MELLIFERA REVIEW ARTICLE

Importance of Nutrition for Honey Bee Health

*Kübra ULUTAŞ[1], Aslı ÖZKIRIM[1,2]

[1]Hacettepe University Faculty of Science Department of Biology, Beytepe, ANKARA-TURKEY

[2] Hacettepe University Bee and Bee Products Application and Research Center, Beytepe, ANKARA-TURKEY

*Corresponding author: kubraulutas16@gmail.com

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A B S T R A CT

Adequate nutrition supports the development of honey bee colonies' health. The quality and the nutritious components of the food help bees to be healthy. Honey bee colonies health can not be measured by the fact that they are purified from diseases. Colonial health status is also measured by the presence of well-nurtured individuals who can nurture new offspring in a healthy manner, and their ability to resist stress sources such as periodic starvation, infections, insecticides and parasites. This review will concentrate on the studies that focused on nutrients honey bees and their effects on honey bee health.

Keywords: nutrition, bee health, honey bee, honey, pollen, protein

Introduction

Nutrition is the name given to the activity of acquiring substances taken from the outside in order to meet the energy required to maintain the vitality. Just like every living species, honey bees need nutrients to survive. The natural food that honey bees gather and produce are royal jelly, pollen, nectar and honey [1].

Honey bees are social insects, often regarded as super-organisms [2]. Thus, nutrition can be investigated on three levels – colony nutrition, adult nutrition and larval nutrition – with increasing complexity, because disorders in prior stages affect subsequent stages, and vice versa.

1.Royal Jelly

Royal jelly is a secretion that forms in the glands in the hypopharynx of worker bees [2]. It is fed to the all the larvae in the colony. This secretion is what makes all the difference in the caste system. When larvae nourished with only royal jelly in its lifetime this turns them into queens [1]. This level of differentiation from one level organism to another is major in evolution [3]. Queens are larger in body size, they have shorter development time than worker bees, queen bees have more lifespan and they can reproduce while the workers are sterile [4].

Apart from water royal jelly's most substances are, 12.5% crude protein including small amounts of different amino acids and fatty acids which their percentage can be up to 5% [2]. The main acid is 10-hydroxy-2-decenoic acid (10-HDA) and with this fatty acid royal jelly can be identified [5]. The cause of dimorphism seen between the worker and queen bee class is due to feeding on royal jelly, not genetic differences. In 2011, Kamakura Masaki claimed that this diversity was beacuse of a protein sized 57 kDa, named as royalactin. Royalactin has been shown to shorten the developmental period of honey

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bees while increasing body size and ovarian development. Surprisingly, it was observed that *Drosophila melanogaster* showed similar effects with royalactin too [6]. However, there are opposing views on the correctness of this function of Royalactin [7].

2.Pollen

Worker bees feed on royal jelly only for three days while queen bee feed on it for the rest of her life.[8] After emerging from the combs main brood food consists of protein. Pollen is the natural source of protein for honey bee colonies. According to Crailsheim et al. [9], the pollen requirement of two 10-frame colonies is 13,4 and 17,8 kg per year.

There is a need for 25-37,5 mg of protein to grow a larvae [10]. An important percentage of the protein fed to larvae is taken from bee bread which is processed pollen. The nurse bees turn the pollen into a higher quality bee bread with their hypopharyngeal glands and enzymes. After regurgitating these pollens with their natural microflora, honey bees will store them in the combs. *Bacillus* genus is the responsible one for this fermentation [11]. Storage of the pollen as bee bread in combs is achieved by fermentation. More work needs to be done on how the viability of the spores in pollens contaminatinated by Nosema is affected during this process [12]. *N.ceranae* spores are developing much more rapidly in the short term when bees are fed on diet with higher nutritional value, such as bee bread of polyfluoral origin, compared to bees fed on a lower quality diet [13].

In another study [14] on bee bread and *N.ceranae*, bee bread was used as a natural protein source and supplementary protein was used in the other group. In the aftermath of feeding with a natural protein source, sports development is more common. Survival rates of bees were in bees fed by bee bread was much more higher compared to those fed with unnatural supplement foods. *N.ceranae* is dependent on hosts proteinous nutrients and when the protein components are high in the honey bees diet, spores show increasing development. This is shown in many studies [15], Porrini et al. [13], Basualdo et al. [14], and Zheng et al. [16] Bee bread fasten the larval development [17]. Nurse bees also give less nutrients and control younger larvae than older ones [1].

Honey bee colonies are immensely dependent on the pollen that are collected from different plants [18]. However monocultures makes it very difficult for honey bees to gather all their essential nutrients from pollens. And this might endanger the colonies [19]. Poor pollen storage may prevent adults from feeding well the larvae or prevent all the larvae from growing to mature ones. As a result, in the next generation it increases the likelihood of degradation of the number of individuals or the health problems. Both larval and adult bees are highly dependent on the nutrient deposits of the colony. And adults may adapt their foraging or larval care strategies to these nutrient deposits [20]. During winter colonies depend on these stores, they will feed on stored honey and bee bread [21].

High quality pollens increases the hypopharyngeal glands' development. And thanks to this, these nurse bees can produce high protein larval food and this will directly effect the brood rearing in a positive way [22]. Also they will produce high quality royal jelly fort the queen. In the lack of proteinous food, bees show cannibalism; they start eating eggs and broods in the colony [23, 24, 25]. 66% to 74% of the dry weight of the adult bees is composed of protein [20].

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Cage experiments have shown that adult bees can survive by feeding on carbohydrates for a long time but the bees that continue to feed on pollen have a longer life [26]. Young adults go through physiological changes like the ripening of flight muscles and protein uptake are very important in this period [27].

Protein-rich diets can be applied in the early spring when the amount of pollen is low to improve colony growth, or where there are low-quality pollen sources [28]. Proteins obtained from sources such as soybean meal, milk, algae and brewer's yeast are used as protein sources in pollen-free diets. [29] Pollen also contains vitamins, minerals and lipids that are useful for bee health and brood rearing [30].

3. Honey

Honey is a product of honey bees that is a food substance that is produced from plants' nectars or insects secretions through regurgitation, enzymatic activity, and water evaporation [31,32]. Honey mainly have glucose and fructose, but it also has 25 different oligosaccharides [33]. Honey composition diffirentiates according to its geographical and plant origin, but also its processing [34,35]. While foraging honey bees use nectar's energy to flight metabolism [36]. Bee digestive enzymes, invertase, amylase, and diastase, participates in honey making [37]. The amount of sugar of nectar have, assesses the energy content [38]. In the first three days of brood development, 18% of the food is sugar (fructose and sucrose), while in the last two days it is 45% [39].

Honey has a component named HMF (hydroxymethylfurfural) which is toxic to the bees. [40] HMF occurs by acid-catalyzed dehydration of hexose sugars such as fructose, and by keeping the honey in warming or improper storage conditions. HMF experiments were performed on the larvae grown in the experimental environment [41]. Concentration under 750 ppm HMF didn't show mortality increase on the larvae. But more than 750 ppm showed 100% mortality. Also some sugars like, mannose, galactose,arabinose,lactose etc are also toxic to the bees [42]. In HFCS, fructosyl-fructoses and some unknown carbohydrates were found [43]. When bees naturally gather nectar fructosyl-fructoses were not found in the honey.

According to Neff and Simpson [44], the nectars that have hectose sugars are highly attractive to the bees. Also larvae have more glycogen storage than the adult bees [45]. Adult bees need approximately 4 mg of sugar per day [42]. The transformation of nectar to honey starts the on the way to hive [46]. The sugar concentration of 20% of the nectar becomes twice as much by the time the worker bee returns to the hive. Haydak [23] reported that "Adult bees can rear their brood when fed a pure carbohydrate diet. Brood rearing in this case continues for a relatively short period of time".

4.Vitamins and Minerals

Water soluble vitamins, in contrast to fat soluble, are common in pollen, but the content of vitamin C, for example, varies throughout the season according to different floral sources. No relationship has been found between the vitamin C level of pollen collected by free-flying honey bees and brood production [26]. Furthermore,prepupae reared by bees constrained to a vitamin C-free diet contained similar vitamin C levels than did those reared by bees fed vitamin C-enhanced diets. Therefore, honey bees (or their symbiotic microorganisms) are assumed to be able to synthesize vitamin C.

A mixture of the fat soluble vitamins A, D, E and K in the diet substantially improved the amount of brood produced, although these vitamins are not regarded essential

[32]. The same result was obtained when only vitamins A or K were seperately added to the diet. Honey bees obtain inorganic elements mainly from pollen, and according to Crailsheim [39] bees reared during pollen shortages contain similar quantities of most minerals compared to bees reared during favorable foraging conditions. This suggests other important sources of minerals like nectar and water or the existence of endogenous mineral pools in adults. Brood rearing significantly increased when Haydak [1] added 1% of pollen ash to a synthetic diet, but levels exceeding 2% appeared to be disadvantageous.The authors recommended a diet containing 1000 ppm potassium, 500 ppm calcium, 300 ppm magnesium and 50 ppm each of sodium, zinc, manganese, iron and copper for further investigation of the mineral requirements of honey bees.

Discussion

Carbohydrates, proteins, lipids, vitamins and minerals available to honey bees are factors responsible for the amount of progeny produced, longevity and health of adults and for the survival and productivity of a colony. Colonies facing a limitation of an essential nutrient, such as pollen in general, or an essential amino acid or vitamin in particular, will cease brood production and may not survive if not supplied with the missing nutrient.

Honey bees have evolved many strategies to cope with parasites and pathogens, but if they are nutritionally stressed, they face a major battle. Therefore, future research must take into account the interaction of possible nutrition-related effects with other factors, such as the influence of nutrition on susceptibility or tolerance of honey bees to parasites, pathogens and pesticides, the energetic stress of bees caused by parasites [31,34,39,40,43] and the role of nutrition in building up the honey bee's immune system [12,13]. The studies of Page and Peng [4] and Kamakura [6] and Higes et al. [12] raise the important question of how the honey bee's ability to defend pathogens is hindered when they are malnourished and how this ability may be improved by adequate nutrition.

To achieve well-fed and healthy colonies we recommend balanced nutrition for colonies, especially when they are placed in a difficult environment or used for pollination [9,11,19,23,26,39,42,43,46]. Balanced nutrition is best supported by growing a diversity of plants, even near agricultural areas, as a natural mixture of different pollens is the optimal source of proteins and vitamins for honey bees [17].

Bal Arıları İçin Beslenmenin Önemi

Öz: Yeterli beslenme, bal arısı kolonilerinin sağlığının gelişmesini desteklemektedir. Gıdaların kalitesi ve besleyici bileşenleri, arıların sağlıklı olmasına yardımcı olmaktadır. Bal arısı kolonisi sağlığı, hastalıklardan arındırılmış olması ile ölçülememektedir. Koloni sağlık durumu da, sağlıklı bir şekilde yeni yavru besleyebilen iyi beslenmiş bireylerin varlığı ve periyodik açlık, enfeksiyonlar, insektisitler ve parazitler gibi stres kaynaklarına direnme yetenekleriyle ölçülür. Bu derleme, besleyici bal arılarına ve bal arısı sağlığı üzerindeki etkilerine odaklanan çalışmalara yoğunlaşacaktır.

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