**Honey bee nutrition and artificial and supplementary feeding**

Dimpee Boruah

Dept. of Life Sciences

Dibrugarh University

Dibrugarh, Assam, 786004

E-mail: dimpeeboruah987@gmail.com

**ABSTRACT**

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

**Key words -** honey bee, nutrition, nectar, pollen, supplements, substitutes, dearth period, artificial feeding

**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 protein, vitamins and minerals and nectar is the source of their carbohydrate requirement. 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 the nutritional requirements, growth of colonies and development of broods 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 flows and negatively affects bee product production and pollination activity. If the flow is weak or the colonies are used for pollination for extended periods of time, the colony may not have enough reserves [2].Bee nutrition is also threatened by climate change. Plant adaptations to climate change, such as altered flower, nectar, and pollen output, will modify the amount of available resources, which could have disastrous effects for honey bees [3]. To maintain the normal growth of the impoverished bee colonies under these circumstances, 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 feedingi.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 stimulates colony growth and confers resilience to environmental stress by replacing dying bees.Depletion of storage pollen of honey bee colonies are greatly affected by adverse climatic conditions. Pollen must therefore be available in sufficient quantities throughout the brood producing season to support population growth.Different combinations of ingredients have been used as a partial or full replacement for natural pollen. Artificial bee diets commonly incorporate protein-rich ingredients such as soy, pea, yeast, casein, egg, and microalgae.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 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, the growth and development of young bees as well as the rearing of larvae require proteins, lipids or fats, minerals, and vitamins.

**A. Proteins and amino acids**

For honey bees, pollen is their only source of natural protein. 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 arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine 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 [8].Free amino acids appear to reduce bee lifespan. The best way to give amino acids to bees is in the form of crude protein from pollen or feed with an amino acid profile that closely resembles jelly proteins [9].

**B. Carbohydrates**

Honey bees' primary energy source is carbohydrates 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. A 50,000-bee colony requires around 700 pounds of sugar each year [10]. A large part of the diet of the colony is consist of carbohydrates 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 glucose, fructose, sucrose, trehalose, maltose, and melezitose. They cannot utilize the carbohydrates galactose, mannose, lactose, raffinose, dextrin, inulin, rhamnose, xylose, or arabinose [11].

**C. 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, such as linoleic acid, γ-linoleic α-linoleic acid, and palmitic acid, are important lipid constituents that can comprise up to 80% of the lipid content. The ratios in which dietary lipids occur compared to other nutrients have an effect on their health benefits. A 10:1 protein to lipid content ratio and a low linoleic acid: linoleic acid ratio, while normally balanced in pollen, are ideal for bee health, with larger ratios and concentrations of some fatty acids causing increased mortality [9].

Sterols are the one of the components of cell membranes and many external surface waxes on the bee’s exoskeleton. 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].

**D. Vitamins**

Nectar and pollen both contain many vitamins and minerals. Pollen contains the B-complex vitamins (thiamine, riboflavin, pyridoxin, pantothenic acid, niacin, folic acid and biotin). These vitamins are crucial for hypopharyngeal gland development [15]. Pentatonic acid is necessary for queen and worker differentiation among the bees. Riboflavin and nicotinic acid play a vital role in initiating brood rearing. Additionally, the production and content of brood food may be impacted by the presence or absence of specific vitamins. [11]

**E. Minerals**

The minerals known to be required in the diet of vertebrates (sodium, potassium, calcium, magnesium, chlorine, phosphorus, iron, copper, iodine, manganese, cobalt, zinc, and nickel) have all been shown to be needed by some species of insects. Pollens contain all of these minerals, and honey bees utilize them in their vital life processes.[11]

**F. Water**

Without water survival of bees near impossible.A supply of water should be available to bees at all times. Water is an essential part of the diet of bees, and a lack of it adversely affects their nutrition, physiology, brood rearing, and normal behavior. Bees gather it, 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. When the bees are in need of water, the beekeeper should supply it to them in open pans or trays with floating supports like wood chips, corks, or plastic sponge. [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. However, with commercial interests in mind, several hive products are extracted from bee colonies that require supplementation 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 starve during the dearth period due to a lack of food. Furthermore, drifting occurs under these conditions. The bees are fed artificial diets made from edible substances. This aids in the restoration of bees throughout the dry season [17].

**A. Sugar syrups (Carbohydrate supplement)**

Depending upon different seasons, different concentrations of sugar syrups are prepared for honey bees. Sugar is fed even in dry form or in the form of candy. Feeding sugar syrups help to keep the bee population alive during extreme storage of nectar and honey. This supplemented feeding also stimulates the colony to rear more brood [18].

Maintainingproper concentration and quantity of sugar syrups is an important task. For colony stimulation in spring or when queen rearing and general feeding, 1:1 concentration of sugar and water is taken by volume. 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, d two parts of sugar is dissolved in one part of boiling water and tartaric acid is added to prevent crystallization. The syrup can be fed by filling in empty combs of the needy colonies [17,18].

**B. Sugar candy or dry sugar(Carbohydrate supplement)**

If the weather is warm and the bees can fly freely, dry 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].

**C. Pollensupplement**

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 three parts of fat free soy flour and two parts of sugar syrup (prepared by dissolving two parts of sugar in one part of water). This is fed to the bee colonies as supplements [17].

**D.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 need to include ingredients that balance honey bee nutritional requirements to avoid high levels of toxic substances. Some of the ingredients considered as pollen substitutes are soya flour, canola flour, linseed flour, sunflower flour, torula yeast, brewers yeast, bakers yeast, vitamin and mineral supplements, fish meal, peanut flour, skim milk powder, powdered casein, sodium caseinate, lactalbumin, pollard. [18]

**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 nutrition content, sustainability, and amenability to trait manipulation, algae could potentially be developed into novel nutritional supplements that can strengthen bee populations in the face of environmental stress [21]. Honey bees appear to benefit at the colony level in their fecundity, brood rearing, colony population size, and production of honey and wax, when fed with algae products [22]

Microalgae is considered nutritious and sustainable feed ingredient. Eukaryotic microalgae in the genus *Chlorella* and prokaryotic cyanobacteria (blue-green microalgae) *Spirulina* are excellent sources of protein, fatty acids, sterols, and other bioactive compounds. These microalgae are digestible by honey bees and appear to reproduce the growth characteristics of a natural pollen diet.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 bioavailable protein and phytochemicals, particularly carotenoids, which may enhance stress response pathways in bees [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 an all-encompassing artificial diet that meets the nutritional requirements of bees under diverse management conditions has yet to be developed [25].

**REFERENCES**

1. Saffari, A. M., Kevan, P.G., and Atkinson, J.L. "A promising pollen substitute for honey bees." American Bee Journal, Vol.144, no. 3, PP. 230-231, 2004.
2. Kumar, S. "Analysis of essential amino acid contents in forager bees of *Apis mellifera L*. fed on artificial diets (Nectar and pollen supplements)." Journal of Entomological Research, Vol. 41, no. 2, PP. 197-202, 2017.
3. Settele, J., Bishop, J., and Potts, S. G. "Climate change impacts on pollination." Nature Plants, Vol. 2, no. 7, PP.1-3, 2016.
4. Kumar, R., and Agrawal, O.P. "Comparative performance of honey bee colonies fed with artificial diets in Gwalior and Panchkula region." J. Entomol. Zool. Stud, Vol.2, no. 4, PP. 104-107, 2014.
5. Ricigliano, V. A., Williams, S.T., and Oliver, R. "Effects of different artificial diets on commercial honey bee colony performance, health biomarkers, and gut microbiota." BMC veterinary research, Vol. 18, no. 1, PP. 1-14, 2022.
6. Mortensen, A., N., Jack, C., A., Bustamante, T., A., Schmehl, D. R., andEllis, J., D. "Effects of supplemental pollen feeding on honey bee (Hymenoptera: Apidae) colony strength and Nosema spp. infection." Journal of Economic Entomology, Vol. 112, no. 1, PP. 60-66, 2019.
7. Brodschneider, R., and Crailsheim, K. "Nutrition and health in honey bees." Apidologie , Vol. 41, no. 3, PP. 278-294,2010.
8. de Groot, Antonius Petrus. “Protein and Amino Acid Requirements of the Honeybee (*Apis mellifica L.)”.* W. Junk, 1953.
9. Wright, G., A., Nicolson, S., W., and Shafir, S. "Nutritional physiology and ecology of honey bees." Annual review of entomology, Vol. 63, PP.327-344, 2018.
10. Tsuruda, J. M., Chakrabarti, P., and Sagili, R.R."Honey bee nutrition." Vet Clin Food Anim, Vol. 37, PP. 505-519, 2021.
11. Moeller, F. E., Kauffeld, N. M., Herbert Jr, E. W., and Shimanuki, H. "Supplemental feeding of honey bee colonies." United States Departament of Agriculture. Agriculture Information Bulletin, PP. 413, 1977.
12. Roulston, T. A. H., and Cane, J. H. "Pollen nutritional content and digestibility for animals." Plant systematics and Evolution, no. 222, PP. 187-209, 2000.
13. Delaney, D."Honey bee nutrition."MAAREC Publication, Vol. 1.4, 2015.
14. Herbert Jr, E. W., Vanderslice, J. T., and Higgs, D. J. "Vitamin C enhancement of brood rearing by caged honeybees fed a chemically defined diet." Archives of insect biochemistry and physiology, Vol. 2, no. 1, PP. 29-37, 1985.
15. Herbert Jr, E. W., and Shimanuki, H. "Chemical composition and nutritive value of bee-collected and bee-stored pollen." apidologie, Vol. 9, no. 1, PP. 33-40,1978.
16. Groot, A. P. D. "Protein and amino acid requirements of the honeybee (*Apis mellifica L*.)." (No Title), 1953.
17. <https://egyankosh.ac.in/bitstream/123456789/41540/1/Exercise-6.pdf>
18. Somerville, D. "Honey bee nutrition and supplementary feeding." Agnote DAI/178. NSW Agriculture, PP. 1034-6848, 2000.
19. Morais, M. M., Turcatto, A. P., Pereira, R. A., Francoy, T. M., Guidugli-Lazzarini, K. R., Goncalves, L. S., ... and De Jong, D. "Protein levels and colony development of Africanized and European honey bees fed natural and artificial diets." Genetics and Molecular Research, Vol. 12, no. 4, PP. 6915-6922, 2013.
20. Ricigliano, V. A., and Simone-Finstrom, M. "Nutritional and prebiotic efficacy of the microalga *Arthrospira platensis (spirulina*) in honey bees." Apidologie, Vol. 51, no. 5, PP. 898-910, 2020.
21. Ricigliano, V. A. "Microalgae as a promising and sustainable nutrition source for managed honey bees." Archives of insect biochemistry and physiology, Vol. 104, no. 1, PP. e21658, 2020.
22. Nichols, B. J., and Ricigliano, V. A. "Uses and benefits of algae as a nutritional supplement for honey bees." Frontiers in Sustainable Food Systems, Vol. 6, PP. 1005058, 2022.
23. Ricigliano, V. A., Cank, K. B., Todd, D. A., Knowles, S. L., and Oberlies, N. H. "Metabolomics-guided comparison of pollen and microalgae-based artificial diets in honey bees." Journal of Agricultural and Food Chemistry, Vol. 70, no. 31, PP. 9790-9801, 2022.
24. Klein, A. M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., and Tscharntke, T. "Importance of pollinators in changing landscapes for world crops." Proceedings of the royal society B: biological sciences, Vol. 274, no. 1608, PP. 303-313, 2007.
25. Manning, R. "Artificial feeding of honeybees based on an understanding of nutritional principles." Animal Production Science, Vol. 58, no. 4, PP. 689-703, 2016.