Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 03 (MAY-JUNE, 2026)
Available online at http://www.agriarticles.com

Defence Mechanisms in Silkworm (*Bombyx mori*) Against Microbial Infection

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A defence mechanism refers to the biological processes by which an organism copes with and reduces the impact of threats arising from unfavorable or harmful stimuli. These threats may include stress conditions, pathogen attacks, and other environmental challenges. The primary defence of the silkworm against pathogens involves the prevention of infection through structural barriers such as the integument and the peritrophic membrane, which surrounds the food bolus and protects the midgut epithelium. Secondary defence is provided by the haemolymph through cellular and humoral immune responses (Montano et al., 2011).

I. Non-Specific (Primary) Defence Mechanisms

Non-specific or primary defence mechanisms are classified into **morphological, behavioural, physiological, biochemical, and genetic defences** (Narayanan, 2004).

1. Morphological Defence

a) Integument: The integument of insects acts as a strong barrier against microbes such as viruses, bacteria, and protozoa. The waxy epicuticular layer of the silkworm contains free medium-chain saturated fatty acids, such as caprylic, capric, and linoleic acids, which inhibit fungal invasion. Higher concentrations of these fatty acids are observed in silkworm strains resistant to aspergillosis. Lipids in the epicuticle of *Bombyx mori* inhibit the invasion of *Beauveria bassiana* and *Paecilomyces fumosoroseus*.

b) Peritrophic Membrane: The peritrophic membrane is composed of chitin, proteins, mucopolysaccharides, and hyaluronic acid-like compounds. It acts as a protective barrier in the midgut and is resistant to bacterial penetration. In silkworms, it can also absorb BmCPV under in vitro conditions.

2. Behavioural Defence

Behavioural resistance occurs when insects actively avoid or repel pathogens. For instance, highly active mosquito species show a lower prevalence of infection by the nematode *Romanomermis culicivorax* than less active ones. Similarly, scarab larvae avoid infection by removing nematodes from their mouthparts.

3. Physiological Defence

Grasshoppers and locusts elevate their body temperature above ambient levels through basking behavior by orienting themselves toward solar radiation. This raises their internal thoracic temperature to 38–42°C, producing a "behavioural fever" response. Thermoregulation in *Melanoplus sanguinipes* has been shown to reduce fungal infections caused by *Beauveria bassiana* and *Metarhizium anisopliae*.

4. Biochemical Defence

a) Eicosanoids: Eicosanoids are biologically active, oxygenated metabolites of arachidonic acid and other C20 polyunsaturated fatty acids. Major groups include prostaglandins, epoxy-eicosatrienoic acids, and lipoxygenase products, all of which play important roles in immune responses.

b) Superoxide Dismutase (SOD): Reactive oxygen species (ROS) are generated during normal metabolic processes. Superoxide dismutase (SOD) converts superoxide radicals into hydrogen peroxide and oxygen, thereby reducing oxidative stress. Increased SOD activity has been observed in the haemocytes and haemolymph of *Bombyx mori* following bacterial infection.

5. Genetic Defence

Resistance to viral diseases such as NPV, cytoplasmic polyhedrosis virus (CPV), and infectious flacherie virus (IFV) is controlled by polygenes, primarily associated with midgut defence mechanisms such as antiviral activity of gut juice and characteristics of the peritrophic membrane. Resistance to densonucleosis is controlled by major genes—either recessive (nsd-1, nsd-2) or dominant (nid-1).

II.Specific (Secondary) Defence Mechanisms

I. Cellular Immunity

a) Phagocytosis:

Phagocytosis involves several steps:

- Recognition of foreign particles by haemocytes
- Chemotactic attraction of haemocytes toward pathogens
- Attachment of particles to the cell surface
- Ingestion through pseudopodia or membrane invagination
- Formation of phagocytic vacuoles
- Digestion by lysosomal enzymes
- Release of indigestible materials by exocytosis

b) Haemolymph Coagulation: Haemolymph coagulation is an important immune response involved in wound healing and prevention of pathogen entry. Granulocytes and oenocytoids accumulate at wound sites and play a key role in clot formation.

c)Nodule Formation: Nodule formation involves aggregation of haemocytes that entrap invading microbes. It is particularly effective in clearing large numbers of bacteria from the haemolymph.

d) Encapsulation: Encapsulation occurs in two stages: first, haemocytes aggregate around the foreign body; second, haemocytes lyse and release signals that attract additional haemocytes, such as plasmatocytes, which complete capsule formation. The pathogen is immobilized and eventually killed within the capsule.

II. Humoral Responses

a) Activation of Prophenoloxidase Cascade:

Phenoloxidase is responsible for melanization and exists in an inactive form (prophenoloxidase). It is activated by proteinaceous factors upon injury or infection. This enzyme catalyzes the oxidation and polymerization of phenols and catechols, playing a vital role in defence. However, excessive activity can be harmful due to its cytotoxic effects.

b) Antimicrobial Proteins in *Bombyx mori*:

Various antimicrobial and antiviral compounds have been identified in silkworms (Buhroo et al., 2013), including:

- **Cecropins:** Antibacterial proteins that lyse bacterial cell membranes; produced following injury or infection
- **Attacins:** Larger proteins that act on the outer bacterial membrane and enhance the activity of other antimicrobial agents
- **Lebocins:** Proline-rich peptides (Lebocin 1–4 identified in silkworms)
- **Moricin:** Exhibits strong antibacterial activity, particularly against *Staphylococcus aureus*

- **Gloverins:** Glycine-rich proteins with multiple isoforms
- **Defensins:** Basic peptides with antimicrobial properties (Types A and B identified in *Bombyx mori*)

Conclusion

A review of the available literature reveals that silkworms have developed highly efficient defence mechanisms against invading microorganisms through both immunological and genetic resistance. Immune responses in *Bombyx mori* are mediated by circulating haemocytes, which play a crucial role in innate immunity through processes such as phagocytosis, encapsulation, and activation of the phenoloxidase cascade. Additionally, the synthesis of antimicrobial proteins through various biochemical pathways and gene expressions significantly contributes to defence against pathogens. These mechanisms provide valuable insights and serve as effective tools for disease management in sericulture, ultimately improving silk quality and productivity.

References

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