

# HONEY BEE NUTRITION AND ARTIFICIAL AND SUPPLEMENTARY FEEDING

## Abstract

Honey bees, one of the most commercially, ecologically, and agriculturally significant insects, primarily rely on pollen and nectar for their nourishment. A sufficient supply of nutrients like carbohydrates, proteins, lipids etc. is necessary for the excellent health of honey bee colonies. However, during times of famine dearth when unfavorable weather conditions arise, bee colonies grow and survive at a lower rate because of the unavailability of food. That is why, the bee colonies may require artificial nutrition, such as pollen and nectar supplements or substitutions, to successfully continue egg laying, brood rearing, and foraging. This chapter highlights the nutrition such as proteins, amino acids, carbohydrates, lipids, sterols, minerals, vitamins, and water that are required for honey bees' development and different nectar and pollen supplements and substitutes for maintaining healthy bee colonies.

**Key words:** honey bee, nutrition, nectar, pollen, supplements, substitutes, artificial feeding

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## **I. INTRODUCTION**

One significant social insect that benefits agriculture is the honey bee. Pollen and the nectar of flowers are the natural foods of honey bees. Pollen is considered as the major source for fulfilling the requirements of proteins, vitamins and minerals and nectar is the source of their carbohydrates requirement. Since each organism needs a particular sort of nutrient to maintain a healthy life, bees also need a variety of nutrients, including water, carbohydrates, proteins, vitamins, and minerals. In India, the summer and rainy seasons have unfavorable weather conditions for bees, and there are extremely little nectar and pollen resources available during these times of year. [1]. This period when development of broods, the nutritional requirements and growth of colonies of honey bee remains unfulfilled due to the unavailability of desired food source is considered as dearth period. When there is a severe lack of pollen and nectar, bee colonies suspend or drastically curtail "brood rearing," which weakens the colonies right before foraging and negatively affects bee product production and pollination activity. If the foraging activity is weak or the colonies are used for pollination for extended periods of time, the colony may not have enough reserves which lead to early death of bees [2]. On the other hand, bee nutrition is also threatened by climate change. Plant adaptations to climate change, such as altered nectar, flower and pollen, will modify the amount of available nutrients, which could have disastrous effects for honey bees [3]. To maintain the normal growth of the impoverished bee colonies under these circumstances, supplementary and artificial feeding becomes highly important.

## **II. NEED OF ARTIFICIAL FEEDINGS**

The diet which is generally not the natural food of the organism is known as artificial diet. Artificial feeding i.e. pollen and nectar supplements or substitutes are sometimes necessary to the bee colonies for successful continuation of egg laying, brood rearing and foraging. Artificial feeding is advantageous during dearth period to well-maintain enough bee population. Various workers have tried a multiple numbers of pollen substitute or supplement formulations. A pollen supplement or replacement will be helpful in saving weaker colonies and preserving a sufficient bee population [4].

Modern beekeeping pays special attention to pollen nutrition. Pollen promotes colony expansion and increases resistance to environmental stress. Depletion of storage pollen of honey bee colonies is greatly affected by adverse climatic conditions. In order to maintain bee population development; pollen must be accessible in adequate amounts throughout the brood-rearing season. As a partial or complete replacement for natural pollen, several combinations of substances have been implemented. In artificial bee diets, protein-rich substances like yeast, soy, egg, pea, casein, and microalgae are frequently used. Protein-rich substances are included in artificial honey bee diets to mimic or supplement pollen nutrition [5]. Beekeepers generally provide artificial "pollen substitute" diets in the periods of inadequate pollen and to strengthen the colony prior to pollination mechanism [6].

## **III. THE NUTRITIONAL REQUIREMENTS OF HONEY BEE**

For growth, development, maintenance, and reproduction, honey bees need carbohydrates, water, proteins, lipids, minerals, and vitamins. The main sources of carbohydrates for bees in their diet are nectar, while pollen provides all the other essential

nutrients. While water and carbohydrates (honey or sucrose) can keep adult bees alive, and for the growth and development of young bees as well as the rearing of larvae require proteins, lipids or fats, minerals, and vitamins. Honey bees benefit from good nutrition in several ways, including increased lifespan, defense against various pathological conditions, formation of diverse caste systems among bees, and development of neurological and behavioral traits [8].

- 1. Proteins and Amino Acids:** For honey bees, pollen is their prime source of natural protein. Pollen contains between 2.5% to 61% protein. The royal jelly is also an excellent source of proteins for queen and larval development [10]. A key component of bee growth, immunology, and stress responses is protein acquired from pollen [7]. The survival of the bee colony depends on the protein content of pollen and plays a major in artificial diet development. In particular, the amino acids lysine, arginine, methionine, histidine, isoleucine, phenylalanine, leucine, threonine, valine and tryptophan are considered essential for honey bees. As these amino acids are taken by honey bees from external sources, so they must be present in the diet for their proper nutrition [16]. Free amino acids appear to reduce bee lifespan. The ideal way to supply amino acids to bees is in the form of pollen's crude protein or feed them with closely resembles the amino acid profile of jelly protein [9].
- 2. Carbohydrates:** Honey bees' primary energy source carbohydrates are found in flower nectar; however, bees may also collect honeydew secretions from sap-feeding insects. Foraging worker bees (females) collect nectar and store it in the crop or "honey stomach" until they return to the colony and discharge it on a receiver bee. The enzyme invertase along with other enzymes transformed the nectar into honey by reducing the water content. A 50,000-bee colony requires around 700 pounds of sugar each year [10]. A worker bee larva feed 59.4 mg of carbohydrates during its larval phase, and an adult worker bee requires around 4 mg of sugar each day for optimal survival [8]. Adult honey bees have smaller glycogen reserves than larvae. The different metabolic enzymes may responsible for the variations in carbohydrate utilization between adult honey bees and larvae [10]. Carbohydrate is the major constituents of the diet of honey bee colonies and is required by both the larva and adult for normal growth and development. The primary purpose of carbohydrates in the diet is to provide energy for bodily processes such wax formation, muscular activity, and the creation of body heat. Adult bees can live on the carbohydrates fructose, glucose, sucrose, maltose, and trehalose. They cannot utilize the carbohydrates like mannose, galactose, lactose, raffinose, dextrin, inulin, xylose, rhamnose, or arabinose [11].
- 3. Lipids, Fats and Sterols:** In the constituent of pollen, lipids can be weighted from as low as 2% to as high as 60 % depending upon the different types of pollen [12]. Essential fatty acids, which can make up to 80% of the lipid content, include  $\gamma$ -linoleic,  $\alpha$ -linoleic acid, linoleic acid, and palmitic acid. They are significant lipid constituents of honey bees. The health advantages of dietary lipids depend on how they are distributed in relation to other nutrients. While generally in balanced pollen, a low linoleic acid: linoleic acid ratio and also 10:1 protein to lipid content ratio are best for bee health, due to the fact that higher ratios and concentrations of specific fatty acids increase the risk of mortality [9]. The learning behavior of honey bees shows tremendous improvement with low omega6 : omega 3 fatty acid ratios in many studies [10].

One of the building blocks of plasma membranes and several exterior surface waxes on the bee exoskeleton are sterols. But insects including honey bee are not able to synthesize their own sterols like humans. Therefore, they must be present in the diet of bees. Honey bees use sterols acquired from plant sources as precursor molecules for many metabolic processes [13]. Cholesterol is also important components for proper growth and development of honey bee. It is the precursor of molting hormone, Ecdysone. Diets supplemented with cholesterol are essential for supporting large amounts of sealed brood [14].

4. **Vitamins:** In addition to providing mostly carbohydrates and proteins, nectar and pollen are also significant sources of vitamins and minerals. The B-complex vitamins, including, riboflavin, thiamine, pantothenic acid, pyridoxine, folic acid, biotin and niacin, are present in pollen. These nutrients are essential for the development of the hypopharyngeal gland. [15]. Pentatonic acid is necessary for differentiation of queen and workers among the bees. To start brood rearing, riboflavin and nicotinic acid are also considered as essential vitamins. Additionally, the production and content of brood food may be impacted by the presence or absence of specific vitamins. [11]
5. **Minerals:** Some kinds of insects have been showed to require the same minerals that are known to be essential to the diet of vertebrates (iodine, sodium, calcium, magnesium, cobalt, chlorine, potassium, phosphorus, nickel, copper, manganese, zinc, and iron). All of these minerals are present in pollen, and honey bees use them in their vital life processes [11].
6. **Water:** Without water survival of bees near impossible. Bees should always have access to an adequate supply of water. Bees need to take water to survive, and when they don't, their physiology, ability to raise their young, and regular behaviour suffered adversely. Bees gather water and they mostly use it to dilute thick nectar and honey, keep the hive's humidity levels at their ideal levels, and chill the hive's atmosphere in hot weather [16]. Further, to prepare food and supply minerals to larva, water is the most necessary element. As it is not stored in pollen and honey in hive, bees need to collect water as per their need. [8]. When the bees are in need of water, the beekeeper should supply it to them in open trays or pans with floating supports like wood chips, plastic sponge or corks. [16].

#### IV. DIFFERENT ARTIFICIAL AND SUPPLEMENTED FOOD FOR HONEY BEE NUTRITION

When availability of pollen and nectar are enough, then bees collect some extra food for the future uses. But, when dearth period started, this extra food was not much helpful for proper development of honey bees. Therefore, beekeepers commercially provide several products to the bee colonies that required as supplements for bee survival. Colonies are fed sugar in various forms to enhance honey and nectar, and pollen substitutes or supplements are given in place of pollen. The bees are fed artificial diets made from edible substances. This aids in the restoration of bees throughout the dry season [17].

1. **Sugar Syrups (Nectar supplement):** Depending upon different seasons, different concentrations of sugar syrups are prepared for honey bees. Sugar is fed in the form of candy or in the dry form. Feeding sugar syrups help to keep the bee population alive

during extreme shortage of nectar and honey. This supplemented feeding also stimulates the colony to rear more brood [18].

Maintaining proper concentration and quantity of sugar syrups is an important task. At the duration of queen feeding or general feeding and in spring, for the stimulation of colony, 1:1 concentration of sugar and water is taken by volume for feeding. For preparing simulative feeding, dilute syrup 1:2 concentration of sugar and water is mixed by volume. Feeding should be done using concentrated sugar syrup in the winter or at the end of the autumn. To prepare heavy sugar feeding, 2:1 concentration of sugar and boiling water is taken by volume and tartaric acid is added to prevent crystallization. The syrup can be fed by filling in empty combs of the needy colonies [17,18].

2. **Sugar Candy or Dry Sugar (Nectar Supplement):** If the weather is warm and the bees can fly freely, then dry form of sugar can be supplied to the colonies. Sugar can be provided on the inner cover with its hole open. Sugar candy is prepared by dissolving 7.5 kg cane sugar (table sugar) and 1.5 kg glucose in four cups of water by stirring and boiling mixture until temperature of syrup rises to 116°C. When the syrup is cooled down and then it is thickened by intense beating. After that, the candy is molded in wax paper and ready to be fed to the colonies [17].
3. **Pollen Supplement:** To make easily acceptable to the honey bee colonies, stored pollen is mixed with different other ingredients. To prepare pollen supplement, one part of stored pollen is added in two parts of sugar syrup (prepared by dissolving two parts of sugar in one part of water) and three parts of fat free soy flour. This is fed to the bee colonies as supplements [17].
4. **Pollen Substitutes (Artificial Feeding):** For keeping honey bee colonies strong and healthy, pollen substitute meals are a great resource. In some countries or regions, certain diets may be effective, but in others they may be ineffective or not economically feasible [19].

Substitutes must contain elements that balance the nutritional requirements for honey bees to avoid high levels of toxic substances. Some of the ingredients considered as pollen substitutes are skim milk powder, soya flour, peanut flour, canola flour, brewer's yeast, linseed flour, sunflower flour, torula yeast, bakers yeast, lactalbumin, vitamin and mineral supplements, fish meal, pollard, powdered casein, sodium caseinate etc [18]. These ingredients are also mixed with each other in different combinations to improve artificial feedings.

5. **E. Microalgae (Artificial feeding):** Algae biomass has potential as an alternate feed source and a source of natural compounds that can improve honey bees health [20]. Due to their sustainability, and amenability to trait manipulation and nutrition content, algae could potentially be developed into novel nutritional supplements that can strengthen bee populations to face the environmental stress [21]. Honey bees appear to benefit at the colony level in their population size, brood rearing, fecundity, and production of honey and wax, when fed with algae products [22]

Microalgae is considered nutritious and sustainable feeding ingredient. Prokaryotic cyanobacteria (blue-green microalgae) *Spirulina* and eukaryotic microalgae in the genus *Chlorella* are excellent sources of protein, sterols, fatty acids, and other bioactive compounds. These microalgae appear to resemble the characteristics of a natural pollen diet and are digestible by honey bees. Pollen and microalgae diets demonstrated equivalent nutritional and metabolomic consequences in bees, especially after distinctive diet aspects were removed. *Chlorella* contained more essential fatty acids than *spirulina*, which contributed to its higher nutritional value. *Spirulina*, on the other hand, is a promising source of available protein and phytochemicals, particularly carotenoids, which may enhance bee's stress response pathways [23].

## V. CONCLUSION

35% of the world's food is produced by managed bee colonies, and their services and products support a multi-billion dollar worldwide economy that helps the agricultural, food production and pharmaceutical industries [24]. Therefore, management of the health of bee colonies during the pollen and nectar scarcity period is an important task for the bee-keepers to get the constant commercial benefit. Supplemental and artificial feeding is a management strategy with significant financial and labor costs for large-scale beekeepers. In particular, supplement and substitute feeding is anticipated to encourage brood generation and colony population expansion prior to pollination services. Different types of artificial foods are developed by researchers but there is still a need to produce a comprehensive artificial diet that satisfies bee's nutritional needs in a diverse of management conditions [25].

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