HONEY BEE NUTRITION

by L. N. Standifer[*]

A general knowledge of honey bee nutrition helps in understanding how the bee grows and how the colony develops and maintains itself.

The anatomical and vital physiological systems usually associated with living animals are present in the honey bee. Food enters the alimentary canal (see diagram) of the adult bee by way of the mouth and the long tubelike esophagus, which extends through the thorax and into the abodmen, where it enlarges to form the honey stomach. Nectar is transported in the honey stomach from the flower to the hive. Immediately behind the honey stomach is the proventricular valve. It retains the nectar load in the honey stomach, lets food pass into the midgut, but prevents food from returning. The midgut or ventriculus is a relatively large segment of the alimentary canal, lined on the inside with peritrophic membrane. Beyond the midgut are the short, small intestine, the large intestine or rectum, and finally the anus.

The adult honey bee has six sets of paired glands located in the head and thorax. The labial glands are generally believed to be associated with the alimentary canal. They deliver their secretions at the base of the labrum. Their function is dependent on the age of the bee and on the work in which it is engaged.

The hypopharyngeal or brood food glands produce

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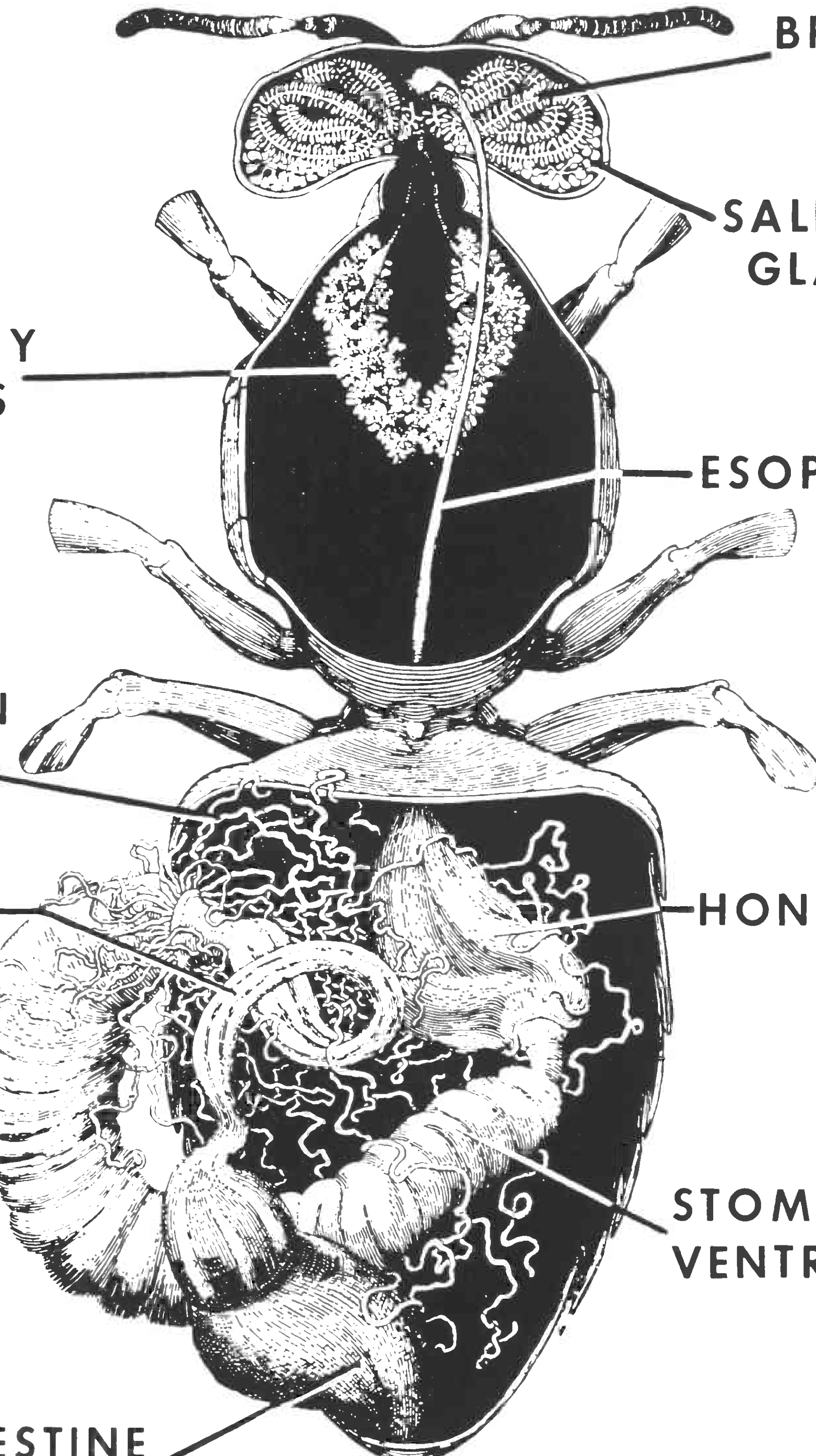

Figure 1. The alimentary canal of adult worker honey bee

the food called royal jelly. Most of the larval food comes from these glands. They also supply food for the adult queen and possibly adult drones. They are fully developed only in the worker bee. Royal jelly is milky in appearance, slightly acid, and rich in digestive enzymes, proteins, carbohydrates, fats, and vitamins.

The mandibular glands are saclike, single structures located immediately above the mandibles. They are extremely large in the queen, smaller in the worker, and vestigial in the drone. They do not vary in size with age or occupation. However, if the newly emerged bee does not consume adequate protein during the first few days of adult life, these glands do not develop fully.

The secretions from these glands in queens contain a compound called queen substance, which is essential for social unity of the colony. This substance is not in the glandular secretions of worker bees. Workers probably use the secretion from their glands to prepare and manipulate wax for building comb. It may also be used to soften the pupal cocoons of bees and is found in royal jelly.

The primary function of the postcerebral glands, located in the back of the head, is to provide the enzymes necessary for the digestion of foodstuff consumed by the bee.

The thoracic or salivary glands in the anterior part of the thorax secrete a corbohydrate-splitting enzyme, invertase, in large amounts.

The function of the postgenal glands in the lower inner wall of the head and the sublingual glands at the base of the bee tongue is unknown.

Two pairs of rectal glands or pellets on the sides of the rectum are associated with fat absorption.

Beeswax is secreted by specialized cells called wax glands on the underside of the abdomen of the worker bee. Generally wax glands become fully developed about the 15th day of adult life. Secreted beeswax appears as thin, delicate scales or flakes. It is a byproduct of metabolism and directly follows the digestion of large quantities of nectar or other sugars. The bees use wax to form the cells of the comb in which food is stored and brood is reared.

When wax is needed for comb building, the 16-to 24-day-old bees fill their honey stomachs, then hang together in vertical sheets or festoons. The wax scales are secreted, then removed with the hindlegs, and passed forward to the mouth, where they are worked by the mandibles and subsequently applied to the edge of the comb. The wax glands shrink and become nonfunctional between the 20th and 25th day of adult life, or about the time worker bees become field-foraging bees.

DIGESTION

The movement of pollen through the alimentary canal of the adult bee reveals something of the digestive process. Ten minutes after the material is fed to the bee, the pollen grains are clustered at the proventriculus. Thirty minutes after feeding they are within the peritrophic membrane in the forepart of the ventriculus. Ninety minutes after feeding, the peritrophic membrane-enwrapped pollen mass enters the anterior or small intestine. At the end of two hours the pollen is within the small intestine or just entering the large intestine or rectum. The peritrophic membrane that encircles the pollen grains in the midgut persists in the rectum for a considerable time before all is voided in the feces.

The fatty acids in pollen are made water soluble by neutralization with alkalies in the alimentary canal secretion. The proteins are broken down into peptides, and these are further hydrolyzed into amino acids.

The lipids of bee food occur chiefly in pollen. The lipid-splitting enzyme lipase is abundant in the midgut of the adult worker and drone. Its value in digesting the lipids is unknown. In higher animals lipids are digested by lipase or esterase into free fatty acids and glycerol.

NUTRITIONAL REQUIREMENTS

Honey bees and other insects have no unusual nutritional requirements. They require carbohydrates, proteins, fats, minerals, vitamins, and water for growth, development, maintenance and reproduction. Nectar and honeydew are the chief sources of supply for carbohydrates in the diet of bees, and pollen furnishes all the other indispensable constituents.

Adult bees can live on corbohydrates glucose, fructose, sucrose, trehalose, maltose and melezitose. They cannot utilize the carbohydrates galactose, mannose, lactose, raffinose, dextrin, insulin, rhamnose, xylose, or arabinose. Beekeepers often feed suscrose if a shortage of nectar or honey exists. Bees also utilize fruit juices and certain occasional plant juices. A small amount of carbohydrates is also obtained from pollen. The adult bee can survive on corbohydrates; however, proteins, fats, minerals, and vitamins are necessary in rearing the immature stages.

Proteins of a precise quality and definite amino acid composition are required for optimum growth and development of the brood food-producing hypopharyngeal glands and no doubt others. When nursing duties are finished (between 10th and 14th day of adult life) and field duties are undertaken, the requirements for protein decrease, and the chief dietary constituent becomes the carbohydrates obtained from nectars and honey.

Fats, like carbohydrates, are also used as sources of energy. Bees probably require and utilize some of the fats in pollen they consume. However, chemical analyses of feces show that large amounts of fats in the pollen consumed by bees pass through the digestive tract and are not utilized.

Water is necessary in the diet for diluting concentrated honey. It is also used in air-conditioning the cluster. Normally bees do not store water as they do nectar and pollen. It is collected only when needed.

The nutritional value of the enzymes, coenzymes, and pigments found in pollen is largely unknown.

SOURCES AND CHEMICAL COMPOSITION OF FOODS

NECTAR When nectar is collected, it may contain from 5 to 75 percent soluble solids (sugars), most of which is in the 25 to 40 percent range; the remainder is water. The primary sugars are sucrose, glucose, and fructose. As the nectar is manipulated and finally stored as honey, much of the sucrose is inverted to glucose and fructose, usually in about equal amounts.

HONEYDEW Various species of insects secrete a material called honeydew, which bees collect and store in the comb. Honeydew has a high percentage of dextrins and melezitose. It is generally considered a poor source of carbohydrates for bees.

PLANT JUICES Bees often collect juices from overripe fruit and various plant exudates that are rich in sucrose or related sugars. They usually do this only when nectar is not available.

POLLEN Pollen furnishes all the other indispensable constituents of the diet, except water, that are required for vital activity, including rearing young bees. Not all pollens are alike nutritionally, and bees grow and develop better on some than on others.

In nature bees generally utilize a mixture of pollens in their diet. This is eaten by adult bees and is fed to worker and drone larvae after they are 3 days old. Co

Table 1. Amino acid content of average pollen and sweet corn pollen, expressed as per cent of crude protein

Component	*Average pollen percent*	*Sweet corn pollen percent*
Arginine	5.3	4.7
Histidine	2.5	1.5
Isoleucine	5.1	4.7
Leucine	7.1	5.6
Lysine	6.4	5.7
Methionine	1.9	1.7
Phenylalanine	4.1	3.5
Threonine	4.1	4.6
Tryptophane	1.4	1.6
Valine	5.8	6.0

Other constituents of pollen include:

Constituent	*Amount Per cent*
Fats	1.3 -19.7
Mineral (ash):	
Calcium	1.00-15.00
Chlorine	0.60- 0.90
Copper	0.05- 0.08
Iron	0.01-12.00
Magnesium	1.00-12.00
Phosphorus	0.60-21.60
Potassium	20.00-45.00
Silicon	2.00-10.40
Sulfur	0.80- 1.60

	Micrograms per gram identified
Vitamins:	
Ascorbic acid	131.00-721.00
Biotin	.19- .73
D	.20- .60
E	.00- .32
Folic acid	3.40- 6.80
Inositol	.30- 31.30
Nicotinic acid	37.40-107.70
Pantothenic acid	3.80- 28.70
Pyridoxine	2.80- 9.70
Riboflavin	4.70- 17.10
Thiamine	1.10- 11.60

sumption and digestion of pollen by adult bees are essential, since they can only produce brood food from pollen that they have eaten. This brood food, or royal jelly, is fed to all larvae the first 3 days of life and to the queen bee throughout her larval and adult life. Royal jelly has the following approximate chemical composition (in percent): water 66, dry matter 34; of the latter, carbohydrate 13, protein 12, fat 5, ash 1, and undetermined matter including vitamins, enzymes, and coenzymes 3.

Bee-collected pollens are comparatively rich in the carbohydrates. Reducing sugars range from 15 to 43 percent, with an average of about 29 percent. The glucose, fructose, sucrose, raffinose, and stachyose content is not significant, although the bees apparently utilize those that are available. Corn pollen, for example, has a high starch content. The pollen shell is not utilized by bees, but is eliminated with the feces after the internal matter has been removed by digestive processes.

The protein value of pollen varies from 10 to 36 percent. The amino acid content of average pollen and sweet corn pollen with a crude protein of 26.3 and 26.9 per cent, respectively, is shown in Table 1.

All the amino acids 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 pollens consumed.

Bees also occasionally collect spores and store them as pollen. Although spores can be utilized as a proteinaceous food, they do not stimulate brood rearing and are generally considered a poor substitute for pollen.

ARTIFICIAL DIETS

The beekeeper can supplement the diet of nectar or honey with sucrose. This is usually mixed with about an equal amount of water and fed as sirup.

There is no substitute for pollen. Various materials, including brewer's yeast, soybean flour, dry skim milk, and egg albumin, mixed with honey or sugar water, have been fed to bees, but the colony stimulation is minor compared to that derived from fresh pollen. The addition of dried pollen trapped from colonies earlier increases the stimulation slightly.

The two most commonly used artificial diets are the pollen supplement diet and the pollen substitute diet. Their composition is as follows:

Materials	*Percent*
Pollen supplement:	
Sugar-water (2 parts sugar to 1 part water by weight)	67
Pollen-soy mix (1 part fresh dry pollen to 3 parts soybean flour by weight)	33
Pollen substitute (dry mix):	
Soybean flour	20
Casein	30
Brewer's yeast	20
Dry skim milk	20
Dried egg yolk	10

Few problems facing the apiculture industry today require immediate research attention as much as the development of an artificial or chemically defined diet for honey bees as a substitute food for pollen. Work on nutrition and physiology of the honey bee may soon lead to an artificial diet for bees.