Honey Bee Nutrition and Supplemental Feeding

By L. N. Standifer, *Entomologist, Science and Education Administration, Carl Hayden Center for Bee Research, Tuscon, Ariz. 85719.*

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The natural diet of the adult honey bee is pollen and honey. Sometimes, however, when nectar is not available, bees collect sweet-tasting juices from overripe fruit and plant exudates. Also, certain insects secrete honeydew, which bees may collect and store as honey. During periods when no pollen is available, bees may collect powdery animal feed or spores from plants and store this material as they would pollen. This may have some food value but does not sustain brood rearing and is considered a poor substitute for pollen.

Nutritional Requirements

Honey bees require proteins (amino acids), carbohydrates (sugars), lipids (fatty acids, sterols), vitamins, minerals (salts), and water, and these nutrients must be in the diet in a definite qualitative and quantitative ratio for optimum nutrition.

Proteins and Amino Acids

Adult worker bees (1 to 14 days old) obtain dietary protein from pollen which workers collect and bring back to the hive; adult drone bees (1 to 8 days old) obtain dietary protein from food supplied by young workers which is a mixture of glandular secretions, pollen, and honey; and larval and adult queens obtain their protein from royal jelly secreted by young worker bees. Royal jelly also is fed to worker larvae less than 3 days old. Royal jelly is a secretion of the hypopharyngeal glands of worker bees normally 5 to 15 days of age. It is a creamy, milky white, strongly acid substance with a moisture content of 65 to 67 percent and rich in protein lipids, reducing sugars, B vitamins, vitamin C, and minerals.

Honey bees require specific amino acids for normal growth and development, reproduction, and brood rearing. The protein and amino acid requirements of larval and adult queens are unknown, but we have a fairly comprehensive knowledge of the chemical constitution of their basic food, royal jelly.

During the first 5 or 6 days of adult life, worker bees consume large amounts of pollen to obtain the protein and amino acids required to complete their growth and development. If young adult worker bees do not consume needed proteins, their hypopharyngeal glands (brood food glands) will not develop completely, and their royal jelly will not support normal growth and development of worker larvae or egg production in the adult queen. The requirement for protein decreases when worker bees discontinue nursing (between 10th to 14th day of adult life). Subsequently, the chief dietary constituent becomes carbohydrates obtained from nectars and honey.

Carbohydrates

Carbohydrates are abundant in the natural diet of the honey bee and are used mainly for the production of energy, but may be converted to body fats and stored. Some carbohydrates can be utilized by bees, some cannot, and some are toxic. Adult bees thrive on glucose, fructose, sucrose, trehalose, maltose, and melezitose, but they cannot use rhaminose, xylose, arabinose, galactose, mannose, lactose, raffinose, dextrin, or insulin. Differences in carbohydrate utilization between larvae and adults may be due to the absence of appropriate enzymes.

Lipids

Information on the nutritional need for dietary lipids (fatty acids, sterols, and phospholipids) in honey bees is fragmentary and inconclusive. Generally, lipids are used for energy, synthesis of reserve fat and glycogen, and for the functioning of cellular membranes. The lipid composition of adult bees differs from that of pollen. However, a phospholipid found in pollen also is found in the body tissue of adult bees. Another substance, 24-methylene cholesterol, also found in pollen, is the major sterol of the body tissue of adult queen and worker bees. Possibly, certain lipids have a significant role in the lubrication of food when it is ingested and prepared for absorption. All insects studied critically were found to require a dietary sterol; therefore, it is reasonable to assume the honey bee also requires this lipid.

Vitamins

When bees begin producing royal jelly for the young larvae and the queen, they need a diet high in vitamins. Nurse bees seem to need the following vitamin B complex for brood rearing: thiamine, riboflavin, nicotinamide (niacin, nicotinic acid), pyridoxine, pantothenate (pantothenic acid), folic acid, and biotin. Pantothenic acid is needed in worker-queen differentiation and nicotinic acid, in initiating brood rearing. In addition to these vitamins, ascorbic acid (vitamin C) also seems essential for brood rearing.

In general, the vitamin needs of a honey bee colony are satisfied as long as the pollen stores are abundant in the hive or fresh pollen is available to bees in the field. Micro-organisms naturally present in the alimenatry canal of bees may provide vitamins, and other essential substances, which may make an otherwise unsuitable diet adequate.

Minerals

Minerals required in the diet of humans and other vertebrates (sodium, potassium, calcium, magnesium, chlorine, phosphorus, iron, copper, iodine, manganese, cobalt, zinc, and nickel) are needed by some species of insects. Pollens contain all these minerals, some of which are required by bees.

Water

Water is collected by bees and used primarily as diluent for thick honey, to maintain optimum humidity within the hive, and to maintain appropriate temperatures in the brood area. The amount of water required and collected by a colony is generally correlated with the outside air temperature and relative humidity, strength of colony, and amount of brood rearing in progress.

Ingestion and Digestion

Food enters the alimentary canal (fig. 1) by way; of the month and passes through the *esophagus* to the *honey stomach*. In the honey stomach hydrolyzing enzymes break down the principal sucrose of nectar to the simpler monosaccharides glucose and fructose present in honey. Immediately behind the honey stomach is the *proventricular value* or honey stopper. It retains the nectar load in the honey stomach, controls passage of food into the *midgut*or ventriculus, and prevents food substances in the midgut from

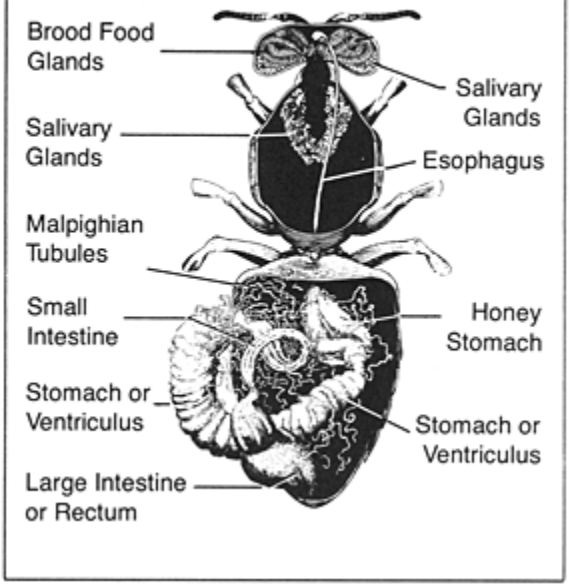

Figure 1. - Alimentary canal of adult worker honey bee.

returning to the honey stomach.

The midgut is a relatively large segment of the alimentary canal, where food is temporarily stored and most digestion occurs. The inner wall of the midgut is lined with a *peritrophicm membrane*, presumably to protect the cells from damage by the gut contents.

The alimentary canal is completed by a short *small intestine* and a large *intestine* or *rectum* that comprises the *hindgut* where food digestion is completed. Undigested food residues are reformed into feces in the rectum and eliminated through the terminal *anus*. Passage of pollen through the alimentary canal of adult bees requires about 2-1/2 hours. Feces of adult bees contain almost intact, empty pollen grain shells.

The complex foods ingested by bees must be broken down (digested) into simpler units before they pass through (absorbed) the gut wall into the hemolymph (blood) for ultimate assimilation and utilization. Digestion depends on the activity of enzymes. Enzymes are present in the secretions of the salivary, postcerebral, and hypopharyngeal glands and in the secretions of the midgut epithelial cells. In addition, digestion may be facilitated by the micro-organisms present in the alimentary canal. Compound sugars must be broken down by enzymes to simple sugars before they can be absorbed and utilized.

Bees apparently do not have the enzymes or micro-organisms needed to digest the complex carbohydrates (cellulose, hemicellulose, and pectin) in the outer wall of pollen grains. Enzymes gain access to food inside punctured pollen grains and also by dissolving the “soft germinal pore areas” with digestive enzymes. Enzymes that digest protein are abundant in the alimentary canal of the adult bee and are furnished almost entirely by the midgut and hypopharyngeal glands. Proteins are first broken down to peptones and polypeptides; and these, in turn, are hydrolyzed to amino acids.

The lipid-splitting enzyme lipase is abundant in the midgut of adult workers and drones. In higher animals, lipids are digested by lipase or esterases into free fatty acids and glycerol. The fatty acids are made water soluble by neutralization with alkalies in the alimentary canal. Some insects produce enzymes that hydrolyze certain phospholipids (that is, ecithin and spingomyelin), but probably digestion of the esters and fatty acids usually results from the activity of bacteria. Certain lipids may be absorbed unchanged also.

Food absorption begins in the upper portion of the large intestine and is completed in the rectum, where water salts and other organic molecules are selectively absorbed. There are two pairs of rectal glands or pads on the sides of the rectum that function in water and possibly fat absorption.

Sources and Chemical Composition of the Natural Foods

Nectar

Nectar is the major source of carbohydrate in the natural diet of honey bees. It may contain 5 to 75 percent soluble solids (sugars) although most nectars are in the 25- to 40-percent range. The primary sugars are sucrose, glucose, and fructose. As nectar is manipulated and finally stored as honey, much of the sucrose is inverted to approximately equal parts of glucose and fructose. A normal-sized honey bee colony may use the nectar equivalent of 300 to 500 pounds a year.

Pollen

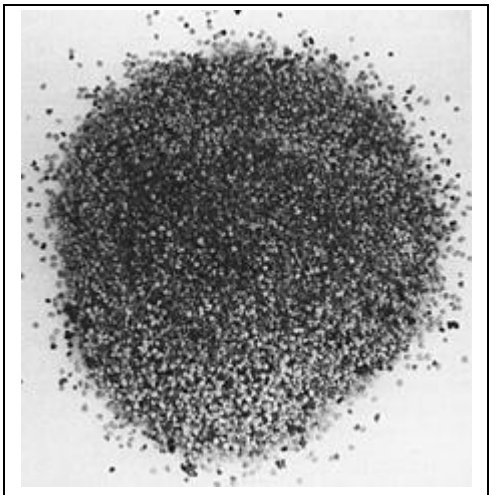

Figure 2. - Pollen pellets trapped from bees on their return to the hive.

Pollen is eaten by adult bees and fed (via the mixture of glandular secretions, honey, and pollen supplied by nurse bees) to worker and drone larvae after they are 3 days old. Unlike young house bees, field bees do not require pollen in their diet. Stored pollen (bee bread) is consumed by nurse bees (fig. 2). Under natural conditions, pollen collected by bees is usually stored on the periphery of the brood area (fig. 3). In a colony rearing brood, pollen placed next to a comb full of eggs is consumed in 2 or 3 days; if placed on the periphery of larvae, it is used by nurse bees within 1 or 2 days but it may be stored for much longer periods of time. A normal-sized colony may consume 100 pounds or more pollen a year. Not all pollens are nutritionally alike; bees generally collect and utilize a mixture, and many individual pollens are nutritionally inadequate.

The protein content of pollens varies from 10 to 36 percent. Some pollens contain proteins that are deficient in certain amino acids required by bees. All the amino acids listed in table 1, except threonine, are essential for normal growth of the young adult bee. With the exception of histidine and perhaps arginine, they cannot be synthesized by bees and must be obtained from the consumed pollens or from some other appropriate protein source.

An average pollen mixture contains lipids (fats) and the following minerals: calcium, chlorine, copper, iron, magnesium, phosphorus, potassium, silicon, and sulfur. Vitamins include ascorbic acid, biotin, vitamins D and E, folic acid, mositol, nicotinic acid, pantothenic acid, pyridoxine, riboflavin, and thiamine. Amino acid content is listed in table 1.

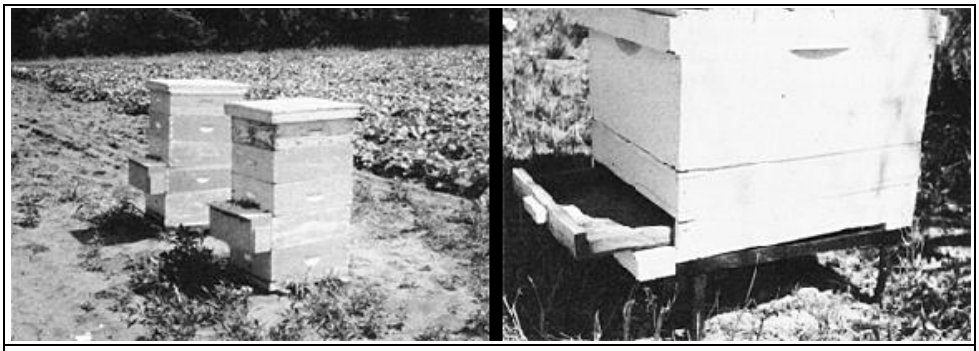

Figure 3. - Two types of pollen trap: Left, Emmett Harp type; right, O.A.C. type.

Supplementary Feeding of Honey Bee Colonies

Honey bees can be fed various foodstuffs to supplement inadequate supplies of pollen or honey. In early spring before pollen and nectar are available or at other times of the year when these materials are in short supply, supplementary feeding may help the colony survive or make it more populous and productive. As modern land-use practices reduce dependable nectar and pollen supplies, the need for supplemental food becomes more and more urgent. Colonies provided with adequate stores in the autumn may not need supplemental foods. However, if the spring weather is unusually cold and rainy, colonies may need supplemental foods for subsistence and continued brood rearing until nectar and pollen can be collected. A sudden curtailment of food when brood-rearing activities are in progress will result in reduced bee population.

In practice, beekeepers feed their bees supplemental foods to develop and maintain colonies with optimum populations for:

1. Nectar flows,

2. Pollination of crops,
3. Autumn and spring divisions,
4. Queen and package-bee production, and
5. Overwintering. Supplemental feeding may also be of value for building up colonies after pesticide damage.

Protein Supplemental Foods for Bees

Numerous kinds of plant and animal products have been fed to bees in attempts to find a substitute to replace pollen in their natural diet. None has been found that is a complete replacement for natural pollen. Certain protein foodstuffs, however, will improve nutrition and ensure continued colony development in places and times of shortage of natural pollen.

Wheast, (1) soybean flour, and several brewer's yeast products -fed singly or in combination -are palatable to bees and contain the quality and quantity of proteins and amino acids, lipids, vitamins, and minerals required for growth and development of individuals and reproduction of the colony. The yeast products and soybean flour formulations presented in this publication can be fed as a dry mix or moist cake inside the hive or as a dry mix in open feeders outside the hive. Bees are unable to collect wheast in its original dry state because of its large particle size; therefore, it must be fed as moist cake inside the hive.

TABLE 1. - *Amino acid content of average pollen expressed as percent of crude protein*

Constituent	Average pollen (crude protein, 26.3%)
Arginine	5. 3%
Histidine	2. 5%
Isoleucine	5. 1%
Leucine	7. 1%
Lysine	6. 4%
Methionine	1. 9%
Phenylalamine	4. 1%
Threomine	4. 1%
Trypotophane	1. 4%
Valine	5. 8%

The choice of sugar to use in protein diets depends partly upon the cost of sugar. Equally important is to use a sugar or sugar syrup that will not cause the moist cake to become hard in a few days when exposed to the warm and comparatively dry environment of the brood nest. Sucrose (cane or beet sugar), isomerized corn syrup, (2) and type-50 sugar syrup (3) with protein supplements produce cakes that maintain their consistency for long periods. Cakes prepared with honey maintain their consistency for a prolonged period. However, it is comparatively expensive, and may transmit bee diseases.

The addition of 10 to 12 percent pollen to a supplement fed to bees improves palatability. The addition of 25 to 30 percent pollen improves the quality and quantity of essential nutrients that are required by bees for vital activity. A bulletin providing several formulae for protein supplemental diets has been published by the Department.

To prepare moist pollen supplement cakes for feeding inside the hive, first dissolve the granulated sugar in the volume of water indicated in the formula. Subsequently, add the brewer's yeast, torula yeast, wheast, soybean flour, or other suggested material to the sucrose syrup and stir thoroughly. Bee-collected pollen pellets should first be dissolved in water (one-third gallon of water for each pound of pollen pellets) since they do not readily soften in sucrose syrup. The pollen-water suspension is then mixed with the sucrose syrup. More water may be necessary in formulae containing pollen. Each beekeeper should experiment with the formulations to determine the amount of water necessary. In humid areas, the suggested amount of water may be excessive.

Do not use pollen from diseased colonies or from an unknown or questionable source. Preferably, the beekeeper should get the pollen from his own disease-free colonies to avoid possible infection from pollen. The pollen should be stored in a freezer or dried and stored in air-tight containers. Dried pollen more than 2 years old loses much of its nutritional value. Pollen can be used to replace other protein material in any formula.

After thoroughly mixing the combined materials, the final product should be of a doughlike consistency. It should then be divided into 1-1/2 pound cakes and wrapped in waxed paper to prevent the loss of moisture. If cakes are not fed on the day prepared, they can be held in a cool place for several days or in a freezer for several weeks without deterioration or loss of food value.

Protein supplements can be fed any time inside the hive on the top bars or in division-board feeders. When weather permits bees to fly, the materials can be fed in the open, in trays, boxes, tubes, or other open containers. When the supplement is supplied to bees as a moist cake inside the hive, it should be in close proximity to the unsealed larvae in brood combs where nurse bees have ready access to it. A dry mix of moist formulae can be prepared by replacing the water with an equivalent amount of sucrose. Dry mix is usually fed in open feeders. To protect it from rain or dew, the feed should be placed under a roof or hive cover where it is readily accessible to the bees (fig. 4).

Therapeutic drugs may be incorporated in the protein or carbohydrate foods for control of bee diseases. Drugs, however, should never be fed to a colony during or 5 weeks before a major nectar flow. All medicants that are presently recommended for the prevention or treatment of brood diseases and Nosema can be fed in pollen and carbohydrate (dry sugar or syrup) supplements.

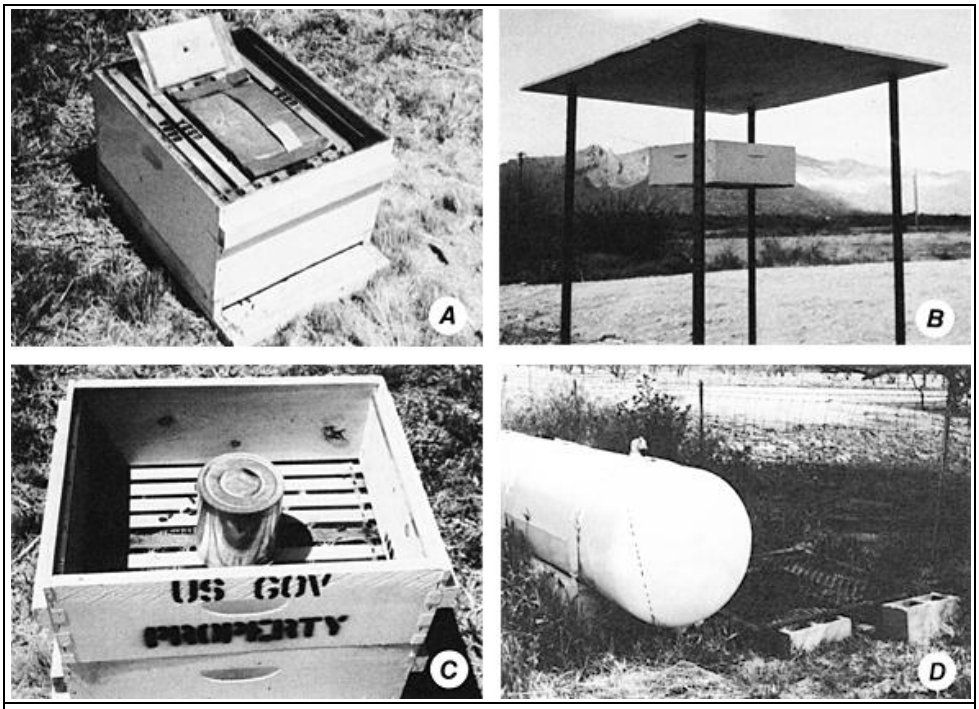

Figure 4. - A, Feeding pollen supplement in waxed paper, water in sponge in plastic bag, and sugar syrup in a frame feeder inside the hive; B, feeding dry pollen substitute outside the hive; C, feeding sugar syrup from an inverted pail; D, water supply tank with attached metal feeding pan (excelsior on wooden slats prevents drowning and steel grid excludes wildlife).

Carbohydrate Supplemental Foods for Bees

Proper colony management should ensure adequate honey reserves or stores in the hive at all times, but feeding sugar may sometimes be necessary. Whenever the honey supply in the colony is low and nectar in the field is in short supply, or inaccessible due to adverse weather, the colonies should be fed sugar supplement. Brood rearing requires a large amount of honey and pollen.

Cane or beet sugar, isomerized corn syrup, and type-50 sugar syrup are satisfactory substitutes for honey in the natural diet of honey bees. The last two are supplied only as a liquid to bees.

Preparation and feeding

Cane or Beet Sugar Syrup. - For spring feeding, mix one part by volume (two parts for autumn feeding) of sugar with one part water heated to 50° to 65°C (about 140°F).

Isomerized corn syrup or type-50 sugar syrup. - Dilute syrup with an equal volume of water. Sugar syrup can be supplied to bees inside the hive by one of the following methods:

1. *Friction-top pail.* - Puncture several holes in the cover and invert pails on the top bars of the frames or over the hole in the inner cover only and place an empty hive and the hive cover over all.
2. *Combs within the brood chamber.* - When some of the combs are empty, sugar syrup can be poured directly into the cells with a sprinkling can.
3. *Division board feeder.* - A container that replaces a comb in the brood nest. A plastic bag type is also available.
4. *Boardman feeder.* - This feeder is widely used, especially by hobby beekeepers. Its capacity is small, however, and the syrup, being outside, tends to cool down excessively at night. In addition, the air in the feeder may expand during the day, forcing the food out of the container faster than the bees can consume it, and its exposure to other bees may stimulate robbing.

When package bee colonies are established on empty combs or comb foundation, they should be fed thick syrup (two parts sugar and one part water) for 2 or 3 weeks. Colonies also are fed sugar syrup to stimulate brood rearing for queen and package-bee production to meet early shipping date schedules by producers.

Precautionary measures if robbing is a danger

1. Feed late in the day.
2. Disturb the bees as little as possible.
3. Reduce hive entrances.

Feeding dry sugar

As an emergency measure in late winter when it is too early to feed sugar syrup, bees may be fed dry sugar by placing a pound or two on the inverted inner cover. Some beekeepers increase the feeding space by providing a wooden rim on top of the inner cover.

Preparation and feeding of sugar candy

Mix one part sugar with one part water by weight and heat this mixture until it becomes the thickness of fudge (soft-ball stage). Pour the candy mix on waxed paper and allow to harden. Feed by placing the candy on the top bars directly over the brood nest and cluster.

Supplying Bees With Water

A supply of water must be available to bees at all times. A lack of it adversely affects the nutrition, physiology, brood rearing, and normal behavior. If a natural source is not within a half-mile or less, a supply should be provided. Pan or trays in which floating supports-such as wood chips, cork, or plastic sponge-are present may be satisfactory.

The beekeeper who sees that his colonies always have adequate provisions of food and water is likely to have strong, productive colonies.

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Notes

1 - A dairy yeast (Saccharomyces jragilis) grown in cottage cheese whey containing 54 to 60 percent protein.
2 - Produced by means of a multiple enzyme-conversion of corn syrup and composed largely of the simple sugars glucose (dextrose) and fructose (levulose).
3 - Contains 77 percent solids by volume, equal parts of dextrose and levulose, 1.1 kilograms of dry weightjliter, 0.5 percent ash, specific gravity of 1.39, and a pH of 4.8 to 5.7. Coe Sales Company, Phoenix, Ariz.