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Importance of Minerals in Silkworm Nutrition: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

The amount of silk produced by silkworms is influenced by several factors. The silkworm's nutrition is the most important element for good quality cocoon and silk production as it is dependent on the healthiness of the silkworm. Health, growth and resistance to biotic factors are directly dependent on the nutrition of the silkworm which is derived from the food. Consuming a well-balanced nutritious food is particularly important for silkworms, since they only consume throughout their larval period. Among the different nutritional requirements by the silkworm, minerals plays an important role. Minerals are not synthesized within insects, although they are essential elements and affect various metabolic processes. Minerals affect the growth and development of larva, economic cocoon characters and silk yield. Many functions of the neuromuscular, reproductive and hormonal systems among others can be efficiently controlled by adding micronutrients and trace elements such as minerals to the diet.

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1. INTRODUCTION

“Insects and other animals have similar nutritional needs. The prime component of a living being’s is good growth and development and its dietary intake. One of the most important factors for the growth and development of insect species is its nutritional requirement and metabolism in the body” [1]. “The nutrition of silkworm has been of primary importance in sericulture, because not only good growth of the larva and survival but also cocoon and egg production has been known to be influenced by the nutritive value of the nourishment” [2]. “The quality of food directly influences the growth and development of the insect and ultimately the quantity and quality of product produced by them” [3,4].

Mulberry silkworm (*Bombyx mori* Linnaeus) is a monophagous in nature among the four commercial silkworms such as eri (*Samia ricini* Donovan), muga (*Antheraea assamensis* Helfer) and tasar (*Antherea mylitta* Drury). Silkworms feeds vigorously to fulfill their nutritional requirements they solely depend on their nutritious host leaves. Not only the growth and development of the silkworm depends on the quality food ingested by them but also it reflects on the yield of quality silk. Any nutritional imbalance in their food results in poor larval development and inferior quality of yield silk. The silkworm *B. mori* converts approximately 72-86% of the protein available in the mulberry leaf into silk protein, 30% from the tissue and blood and 60% of the absorbed amino acid utilized for silk production [5]. Poor and unhealthy larval development is the result of nutritional imbalance in their diet which leads to the poor cocoon production.

“Quantitative requirement of each nutrients and the required balance of nutrients for optimum level of nutrition may vary within and between species owing to many factors including synthetic ability of the insect and metabolic activities involving specific interactions between certain nutrients” [6]. “In terms of nutrition, a mineral is a chemical element that an organism needs as an essential nutrient in order to successfully carry out functions which are important to life. They are found in ionized form in the body of an organism. Among the different minerals, metals and their salt cations play an important role as catalyst on the structural components of large molecules with a specific function which are crucial for the better functioning of life” [7]. “Mineral salts played an important role in the nutrition of silkworm” [8]. “In relation to other nutritional needs, mineral nutrition has received less attention and it is unknown how much of a quantity is needed for insects” [9]. Minerals are important components of the silkworm diet and plays an important role in regulating the osmotic pressure of intracellular and extracellular fluids and participate as cofactors in various enzyme systems [10]. “Micronutrients are required in small quantities but are essential for insect nutrition. Mineral affects not only yield components significantly, but also food consumption, co-efficient of utilization and larval development” [11]. “Potassium, sodium, phosphorus, magnesium, manganese, zinc, and copper are important for the growth and development of insect” [12]. “Lack or deficiency of a micronutrient has a significant negative impact on insect biology. Larvae of *Bombyx mori* L. are known to require appreciable amounts of potassium (8000-9000 ppm), phosphate (2000-6000 ppm) and magnesium (1000 ppm)” [13]. “It has been reported that 28% of the silkworm larval structure at different stages includes absorbed minerals” [14]. “By supplementing a diet with micronutrients and trace elements *i.e.* minerals, the various functions of the hormonal system, neuromuscular system, and reproductive system can be modulated effectively” [15]. Therefore, studies related to qualitative and quantitative requirement of minerals in silkworm is essential for improvement of the diet of silkworm.

Minerals are classified as macro and micro minerals. Calcium, phosphorus, potassium, sodium, magnesium, sulfur and chlorine are the macro minerals. Macrominerals are present in larger quantities in the animal's body and also needed in larger quantities in food. Micro minerals such as iron, iodine, cobalt, copper, zinc, manganese, molybdenum, selenium, chromium and fluorine are also known as trace elements since they are needed in lesser amounts in an animal's food or are found in the human body in low proportions. In the present study, the necessity of several minerals for the nutritional needs of silkworms is reviewed.

As minerals are essential for healthy growth and development of silkworm, deficiency of these elements cause some negative impact on it. In *B. mori*, lower body weight is the consequence of lower consumption of potassium, calcium, magnesium, and phosphorus [16]. The cocoon and silk characteristics of mulberry silkworms are seriously affected by phosphorus imbalance [17]. Low levels of sulfur-containing amino acids result from a deficiency in sulfur, which lowers protein synthesis and interferes with the synthesis of silk [18]. The altered iron content in mulberry leaf resulted in the reduced larval weight, cocoon weight and silk filament length [19].

2. UTILIZATION OF DIFFERENT MINERALS AND THEIR SALT CATIONS IN SILKWORM NUTRITION

2.1 Calcium (Ca)

The fat body of insect is the main mediator of protein synthesis and amino acid metabolism [20]. Oral supplementation of calcium chloride to silkworm larvae singnificantly increase the fat body glycogen and haemolymph trehalose in silkworm body. Calcium is an important element that highly influences the metabolism of silkworm [21]. It is also an important element for silk formation in silkworm [22]. Feeding of calcium treated (0.1%) mulberry leaves gave the best results regarding larval development and cocoon weight [23]. Egg shell *i.e.,* egg chorion contains a large amount of calcium. *Antheraea assamensis* Helfer, the muga silkworm, used to eat its egg shell after hatching, which is regarded as a positive sign [24].

2.2 Phosphorus (P)

Phosphorus influences growth in most invertebrates and provide support for the growth rate hypothesis [25]. But in the environment phosphorus is extremely limited, often being 10-20 times lower in plants than what invertebrate herbivores require [25]. In this context it is an essential mineral for growth and development of the phytophagous silkworms. Phosphorus increases the growth and economic character of silkworm *B. mori* L [26].

2.3 Potassium (K)

Potassium is an unique element which promotes the growth of silkworm to maximum extent [18]. Haemolymph trehalose and fat body glycogen content increased after feeding with potassium sulphate [27]. The oral supplementation with potassium permanganate and potassium chloride to mulberry silkworm increase the fat body and haemolymph proteins and at the same time the weight of silk gland, cocoon and shell weight are also significantly increased [28]. Potassium nitrate supplementation of mulberry leaves markedly enhanced the silkworm *B. mori's* fat body glycogen, haemolymph trehalose, protein, and lipid levels [29,30]. Fecundity of adult moth is enhanced by feeding potassium iodide in *B.mori* [31].

2.4 Magnesium (Mg)

The overall process of trehalose production requires magnesium [32]. Mineral salt of magnesium chloride significantly increased the fat body glycogen, protein, total lipids and haemolymph protein and trehalose in the silkworm *Bombyx mori* [33]. Magnesium ion is important for silk formation in silkworm [22]. Supplementation of mulberry leaves with magnesium sulphate has been found to enhance the commercial characters of *B. mori* at 0.25 and 0.50% concentrations [34].

2.5 Iron (Fe)

Iron is needed by all the living organisms and plays a crucial role in several ways like physiological processes, including neuronal function, detoxification, DNA synthesis, production of blood and cellular respiration [35]. It increases the growth of silkworm as well as the economic characters of cocoon [36].

2.6 Cobalt (Co)

Cobalt is essential for the various physiological processes in insects, including immune function and resistance against the pathogens [37]. Cobalt sulphate increases the rate of protein synthesis in early stages in the larvae of *Samia ricini* [38]. In mulberry silkworm's silk glands' lipid composition is influenced by cobalt chloride [39]. It has also been recorded that presence of cobalt supplemented in the silkworm diet increase the silk yield [40,41].

2.7 Copper (Cu)

Supplementation with copper sulphate to the silkworm feed significantly increased the larval weight, fecundity, cocooning and moth emergence in *B. mori* [32,42]. Silkworm larvae when fed on mulberry leaves treated with 0.2N % + 0.03% K + 0.01% Ca + 0.05% copper concentrations consumed more food, gained more larval weight and produced heavier cocoons [43].

2.8 Zinc (Zn)

Zinc is the only heavy metal with amphoteric properties and dissolves freely in water and bases to form zincates. Since 1930s, zinc has been widely recognized as an important constituent of animal diet and is widely distributed in all animal tissues. Cofactor function of zinc is considered of almost universal importance to organisms and trace elements can be essential for insect in general [15]. It plays a vital role in synthesis of lipids, proteins and carbohydrates and also in reducing the duration of larval and pupal stages of mulberry silkworm, *B. mori* L [39]. The use of zinc positively influences the mass of the silk glands and also increases the weight of cocoon and cocoon shell [10]. It also plays an important role in augmenting the growth and antioxidant protection of the larvae of *Antheraea mylitta*, which may improve the larval fitness, quality and quantity of silk production [44]. Moreover, mulberry leaves fortified with zinc increases the fecundity, quality parameters of cocoons like higher cocoon shell ratio, silk-body ratio, raw silk percentage, denier of the silk. It lowers the floss-shell ratio by decreasing the floss protein synthesis in *B. mori* silkworm [45]. Zinc chloride ($ZnCl_2$), a binary salt of zinc is a potent modulator for overall growth and development of eri silkworm and positively influences the economic parameters of eri cocoon [46].

2.9 Nickel (Ni)

Nickel is also an essential element in the nutrition of organisms [47]. Nickel supplementation shortened the larval period and increased significantly all economic parameters of silkworm *B. mori* L. [48,49]. Growth and development of the silkworm enhanced when they reared on host leaves supplemented with nickel chloride. It increases total lipid of the fat body in silkworm *B. mori* [50].

2.10 Selenium (Se)

Selenium is well known for its beneficial effects and it is an essential micronutrient for both human and animals [51]. It is a cofactor in many enzymes protecting the cell against free radicals and maintains high tissue antioxidant level [52]. Use of selenium in silkworm, leads to an improvement of the larval weight, silk gland weight, cocoon weight, shell weight, filament length [10,53].

3. CONCLUSION

In pursuance of silkworm nutrition, mineral elements are indispensable to enhance the larval development and cocoon yields but the mode of complementation, right dosage, time of application, number of sprays all have to be examine to secure maximum benefit from such nutrition. If suitable dose and treatment are advocated and practiced at the research level, this can give much needed boost to overall production of the silk and seed. The quality of leaf has got direct influence on the health, growth and survival of silkworm. Though minerals are not synthesized within the insect body, it is very much essential for overall growth and development of the insect. Since the silkworms are the commercially important insect, to improve economic characters and better growth of silkworm, more research works should be done on silkworm food additives such as the minerals.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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