Honey bee nutrition and feeding bees

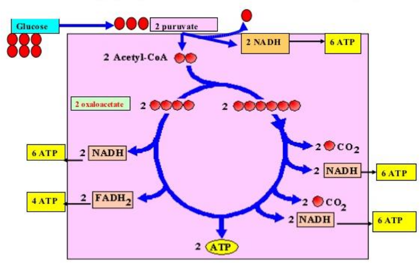
Zachary Huang
Michigan State University

What are the four things bees forage for?

- Nectar
- Pollen
- Water
- Propolis

Nectar is the main source of carbohydrates for honey bees
Unlike us, they cannot survive on protein alone.

Honey bees need carbohydrates as an energy source.
All carbohydrates are first converted to glucose to produce ATP.

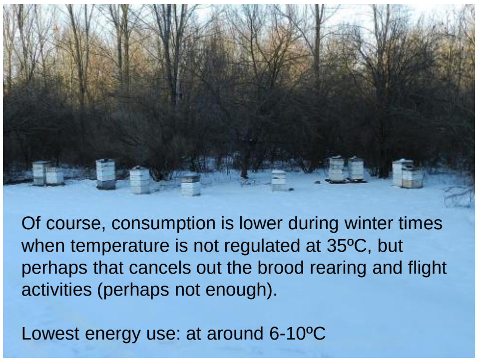


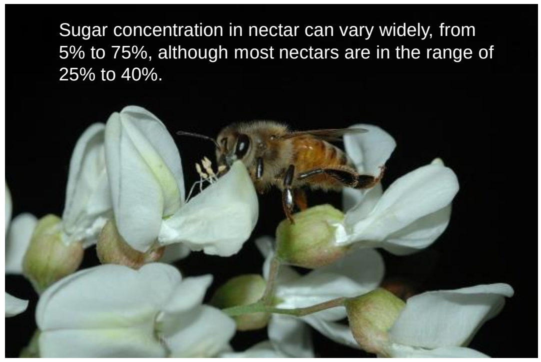
Glucose

- Used directly by the cell for energy
- Stored as glycogen in the muscles and liver
- Converted to fat and stored for energy

10 mg /day dry sugar
(~ 22µl 50% syrup)

A colony (~50,000 bees) needs 1.1 liter (~ 2 pounds) of 50% sugar syrup per day, which does not include brood rearing and other activities. A colony of this size, therefore will consume almost 700 pounds of nectar per year!





Average concentration: 26% sugar, volume 0.5 – 2 ul

PMC full text: Ann Bot. 2006 May; 97(5): 767–777.
doi: 10.1093/aob/mcl033

TABLE 2.

Means and standard deviation of nectar sugar concentration and sugar ratio, nectar volume covered and nectar standing crop of flowers in different pollination syndromes

Syndrome	*n*	Conc. (%w/w) $\bar{x}$ ± s.d.	Sugar ratio S/(F + G) $\bar{x}$ ± s.d.	Nectar volume 24 h covered (μL) $\bar{x}$ ± s.d.	Standing crop 0600–1800 h (μL) $\bar{x}$ ± s.d.	Mann–Whitney *U* Nectar volume covered *vs.* standing crop
Myiophilous	6[1]	31·1 ± 15·2	1·2 ± 1·8 [a]	0·7 ± 0·3 [a,b,c]	0·2 ± 0·2 [a,b,c]	$z = 2·2$, $P = 0·025$
Melittophilous	17[2]	25·9 ± 12·8	2·9 ± 3·2	2·0 ± 1·8 [e,g,h]	0·5 ± 0·3 [d,e]	$z = 2·3$, $P = 0·021$
Ornithophilous	13	17·0 ± 5·1	2·6 ± 0·9	20·6 ± 17·2 [a,d,e]	2·6 ± 1·9 [a,d]	$z = 3·4$, $P = 0·000$
Sphingophilous (including one psychophilous species)	7	16·8 ± 3·9	6·4 ± 5·6 [a,b]	26·5 ± 18·5 [b,f,g]	8·8 ± 12·5 [b]	$z = 3·8$, $P = 0·000$
Chiropterophilous	4	14·1 ± 5·9	0·6 ± 0·2 [b]	85·7 ± 17·7 [c,d,f,h]	4·5 ± 3·5 [c,e]	$z = -2·2$, $P = 0·025$
ANOVA/K–W ANOVA		$F_{4,42} = 3·7$ $P = 0·011$	$F_{4,41} = 4·3$ $P = 0·005$	$F_{4,40} = 29·3$ $P = 0·000$	$H(4, 7) = 27·4$ $P = 0·000$	

Mann–Whitney *U*-test of significant differences between covered nectar volumes and standing crop.

n = number of species, [1]number of species nectar production: *n* = 4 myiophilous syndrome; [2]number of species sugar ratio: *n* = 16 melittophilous syndrome.

A same letter following the values indicates significantly different pairs after ANOVA with following Tukey–Kramer HDS *post-hoc* test (α = 0.05) or Kruskall–Wallis ANOVA with Tukey–Kramer *post-hoc* test (α = 0.05).

Factoid: "Honey bees will tap about *two million* flowers and fly 50,000 miles (80,000 km) to make one pound (454 g) of honey"

25 mg per trip, 30% sugar for that 25 mg, honey has 18% water, so
25 mg = 22 mg

454 g / 22 mg = 206,363 loads

Average amount of nectar per flower: let us assume 2 ul (~2 mg)
One load will need 13 flowers.

206,363 * 13 = 2.6 million flowers.

If each load (25 mg) is a round trip of 2 miles, then it needs 206,363 x 2 =400,000 miles. Most likely it might more than 2 miles!

Feeding bees

- Frame feeder: inside colony, have to open hives, but nothing outside
- Top feeder: bucket (need extra hive body) or hive top feeder
- Feeder at hive front: smaller, but can see levels easily
- Spring: 1:1 ratio (sugar:water): why?
- Fall: 2:1 ratio (sugar:water): why?

Frame feeder (division board feeder)

[redacted]

Boardman Entrance Feeder

Pollen

Fig. 2. A worker foraging for pollen on a crocus (*Crocus sativas*, Iridaceae), an important spring flower to provide honey bees with early pollen. (Zachary Huang photo)

Bees have special structures for pollen collection

Plumose hairs

Bees have special structures for pollen collection


Pollen combs

Pollen baskets

Pollen in pollen-baskets

Flower constancy: staying on the same flowers

Beebread (fermented pollen) in cells

Nutrition in pollen

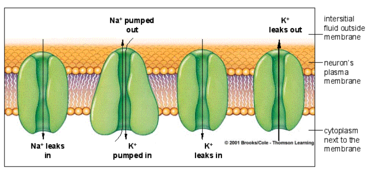
- Protein
- Minerals
- lipids, and
- vitamins

Why minerals?

Sodium and Potassium are essential elements of nerve cells for signal transduction.

Maintaining Resting Potential

K^+ and Na^+ can't diffuse across bilayer



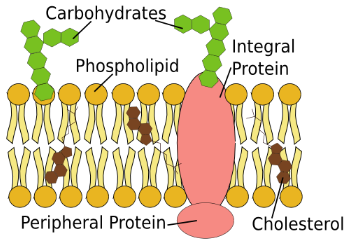
Why minerals?

Many enzymes need minerals to function

Co-factors: Mg, Mn, Cu, Zn, K

Lipids

Cell membranes are composed of lipid bilayers



Insects cannot synthesize cholesterol de novo
Must be obtained in food.

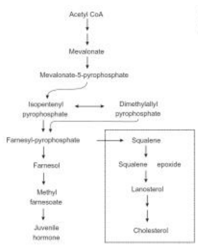


FIGURE 1.28 The isoprene pathway toward the synthesis of JH. Components and pathway within the box are not present in insects.

Klowden 2013

Vitamins

Vitamin B complex needed for brood rearing:
- thiamine,
- riboflavin,
- nicotinamide,
- Pyridoxine
- pantothenic acid
- folic acid, a
- biotin.

Ascorbic acid (=vitamin C) also essential for brood rearing.

Not All Pollens Are Created Equal

Pollen that shortens bee life:

Ragweed (*Ambrosia)*
Rust spore (*Uromyces)*
Cattail (*Typha)*
Mexican poppy (*Kallstroemia)*

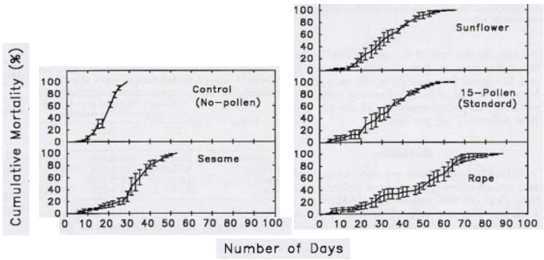
OK pollen

Terpentine bush (*Haplopappus)*
Desert broom *(Baccharis)*
Dandelion (*Taraxacum)*

Highly nutritious pollen

Mormon tea *(Ephedra)*,
Mesquite *(Prosopis)*,
Blackberry *(Rubus)*,
Cottonwood *(Populus)*
Rapeseed/canola (Brassica)
Almond (Prunus)

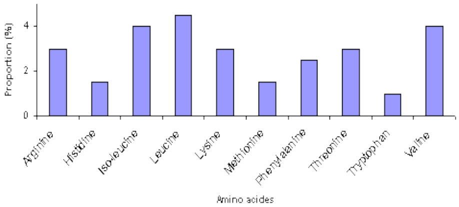
Mortality of bees fed various types of pollen



Schmidt et al, 1995, J. Econ. Entomol 88: 1591-95

Good pollen:
1. high amount of crude protein (18% or higher)
2. balanced amino acids

Proportion (%) of 10 essential AA needed by bees



(deGroot, 1953).

Dandelion pollen is low for isoleucine & valine

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Table 2. Comparison of pollen adequacy as a protein source for honey bees (evaluation relative to threonine concentration)

Amino acid	Bee requirement[a]	Dandelion pollen: Bee-collected: Wyo.	Md.	Wash.	Utah	Wis.	$\bar{x}$	Hand-collected, Ariz. $\bar{x}$
Threonine	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Arginine	3.0	2.4	2.7	6.0	3.9	4.4	3.9	3.1
Phenylalanine	2.5	2.8	2.5	3.9	3.1	2.7	3.0	3.3
Leucine	4.5	2.5	3.6	6.3	5.1	4.6	4.4	5.4
Isoleucine	5.0	2.5	2.9	3.1	2.9	2.9	2.9	3.5
Lysine	3.0	8.3	3.0	10.7	7.8	5.1	7.0	7.2
Histidine	1.5	6.5	5.0	6.7	5.4	3.6	5.4	3.4
Valine	4.0	1.1	1.5	1.5	1.3	1.8	1.4	3.6
Methionine	1.5	1.4	1.6	2.8	0.7	1.2	1.5	1.3

Underlined values are possibly deficient in terms of requirement.
[a] From DeGrott (1953).

Polyfloral pollen is healthier to bees

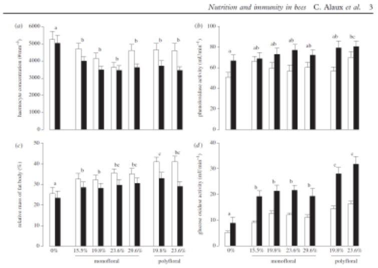


Figure 1. Effect of pollen diet on IC in 5 (open bars) and 10 days old bees (filled bars). (*a*) Haemocyte concentration, (*b*) phenol-oxidase activity, (*c*) fat body mass and (*d*) GOX activity. Eight bees per cage for each experimental group were analysed for each immune parameter. The protein percentage of each pollen diet is indicated on the *x*-axis. Each letter indicates significant differences between diets ($p < 0.05$, Newman–Keuls post hoc tests). No significant interaction between the diet and age factors was found ($p > 0.05$ for each immune parameter). Data show mean ± s.e.

Pollen stress reduce bee resistance to *Nosema apis*

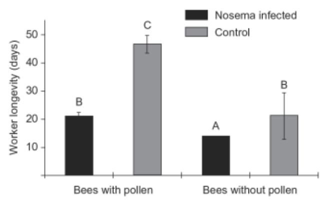


Figure 3. Longevity (days ± SE) of caged worker bees that were fed with pollen, without pollen, and then either infected with *Nosema apis* (black) or not infected as a control (grey) (data from Rinderer and Kathleen, 1977, Table 1, Experiment 1). Bars with different letters were significantly different (P<0.05) by LSD after ANOVA.

Pollen stress reduce bee resistance to *Nosema cerana*

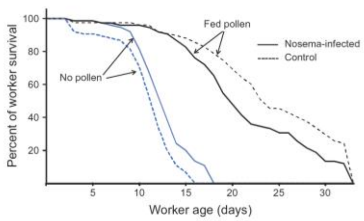


Figure 4. Survival of caged honey bee workers that were fed with pollen (black), or without (blue), and then infected with *Nosema ceranae* (solid lines), or not infected with *Nosema ceranae* (broken lines) (Z.Y. Huang, unpublished data).

Pollen stress reduce bee resistance to pesticides

Table 1. Effect of protein nutrition on honey bee resistance to pesticides. All six listed pesticides showed a shift to lower LD50, indicating that bees were becoming more sensitive to pesticides when protein was deficient. Data from Wahl and Ulm (1983).

Pesticide	LD 50 (µg/bee)	
	Normal feed	Protein deficient
Tormona 80	709.3	482.3
Hedonal	147.2 - 151.9	113.3 - 117.0
U 46 KV	92.6 - 122.5	64.8 - 85.8
Thiodan 35	61.7	31.45
Cupravit	32.0 - 47.9	18.9 - 28.3
Rubitox	16.85	11.45

Pollen requirement

Rearing one larva requires 25-37.5 mg protein,
=125-187.5 mg pollen (Hrassnigg and Crailsheim, 2005),
I assume 150 mg here.

Thus to raise one deep frame of brood (5000 cells), one need 750 gram of pollen = 1.65 lbs!

A healthy colony has about 5-6 frames, i.e. they will need about 10 lbs of pollen during the 5-10 day period.

Bees can raise brood (of poor quality) using their own body protein, but this is not sustainable (about one brood cycle).

Quiz: why do bees come to your bird-feeder?

Pollen substitutes

A good pollen substitute should have:

1). Palatability (readily consumed by bees),
2). Digestibility (easily digested by bees), and
3). Balance (correct AA balance and enough crude proteins).

Pollen substitutes

Name	**% Protein**	(R. Oliver)
Bee-Pol®		
Bee-Pro® (soy based)		(29.9%)
Feed-Bee® (Canadian)	19.4%	(34.4%)
MegaBee® (Dadant)	13.5%	
UltraBee (Mann Lake)	20.2%	

In caged bees, bee bread performed much better than pollen.

Table 2. Mean ± SD protein titer (μg/μl hemolymph) measured in individual *A. mellifera* workers fed on the different diets, at 0, 2, 4, and 6 d, and mean relative vitellogenin titers (% of highest control peak) of 6-d-old bees fed on the same diets from emergence

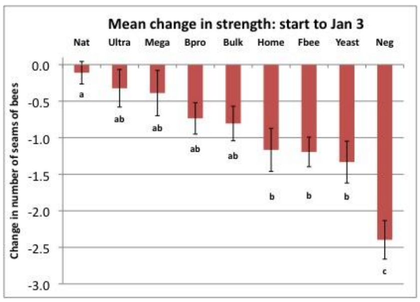
Age, d	Diets				
	Bee bread	Soybean/Yeast	Pollen	Corn meal	Sucrose
			Protein titer		
0	7.50 ± 1.53	5.73 ± 2.12	4.41 ± 0.71	7.03 ± 1.68	7.10 ± 2.12
2	9.11 ± 2.17	7.16 ± 1.15	7.66 ± 2.43	6.72 ± 1.10	4.34 ± 1.41
4	14.93 ± 2.42	10.58 ± 3.35	8.13 ± 1.71	4.27 ± 1.13	3.78 ± 2.15
6	27.57 ± 7.41	24.06 ± 2.54	11.36 ± 2.92	3.98 ± 1.02	2.17 ± 1.14
			Vitellogenin titer		
6	68.76 ± 20.07	47.40 ± 13.05	26.85 ± 6.01	10.96 ± 1.68	5.48 ± 1.37

Feedbee and Beepro gave higher blood protein than pollen

Table 1. Crude protein (%) of the protein sources and mean protein titers (μg/μl haemolymph) of the haemolymph of individual six day old *Apis mellifera* workers, fed on artificial diets or pollen from day 0 (when the newly-emerged bees were placed in the cages). The haemolymph was collected from five to six bees (analysed individually) from each of three sequential repetitions (cages of 100 bees). The protein contents of the diet materials (before mixing with sucrose to prepare the diet patties) were obtained by analyses made by Industrial Laboratories of Canada Inc. (Feedbee®), and by the manufacturer (Bee-Pro®), except for the pollen and acacia pod flour, which were analyzed in Brazil.
*Protein titers followed by the same letter are not significantly different from each other (Tukey's test, α = 0.05).

Diet	Crude protein content	Protein titer* in the haemolymph	Standard deviation of the protein titers	N (number of bees tested)
Feed-Bee®	36.4	9.42[a]	4.09	18
Bee-Pro®	29.9	8.95[abc]	3.51	16
Pollen	20	6.26[bc]	2.19	17
Acacia pod flour	22	6.00[c]	2.67	15
Sucrose	0	3.56[d]	1.62	17

Pollen > Ultra > Mega > Feedbee?



Take home message

1. No substitute is as good as pollen
   because no substitute can be used for more than 2 brood cycles without pollen
   no bumble bees can be raised from subs.

2. UltraBee and MegaBee seems to be better than others, though not statistically not different.

3. Best strategy: trap your own pollen during surplus time, feed back during dearth. Store frozen.

Mixing Megabee powder with 2:1 syrup, 4% oil

Why do bees need water?

During summer: to cool down the hive by using evaporative cooling!

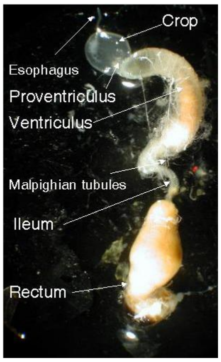
Brood rearing: to dilute honey so they can be fed to larvae
During winter time they have access to condensation (usually too much water!)

Why water foraging is risky?

Foragers preload with fuel at very small margin (10-20%)

Change of wind or temperature will render the bee with no energy!

So providing water will save their lives!



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https://pollinators.msu.edu/_pollinators/assets/File/FeedingHoneyBees-Final.pdf

Questions?

Zachary Huang: bees@msu.edu