

Value of Pollen Substitutes for Brood Rearing of Honeybees¹

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In previous publications (Haydak & Tanquary 1943) the use of a mixture consisting of four parts of soybean flour and one part of dry skim milk by weight was recommended for feeding of bees when reserves of pollen are not present in the hives and a new supply is not available in nature. Although the controlled experiments showed that dried yeast was superior to dry skim milk as a food for bees, the latter was selected because of its inexpensiveness and general availability. As the war has caused a shortage of dry skim milk it was deemed necessary to investigate the efficiency of some other more available food materials, namely dried brewers' yeast, dried egg yolk and pollen collected by bees as supplements to soybean flour.

The procedure in these experiments did not appreciably differ from that described previously (Haydak & Tanquary 1943). However, in order to evaluate the influence of tested foods on the brood rearing activity of bees more thoroughly, the experiment was carried for three consecutive ten-day periods instead of one as was done in the previous tests. The appearance of the first sealed cell in each colony was noted and ten days later the total number of sealed cells and that of the unsealed larvae were ascertained. Then each colony was supplied with a cake made of 200 grams honey and 70 grams dry pollen substitute. The counting of the total brood was later repeated at the end of each 10-day period.

Soybean flour produced by the expeller method and containing about 7 per cent fat was used. Two types of dried brewers' yeast were tested: "Medicinal" yeast, used for human consumption, and "animal" yeast utilized in animal feeding. Dried egg yolk produced by the spray process served for supplementing the soybean flour—"medicinal" dried brewers' yeast mixture. Pollen collected by the bees at the University apiary during the

month of August of the previous year was used for mixing with soybean flour. The experiment was started by the middle of July 1944. Two colonies made of about 10-hour old bees which had never eaten any pollen were employed for testing each of the foods. Dry skim milk, "animal" dried brewers' yeast and pollen were mixed with soybean flour in the proportion of one to four by weight. "Medicinal" yeast-soybean flour proportion was 1:9 by weight. Five per cent of dried egg yolk was added to medicinal yeast-soybean flour mixture. Because it was necessary to soak the pollen pellets in water before mixing with soybean flour and honey, the paste for distribution to the cells of the combs for feeding bees during the first 10-day period was made as follows: 35 grams dry pollen substitute mixture, 20 cc. water, and 200 grams honey.

The strength of each colony at the beginning of each 10-day period was established by subtracting the weight of dead bees from the original weight of bees used in establishing the nucleus. This was done in order to ascertain to what extent the strength of the colonies would be correlated with the variations in the results obtained. The queens added to the nuclei were all good layers, forming compact brood nests in the colonies from which they were taken out.

The indices of food efficiency were obtained by assigning one point to the food giving the lowest average brood production in each category (sealed and unsealed larvae) and dividing by this lowest average the averages of the brood counts in the colonies supplied with other foods. The sum of points for sealed and unsealed brood gave the index for each ten-day period; the sum of indices for the three periods gave the total index of food efficiency.

The results of the experiment are presented in Table 1. From the table it is evident that the strength of the colonies used in the experiment may be considered to be about equal. Certainly slight differences in the weight of the initial population did not influence the outcome of the feeding in

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Table 1.—General results with feeding pollen substitutes.

SUPPLEMENT TO SOYBEAN FLOUR	STRENGTH OF COLONIES			MORTALITY	I PERIOD		II PERIOD		III PERIOD		STRENGTH AT THE BEGINNING OF II PERIOD	STRENGTH AT THE BEGINNING OF III PERIOD	INDEX OF FOOD EFFICIENCY			TOTAL INDEX OF FOOD EFFICIENCY
	gm.	gm.	per cent		Sealed Cells No.	Un-sealed Larvae No.	Sealed Cells No.	Un-sealed Larvae No.	Sealed Cells No.	Un-sealed Larvae No.			I Period	II Period	III Period	
Skim milk powder	835	215		1297	95	60	588	71	341	740	509					
	825	245		1077	0	50	729	35	337	751	413					
	Average	830	229	27.6	1167	48	58	659	53	339	736	461	2.5	2.4	6.0	10.9
Pollen	820	218		636	313	181	26	21	12	725	550					
	825	270		925	2	335	928	378	123	708	501					
	Average	823	244	29.0	780	157	258	477	200	68	717	526	4.3	5.4	5.0	14.7
"Medicinal" Dried Brewers' Yeast	849	232		609	236	936	333	610	155	684	487					
	837	291		1402	359	549	898	773	105	659	412					
	Average	843	261	31.0	1005	298	743	716	692	130	672	450	7.5	14.3	15.1	36.9
"Animal" Dried Brewers' Yeast	857	285		1042	567	466	914	591	150	690	508					
	862	238		1039	495	153	835	916	097	757	585					
	Average	859	262	30.5	1041	431	310	885	754	424	724	546	10.3	7.1	20.4	37.8
"Medicinal" Dried Brewers' Yeast and Dried Egg Yolk	840	215		1402	258	336	1585	883	294	709	511					
	814	249		1615	903	679	1016	442	603	641	491					
	Average	827	232	28.0	1509	581	508	1201	663	440	675	501	14.0	11.3	19.1	44.4

each group because some of the nuclei containing less bees produced more brood. The same can be said about the strength of the colonies at the beginning of the second and the third 10-day periods, even when the increase in the strength of the colonies due to the addition of the newly emerged bees produced by respective colonies is taken into consideration. Mortality in the experimental colonies was about the same proportion.

All the colonies used in the experiment reared brood. However, throughout the duration of the test those nuclei which were fed dried brewers' yeast mixture with or without an addition of dried egg yolk showed a better performance than those fed either dry skim milk or pollen formulas. It is of interest to note that there was a very small number of unsealed larvae in the colonies fed dried skim milk at the end of the first 10-day period, and the larvae present ranged from hatched to those one and a half days old. Although there were more unsealed larvae during the last two periods, only a few of the larvae were 3 to 6 days old (19 total), the age of the remainder being less than 3 days. The last count of brood showed the age of the majority of the larvae to be from hatched to about 1 day old,

only a few being two and a half days old. The number of sealed cells in the second and the third periods was also very low. One of the possible causes of such results may have been the low consumption of the dry skim milk supplemented cakes, actually the lowest of all the experimental colonies. The fact that the bees of the initial population developed their bodies normally and produced a considerable amount of normal brood during the first ten-day period would support this assumption.

Pollen-fed colonies showed a better performance. Although the age of the unsealed larvae at the end of the first period ranged in both colonies only from hatched to two and one half days old, the brood rearing in one of the colonies in the second period was normal, unsealed larvae being represented by all ages as it occurs in a normal outside colony. The other pollen-fed colony behaved like those fed dried skim milk. At the end of the third period both pollen-fed colonies had a majority of hatched to day-old larvae and only very few older larvae were present in the colony which reared brood normally in the second period. As a matter of fact, the colony with the better performance had fewer original bees at the beginning of

Table 2.—Total brood rearing activity of experimental colonies.

SUPPLEMENT TO SOYBEAN FLOUR	TOTAL SEALED CELLS No.	TOTAL UNSEALED LARVAE No.	TOTAL BROOD NO. OF CELLS	BROOD PRODUCTION INDEX	
				Index for Sealed Cells	Total Index
Skim milk powder—	1278	1046	2324	1.0	1.2
Pollen	1238	702	1940	1.0	1.0
"Medicinal" Dried Brewers' Yeast	2440	1144	3584	2.0	1.8
"Animal" Dried Brewers' Yeast	2105	1740	3845	1.7	2.0
"Medicinal" Dried Brewers' Yeast and Dried Egg Yolk	2680	2231	4911	2.2	2.5

the second and the third periods. Pollen-supplemented cakes were consumed satisfactorily.

The brood rearing in the colonies fed both kinds of dried brewers' yeast with or without an addition of dried egg yolk was about normal. This is evident from a comparison of the number of unsealed larvae with the number of sealed cells in consecutive periods. In no case was there so great a difference as in the colonies fed dried skim milk or pollen. The consumption of the dried brewers' yeast supplemented cakes, with or without an addition of dried egg yolk, was satisfactory.

A number of dead unsealed larvae was observed in every experimental colony during the first period, the largest number being in the colonies fed pollen and "animal" dried yeast, the lowest in those fed "medicinal" dried yeast and dry skim milk. This phenomenon gradually disappeared and no dead larvae were present in the third period. Also some pupae were removed by the bees from sealed cells. This happened in all the colonies under experiment.

Periodical microscopic examinations did not show any spores of *Nosema* or other diseases of adult bees.

In order to evaluate the total brood production in each of the food groups of the experimental colonies, the total numbers of sealed cells, those with unsealed larvae and the combined number of sealed and unsealed larvae were computed for the whole experimental period in each group of colonies used in the test (Table 2).

It is evident from the table that the difference in the results is not as great as when the brood rearing activity is computed separately according to the periods and the age of the brood. The total brood production in the colonies fed dried skim milk and the pollen in addition to soybean

flour was about the same. The colonies fed dried brewers' yeast with or without dried egg yolk supplement, produced about twice as much brood, no matter whether we count only sealed cells or total brood. The indices for open brood were not computed because many of the larvae in the colonies fed dried skim milk and, to a lesser degree, in those fed pollen supplement never reached the sealing stage.

After the end of the experiment the cages with the colonies used for testing dried animal yeast and dried egg yolk cakes were placed in a greenhouse. The colonies were somewhat strengthened by an addition of bees from the "medicinal" dried yeast-fed nuclei, and were given "animal" dried yeast-soybean flour cakes *ad libitum*. Periodical brood counts were made to establish how long the bees fed a pollen substitute will continue their brood rearing activity. The colonies gradually weakened but on November 1 all of them still had sealed cells and unsealed larvae of all stadia. Pollen substitute cakes were consumed well. However, on November 22 only one, the strongest of the colonies, had 39 sealed cells and 17 larvae in all stadia present. The brood was normal and healthy in appearance. The rest of the colonies stopped their brood rearing activity, only a few bees and a queen remaining in each hive. The fact that the bees could rear brood normally for four months while given dried brewers' yeast-soybean flour cakes in confinement proves without any doubt that the mixture is an effective food for bees.

The question arises why soybean flour alone is not an effective food for bees. Heat-treated soybean oil meal or flour is considered to be an excellent protein source for many domestic animals (Barnes & Maack, 1943). On the levels that soy-

bean flour is fed to bees there is apparently no danger of deficiency of any amino-acids which are known to be essential for the normal development of higher animals. Under natural conditions pollen alone supplies all the essential factors necessary for the proper development of bee population. Although pollens have a high nutritive value, nevertheless experiments conducted by Vivino and Palmer (1944) with feeding ether extracted mixed pollens to rats indicated that pollen proteins are probably deficient in tryptophane and methionine (or cystine). This

preparing pollen substitutes are compared (Table 3).

From table 3 it is evident that soybean flour is significantly deficient in riboflavin and an addition of any of the supplements used in the experiment increases the riboflavin value of the diet of bees. Insects are known to require riboflavin for their normal development (Fraenkel & Blewett 1943). Whether it is the sole factor in soybean flour which makes it inadequate for the normal development of bees remains to be seen.

SUMMARY.—Queenright colonies of

Table 3.—Vitamin content of foods per 100 grams (fresh basis)

FOODS	THIAMINE MICROGRAMS	RIBOFLAVIN MICROGRAMS	NIACIN MICROGRAMS	RIBOFLAVIN PER 100 GM. OF CORRESPONDING POLLEN SUBSTITUTE		REFERENCE
					MICROGRAMS	
Soybean flour	1263	320	3400			} Barnes & } Maack 1943
Dried skim milk	380	2400	1000	736		
Pollen	928	1850	20000	626		} Vivino & } Palmer 1944
"Medicinal" Dried Brewers' Yeast	10000	6000	60000	888		
Animal Dried Brewers' Yeast	9000	4000	—	1058		} Average from } analyses of } several com- } mercial com- } panies

finding would tend to support the assumption that it is not the protein of soybeans which is the limiting factor in the normal development of bee population when soybean flour alone is fed to bees.

Mineral (2.7 to 6.0 per cent) and fat (5 to 7 per cent) contents of soybean flours recommended for preparing pollen substitutes is high enough to justify the assumption that those constituents are supplied in the amounts sufficient for the proper development of bees. (In comparison natural pollens have 1.4 to 4.4 per cent fat and 2.2 to 2.9 per cent mineral content.) However an entirely different picture is obtained when the vitamin content of pollen and the materials used in

about equal strength composed of emerged bees which had never eaten pollen were kept in confinement and fed soybean flour supplemented with one year old pollen, dry skim milk, dried brewers' yeast and dried egg yolk. The mortality of the experimental bees and their brood rearing activity was noted. The experiment lasted for three consecutive 10-day periods. The mortality in all the experimental colonies was about the same. Colonies fed soybean flour supplemented with dried brewers' yeast alone or with an addition of dried egg yolk produced about twice as much brood as those fed soybean flour supplemented with either dry skim milk or pollen.—5-5-45.

LITERATURE CITED

- Barnes, R. H., and J. E. Maack. 1943. "Review of the literature on the nutritive value of soybeans." The Hormel Institute of the University of Minnesota, pp. 63.
- Fraenkel, G. and M. Blewett. 1943. "The vitamin B-complex requirements of several insects." *Biochem. Jour.* 37: 686-92.
- Haydak, M. H., and M. C. Tanquary. 1943. "Pollen and pollen substitutes in the nutrition of the honeybee." University of Minnesota Agr. Exp. Sta. Tech. Bull. 160, pp. 23.
- Vivino, A. E., and L. S. Palmer. 1944. The chemical composition and nutritional value of pollens collected by bees. *Arch. Biochem.* 4: 129-36.