, and application of chemical disinfectants in disease management and highlights their role in enhancing sericulture productivity.

Introduction

The sericulture industry, primarily focused on the production of silk from *Bombyx mori* silkworms, is of significant economic importance, particularly in countries such as India and China, which together account for more than 70% of global silk production (International Sericulture Commission, 2022). As a highly labour-intensive sector, sericulture plays a vital role in rural economies, providing employment to millions of people, particularly in small-scale farming communities. For instance, in India alone, over 9.7 million people are engaged in sericulture and allied activities, contributing to the country's annual silk production of approximately 33,770 metric tons (Central Silk Board, 2021).

However, the domestication of *Bombyx mori* silkworms over centuries has led to a loss of genetic diversity, resulting in reduced resilience to environmental stressors and increased susceptibility to pathogenic infections. This domestication, coupled with intensive breeding programs focused on enhancing silk yield and other economic traits, has further weakened the silkworm's natural immunity. Consequently, disease outbreaks pose a significant threat to silk production, often leading to crop losses Therefore, effective disease management strategies are imperative for maintaining silk productivity and ensuring the sustainability of sericulture, particularly in disease-prone regions.

Common diseases of mulberry silkworm

Silkworms (*Bombyx mori*) are highly susceptible to various diseases caused by bacteria, viruses, fungi, and protozoa, which can severely impact silk production. These pathogens can spread rapidly through silkworm populations, especially in environments with poor sanitation or inadequate care, leading to significant crop losses ranging from 15-25% annually (Ramesh et al., 2020).(Table 1: Diseases of mulberry sericulture)

Table 1: DISEASES OF MULBERRY SILKWORM

Sl.No	**Name of the Disease**	**Causative Organism**	**Symptoms**
1	**Protozoan disease**		
a.	Pebrine (protozoan disease)	Nosema bombycis Family: Nosematidae	• Larval growth retarded • Pebrine spores in homogenate • White pustules on silk gland
2	**Flacheri(Bacterial Disease)**		
a.	Bacterial disease of the digestive tract	Streptococcus Sp StaphyloccusSp Family:Streptococceae	• Cephalothoracic region becomes translucent • Excrete chain type faecal bodies
b.	Bacterial Septicemia	Serratia marcescens . Streptococcus sp Bacillus sp	• Larval body straightened with Bacillus s swollen thoracic region • Decreased appetite
c.	Sotto disease	Bacillus thuringiensis var. sotto	• Larvae Show symptoms of toxicity convulsions • Diseased larvae develop spasm and tremor, paralysis collapse and dies

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3.	**Viral Diseases**		
a.	Nuclear polyhedrosis (Grasserie)	Bombyx mori nuciear polyhedrosis virus (BmNPV) Family :Baculoviridae	• Swollen intersegmental region • Turbid white haemolymph • Polyhedral in haemolymph
b.	Cytoplasmic polyhedrosis	Bombyx mori cytoplasm polyhedrosis virus (BmCPV) Family: Reoviridae	• Larvae will be retarded in growth, become dull and flaccid • Sometimes rectal protrusion is obtained
c.	Infectious flacheri	Bombyx mori Infectious flacherie virus (BmIFV) Family: Picornaviridae	• Larvae will be retarded in growth becomes dull, soft and flaccid • Cephalothoracic region will be translucent
d.	Densonucleosis	Bombyx mori Densonucleosis virus (BmDNV) Family: Parvoviridae	• Retardation of growth shrinkage of bod • Empty headed,diarrhea, head and thorax upheld motionless
	Muscardine Disease (Fungal Disease)		
a.	White muscardine	Beauveria bassiana Family: Moniliaceae	• Larvae loose appetite and becomes inactive • Dead larvae are hardened and changes into white
b.	Green muscardine	Nomuraearileyi Family: Moniliaceae	• Infected larva loose appetite and becomes inactive • Dead larva are hardened and mumified
c.	Aspergillosis	Aspergillus flavus Aspergillus oryazae	• Diseased pathogen mainly infects 1st and 2nd and instar silkworm • The infected larva become lustrous and dies

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Effective disease management involves maintaining hygiene, proper ventilation, temperature control, and the use of disinfectants to prevent outbreaks. Early detection and timely intervention are crucial for protecting silkworm crops and ensuring high-quality silk production.

Disinfection

Disinfection is the process of eliminating or reducing harmful microorganisms, such as bacteria, viruses, fungi, and protozoa, from surfaces or environments to prevent the spread of diseases. It involves the use of chemical agents, heat, or ultraviolet light to kill or inactivate pathogens. Disinfection is crucial in maintaining hygiene in various settings, including healthcare, food processing, and agriculture, to minimize the risk of infections. It differs from sterilization, which aims to remove all forms of microbial life, as disinfection primarily targets harmful pathogens. Regular disinfection practices are essential for maintaining safe and healthy environments

In sericulture, to prevent the outbreak of diseases among silkworms, disinfection is a critical practice. Effective disinfection protocols are crucial for reducing pathogen loads in the rearing environment before the introduction of silkworms. Disinfection serves as the first line of defense against diseases by eliminating residual pathogens from previous rearing cycles. This ensures a sanitized environment, reducing the risk of disease transmission during the rearing process. It involves thorough cleaning of rearing rooms, equipment, and tools with disinfectants like bleaching powder or formalin to kill harmful pathogens.

The general disinfection methods are categorised as follows;

1. Physical Disinfection: This method employs physical agents to eliminate pathogens. Common techniques include:

- **Heat**: Methods like autoclaving (using steam under pressure) and boiling are effective in killing microorganisms by denaturing proteins and disrupting cellular functions.
- **Ultraviolet (UV) Light**: UV radiation disrupts the DNA of microorganisms, rendering them inactive and unable to reproduce.

2. Chemical Disinfection: This method uses chemical agents to destroy or inhibit the growth of microorganisms. Common disinfectants include:

- **Chlorine Compounds**: Effective against a wide range of pathogens and used in water treatment.
- **Alcohols**: Such as isopropyl and ethyl alcohol, are effective against bacteria and viruses

3. Mechanical Disinfection: This method includes physical processes to remove contaminants rather than kill them. Techniques include:

- **Filtration**: Mechanical filters can trap pathogens from air and water, effectively removing them from the environment.
- **Scrubbing**: Physical removal of microorganisms from surfaces through manual or machine scrubbing.

4. Biological Disinfection: This method utilizes living organisms or their products to control pathogenic microorganisms. Common approaches include:

- **Probiotics**: Beneficial bacteria can outcompete pathogens for resources, helping to reduce harmful microbial populations.
- **Enzymatic Cleaning**: Enzymes can break down organic matter, making it easier to remove pathogens.

The chemical method of disinfection involves the strategic deployment of specifically selected germicidal agents, whose antimicrobial properties are precisely tailored to target and eradicate microorganisms, thereby ensuring a thorough and efficacious disinfection process. The chemicals used for the disinfection are said to be disinfectants. The utilization of chemical disinfectants gained considerable momentum following Joseph Lister's groundbreaking discovery in 1867, wherein he conclusively demonstrated the antimicrobial efficacy of phenol, thus laying the groundwork for development and application of chemical disinfectants, which have since transformed the field of disinfection and sterilization. Chemical disinfection is widely preferred as a common practice across various sectors, including healthcare, food service, and agriculture, due to its effectiveness and versatility.

Ideal disinfectant

An ideal disinfectant should possess the following key characteristics:

1. **Broad-spectrum efficacy**: The disinfectant should demonstrate potent antimicrobial activity against a wide range of microorganisms, including bacteria, viruses, fungi, and spores, at minimal concentrations while ensuring safety for humans, animals, and plants.
2. **Rapid microbicidal action**: The disinfectant should produce a fast kill, achieving complete microbicidal efficacy within a brief contact time, typically ranging from minutes to an hour.
3. **Environmental stability**: The disinfectant should remain effective in the presence of organic matter (e.g., blood, sputum, feces) and be compatible with soaps, detergents, and other chemicals encountered during use.
4. **Low toxicity**: The disinfectant should be non-toxic to users and occupants when diluted to ready-to-use concentrations.
5. **Material compatibility**: The disinfectant should not corrode instruments, metallic surfaces, or cause deterioration of fabrics, rubber, plastics, and other materials.
6. **Residual antimicrobial effect**: The disinfectant should leave a persistent antimicrobial film on treated surfaces.
7. **Ease of use**: The disinfectant should have clear label instructions, be odorless or have a pleasant odor, and enable effortless application under diverse practical conditions.
8. **Cost-effectiveness**: The disinfectant should be economical, with a balance between the cost of the concentrate and the coverage area per unit of dilution.
9. **Physicochemical properties**: The disinfectant should be soluble in water, stable in concentrate and use-dilution, and possess good cleaning properties.
10. **Environmental friendliness**: The disinfectant should be eco-friendly, minimizing harm to the environment upon disposal.

It is important to note that no single disinfectant possesses all these ideal characteristics. The choice of disinfectant depends on the specific application, target microorganisms, surface type, and environmental conditions. Careful selection and application of disinfectants are crucial for effective microbial control while ensuring safety and compatibility with the target environment.

General disinfectants used for disinfection can be categorized into distinct groups:

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i. **Halogens**: This group includes chlorine and iodine, which are effective in oxidizing cellular components, thereby destabilizing microbial structures and preventing infections.

ii. **Heavy Metals**: Compounds such as mercuric chloride, mercurochrome, and metaphen fall under this category. Heavy metals exert their antimicrobial effects by binding to proteins and inhibiting enzymatic activity, though their use has diminished due to toxicity concerns.

iii. **Phenolic Compounds**: Disinfectants like Lysol and creosols belong to this group. They are known for their ability to denature proteins and disrupt microbial membranes, making them effective for long-lasting disinfection (Gerald McDonnell et.al, 1999).

iv. **Alcohols**: Ethyl and isopropyl alcohol are commonly used as disinfectants. They act by denaturing proteins and disrupting cell membranes, providing rapid antimicrobial action.

v. **Aldehydes**: formaldehyde and glutaraldehyde, are potent chemical disinfectants known for their broad-spectrum antimicrobial activity against bacteria, viruses, and fungi. They work by cross-linking with proteins and nucleic acids, effectively denaturing microbial cellular structures. Due to their effectiveness, aldehydes are commonly used for disinfecting medical equipment and surfaces in healthcare settings, although they require careful handling due to potential toxicity and irritant properties..

vi. **Ethylene Oxide**: Products like carboxide and cryocide are utilized for their ability to penetrate materials and effectively sterilize equipment and surfaces, particularly in settings where heat-sensitive items are present.

These disinfectants are selected based on their efficacy, safety, and suitability for specific applications, ensuring optimal health and productivity in the respective fields.

Chemical disinfectants in sericulture

In sericulture, to prevent the outbreak of diseases among silkworms, disinfection is a critical practice. Effective disinfection protocols are crucial for reducing pathogen loads in the rearing environment before the introduction of silkworms. Disinfection serves as the first line of defence against diseases by eliminating residual pathogens from previous rearing cycles. This ensures a sanitized environment, reducing the risk of disease transmission during the rearing process. It involves thorough cleaning of rearing rooms, equipment, and tools with disinfectants like bleaching powder or formalin to kill harmful pathogens.

The use of chemical disinfection in sericulture dates back to the early 20th century, when the first chemical disinfectants were developed and introduced to control diseases in silkworms. By the mid-20th century, chemical disinfection became a widely accepted and standardized practice, particularly in Japan and Europe, with the standardization of protocols occurring in the 1960s-1970s, including the establishment of recommended disinfectants, concentrations, and exposure times. Since then, chemical disinfection methods have continued to be refined and improved, with the development of new disinfectants and application techniques, solidifying its role as a crucial component of modern sericulture practices.Table shows the studies on effective chemical disinfectants in sericulture. (Table 2: Various studies on effective chemical disinfectants in sericulture) & (Figure1: Disinfection schedule for maintenance of rearing house using chemical disinfectants).

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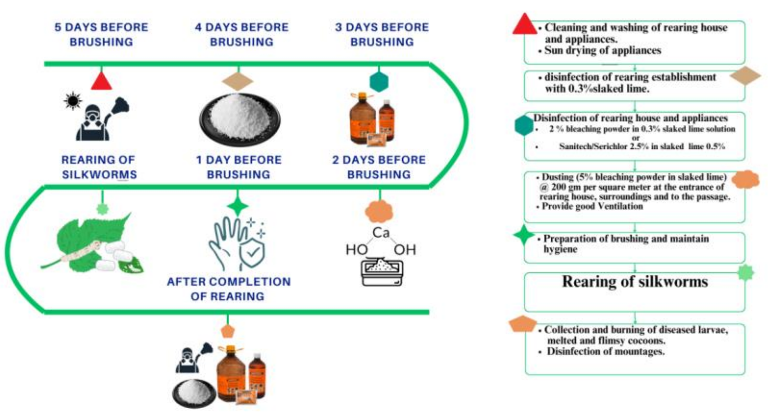

Figure1: Disinfection schedule for maintenance of rearing house using chemical disinfectants

Chemical Disinfectant	Active Ingredient	Application	Effectiveness	Limitations	References
Sodium Hypochlorite	Bleach	Disinfection of rearing trays and tools	Broad-spectrum efficacy against bacteria, viruses, and fungi.	Can be corrosive to some materials; must be diluted appropriately.	Sathe and Kale, A. A. (2020).
Formalin	Formaldehyde	Disinfecting silkworm eggs and surfaces	Effective against bacteria, viruses, and fungi.	Toxicity concerns; requires careful handling and ventilation.	NIFT Report, 2017
Hydrogen Peroxide	3% to 30% solution	Surface disinfection and equipment cleaning	Effective against a wide range of pathogens; decomposes into non-toxic byproducts.	May require longer contact time for effectiveness; can be corrosive at higher concentrations.	Kumar and Kumar (2020).
Quaternary Ammonium Compounds	Benzalkonium Chloride	General surface disinfection in rearing areas	Effective against bacteria and some viruses; residual antimicrobial activity.	Less effective against spores and some viruses; may cause irritation.	Rao and Rao (2018).
Iodophors	Iodine complex	Disinfection of feeding utensils and equipment	Effective against bacteria, fungi, and some viruses.	May stain surfaces; effectiveness can be reduced in organic matter.	Ramaswamy and Suresh, S. (2019
Calcium Hypochlorite	Chlorinated lime	Water treatment and disinfection of equipment	Effective against a wide range of pathogens in water.	Can be less stable than sodium hypochlorite; must be stored properly.	Malakar, M. (2018).
Peracetic Acid	Peracetic Acid	Disinfection of equipment and surfaces	Highly effective against bacteria, fungi, and viruses; acts quickly.	Corrosive to some materials; requires careful handling.	Sweeney & Kelly (2019).

Chemical Disinfectant	Active Ingredient	Application	Effectiveness	Limitations	References
Chlorine Dioxide	Chlorine Dioxide	Disinfection of water and surfaces	Effective against a broad range of pathogens, including viruses and spores.	Requires careful monitoring of concentration; can produce harmful byproducts if not managed correctly.	WHO, 2020
Citric Acid	Citric Acid	Cleaning and mild disinfection	Antimicrobial properties; useful in cleaning agents.	Less effective as a primary disinfectant; may require longer contact times.	Khare and Jain (2021)

Table 2: Various studies on effective chemical disinfectants in sericulture

Key Chemical Disinfectants in Sericulture: Applications and Efficacy

The most widely employed disinfectants in sericulture include formalin, bleaching powder, slaked lime, and chlorine dioxide (commercially known as Sanitech, Serichlor, or Asthra). These chemicals play a crucial role in maintaining asepsis and preventing microbial contamination in sericulture practices, ensuring the health and productivity of silkworms. This (Table 3: Major Chemical Disinfectants Used in Sericulture**)** succinctly highlights the major chemical disinfectants used in sericulture, summarizing their key uses and actions (Table 4: Comparison of Disinfectants in Sericulture: Activity, Applications, and Effectiveness).

Compound	**Chlorine (0.01 – 5%)**	**Iodine Iodophor (0.5 – 5%)**	**Chlorophexidine (0.05 – 0.5%)**	**Alcohol (70-90%)**	**Oxidizing (0.2-3%)**	**Phenol (0.2-3%)**	**Quaternary ammonium (0.1-2%)**	**Aldehyde (1-2%)**
Bactericidal	Good	Good	Very Good	Good	Good	Good	Good	Very Good
Viricidal	Very Good	Good	Very Good	Good	Good	Good	Good	Very Good
Viruses (enveloped)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Viruses	Yes	Yes	No	No	Yes	No	No	Yes

(non - enveloped)								
Bacterial spores	Fair	Fair	Poor	Fair	Fair	Poor	Poor	Good
Fungicide	Good	Good	Fair	Poor	poor	Good	Good	Good
Protozoal parasites	Fair	Poor	Poor	Poor	Poor	Poor	Fair	Good
Effective oraganic matter	Poor	Fair	Fair	Fair	Poor	Good	Poor	Good
Inactivation by soap	No	No & yes	No	No	No	No	Yes	No
Effective in hard water	Yes	No	Yes	Yes	Yes	Yes	No	Yes
Contact time (Min.)	5-30	10-30	5-10	10-30	10-30	10-30	10-30	10-60
Residual activity	Poor	Poor	Good	Fair	Poor	Poor	Fair	Fair

Table 3: Comparison of Disinfectants in Sericulture: Activity, Applications, and Effectiveness

Disinfectant	Composition & Formula	Properties	Effectiveness & Usage	Limitations & Precautions
Formalin	Aqueous solution of formaldehyde (36-40%); Molecular formula: CH_2O	Strong disinfectant, works by extracting oxygen from germ cells	Effective with 2% formalin + 0.5% slaked lime; optimal conditions: >25°C and 70% humidity	Polymerizes into trioxymethylene during storage, ineffective as a spray, carcinogenic
Bleaching Powder	Calcium hypochlorite; Chlorine content ≥ 30%	Strong oxidizing action; releases nascent oxygen	2% bleaching powder + 0.3% slaked lime solution used; requires thorough surface saturation	Degrades if exposed to moisture/light; must be stored sealed

Slaked Lime	Calcium hydroxide [$Ca(OH)_2$]; derived from calcite, calcium oxide	Environmental-friendly, antiviral, absorbs moisture (up to 30% of weight)	Applied as lime dust or in combination with other disinfectants; reduces disease incidence by up to 25%	Powder should be sieved and hydrated properly for effective use
Paraformaldehyde	Polymeric formaldehyde compound	Crystalline form, releases formaldehyde gas upon heating (120-140°C)	Effective against bacteria, viruses, fungi; optimal at 60-80% humidity	Requires heating for sublimation, formaldehyde release
Chlorine Dioxide (ClO_2)	Marketed as Sanitech and Serichlor; recommended concentration: 500 ppm	Strong oxidizer, 2.5 times more effective than chlorine, minimal reactivity with organic compounds	Residual protection lasts 7 days; shelf life of 6 months	Minimal corrosiveness, activatable at use time
Asthra	Broad-spectrum room disinfectant, powder form	Effective against various pathogens	Two sprays per crop (after rearing and 3 days before brushing); 50g mixed with 100L water	Requires strict adherence to application protocol

Table 4: Major Chemical Disinfectants Used in Sericulture

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Factors Responsible for Enhancing Disinfectant Efficiency in Sericulture

For disinfectants to achieve maximum efficacy, several critical factors must be optimized:

1. **Hydration**: Adequate hydration (around 50% v/v) enhances microbial inactivation, facilitating coagulation and penetration into microbial cells. Insufficient hydration reduces efficacy by 20-30% and can increase resistance by up to 50%, particularly impacting spore-forming organisms (Maillard, 2002).
2. **Time**: Effective disinfection relies on sufficient contact time (typically 10-30 minutes), allowing necessary chemical and physical reactions to proceed. Required times vary based on the disinfectant and the type of microorganism, with shorter contact times (e.g., 5 minutes) for agents like quaternary ammonium compounds (McDonnell & Russell, 1999).

3. **Temperature**: Elevated temperatures (above 20°C) improve disinfectant effectiveness by reducing surface tension and increasing reaction rates. For example, bleach achieves optimal results at approximately 30°C, although temperatures above 50°C may compromise disinfectant stability (Rutala et al., 2008).

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4. **Concentration**: Higher concentrations (e.g., 5-10%) are generally more effective, but excessive amounts (over 20%) may cause unnecessary toxicity and waste. Optimal concentrations are disinfectant-specific, as with phenolics, effective between 7-12% (Bloomfield et al., 2001).

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5. **pH**: Alkaline conditions (pH 8-9) can enhance disinfection, improving efficacy by 15-25% depending on the disinfectant. High pH levels may damage surfaces, so careful monitoring is necessary, especially for compounds sensitive to pH variations (Sagripanti&Bonifacino, 1996).
6. **Physical and Chemical Actions**: Increased H^+ or OH^- ions enhance disinfectant interaction with microbial cells. Adjusting ion concentrations improves the disinfectant's potency and ensures optimal stability (Kumar & Anand, 1998).
7. **Osmotic Pressure**: High osmotic pressure can inhibit disinfectant effectiveness by dehydrating microbial cells, increasing resistance. Pathogens may adapt, reducing their susceptibility to disinfection. This is a factor when selecting solutions for environments with varied osmotic pressures (Carpenter et al., 2017).

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8. **Surface Tension**: Lower surface tension enhances penetration, ensuring better disinfectant contact with microbial cells. A surface tension of 30-40 mN/m is often optimal, improving disinfectant coverage and effectiveness (Reichert et al., 2008).

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Environmental concerns in using chemical disinfectants in sericulture

The use of chemical disinfectants in sericulture raises both environmental and silkworm health concerns. Disinfectants like formalin and chlorine dioxide, though effective, can release harmful fumes and residues that pose risks to workers, silkworms, and the surrounding ecosystem. Formalin, for instance, is a carcinogen, and its fumes can be hazardous if not properly ventilated. Bleaching powder and chlorine dioxide can react with organic matter, potentially leading to toxic byproducts, while excessive lime application may alter soil pH and affect local flora. For silkworms, improper disinfection or inadequate safe periods can lead to respiratory distress or even death due to lingering chemicals in the rearing environment.

Safe period help prevent exposure of silkworms and humans to harmful fumes or residues from disinfectants are as follows

- **Formalin**: 24-48 hours after application. Ensure thorough ventilation to clear fumes before reintroducing silkworms.
- **Bleaching Powder**: 12-24 hours. Proper ventilation is required to allow the chlorine smell to dissipate.
- **Chlorine Dioxide (Sanitech/Serichlor)**: 24 hours. Adequate ventilation is necessary after application.
- **Asthra**: 12-24 hours. Follow the recommended protocol and ensure the room is well ventilated before reintroduction.

Ensuring safe usage, proper ventilation, and environmentally friendly practices are crucial to minimizing these impacts and maintaining both silkworm health and environmental balance.

In addition, chemical disinfectants possess the issues of storage and stability that affect the efficacy of products like bleaching powder and formalin, as exposure to light or moisture can degrade these chemicals, leading to less effective disinfection (Balavenkatsubbaiah et al., 1994). These constraints emphasize the need for careful handling, appropriate environmental conditions, and eco-friendly alternatives where possible.

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Conclusion

In summary, sericulture is a vital industry, enriching rural economies and fueling the global silk market. Ensuring disease-free rearing environments through effective disinfection is key to producing healthy silkworms and high-quality silk. Chemical disinfection, with its powerful pathogen-killing capabilities, remains a cornerstone of this effort. Yet, harnessing these chemicals demands careful handling and environmentally responsible practices to safeguard workers, silkworms, and the surrounding ecosystem. Striking this balance is essential for a resilient, sustainable sericulture industry that thrives on quality, safety, and environmental stewardship.

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