CONSUMPTION OF THREE DRY POLLEN SUBSTITUTES IN COMMERCIAL APIARIES

Abdolreza Saffari[1], Peter G. Kevan[1], James Atkinson[2]

[1]Department of Environmental Biology,
University of Guelph, Guelph, Ontario N1G 2W1, Canada.
e-mail address: pkevan@uoguelph.ca
[2]Department of Animal and Poultry Science,
University of Guelph, Guelph, Ontario N1G 2W1, Canada.

Received

S u m m a r y

The palatability tests were done in commercial apiaries in early spring 2004. In this trial, three different feeds, Feedbee®, TLS Bee Feed and Bee-Pro® were fed to 153 colonies in 12 bee yards for 6 weeks (March 25th - May 6th) in southern Ontario. Two methods of feeding were used: 1) No-choice feeding, where each yard received only one of the three feeds, and 2) Choice feeding, where each yard received all three experimental feeds. The mean feed intake (g/colony/6 weeks) of Feedbee® was 960 g and 883 g for the first and second feeding methods respectively. These amounts were significantly greater ($p>0.05$) than for the other two feeds. The amount of Bee-Pro® consumed (g/colony/6 weeks) in the two feeding methods was 224 g and 106 g and for the TLS Bee Feed, 115 g and 52 g respectively. These results indicate that Feedbee® in powder/dry form is highly palatable to honey bees. The results show that it is well accepted by bees during the shortage or absence of natural pollen.

Keywords: pollen, substitute diet, feed, honey bees, palatability, consumption rate.

INTRODUCTION

The development of a pollen substitute for honey bees has long been an area of interest to the beekeeping industry. The possibility of improving the efficiency of beekeeping by providing proteinaceous feed lies, in part, in the development of an effective pollen substitute to feed the colonies when pollen is scarce (e.g. Zahra and Talal, 2008), especially in preparation for early nectar flows (Skubida et al., 2008). Providing proteinaceous feed to stimulate colony strength would then help, in maximizing honey production and crop pollination, to overcome pesticide damage and resistance to parasites and diseases, and for package-bee production, The key to producing efficient feed for animals, including insects, is obviously through using the most nutritive ingredients with regards to palatability, animal health and overall cost (Wilson et al., 2005; Macdonald et al., 2002; Forbes, 1995). However, even the most nutritionally balanced feed, which contains all the required nutrients, can have no beneficial value if the animals do not ingest it. In other words, the practical value of a feed is critically dependent on its acceptance by the animal (Wilson et al., 2005; Macdonald et al., 2002; Forbes, 1995).

The new diet, named Feedbee®, is claimed by the manufacturers (Bee Processing Enterprises Ltd., Toronto, Ontario, Canada) to be constituted as a practically balanced diet based on several factors. These factors include: knowledge of the nutritional requirements, digestive capacity, and pollen consumption by honeybees (House, 1961; 1964; Dietz, 1969; Moritz and Crailsheim, 1987; Herbert, 2000; Cohen, 2004), nutritional composition of animal feed stuffs (NRC, 1994; Novus International, 1994),

Journal of Apicultural Science

chemical content of a honeybee's body and royal jelly (Nation and Robinson, 1971; Knecht and Kaatz, 1990), availability of the ingredients in the market, animal and insect feeds and feeding (Dadd, 1973; Jouanin et al., 1998; Wilson et al., 2005; Cheek, 2005; Macdonald et al., 2002), palatability and anti-nutritional issues (Baumont, 1995; Gheradi and Black, 1995; Provenza, 1995; Burgess et al., 1996; Angkanaporn et al., 1997; Nandi et al., 1999; Pham-Delègue et al., 2000), pollen chemistry (Lundén, 1954; 1956; Barbier, 1970; Somerville, 2001), and

Table 1

Gross nutritional analyses of the bee collected pollen, Feedbee®, and Bee-Pro® and TLS Feed used in this study

Diets	Protein %	Fat %	Carbohydrates %	Ash %
Pollen *	21.2	9.9	55.9	4.1
Feedbee®*	36.4	3.9	51.8	3.1
Bee-Pro®**	40	3.8	NA***	7
TLS	NA	NA	NA	NA

*These diets were analysed by INDUSTRIAL LABORATORIES OF CANADA INC., 95 Townline Rd. Tillsonburg, On, N4G 5Y2
** The nutritional information was taken from the Bee-Pro® bags
***NA means information not available

Table 2

Nutritional analysis of Feedbee® and the bee collected pollen used in this study

	Feedbee®	Pollen
Protein	36.4%	21.2%
Moisture	4.8%	8.9%
Fat	3.9%	9.9%
Ash	3.1%	4.1%
Carbohydrates	51.8%	55.9%
Energy	388 kcal/100g	398 kcal/100g
Vitamin A	181 IU/100g	180 IU/100g
ß Carotene	1770 IU/100g	1798 IU/100g
Iron	12.8 mg/100g	35.0 mg/100g
Arginine	0.934%	1.759%
Histidine	0.443%	0.791%
Isoleucine	0.606%	0.962%
Leucine	1.561%	3.169%
Lysine	1.180%	1.483%
Methionine	0.405%	0.606%
Phenylalanine	1.127%	2.135%
Threonine	1.032%	1.592%
Tryptophan	0.221%	0.366%
Valine	0.854%	1.388%

production cost. Feedbee® is free from soy, pollen and any hive products. The actual constituents are regarded as a trade secret as are the constituents of Bee-Pro® and TLS Bee Food.

The gross nutritional makeup of the pollen used in this study, Feedbee®, and Bee-Pro® are presented in Tab. 1. Tab. 2 presents more detailed nutritional analyses of pollen and Feedbee® used in this study. Chemical analyses of Bee-Pro® and TLS Bee Feed were not made because of financial constraints.

Objectives

The main objective of this study was to examine the acceptability (as measured by the amount of material taken from the feeders) of Feedbee® by honeybees in comparison with Bee-Pro® and TLS Bee Feed when fed in powder form to commercially operated honeybee colonies. Palatability can be inferred from acceptability. This is because honeybees are not expected to take non-palatable materials back to the hive unless starving.

MATERIALS AND METHODS

The powder forms of Feedbee ®, Bee-Pro®, and TLS Bee Feed were provided, in accordance with the manufacturers' recommendations. They were provided in pollen supplement/substitute feeders. Feedbee ®, Bee-Pro®, and TLS Bee Feed were provided to successfully overwintered healthy colonies in one and a half or two super hives, all of similar strengths and with similar amounts of honey and pollen stores as determined by visual inspection (Figs. 1 and 2). The visual inspection took place over 6 weeks (March 25th - May 6th) in 2004. The powder feeding trial was done at a time of year when there were no natural pollen sources available. The weather was warm and sunny enough (except for some cool, rainy or blustery days) for the bees to leave their hives and collect the pollen substitutes at the feeders. Over the experimental period the daily maximum temperatures ranged from - 1.6°C to 22.1°C, with a mean of 11.0°C. About half the days (22 of 42) had more than 25% of the amount of possible sunshine.

Fig. 1. A commercial bee yard with one pollen supplement/substitute feeder (centre) in the no-choice powder feeding method where only one of the three feeds (Feedbee®, Bee-Pro® or TLS Bee Feed) was available in a single feeder to the commercially managed honeybee colonies

Journal of Apicultural Science

Fig. 2. A commercial bee yard with 3 pollen supplement/substitute feeders (foreground and at equal distance from the colonies) in the no-choice powder feeding method where all three feeds (Feedbee®, Bee-Pro® and TLS Bee Feed) were available separately in one of the three feeders to the commercially managed honeybee colonies

Weather data was obtained from the Elora Research Station (43°39'N 80°25.2'W) data archive, available from the University of Guelph Data Resource Center (http://tdr.uoguelph.ca/). The pollen supplement/substitute feeders were weighed and filled with the assigned feeds and then placed in the middle of the bee yards. The feeders were checked, weighed and refilled with up to 8000g of the same feed every 3 weeks in no-choice and every 2 weeks in choice feeding methods (described below).

Two methods of powder feeding were used.

No-choice powder feeding

In this method 12 commercial bee yards with 4-10 hives in each yard were used for a total of 89 colonies. The sites were located approximately 10 km away from each other and experienced similar climatic conditions. The yards were randomly assigned into 3 groups corresponding to the 3 feed treatments. Four yards (4 replicates) were assigned to each group, which received only one of the feeds during the experimental period. A single pollen supplement/substitute feeder containing one of the feeds was located in the middle of each yard at a more or less equal distance from the hives (Fig.1).

Choice-powder feeding

In this method, 3 commercial yards were used with 20, 23 or 24 colonies in each yard for a total 67 colonies. The yards were at least 10 km apart and experienced similar climatic conditions. Each yard received all of the three feeds in separate pollen supplement/substitute feeders of the same color and condition located in the middle of each yard (Fig. 2).

Statistics

The experimental design used in this study was Complete Random Design. To analyze the following parameters and to determine which treatments were significantly different from each other, the General Linear Model Procedure (Proc GLM) and Tukey's ANOVA test in Statistical Analysis Software (SAS, 1996) were used. Fortunately, all data sets were normally distributed and required no transformation prior to analysis.

The following parameters were analyzed in this study:

• Feed removal mean (g) in no-choice feeding method was analyzed to determine the effect of different treatments on feed intake rate.

• Feed removal mean (g) in choice feeding method was analyzed to determine the effect of different treatments and yards on feed intake rate.

RESULTS

The bees took more of Feedbee® than the other two feeds throughout the experiment, in both the no-choice (Tab. 3) and choice (Tab. 4) feeding methods. In all apiaries, observations ascertained that the bees working at the feeders, packed feed into their corbiculae and flew off.

No-choice Feeding Method

The total mean feed consumption per colony in 6 weeks (Tab. 3) was 960g ± 13.28 which was significantly different (higher) ($P<0.05$, $F_{2,9} = 20.12$) for Bee-Pro® (224g ± 36.26) and TLS Bee Feed (115g ± 8.45).

Choice Feeding Method

The mean amount of Feedbee® consumed (g/colony) by the colonies was 820 g, 900 g, and 930 g in the first, second and third yards, respectively. For Bee-pro® and TLS Bee Feed the mean feed intake was 100 g, 98 g, and 120 g and 52 g, 50 g, and 55 g in three yards respectively (Tab. 4).

The total mean feed intake (g/colony) in three independent yards is also presented in Tab. 4. The total mean intake for Feedbee® was 883g ± 32.83. Feedbee® intake was significantly ($p<0.05$, $F_{2,2} = 241.07$) higher than for Bee-Pro® (106g ± 7.03) and TLS Bee Feed (52g ± 1.45). There was no yard effect on feed intake ($P< 0.24$).

Conclusions

Feeding any pollen substitute to honeybee colonies in powder form is an easy method and consumes minimum time and labour, if weather conditions allow the bees to come out of their hives for foraging. The results of our experiments indicate that Feedbee® was well accepted by honeybee colonies

Table 3

Mean feed intake (g/colony) of colonies in 12 commercial apiaries and total mean feed intake of those 89 commercially operated honeybee colonies that received either Feedbee®, Bee-Pro®, or TLS Bee Feed for 42 days in early spring 2004 during the no-choice powder feeding experiment

Feed-intake in 4 independent yards / Treatments (9000 g/yard)	Yards	Number of colonies/ independent yard	Mean Feed intake of colonies in each independent yard (g/colony)	Total mean feed intake (± ***SE***) for 4 yards (g/colony)
Feedbee®	1	9	977	960 [a] ± 13.28
	2	7	969	
	3	10	973	
	4	4	920	
Bee-Pro®	5	8	213	224 [b] ± 36.26
	6	7	201	
	7	7	271	
	8	10	210	
TLS Bee Feed	9	9	78	115 [b] ± 8.45
	10	7	121	
	11	4	125	
	12	7	136	
Treatment effect:	***P***<0.05,	$F_{2,9} = 20.12$	$R^2 = 0.82$,	

Different letters indicate a significant statistical difference by ANOVA, Tukey's test, GLM Process of SAS program

Journal of Apicultural Science

Table 4

Mean feed intake (g/colony) of 23, 20, and 24 commercial honeybee colonies in three independent commercially operated apiaries and total feed intake of all 67 colonies in three yards that received all three feeds (Feedbee®, Bee-Pro®, and TLS Bee Feed) at the time for six weeks in the early spring 2004 choice powder feeding experiment

Feed-intake in 3 independent yard / Treatments (9000 g/yard)	Mean Feed intake in 1st yard with 23 colonies (g/colony)	Mean Feed intake in 2nd yard with 20 colonies (g/colony)	Mean Feed intake in 3rd yard with 24 colonies (g/colony)	Total mean Feed intake (± *SE*) of all the colonies in 3 independent yards (g/colony)
Feedbee®	820	900	930	883 [a] ± 32.8
Bee-Pro®	100	98	120	106 [b] ± 7.0
TLS Bee Feed	52	50	55	52 [b] ± 1.4
Treatment effect:	$P<0.05$	$F_{2,2} = 241.07$	$R^2 = 0.99$	

Different letters indicate a significant statistical difference by ANOVA, Tukey's test, GLM Process of SAS program

irrespective of the yards or locations, and in the presence or absence of other diets. This can be translated into a higher palatability of Feedbee® over the other two feeds, when fed in powder form. The reasons for the greater acceptability and preference the bees showed for Feedbee® versus the other feeds, especially when the bees had a choice of what to take, are not known. In trials with caged bees, Gregory (2006) and De Jong et al. (2009) found that pollen, Feedbee®, and Bee Pro® all provided a positive effect in raising protein levels in the bees' haemolymph, but Gregory (2006) also noted that other benefits (e.g. colony strength and longevity of individual bees) to her experimental colonies ranked in the order given above.

Detailed experiments involving choice by honeybees would be required to elucidate the importance of scent, taste, and particle size in attraction and forager recruitment to the feed. Such experiments, however, were beyond the scope of this study. Most other studies have used pollen as the control against which to compare the substitute feed, but the cost for this in apiary trials is usually prohibitive. By and large, pollen is preferred over any substitute diet, and the same seems to be true for Feedbee® (Gregory, 2006; Haidmayer et al., 2008). Schmidt and Hanna (2006), based on their experimental results, state that all the pollen substitute diets they tested and reviewed are not readily accepted by honeybees. But more recently developed pollen substitutes, such as Feedbee ®, were not available to them.

ACKNOWLEDGEMENTS

We thank the Ontario Beekeepers' Association for support. The National Research Council of Canada (IRAP) provided some financial support for the development of the technology we describe. Dr. T. Woodcock provided the summarized weather data. We thank local beekeepers, L. Simonfly, J. Connybear, A. Store, V. Nevidon, D and D Krout, P. Milanovich, D. Wood, C. Heimstra, and M. Czajkowski (we apologize if we have forgotten any of our many co-operators) for allowing us to use their apiaries for our trials.

REFERENCES

Angkanaporn K., Ravindran V., Mollah Y., Bryden W. L. (1997) - Homoarginine influences voluntary feed intake, tissue basic amino acid concentrations and arginase activity in chickens. *J. Nutr*. 127, 1128-1136.

Barbier M. (1970) - Chemistry and biochemistry of pollens. *Prog. Phytochem*. 2, 1-34.

Baumont R. (1995) - Palatability and feeding behavior in ruminants, a review. *Ann. Zootech*. 45, 385-400.

Burgess E. P. J., Malone L.A., Christeller J. T. (1996) - Effects of two proteinase inhibitors on the digestive enzymes and survival of honey bees (*Apis mellifera*). *J. Insect Physiol.* 42, 823-828.

Cheek P. (2005) - Applied Animal Nutrition, Feeds and Feeding, 3rd Edition. Prentice Hall, NJ, USA.

Cohen A. C. (2004) - Insect Diets: Science and Technology. CRC Press. Boca Raton, FL, USA.

Dadd R. H. (1973) - Insect nutrition: Current Developments and Metabolic Implications. *Annu. Rev. Entomol*. 18, 381-420.

De Jong, D. da Silva E. J., Kevan P. G., Atkinson, J. L. (2009) - Pollen substitutes increase honey bee haemolymph protein levels as much as or more than does pollen. *J. Apic. Res*. 48, 34 – 37.

Dietz A. (1969) - Initiation of pollen consumption and pollen movement through the alimentary canal of newly emerged honey bees. *Ann. Entomol. Soc. Am*. 62, 43-46.

Forbes J. M. (1995) - Voluntary Feed Intake and Diet Selection in Farm Animals, 1st Edition, CAB International, Wallingford, U.K.

Gheradi S. G., Black J. L. (1995) - Effect of palatability on voluntary feed intake by sheep. 1. Identification of chemicals that alter the palatability of forages. *Aust. J. Agr. Res*. 42, 571-584.

Gregory P. G. (2006) - Protein diets and their effects on worker weight, longevity, consumption and haemolymph protein levels of *Apis mellifera*. Proceedings of the American Bee Research Conference 2006. http://www.feedbee.com/publications/downloads/ABRC.pdf

Haidmayer C., Brodschneider R., Riessberger U., Crailsheim K. (2008) - Consumption of supplemental protein diets in honeybee colonies. Trilateral Symposium on Physiology, Graz, Austria, 18 - 19 September, 2008.

Herbert E. W. J. (2000) - Honey bee nutrition. In: The Hive and the Honey Bee. Chapter 6, pp. 197-233, J.M. Graham [editor], Dadant & Sons. Hamilton, Illinois.

House H.L. (1961) - Insect nutrition. *Annu. Rev. Entomol.* 6, 13-26.

House H.L. (1964) - Contribution of nutritional research to entomology. Entomological Society of America. Central Branch Pro 12: 13-20.

Jouanin L., Girard C., Bonadé-Bottino M., Le Métayer M., Picard-Nizou A., Lerin J., Pham-Delègue M. (1998) - Impact of oilseed rape expressing proteinase inhibitor on coleopteran pests and honeybees. Cahiers Agricultures 7, 6: 331. Transgenic plants and risk assessment.

Knecht D., Kaatz H. H. (1990) - Patterns of larval food production by hypopharyngeal glands in adult worker honey bees. *Apidologie* 21: 457-468.

Lundén R. (1954) - A short introduction to the literature on pollen chemistry. *Svensk Kemisk Tidskrift* 66, 201-213.

Lundén R. (1956) - Literature on pollen chemistry. *Grana Palynologica* 1, 3-19.

Macdonald P., Edwards R.A., Greenhalgh J.F.D., Morgan C. A. (2002) - Animal Nutrition, 6th Edition, Prentice Hall, Upper Saddle River, NJ. USA.

Moritz B., Crailshiem, K. (1987) - Physiology of protein digestion in the midgut of *Apis mellifera* L. *J. Insect Physiol*. 33, 923-931.

Nandi A.K., Basu D., Das S., Sen S. (1999) - High level of soybean trypsin inhibitor gene in transgenic tobacco plants failed to confer resistance against damage caused by Helicoverpa armigera. II T-BRFF Biotek, Indian Institute of Technology Kharagpur 721 302, Plant Molecular and Cellular Genetics, Bose Institute: 1-12, CIT Scheme VII-M, Calcutta 700 054, India.

Nation J. L., Robinson F. A. (1971) - Concentration of some major and trace elements in honeybees, royal jelly and pollens, determined by atomic absorption spectrophotometry. *J. Apic. Res*. 10, 35-43.

Novus International (1994) - Raw material compendium: A compilation of worldwide data sources. 2nd Edition. Novus International Inc., St. Louis, MO, USA.

NRC (National Research Council) (1994) - Nutritional requirements of poultry. 9th revised edition. National Academy of Sciences, Washington, DC, USA.

Pham-Delègue M. H., Girard C., Le Métayer M., Sandoz G., Picard-Nizou A. L., Hennequet C., Pons O., Jouanin L. (2000) - Long-term effects of soybean protease inhibitors on digestive enzymes, survival and learning abilities of honeybees. *Entomol. Exp. Appl*. 92, 21-29.

Provenza F. D. (1995) - Postingestive feedback as an elementary determinant of food preference and intake in ruminants. *J. Range Manage*. 48, 2-17.

SAS (1996) - Version 6.12. SAS Institute, Cary, NC, USA.

Schmidt J. O., Hanna A. (2006) - Chemical nature of phagostimulants in pollen attractive to honeybees. *J. Insect Behav*. 19, 521 - 532.

Skubida P., Semkiw P., Pohorecka K. (2008) - Stimulative feeding of bees as one factor in preparing colonies for early nectar flows. *J. Apic. Sci.* 52(1): 65 - 72.

Somerville D.C. (2001) - Nutritional value of bee collected pollen. A report for Australian Government Rural Industrial Research & Development Corporation, RIRDC Publication Australia No. 01/047. Project No. DNA-134A. (http://www.rirdc.gov.au/reports/HBE/01-047.pdf).

Wilson G. P., Church D. C., Pound, K. R., Schoknecht, P.A. (2005) - Basic Animal Nutrition and Feeding, 5th Edition. John Wiley & Sons, Hoboken, NJ. USA.

Zahra A., Talal M. (2008) - Impact of pollen supplements and vitamins on the development of hypopharyngeal glands and brood area in honey bees. *J. Apic. Sci.* 52(2): 5 - 12.

SPOŻYCIE TRZECH SUCHYCH SUBSTYTUTÓW PYŁKU KWIATOWEGO W PASIEKACH PRODUKCYJNYCH

Saffari A., Kevan P. G., Atkinson J.

Streszczenie

Testy smakowitości przeprowadzono w pasiekach produkcyjnych wczesną wiosną 2004 r. W ramach tego badania 153 rodziny w 12 pasiekach w południowej prowincji Ontario otrzymywały trzy różne karmy: Feedbee®, TLS Bee Feed i Bee-Pro® w okresie 6 tygodni (od 25 marca do 6 maja). Zastosowano dwie metody karmienia: 1) karmienie bez wyboru karmy, w którym każda pasieka otrzymywała tylko jeden z trzech produktów oraz 2) metodę wyboru karmy, w której każda pasieka dostawała wszystkie trzy eksperymentalne produkty. Średnie spożycie karmy (g/rodzina/6 tygodni) Feedbee® wyniosło 960 g oraz 883 g w przypadku odpowiednio pierwszej i drugiej metody karmienia. Ilości te były istotnie wyższe ($p>0,05$) niż w przypadku pozostałych dwóch karm. Ilość spożytej karmy Bee- Pro® (g/rodzina/6 tygodni) w obydwu metodach karmienia wyniosła odpowiednio 224 g i 106 g, natomiast w przypadku karmy TLS Bee Feed wartości te wyniosły odpowiednio 115 g i 52 g. Otrzymane wyniki wskazują, iż Feedbee® w postaci sproszkowanej/suchej smakuje pszczołom miodnym i jest dobrze akceptowany przez pszczoły w okresie niedoboru lub braku naturalnego pyłku.

Słowa kluczowe: pyłek kwiatowy, dieta zastępcza, karma, pszczoły, smakowitość, poziom spożycia.