PALATABILITY AND CONSUMPTION OF PATTY-FORMULATED POLLEN AND POLLEN SUBSTITUTES AND THEIR EFFECTS ON HONEYBEE COLONY PERFORMANCE

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S u m m a r y

Honeybee health is of grave concern to the apicultural industry and to agriculture generally. The quality of diet influences colony health and strength, especially for colonies preparing for over-wintering or starting population build-up in early spring. The palatability of four feeds to honeybees and their effects on colony performance were assessed by three independent feeding experiments made in late fall and early spring with experimental and commercial honeybee colonies in southern Ontario, Canada. The colonies were supplied with patties of bee-collected pollen, Bee-Pro®, TLS Bee food, or Feedbee® or no supplementary feed as the control. The first trial in late fall 2003 used 21 equalized experimental colonies receiving Feedbee®, pollen, or Bee-Pro® for 33 days. The feed consumption for Feedbee® and pollen were both higher than for Bee-Pro®. The second trial used 24 equalized experimental colonies in early spring 2004 for 30 days. Then, feed consumption for Feedbee® and pollen were again both higher than for Bee-Pro®. Also measured in these trials were capped brood area, bee population, and honey production. Results for all three response variables were similar between Feedbee® and pollen, and significantly higher than Bee-Pro® and controls. The third trial used 33 commercially operated colonies (in 2 independent apiaries) that received Feedbee®, Bee-Pro® and TLS Bee food in fall 2004 for 30 days. The results showed Feedbee® had greater consumption than the other two feeds. In all three experiments and for all parameters there were no significant differences between feeding Feedbee® and pollen. The results indicate the potential of Feedbee® for improving colony maintenance and health, build up and production during a shortage or absence of natural pollen.

Keywords: pollen, substitute diet, bees, consumption, brood, population, honey production.

INTRODUCTION

Honeybee health is now of grave concern to the apicultural industry and to agriculture generally. The quality of diet influences colony health and strength, especially for colonies preparing for over-wintering and starting population build up in the early spring. Dietary problems have been one of several factors linked to declines in honeybee health and populations in North American and Europe. Honeybees, like any other animal, have specific nutritional requirements. Necessary protein, carbohydrates, fats, vitamins and minerals are available in their natural foods, which are pollen and nectar. Absence, shortage or even poor quality of pollen results in stunted growth, inferior weight gain of young bees, reduced longevity and poor development of hypopharyngeal glands, leading to insufficient royal jelly production to support normal growth and development of larvae, and normal egg production by the queen (Hays, 1984; Zaytoon et al., 1988). These effects can result in poor colony development and production.

During the shortage or complete absence of pollen (particularly early in the season), or in the presence of only poor quality pollen, beekeepers often feed colonies of honeybees with either pollen substitute (with no pollen) or supplement (with pollen). Ideally, these are materials that provide required nutrients to the bees. There are disadvantages to pollen feeding. Beekeepers often do not collect pollen to add to diets, and commercially available pollen is costly. Furthermore, it may be contaminated with various honeybee pathogens (Herbert and Shimanuki, 1980) or may contain toxic pollen (Schmidt et al., 1987). Ideal pollen substitutes would be readily accepted by honeybees year-round, healthful, rich enough to meet all their nutritional requirements, and inexpensive. To develop such ideal diets has been one of the most enduring apicultural research problems (Haydak, 1945; Abdellatif et al.,1971; Wille and Schafer, 1971; Standifer et al.,1973; Doull, 1980; Herbert et al., 1980; Herbert and Shimanuki, 1980; Schmidt et al., 1987; Winston, 1991; Baidya et al., 1993; Zhelyazkova, 1997; Herbert, 2000; Nabors, 2000; Cohen, 2004; van der Steen, 2007; DeGrandi-Hoffman et al., 2008; De Jong et al., 2009; Saffari et al., 2010).

Many materials, including dried egg yolk (Odlum, 1984), powdered skimmed milk (Haydak, 1967; Zaytoon et al., 1988; Rana et al., 1996), meat scraps (cited by Herbert and Shimanuki, 1979), milk products like whey and wheast (Herbert and Shimanuki, 1979), and soy products (Haydak, 1967; Standifer et al., 1978; Kulincervic et al., 1982) have been used as protein sources to substitute for pollen. Chemically, these materials should satisfy the nutritional needs of honeybees, but their efficacies (as measured, for example, by brood production, colony strength and honey production) have been poor when compared with that of pollen (Saffari et al., 2010). A protein source proposed as a substitute for pollen must consider the issues of palatability, nutritional content, nutritional requirements of bees, and efficacy of the proposed materials. Some animal feed ingredients, like soybean products, have been so popular that even after their failure to show great benefit to honeybees (Herbert and Shimanuki, 1979; Kulincervic, 1982; Hays, 1984; Zaytoon et al., 1988; Chhuneja et al., 1992, 1993; Rana et al., 1996; Schmidt and Hanna, 2006; Saffari et al., 2010) investigators and beekeepers advocate their use because they are the most cheaply available feedstuffs. Even so, some newly developed pollen substitutes appear to rival pollen in acceptability and nutritional value to honeybees (Gregory 2006; DeGrandi-Hoffman et al., 2008; De Jong et al., 2009; Saffari et al., 2010).

To be of nutritional value for animals including insects, the diet must comprise various feed ingredients as alternative sources of nutrition similar to their natural food sources, and have proper texture and consistency to be acceptable to the animal (Herbert and Shimanuki, 1979; Schmidt et al., 1987; Wilson et al., 2005; Saffari et al., 2010). Once ingested, the diet must have nutritional values for that particular animal or insect, be free of any toxic chemicals or anti-nutritional factors, have long shelf life in various conditions, be easily available, and be economical (Schmidt et al., 1987; Herbert, 2000; Wilson et al., 2005; Saffari et al., 2010).

The objectives of our research were to assess and compare the efficacies of four feeds (Feedbee®, Bee-Pro®, TLS Bee Food, and bee-collected pollen) when fed to equalized honeybee colonies in patties placed on the top bars inside their hives. The assessments were:

1. The relative acceptability (as an indicator of palatability and consumption) of the four feeds given to honey bees in patty form to both experimental and commercial honeybee colonies.

2. The relative biological efficacy of the four feeds on brood rearing, bee population, and honey production when fed in patty form in comparison with non-fed controls in both experimental and commercial honeybee colonies.

MATERIALS AND METHODS

Our feeding trials were done in late fall 2003, early spring 2004, and late fall 2004. For the first and third trials, we measured only feed consumption in experimental and commercially operated colonies respectively. In the second trial, we measured feed consumption, capped brood area, bee population, and honey production throughout the spring, summer and into fall. The colonies were kept in standard Langstroth wooden hives (497 mm × 420 mm × 241 mm) with 10 drawn combs (448 mm × 232 mm) in each brood chamber, and equalized (see below) before the trials began. The details of the methods for each set of trials are explained below.

Equalization of Experimental Colonies

For experimental patty feeding trials 28 colonies (single story Langstroth hives) were selected at the University of Guelph apiary. All queens in the colonies were 2 year old sisters and all the colonies were located in one apiary. The colonies were given equal areas of capped brood (207.1 cm^2), measured by the Gridding method (Seeley and Mikheyev, 2003; Amir and Peveling, 2004), 3 frames of honey, and 3 to 4 empty drawn combs (depending on the number of brood frames), and an equal weight of bees (1.80 kg ± 0.05). The same equalized colonies were used for both late fall 2003 and early spring 2004 patty feeding trails while no flowers from which the bees could obtain pollen were in bloom. To weigh the colonies (bee population) and their hives a suspended scale was used (Compact Mechanical Salter Suspended Weigher, Model 235 S - Non - T).

Equalization of Commercial Colonies

For the commercial patty feeding trials in late fall 2004, 15 and 18 colonies of approximately the same weight (30 kg) were selected from two apiaries, respectively. The colonies were weighed with a suspended scale (described above). Selected colonies were then given equal amounts of capped brood (equivalent of two full frames) by dividing the total amount of capped brood obtained evenly between the colonies, 3 honey frames and 3 - 4 empty-comb frames (depending on the given number of brood frames). The two apiaries were approximately 10 km apart, located in Fergus (North 43.728° - West 80.402°) and suburban Elora (North 43.680° - West 80.477°) respectively. Both places have similar climatic conditions. The colonies received Feedbee®, Bee-Pro®, or TLS Bee food in patty form for 30 days. The extent of colony manipulation for equalization of commercial colonies was limited by practical restrictions from the beekeepers.

Patty Preparation

Patties were made by mixing powdered feeds (Feedbee®, Bee-Pro®, pollen, and TLS Bee food) with sugar syrup (60% (w/w) sugar/water concentration) as is commonly used for honeybees (Standifer et al., 1978). Mixtures of different feeds and syrup were prepared separately and thoroughly in a dough maker (Hobart dough mixer, model A200) to make a smooth patty. The patties were wrapped with kitchen wax paper to prevent rapid moisture loss. Patties were 1 cm thick and 15 - 20 cm in diameter, and weighed 500 g (Optiscan Stathmos AB scale).

Top Bar Patty Feeding

The wrapped patties were given few cuts of the wax paper on both sides, and then placed on the top bars inside the experimental and commercial hives so they were immediately and easily accessible to the bees. The patties were checked every 2 - 4 days. The patties were replaced with newly prepared wrapped patties as soon as any one of the colonies completely consumed its given patty.

Preparing Experimental Colonies for Late Fall 2003 Patty Feeding

In this trial, 21 equalized colonies (single story Langstroth hives) were divided into 3 experimental groups located in the University of Guelph experimental apiary. Each group was assigned only one of the three feeds (Feedbee®, Bee-Pro®, or pollen) in patty form. This trial was made after floral pollen sources in the field were finished in late fall 2003 for 33 days while feed consumption was measured.

Preparing Experimental Colonies for Early Spring 2004 Patty Feeding

In this trial, 24 equalized colonies (single story Langstroth hives) were divided into 4 experimental groups located in the University of Guelph experimental bee yard. Three groups received only one of the three feeds (Feedbee®, Bee-Pro®, or pollen) in patty form and the control group did not receive any supplemental feed throughout the experiment. The feeding trial was made in early spring 2004 for a period of 30 days before floral pollen was available in the field.

Preparing Commercial Colonies for Late Fall 2004 Patty Feeding

In this trial, the equalized colonies in each commercial apiary were divided into three equal groups (15 total in the first apiary, 18 total in the second apiary). Each group was assigned one of the three feeds (Feedbee®, Bee-Pro®, or TLS Bee Food), and the feed was supplied in patty form ad libitum for 30 days.

Measuring Bee Populations after Early Spring 2004 Patty Feeding

To measure the mean population of bees in the colonies, at night when all the bees returned to their hives each hive was thoroughly taped closed at the entrance and at any openings that bees could possibly escape through. The hives with bees inside and all the frames were weighed (Compact Mechanical Salter Suspended Weigher, Model 235-6) the next morning (4:00 am), a few hours before sunrise. After sunrise, when the air temperature was around 20ºC, the hives were emptied of bees by shaking all the bees into another box; the empty hives (without bees) were then weighed individually. The weight of the population of bees in each colony was then determined by difference between the full and empty hive. Hive weights and data collection on bee population was carried out in the three months of April, May, and June.

Measuring Capped Brood Area after Early Spring 2004 Patty Feeding

To measure the seasonal course of brood production, the brood frames, without bees, from each hive were photographed (both sides) with a digital camera (Nikon Coolpix 995®). At the same time, the hives were emptied of bees and the bees removed were weighed. In total, 650 pictures were prepared from all brood frames over the three intervals. These pictures were downloaded on computer and the capped brood areas were measured by Photoshop 6.0 following the methods of Knopp et al. (2006).

Measuring Honey Yield after Early Spring 2004 Patty Feeding

To measure the amount of honey produced by each colony, all the empty wooden Langstroth honey supers (510 mm x 423 mm x 144.5 mm), each with 9 wooden and plastic drawn combs (136.5 mm), were marked and weighed with a mechanical platform scale (Detecto Platform Scale, Model 85F-100P). Then, they were added to the hives. The marked supers with honey were weighed again at the time of honey harvest and the weight of honey determined from the difference in the two weights.

Measuring Feed Consumption in Late Fall 2004

The total mass of food added as patties to each hive during the 30 day study period was recorded, and corrected for any unconsumed food remaining at the conclusion of the study.

Statistical Analysis

The experiments used in this study were Complete Randomized Designs (CRD). Total feed consumption, capped brood area, bee population, and honey production were measured and the data used to determine which treatments were significantly different from each other by the General Linear Model Procedure ANOVA and Tukey's Test (SAS version 6.12; SAS Institute; Cary, NC. 1996).

RESULTS

The palatability and efficacy of four feeds on honeybees were assessed by three independent patty feeding experiments carried out with experimental and commercially operated honeybee colonies. The colonies were supplied with either pollen, Bee-Pro®, TLS Bee food, Feedbee® or no supplementary feed. The results of all three experiments supported the superiority of Feedbee® over the other two feeds, and the comparability of Feedbee® to natural bee-collected pollen, in both palatability and efficacy.

Experimental Colonies:

Feed Consumption

Late Fall 2003

The mean feed consumption (g/colony) of Feedbee® was not significantly different from that of pollen, and both were significantly higher ($P<0.05$, $F_{2.18} = 40.5$) than mean consumption of Bee-Pro® (Tab. 1).

Early Spring 2004

The total mean feed consumption for Feedbee® and pollen were not significantly ($P<0.05$) different. Both these values were significantly ($p<0.05$) higher than for Bee-Pro® (Tab. 2).

Capped Brood Area

The capped brood area is presented in cm^2/colony (Tab. 2). The initial capped brood area in all equalized colonies was 207.10 cm^2. The mean capped brood area of colonies treated with Feedbee® and pollen were significantly ($p<0.05$, $F_{3.19} = 21.84$) higher than for colonies fed Bee-Pro® and the control group.

Bee Population

The mean bee population is presented in kg of bees/colony (Tab. 2). The initial bee population was 1.80 ± 0.05 kg/colony. The total mean bee population for colonies fed Feedbee® and pollen were significantly ($P<0.05$, $F_{3.19} = 26.48$) higher than for colonies fed Bee-Pro® and the control group.

Honey production

The mean amount of honey produced by colonies that received Feedbee® and pollen were significantly different ($P<0.05$, $n = 23$, $F_{3.19} = 15.08$) and about double the

Table 1

Total mean feed consumption (g/colony) of 21 experimental honeybee colonies that received Feedbee®, pollen, or Bee-Pro® for 23 days in late fall 2003 patty feeding trial

Treatments	Total mean feed consumption (± *SE*) g/colony
Feedbee®	589 ^{a} ± 23
Pollen	600 ^{a} ± 10
Bee-Pro®	27 ^{b} ± 6
Treatment effect: $F_{2.18} = 40.5$	

Different letters denote a significant statistical difference at p<0.05 by ANOVA and Tukey's test (GLM Process of SAS program)

Table 2

Total feed consumption (mean) (g/colony) in the first month, mean capped brood area in the 3 months of May, June, and July, and bee population (mean) (kg of bees/colony) in the 3 months of May, June, and July, of 23 experimental honeybee colonies that received Feedbee®, pollen, Bee-Pro®, or no-feed (control) in the spring 2004 patty feeding trial

Treatments	Total mean feed consumption (± *SE*) g/colony	Total mean capped brood area (± *SE*) cm^2/colony	Total mean bee weight (± *SE*) kg/colony
Feedbee®	1103 ^{a} ± 51	1338 ^{a} ± 86	3.5 ^{a} ± 0.1
Pollen	1194 ^{a} ± 36	1344 ^{a} ± 130	3.7 ^{a} ± 0.1
Bee-Pro®	295 ^{b} ± 81	578 ^{b} ± 68	2.7 ^{b} ± 0.1
Control	N/A	627 ^{b} ± 52	2.6 ^{b} ± 0.2
Treatment effects:	$F_{3.19} = 118.4$	$F_{3.19} = 21.8$	$F_{3.19} = 6.5$

Different letters within columns denote a significant statistical difference at p<0.05 by Tukey's test (GLM Process of SAS program)

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Table 3

Mean honey yield (kg/colony) of 23 experimental honeybee colonies that received Feedbee®, pollen, Bee-Pro®, or no-feed (control) in the spring 2004 patty feeding trial

Treatments	Total mean honey yield (± *SE*) kg/colony
Feedbee®	71 a ± 5.5
Pollen	71 a ± 6.3
Bee-Pro®	33 b ± 4.4
Control	39 b ± 4.4
Treatment effect: $F_{3.19}$ = 15.1	

Different letters denote a significant statistical difference at p<0.05 by Tukey's test (GLM Process of SAS program)

Table 4

Feed consumption (mean) (g/colony) in two independent yards and total mean feed consumption of 33 (1st yard 15 colonies, 2nd yard 18 colonies) equalized commercial honeybee colonies that received Feedbee®, Bee-Pro®, or TLS Bee food for 30 days in late fall 2004 patty feeding trial

Treatments	Mean Feed consumption g/colony (1st Yard)	Mean Feed consumption g/colony (2nd Yard)	Total mean Feed consumption (± *SE*) g/colony
Feedbee®	1873 a	1921 a	1877 a ± 3
Bee-Pro®	29 b	26 b	27 b ± 5
TLS Bee food	17 b	23 b	20 b ± 2
Treatment effects:			$F_{3.29}$ = 4691.3

Different letters denote a significant statistical difference at p<0.05 by Tukey's test (GLM Process of SAS program)

yields from colonies fed Bee-Pro® and the control group (Tab. 3).

Commercial Colonies

Late fall 2004

The mean consumption of Feedbee® in each independent bee yard and the total mean consumption of Feedbee® was two orders of magnitude greater than the consumption of either BeePro® or TLS Bee Food (Tab. 4).

DISCUSSION

From our three independent patty feeding experiments made on balanced experimental colonies and commercially operated colonies of western honeybees in Ontario in spring or fall, we conclude that soy-based pollen substitutes (Bee-Pro® and TLS Bee Food) are much less accepted than is Feedbee®. Feedbee® and natural, bee-collected pollen were taken by experimental colonies at about the same rates. Thus, we conclude that Feedbee® as a pollen substitute for feeding to honeybees is as acceptable as pollen. The difference in acceptability of Feedbee® or pollen versus soy based pollen substitutes (e.g. Bee-Pro® and TLS Bee Food) is not explained by nutritional value (De Jong et al., 2009) but presumably reflects palatability (Saffari et al., 2010). Although the results of the palatability and take-down trials indicate the acceptability of supplemental natural pollen and Feedbee®, the real test for the nutritional value of a pollen substitute diet for honeybees is that it should result in the same levels of productivity as feeding pollen.

For all experiments and parameters there were no significant differences (p<0.05) in the activities (diet take-down and acceptability) and productivity (capped brood, number of workers present (as weight), and honey production of the experimental and commercially operated colonies provided with Feedbee® or supplemental pollen. The other two diets resulted in significantly less activity and productivity when fed to the colonies under identical situations. Feeding supplemental pollen to honeybee colonies improved their performance, as would be expected, but the similar results obtained from feeding Feedbee® indicate its high potential for improving colony maintenance, build up and production during a shortage of natural pollen.

Most studies have used pollen as the control against which to compare the substitute feed in highly controlled experiments. By and large, pollen is preferred over substitute diets. Gregory (2006) found that FeedBee® was similar to fresh pollen in consumption, and resulted in improved honey bee health (body mass, longevity) when compared to old pollen and to BeePro®. Levels of haemolymph protein, an indicator of the effectiveness of a protein supplement, were also similar in honeybees fed natural pollen, and significantly better than for the other diets. Schmidt and Hanna (2006) found that all pollen substitute diets they tested and reviewed are not readily accepted by honeybees (Feedbee® was not available). It is difficult to make direct and quantifiable comparisons of our results with those of others. Conditions in Ontario are climatically and seasonally unlike those in other studies. Furthermore, few other studies measured the same set of parameters consistently in the same experimental colonies. For example, studies on the USDA Beltsville diets (BBD) used pollen as the control, examined the effects of the diet on brood rearing (Herbert and Shimanuki, 1983), but not on bee populations or honey production. Chhuneja et al. (1993) measured the effect of pollen substitute versus pollen on honey production, but not on the other parameters. The study by DeGrandi-Hoffman et al. (2008) is interesting, but seems not to identify the diets used in their comparative trials.

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ATRAKCYJNOŚĆ SMAKOWA I SPOŻYCIE PYŁKU PODAWANEGO W FORMIE PULPECIKÓW I JEGO SUBSTYTUTÓW ORAZ ICH WPŁYW NA WYDAJNOŚĆ RODZIN PSZCZELICH

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Streszczenie

Zdrowotność pszczół jest bardzo ważna, zarówno dla przemysłu pszczelarskiego, jak i dla całego rolnictwa. Jakość diety wpływa na zdrowie i siłę rodzin, szczególnie rodzin przygotowujących się do zimowli lub podczas wiosennego rozwoju. Dokonano oceny atrakcyjności smakowej czterech rodzajów pokarmu dla pszczół i ich wpływu na rodziny pszczele w trzech niezależnych eksperymentach żywieniowych, przeprowadzonych późną jesienią i wczesną wiosną w pasiekach eksperymentalnych i użytkowych w Ontario w Kanadzie. Rodzinom dostarczono pyłek w formie pulpecików, zebranego przez pszczoły, Bee-Pro®, karmę TLS Bee, lub Feedbee® ; rodziny kontrolne nie otrzymywały pokarmu uzupełniającego. W pierwszym eksperymencie, wykonanym późną jesienią 2003 użyto 21 wyrównanych rodzin eksperymentalnych, które otrzymywały Feedbee®, pyłek lub Bee-Pro® przez 33 dni. Spożycie pokarmu w przypadku Feedbee® i pyłku było wyższe niż Bee-Pro®. W drugim eksperymencie, który wykonano wczesną wiosną 2004 roku, a który trwał 30 dni, użyto 24 wyrównane rodziny eksperymentalne. Wówczas spożycie pokarmu w przypadku Feedbee® i pyłku było również wyższe niż Bee-Pro®. W badaniach tych dokonano również pomiaru powierzchni czerwiu krytego w rodzinach, wielkości populacji pszczół i produkcji miodu. Wyniki dla wszystkich trzech zmiennych były podobne w rodzinach gdzie zastosowano Feedbee® i pyłek, i istotnie wyższe niż dla Bee-Pro® i rodzin kontrolnych. W trzecim eksperymencie użyto 33 rodziny użytkowe (w 2 niezależnych pasiekach), którym przez 30 dni jesienią 2004 roku podawano Feedbee®, Bee-Pro® i TLS Bee. Wyniki pokazały, że spożycie Feedbee® było wyższe niż dwóch pozostałych rodzajów pokarmu. We wszystkich trzech eksperymentach i dla wszystkich parametrów nie zaobserwowano istotnej różnicy między Feedbee® i pyłkiem. Wyniki wskazują na korzystny wpływ pokarmu Feedbee® na poprawę stanu i zdrowia rodzin pszczelich, jak również jej rozwoju i zdolności produkcyjnych w przypadku niedoboru lub braku pyłku naturalnego.

Słowa kluczowe: pyłek, dieta zastępcza, pszczoły, konsumpcja, czerw, populacja, produkcja miodu.