BEE NUTRITION AND POLLEN SUBSTITUTES[1)]

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Excellent detailed reviews of this subject are given in the works of DeGroot (1955), Maurizio (1954), Chauvin (1962) and Wahl (1963). In this talk I will discuss only the role of pollen in the economy of the hive as it is related to the growth and development of adult bees in general and describe the work on pollen substitutes done by me during the past thirty years, for the most part, at the University of Minnesota.

Under normal conditions in the hive honey bees consume honey and pollen. The latter supplies them with proteins, fats, minerals, and vitamins, the substances which apparently are required by all higher animals. What does happen in a normal colony to the bees emerging from the cells? Do they grow? The growth of young animals is characterized, among other factors, by an increase in the proteinaceous materials of their bodies. The increase in protein therefore, may be regarded as constituting a more accurate measure of growth in the narrower sense than mere increase in weight. In other words, if one determines successively the total nitrogen content of the body of the experimental animals, one can judge whether growth is occurring.

Already Strauss (1911) indicated that flying bees have more nitrogen in their bodies than emerging bees. However, for his analyses Strauss used whole bees with the digestive tract intact and the age of the flying bees was also unknown. Haydak (1933, 1934) analyzed separately the changes in the weight and the nitrogen content of the heads, thoraces and abdomens (without digestive tracts) of bees on consecutive days of their life in a normal colony. These analyses demonstrated that there was 92.6% increase in the nitrogen content of the heads, 76% increase in abdomens and 37.5% in the thoraces of 5 day old bees as compared with the newly emerged ones. This indicates that emerging bees must grow to become adults.

To what an extent does pollen contribute to this development? Haydak (1937) established two colonies of bees which have never eaten pollen. One of the colonies received combs with bee bread, the other was hived on empty combs and offered sugar solution only. The activity of the bees in the pollen fed colony was normal in every respect. The bees grew normally, reared brood and produced normal bees. At the start the bees in the sugar-fed colony behaved normally, but their mortality was considerably greater (59.9% during 21 day period) than that in the pollen-fed colony (12.7%). Toward the end of the experiment the bees in the sugar-fed colony exhibited a marked lack of vitality, sitting motionlessy on the combs; they did not pay any attention to their queen and when they tried to fly they also did not show the normal strength. At no time did they rear brood. In 59 days on sugar diet they lost 30% of their dry weight and 29.9% of their nitrogen. When, however, in another case, a colony which was established in the same way and kept on sugar diet for 30 days was given a comb with honey and pollen, the bees increased their weight and nitrogen content to normal levels, started brood rearing and the resulting emerging bees compared favorably in their weight and the nitrogen content with those reared in the control colony. This demonstrates the importance of pollen in the life of bees and also the fact that emerging bees which had lived for an extended period of time on pure carbohydrate diet can increase their weight and the nitrogen content to normal levels and can rear brood normally. This fact is very important biologically, since such pollen starvation of emerging bees may occur in a normal colony during the winter or in other periods of pollen shortage. Such bees, after receiving supply of pollen will become useful members of the bee colony.

The question arises what role does pollen play in the life of adult, already developed, honey bees? To gain this information a colony was made of emerging bees hived on combs having adequate supply of honey and pollen. The bees developed their bodies and started brood rearing. About a week after the first sealed brood cell was noticed the bees were transferred to a new cage and hived on newly built combs containing neither honey nor pollen. Sugar solution and water was given them ad labium. The queen laid eggs and the bees started to feed the hatched larvae in a usual manner. However, the normal nursing activity continued for one week only. All larvae fed after that period were unable to reach maturity. Ten days after the first sealed cells were observed the comb was removed from the colony and placed in an incubator. The weight and the nitrogen content of emerged bees was determined.

During the actual feeding period the nurse bees lost nitrogen from their bodies, the greatest loss (11%) being in the abdomens. The nitrogen content of the emerging bees was also lower, notably in the abdomens, being 18.9% less than that of the controls. This signifies that adult bees can rear brood when fed pure carbohydrate diet, but for a relatively short period of time. For the production of the larvae food they use materials from their own body tissues.

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This colony lived on sugar diet for 189 days, the last bees analyzed being 236 days old. During the protein starvation diet the bees lost 33.7% of their weight and 22.2% of the nitrogen. The greatest loss was in the abdomens, being 72.5% of the weight and 44.7% of the nitrogen content. These experiments demonstrate that pollen plays a very important role in the life of a bee colony.

It is a known fact that there occurs shortage of pollen in the hives which in some localities is very acute. To help the bees at such times beekeepers offered them various food and their combinations. In the past, before I started my work on pollen substitutes, there were several attempts to find value of various foods in the nutrition of honeybee. However, most of the investigators were using the bees of unknown age and were following only one of two criteria in their evaluations.

The suitability of any food in the nutrition of higher animals is determined by feeding it to young experimental individuals which are kept under controlled conditions. The changes in the weight or the size of these animals are recorded, general health is observed, and their general activity is noted. In addition the quality and quantity of the offspring is determined. Therefore in his initial studies of pollen substitutes Haydak (1993) decided to judge the suitability of any nutrient as a food for bees by feeding it, under controlled conditions, to young bees which had never eaten pollen and observing the following data: 1) the changes in weight and the nitrogen content; 2) the mortality of bees; 3) the quality of the reared brood; 4) the quantity of the reared brood; 5) building activity of the experimental colonies. Since it was established that only those bees which had their bodies developed normally could rear brood, in the later experiments only mortality and the quantity of reared brood were followed.

The experimental colonies were formed of 700-800 grams of emerging bees which have never eaten pollen. They were kept in small three-frame nuclei on pollen-free combs in isolated cages in laboratory. Fertile queens were introduced shortly after the experiments started. Tested foods were mixed with honey and the paste was distributed to the cells of the combs. After about a week time the food was given in candy form on top of the frames.

Sugar solution and water were supplied *ad libitum*. Ten days after the first sealed brood cells were observed the number of the sealed brood cells and the open larvae was counted. Next counts followed in the ten-day periods.

Over 30 various foods and their combinations were tested. Finally a mixture of soybean flour and dried brewers' yeast or soybean flour and dry skim milk in proportion 4:1 was recommended. The results are presented in table I.

Table 1

COMPARISON OF POLLEN SUBSTITUTE AND POLLEN SUPPLEMENT

Supplement to soybean flour	Strength of colonies gm.	Mortality per cent.	Brood rearing						Total sealed br. c.	Brood prod. Index
			I Period		II Per.		III Per.			
			Sealed cells No.	Unseal larvae No.	S.c No..	U.1. No.	S.c. No.	U.1. No.	No.	No.
DSM* (4:1)	1.660	27,5	2.334	95	116	1.317	106	678	2.556	1,0
Pollen (4:1)	1.645	29,6	1.559	315	516	954	399	135	2.474	1,0
DBY (9:1)	1.686	31,0	2.011	595	1.485	1.485	1.383	260	4.879	2,0
DBY/DEY (9:1:1/2)	1.654	28,1	3.017	1.161	1.015	1.015	1.325	897	5.357	2,28

*DSM, dried skim milk; DBY, dried brewer's yeast; DEY, dried egg yolk; SBF, soybean flour; CC commercial casein.

From Table 1 it is evident that pollen substitutes containing soybean flour and dry skim milk were equal and that those containing soybean flour and dried brewers' yeast, alone or fortified with dried egg yolk, were superior to pollen supplement in which one year old dried pollen from pollen trap was used.

The next task was to compare the best pollen substitute with beebread available to the bees in the hive. The results are presented in Table 2.

Table 2

COMPARISON OF POLLEN SUBSTITUTE AND BEEBREAD

Diet	Strength of Colony g.	Mortality per cent	Protein in the diet		Brood rearing						Total No. sealed brood cells No.	Brood prod. Index No.
					I Period		II Period		III Period			
			Paste per cent	Candy per cent	Sealed cells No.	Unsealed larvae No.	Sealed cells No.	Unsealed larvae No.	Sealed cells No.	Unsealed larvae No.		
SBF:DBY* (3:1)	1.702	19,3	7,0	14,0	954	346	430	447	598	301	1.982	1,0
SBF:DBY (3:1)/10% Pollen	1.739	17,0	7,0	13,9	2.204	357	592	948	774	298	3.470	1,8
Beebread in combs	1.700	14,0	2,7	20,0	8.502	1.890	2.518	3.064	6.831	3.521	17.851	9,0

* For explanation of symbols see Table 1

Table 3

COMPARISON OF FORTIFIED POLLEN SUBSTITUTES

Diet	Strength of Colony gm.	Mortality %	Protein in the diet Paste %	Protein in the diet Candy %	Brood rearing								Total No. sealed brood cells No.	Brood Prod. Index No.
					I st Period		II nd Period		III rd Period		IV th Period			
					Sealed cells . No.	Unsealed larvae No.	Sealed cells No.	Unsealed larvae No	Sealed No.	Unsealed No.	Sealed cells No.	Unsealed larvae No.		
SBF :DBY: DEY* (31/2:1:1:1/2)	765	16,9	7,4	15,5	1.489	228	386	404	545	228	337	182	2.557	1,0
SBF: DBY: DSM: DEY (21/2:1:1:1/2)	771	19,3	6,4	13,9	2.395	890	685	530	658	365	813	187	4.551	1,8
SBF:CC: DBY: DSM: DEY (1:1 - 1/2:1:/:1:2)	777	16,1	8,3	22,1	3.408	1.173	1.223	1.124	414	1.393	619	768	5.664	2,1
CC:DBY:D SM:DEY (2- 1/2:1:1:1/2)	790	15,7	9,9	30,9	2.811	851	1.054	474	570	962	1.725	419	6.160	2,3
Pollen (2 yr..old)	779	24,6	2,9	19,4	978	229	60	219	72	115	-	-	410	-

\+ For explanation of symbols see Table I

From Table 2 it appears that beebread is vastly superior to pollen substitute not fortified with dried egg yolk. Addition of 10% of one year old pollen to the substitute increased the nutritive value of the diet.

There was also a possibility that the proteins of soybean flour and dried brewers' yeast was inferior to the proteins of pollen as food for the honeybees. Therefore, it was decided to add milk proteins in the form of dried skim milk. On the other hand, the protein content of pollen substitute paste was only 6% and that of the candy only about 12%, while the pollen collected by bees, on an average, contained close to 20%. Therefore, to increase the protein content of the pollen substitute, finally ground commercial casein was added to the latter. The results are presented in Table 3.

Table 3 shows that a simple addition of skim milk solids considerably improved the diet. An increase in the protein content of the diet gave still better results. Two year old pollen, from pollen traps, had an inferior nutritive value.

In the next series of experiments the foods which gave the best results were compared with pollen collected by the bees in the yard at the time of the experiments (Table 4).

Table 4

COMPARISON OF POLLEN AND POLLEN SUBSTITUTES

Diet	Strength of Colony	Mortality per cent	Protein in the diet Paste Candy Per cent		Brood rearing				Total No. sealed brood cells No.	Brood production index No.
					I Period Sealed cells No.	I Period Unsealed larvae No.	II Period Sealed cells No.	II Period Unsealed larvae No.		
SBF: DBY: DSM: DEY +(2-1/2:1:1:1/2)	1.493	9,7	6,3	12,5	4.942	1.633	1.294	3.986	6.236	1,0
SBF:CC: DBY: DSM: DEY (1:1 1/2:1:1/2)	1.481	7,3	8,5	21,2	7.295	2.345	2.859	2.591	10.154	1,6
CC: DBY:DSM: DEY (21/2:1:1: 1/2)	1.502	9,8	9,9	28,1	6.580	1.688	1.510	2.038	8.090	1,3
Pollen (fresh, dried)	1.477	9,2	5,0	12,7	7.933	2.046	1.432	4.214	9.365	1,5

+ For explanation of symbols see Table I

From Table 4 it is evident that pollen substitute supplemented with commercial casein was about of equal nutritional value to the pollen used simultaneously by the colonies in the apiary. The food was consumed well in all cases. However, the consumption of pollen was more than twice than that of the pollen substitute.

On the basis of these results a mixture of soybean flour, dried brewer's yeast and dry skim milk in proportion 3:1:1 was recommended for use in beekeeping practice. This mixture can be fed in a powder form in the open or in the form of candy in the hive. To prepare candy the dry mixture should be incorporated into sugar solution. To make the sugar solution dissolve 2 parts of granulated sugar in 1 part of hot water by volume. Pour one quart of cold sugar syrup into one pound dry pollen substitute and mix thoroughly. To prevent drying cover the candy with waxed paper. Pat the paper down so it adheres to the surface. Allow this to stand over night so the liquid penetrates the dry food particles. The consistency of the cake should allow the candy to stay on top frame bars without running down. You can modify the formula to make the proper consistency of the cake. With a wide scraping knife or a hive tool spread the candy over the waxed paper in a layer about one quarter to one half inch thick. Open the hive and smoke away the bees. Then place the cake directly over the cluster on the top bars so that the waxed paper is on top. Begin giving about a pound of candy to each colony. Repeat every 7 to 10 days

It is advisable, however, before placing the candy in the hives to offer the dry pollen substitutes outside first, so that the nurse bees in the brood nest become familiar with the strange odor and the taste of the food when it is deposited as a pollen substitute beebread in the cells. After a couple of day feeding start giving them pollen substitute as candy. The bees will consume it eagerly.

This formula of pollen substitute is used widely throughout the United States to a great satisfaction of the beekeepers..

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