CAVENDISH BANANAS AND THEIR NUTRITIONAL BENEFIT TO HONEY BEES

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INTRODUCTION

- Honey bees are stressed by various diseases and lack of nutrition.
- This presentation explores how bananas may help the bees.

- This presentation is based on my scientific literature review for the Montana University Master Level Beekeeping Program January–March 2019 and preliminary tests done in my Apiary during 2018.
- **Cavendish Bananas and the Nutritional Benefit to Honey Bees**
  https://tinyurl.com/scientificbanana

Picture: Edward Warburton

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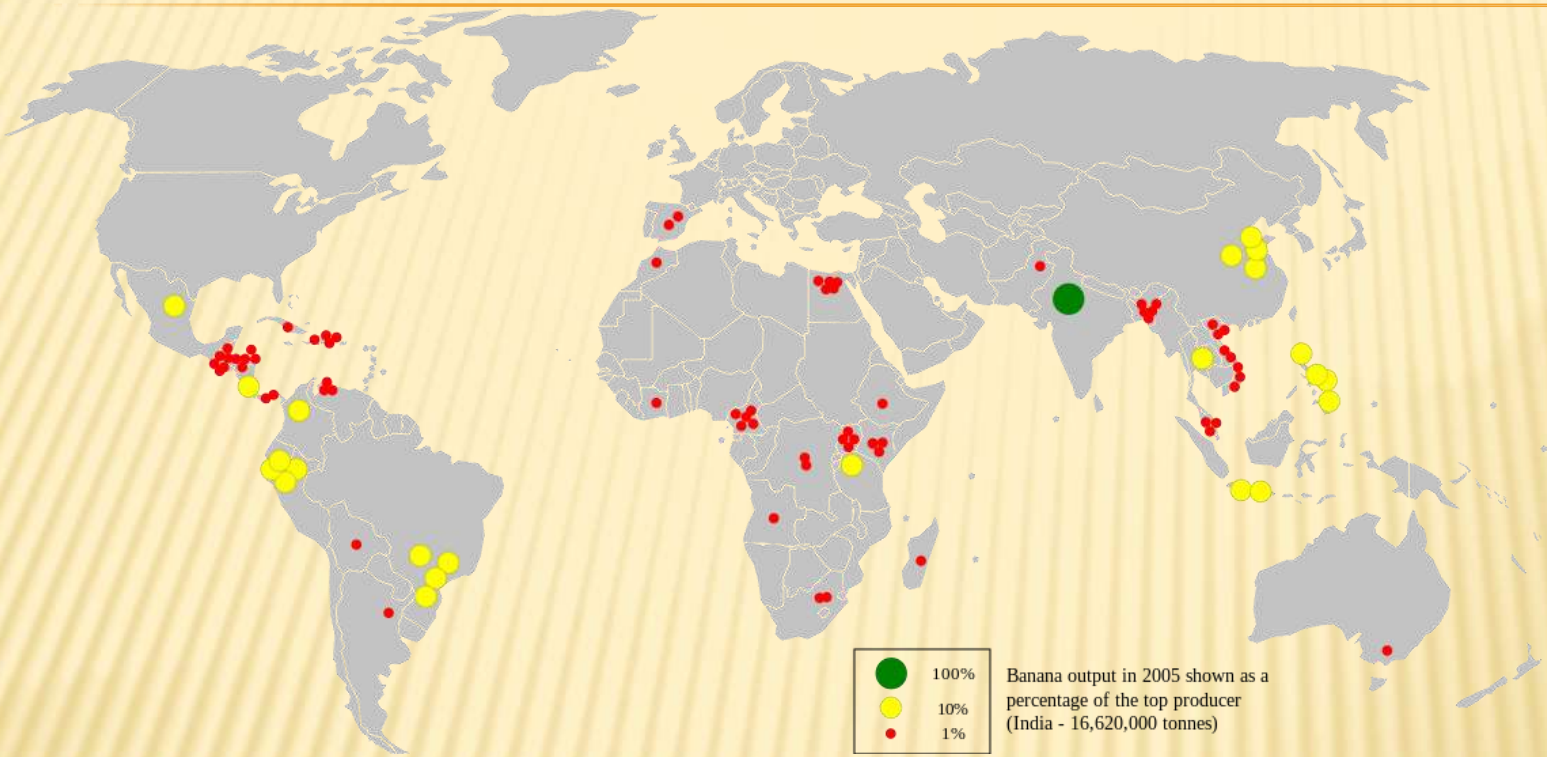
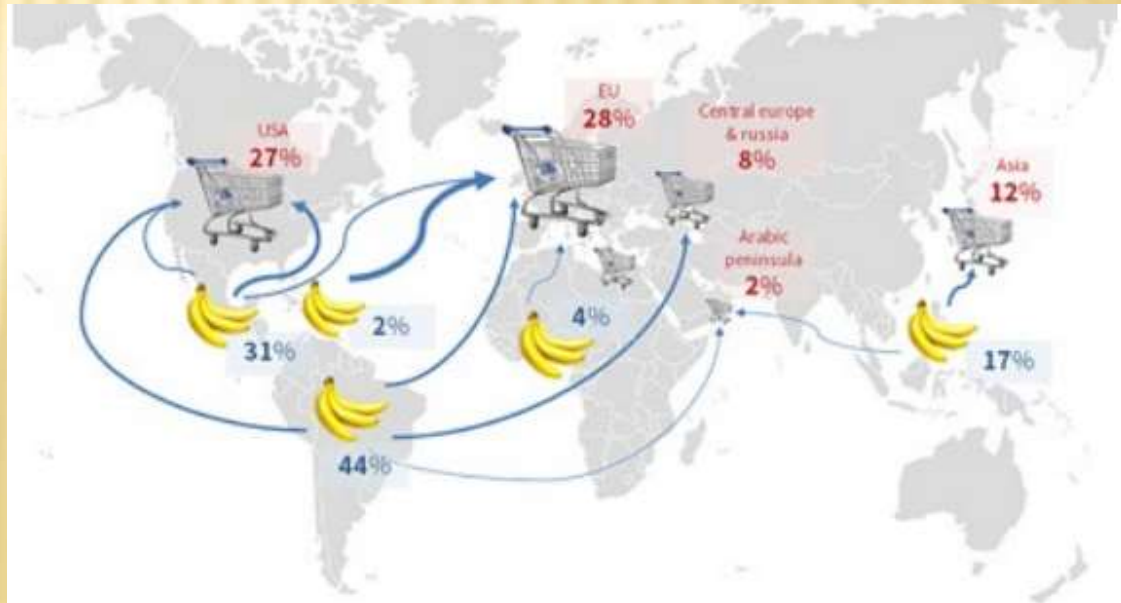


Banana Production Worldwide



Banana Shipping

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WHY BANANAS AND ARE THERE STUDIES?

- Akinwande found that honey bee population can be improved by feeding banana to the hive. He noted a 10% increase in forager population, and an increase in honey production of 20% (Akinwande & Badejo, 2009).
- Neupane and Thapa tested various foods in feeding experiments. They found that honey bees preferentially collected and utilized all syrups containing sugar, pumpkin, banana, maize powder and rice bran. Bees consumed 100% of sugar syrup, 99.5% of the pumpkin syrup and 96.7% of banana. Banana syrup increased the number of brood cells by 16.3%, brood frames by 17.1%, and increased frames covered by bees by 12%. They also looked at the economic cost of feeding and found banana syrup costs only half over sugar syrup alone. Sugar syrup itself produced the highest number of brood frames. They concluded that banana syrup can be used as an alternative off-season supplement feeding of honey bees (Neupane, 2005).
- Sugar, banana, papaya, grapes and guava syrups were fed during offseason in the Himalayas for 3 years. They used the same syrup making methods as Neupane but added 200 grams for fruit flesh to the mix. Honey bees syrup preference was 100% banana, 99.6% papaya, 99.6% sugar, 81.3% grape, and 41.6 guava. Banana syrup fed bees showed the largest brood area, followed by papaya, guava, grapes and sugar syrups. Highest honey and pollen stores production were observed in colonies offered banana syrup. Overall foraging activity was highest in banana syrup fed colonies. They observed that bees would not accept banana syrup after 3 days of preparation, but refrigeration extended that acceptance by up to 5 days. The conclusion was that bananas syrup as a supplemental feeding option during dearth periods can reduce starvation (Pande, 2015).

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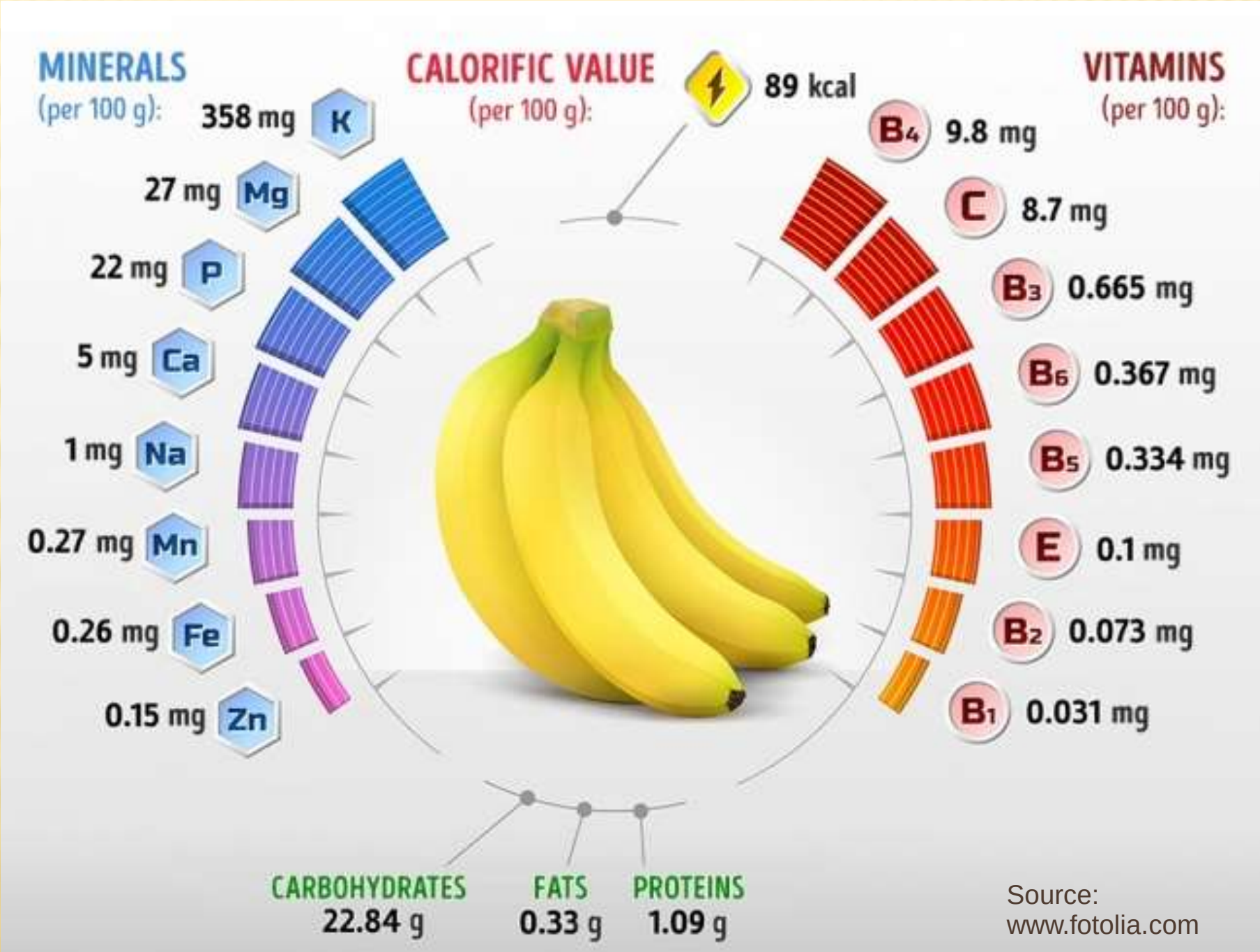
NUTRIENTS IN BANANAS OF INTEREST TO BEES



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NUTRITIONAL PROFILE OF BANANA PULP

Based on one medium sized banana:

Proximates	
Water	88.39 g
Energy	105 kcal
Energy	438 KJ
Protein	1.29 g
Total lipid (fat)	0.39 g
Ash	0.97 g
Carbohydrate, by difference	26.95 g
Fiber, total dietary	3.1 g
Sugars, total	14.43 g
Sucrose	2.82 g
Glucose (dextrose)	5.88 g
Fructose	5.72 g
Maltose	0.01 g
Starch	6.35 g

Lipids	
Fatty acids, total saturated	0.132 g
10:00	0.001 g
12:00	0.002 g
14:00	0.002 g
16:00	0.12 g
18:00	0.006 g
Fatty acids, total monounsaturated	0.038 g
16:1 undifferentiated	0.012 g
18:1 undifferentiated	0.026 g
Fatty acids, total polyunsaturated	0.086 g
18:2 undifferentiated	0.054 g
18:3 undifferentiated	0.032 g
Phytosterols	19 mg

Minerals	
Calcium, Ca	6 mg
Iron, Fe	0.31 mg
Magnesium, Mg	32 mg
Phosphorus, P	26 mg
Potassium, K	422 mg
Sodium, Na	1 mg
Zinc, Zn	0.18 mg
Copper, Cu	0.092 mg
Manganese, Mn	0.319 mg
Selenium, Se	1.2 µg
Fluoride, F 2	2.6 µg

Amino Acids	
Tryptophan	0.011 g
Threonine	0.033 g
Isoleucine	0.033 g
Leucine	0.08 g
Lysine	0.059 g
Methionine	0.009 g
Cystine	0.011 g
Phenylalanine	0.058 g
Tyrosine	0.011 g
Valine	0.055 g
Arginine	0.058 g
Histidine	0.091 g
Alanine	0.047 g
Aspartic acid	0.146 g
Glutamic acid	0.179 g
Glycine	0.045 g
Proline	0.033 g
Serine	0.047 g

Vitamins	
Vitamin C, total ascorbic acid	10.3 mg
Thiamin	0.037 mg
Riboflavin	0.086 mg
Niacin	0.785 mg
Pantothenic acid	0.394 mg
Vitamin B-6	0.433 mg
Folate, total	24 µg
Folate, food	24 µg
Folate, DFE	24 µg
Choline, total 2	11.6 mg
Betaine 2	0.1 mg
Vitamin A, RAE	4 µg
Carotene, beta	31 µg
Carotene, alpha	30 µg
Vitamin A, IU	76 IU
Lutein + zeaxanthin	26 µg
Vitamin E (alpha-tocopherol)	0.12 mg
Tocopherol, gamma	0.02 mg
Tocopherol, delta	0.01 mg
Tocotrienol, alpha	0.07 mg
Vitamin K (phylloquinone)	0.6 µg

Proanthocyanidin	
Proanthocyanidin dimers	0.4 mg
Proanthocyanidin trimers	0.5 mg
Proanthocyanidin 4-6mers	2.2 mg
Flavonols	
Kaempferol	0.1 mg
Quercetin	0.1 mg
Flavan-3-ols	
(+)-Catechin	7.2 mg

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USDA. (2018). *National Nutrient Dataase for Standard Reference.* Retrieved from USDA-Raw Bananas.

CHEMICAL COMPONENTS OF BANANA PEEL

Table 1: Minerals composition of *Musa sapientum* peel

Element	Concentration (mg g^{-1})
Potassium	78.10±6.58
Calcium	19.20±0.00
Sodium	24.30±0.12
Iron	0.61±0.22
Manganese	76.20±0.00
Bromine	0.04±0.00
Rubidium	0.21±0.05
Strontium	0.03±0.01
Zirconium	0.02±0.00
Niobium	0.02±0.00

Table 2: Proximate composition and anti-nutritional content of *Musa sapientum* peel

Parameter	Concentration
Moisture (%)	06.70±02.22
Ash (%)	08.50 ±1.52
Organic matter (%)	91.50±0.050
Protein (%)	00.90±0.250
Crude Lipid (%)	01.70±0.100
Carbohydrate (%)	59.00±1.360
Crude Fibre (%)	31.70±0.250
Hydrogen cyanide (mg/g)	01.33±0.100
Oxalate (mg g^{-1})	00.51±0.140
Phytate (mg g^{-1})	00.28 + 0.06
Saponins (mg g^{-1})	24.00±0.270

- Source:
  B.A. Anhwange , 2008. Chemical Composition of *Musa sapientum* (Banana) Peels. *Journal of Food Technology, 6: 263-266.*

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BLACK'S NUTRIENT REQUIREMENT FOR BEES

Honey bees need nutrients other than sugar. Carbohydrates, proteins, lipids, vitamins, antioxidants, and minerals are needed for growth and development (Brodschneider & Crailsheim, 2010) (Herbert & Hill, 2015). We are trying to find answers to what components in banana may benefit to bee health. De Groot did extensive research on protein and amino acid requirements of the honey bee (De Groot, 1953). Haydak looked at the nutritional requirements of the castes and brood (Haydak, 1970).
We wanted to look at something more comprehensive and more recently published about honey bee nutrition to compare figures. Keep in mind that there are no definite numbers in honey bee nutrition as pollen sources vary in content. Black's research on bee nutrition set a table for a refined pollen substitute (Black, 2006). It includes protein, fatty acids, sterols, minerals, and vitamins. We are using those figures as a baseline for our comparison to nutrients found in bananas.

Black's Nutrient Requirement as mg/kg of a Pollen Substitute (Black, 2006):							
Protein	250,000	Linolenic acid	4,264	Phosphorus	2,657.3	Biotin B7	12.0
Arginine	12,750	Linoleic acid	1,218	Potassium	2,501.9	Choline chloride	450.0
Histidine	5,500	Sterol	1,000	Sodium	312.7	Folic acid B9	12.0
Lysine	16,750			Calcium	156.4	Inositol	450.0
Tryptophan	3,250			Magnesium	312.7	Nicotinic acid B3	450.0
Phenylalanine	10,250			Sulphur	1,876.5	Ca Pantothenate	450.0
Methionine	4,750			Boron	1.6	Pyridoxine hydrochloride B6	45.0
Threonine	10,000			Copper	7.2	Riboflavin B2	45.0
Leucine	19,250			Iron	46.9	Thiamine hydrochloride B1	45.0
Iso-Leucine	12,250			Manganese	16.9	Vitamin B12	3.0
Valine	16,750			Zinc	31.3	Ascorbic acid C	450.0
						Vitamin A	0.4
						Vitamin K	0.4

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PROXIMATES

- Honey bees need minerals and vitamins in addition to carbohydrates, proteins, and lipids to thrive. The question is, do Cavendish bananas offer enough nutrition to make them valuable to honey bees? The USDA Nutritional Database supplied basic information as to what can be found in Cavendish bananas. The table below gives a snapshot of the proximates.
- Moisture content in pulp increases during ripening due to break down of starches into sugars. The moisture migrates from peel to pulp (Mohapatra, Mishra, & Sutar, 2010). Ash has been reported to increase brood, however various percentages on ash on a dry weight basis have been reported. 1% of dry matter is suggested for being great for brood rearing (Herbert & Shimanuki, 1978). Banana is rich in ash within the peel.

Proximates	Ripe banana pulp 100g	Ripe banana peel 100g
Water	74.91 g	
Energy	89 kcal or 371 KJ	
Protein	1.09 g	1.8 g
Total lipid (fat)	0.33 g	
Ash	0.82 g	16.9 g
Carbohydrate, by difference	22.84 g	
Fiber, total dietary	2.6 g	

Source: (USDA, 2018); Peel (Sharaf, Hegazi, & Sedky, 1979), (Adisa & Okey, 1987)

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CARBOHYDRATES

- Carbohydrates are the main energy source for honey bees. Adult bees satisfy their carbohydrate need by collecting nectar. Nectar sugars ranges from 4-60% depending on floral source and environmental conditions (Shuel, 1975). Honey bees prefer sucrose followed by glucose, maltose and fructose. 30-50% sugar concentrations are preferred by honey bees, and concentrations that are less than 5% are rarely visited (Waller, July 1972).
- Some sugars are toxic or reduce lifespan in honey bees. These include mannose, lactose, galactose and raffinose (Barker & Lehner, 1974). These toxic sugars are not present in Cavendish bananas, or so small that they are of no importance.
- Starch is converted into sugar by enzymatic breakdown (Mohapatra, Mishra, & Sutar, 2010). Sugar content increased to 23% in overripe bananas, and sucrose made up 70% of the total sugars in overripe bananas (Marriott, Robinson, & Karikari, 1981).
- The sugar concentration is not very high for honey bees. In an inhive feeding settings bees do not have to use lots of energy to transport it to the hive, which makes it more useful. Overripe bananas contain larger sugar content making it more desirable for honey bees. This suggests sugar supplementation may be needed depending on ripeness.

Sugars	banana pulp g/100g	banana peel g/100g	banana pulp and peel g/100g
Sugars, total	12.23	4.1	8.165
Sucrose	2.39	2.6	2.495
Glucose	4.89	2.4	3.645
Fructose	4.85	6.2	5.525
Lactose	0.00	0.00	0.000
Maltose	0.01	0.00	0.010
Galactose	0.00	0.00	0.000
Starch	6.35	1.20	3.775

Source: Pulp (USDA, 2018); Peel (Mohapatra, Mishra, & Sutar, 2010); Peel and Pulp (Adisa & Okey, 1987)

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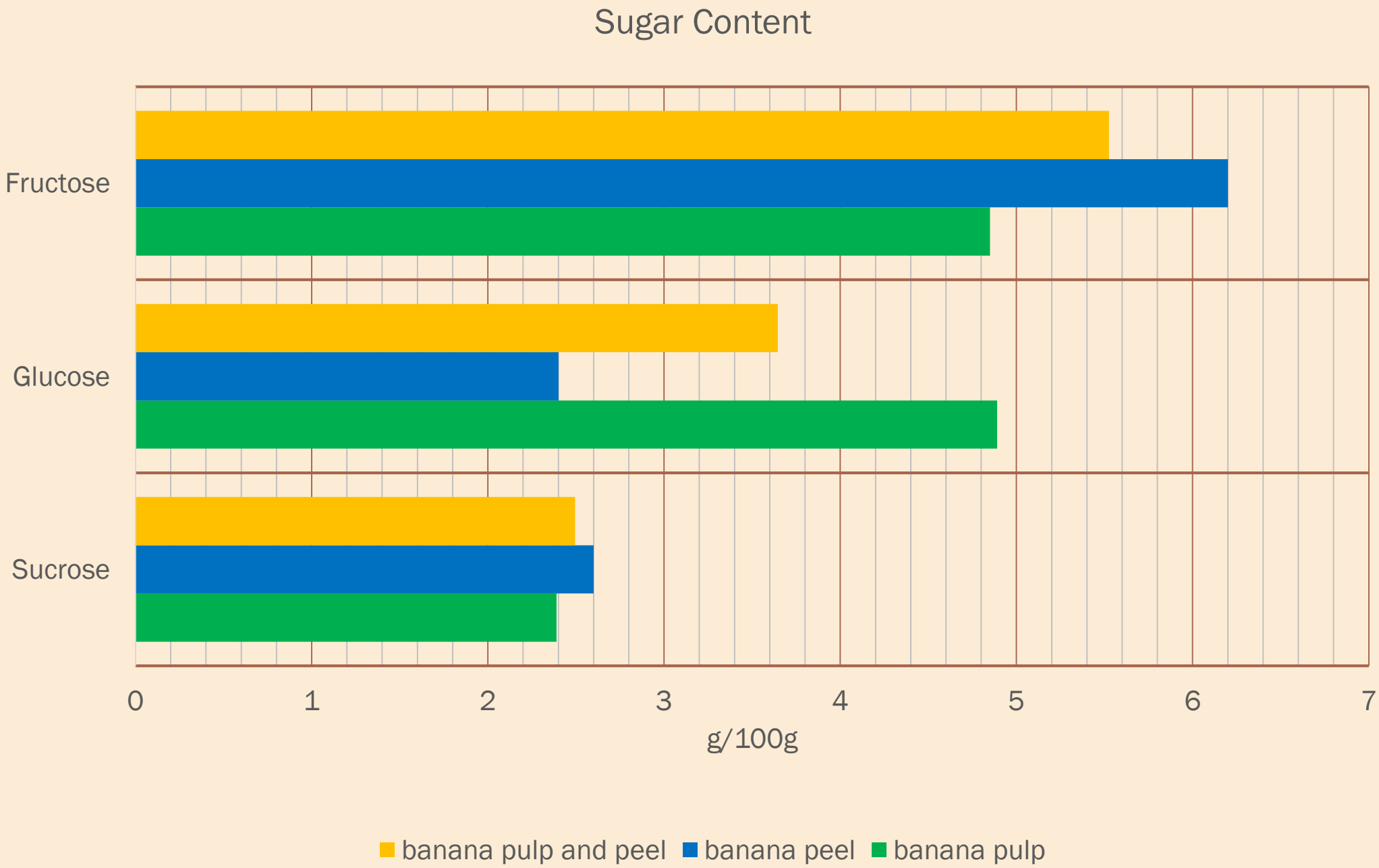
SUGAR CONTENT



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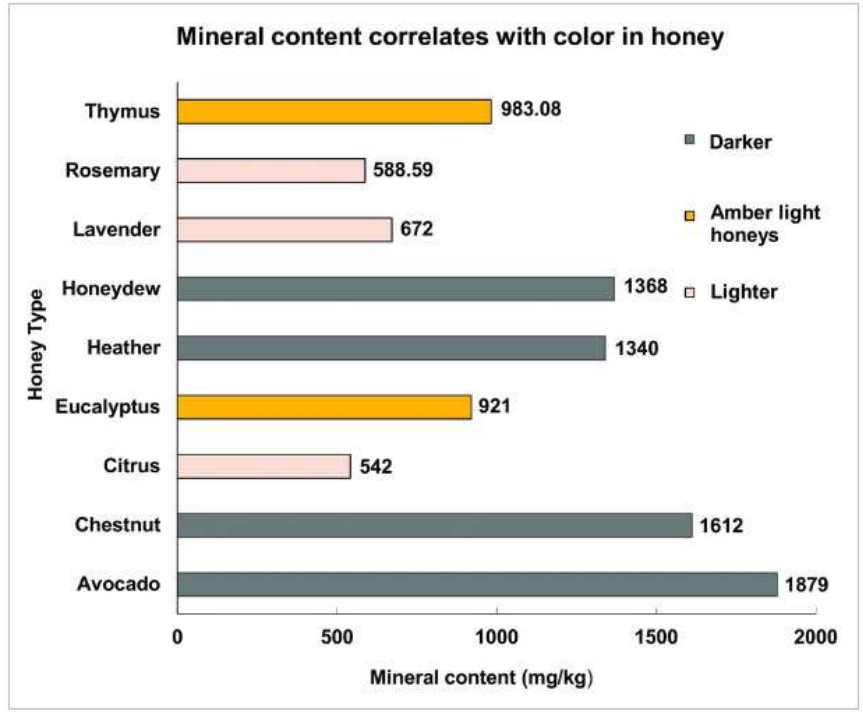
MINERALS INCLUDING POTASSIUM SOURCES FOR HONEY BEES

- The mineral requirements of honey bees are poorly understood.
- High amounts of calcium (Ca), potassium (K), phosphorus (P), and magnesium (Mg) are required by all other insects, including honey bees.
- Excessive levels of sodium (Na), sodium chloride (NaCl), and calcium (Ca) have been shown to be toxic to honey bees. The bee's mouthpart can detect salt levels and bees choose wisely.
- Nectar carries very little potassium (K) and minerals for that matter and plays a very minor role. Dark nectar sources, that produce dark honeys, are higher in mineral levels.
- Pollen on the other hand is the major mineral source for bees.
  Spring and fall pollen is rich in minerals.
  Summer pollen is not complete in the profile and various pollen sources are needed to complete the profile. Bees know that and compensate.



Grembecka, M., & Szefer, P. (2012). Evaluation of honeys and bee products quality based on their mineral composition using multivariate techniques. *Environmental monitoring and assessment*, *185*(5), 4033-47.

Mineral	Dark Honey	Light Honey
Calcium, Ca	227	107
Copper, Cu	1	1
Potassium, K	1241	441
Magnesium, Mg	132	40
Manganese, Mn	10	1
Sodium, Na	23	251
Phosphorus, P	123	129
Zinc, Zn	2	3

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MINERALS

Ample calcium and potassium are needed for muscle activity to generate heat in the hive during the winter months.

- Major minerals found in pollen are potassium (K), calcium (Ca), and magnesium (Mg) and vary depending on the season (Herbert & Miller-Ihli, 1987).
- Hagler found that bees worked onion cultivars 2-4 times more containing lower levels of potassium (K), and therefore producing more honey. Hagler did not look at seasonal foraging behavior (Hagler, 1990).
- Bonoan described the seasonality of salt foraging in honey bees for micronutrients. They found that calcium (Ca), magnesium (Mg), and potassium (K) were the most preferred in fall when pollen was scarce but were avoided during abundance. Potassium (K) intake was very high in fall. Tests with various potassium levels in sugar syrup confirmed his findings (Bonoan, et al., 2017).
- This suggests that these micronutrients may be needed in long-lived winter bees.

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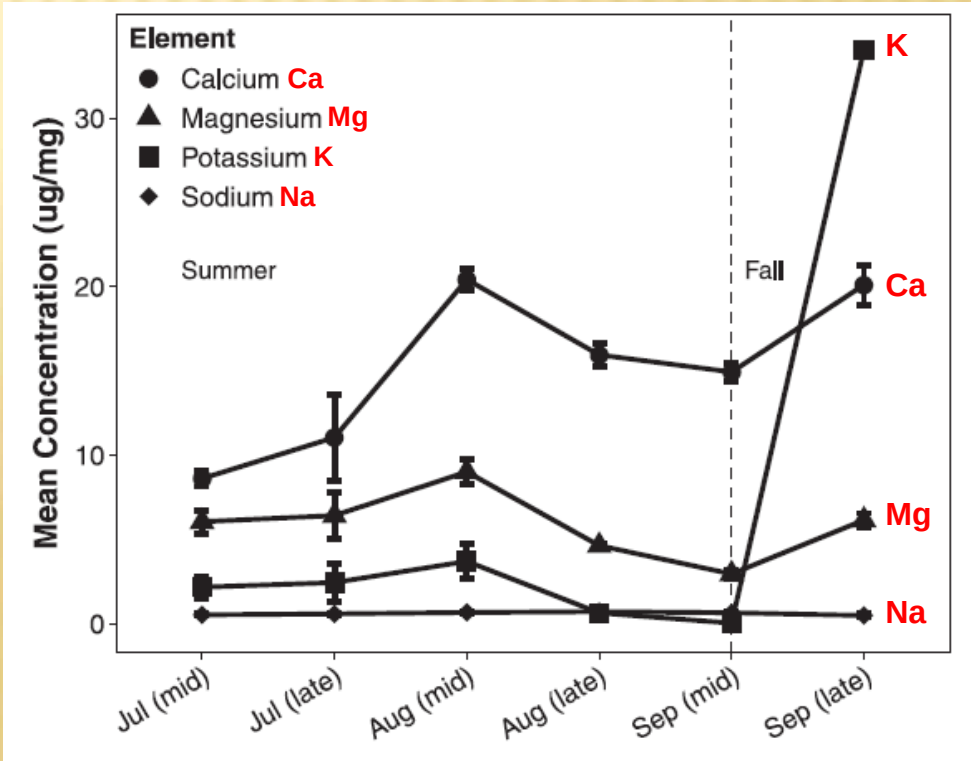
		Water Preference	Predicted Pollen Content	Observed Pollen Content
Calcium Ca	Summer	↓	↑	↑
	Fall*	↑	↓	↑
Magnesium Mg	Summer	↓	↑	↑
	Fall	↑	↓	↓
Potassium K	Summer*	↓	↑	↓
	Fall*	↑	↓	↑↑
Sodium Na	Summer	↑↑	↓↓	↓↓
	Fall	↑↑	↓↓	↓↓

Bonoan, R. E., Tai, T. M., Tagle Rodriguez, M., Feller, L., Daddario, S. R., Czaja, R. A., . . . Starks, P. T. (2017). Seasonality of Salt Foraging in Honey Bees (Apis Mellifera). *Ecological Entomology*, 195-201. doi:10.1111/een.12375



MINERAL CONTENT

- Royal jelly and worker jelly both have high concentrations of potassium (Wang, Ma, Cui, & Wang, 2015), where it acts as a phagostimulant, which is beneficial to developing larvae (Cohen, 2004).
- Calcium is important in the regulation of muscle movement but can cause paralysis in honey bees if taken in excess amounts (Somerville, 2005).
- Phosphate is essential for bioenergetic activity (Bonoan, et al., 2017).
- Zinc increases the antioxidant defenses in honey bees (Zhang, Zhang, Cui, & Xu, 2015).
- Iron is needed in the honey for detecting the magnetic field (Kuterbach, Walcott, Reeder, & Frankel, 1982).
- Our comparison shows high level of potassium in the pulp, but not enough in the peel. Studying the numbers suggest feeding pulp and peel for mineral content. The honey bee's need is somewhat satisfied in all categories, except for phosphorus.
- Manganese remains undetermined due to lack of data on banana peel.
- We feel that banana pulp and peel can improve bee health. Iron is present in banana peel in good quantities.

Minerals	banana pulp mg/kg	banana peel mg/kg	Black's suggested pollen substitute mg/kg
Calcium, Ca	50.00	60.1	156.4
Iron, Fe	2.60	204.0	46.9
Magnesium, Mg	270.00	23.1	312.7
Phosphorus, P	220.00	4.9	2,658.3
Potassium, K	3,580.00	98.3	2,501.9
Sodium, Na	10.00	243.0	312.7
Zinc, Zn	1.50	18.6	31.3
Copper, Cu	0.78	8.5	7.2
Manganese, Mn	2.70	ND	46.9

Source: Pulp (USDA, 2018); Peel (Mohapatra, Mishra, & Sutar, 2010); (Black, 2006)

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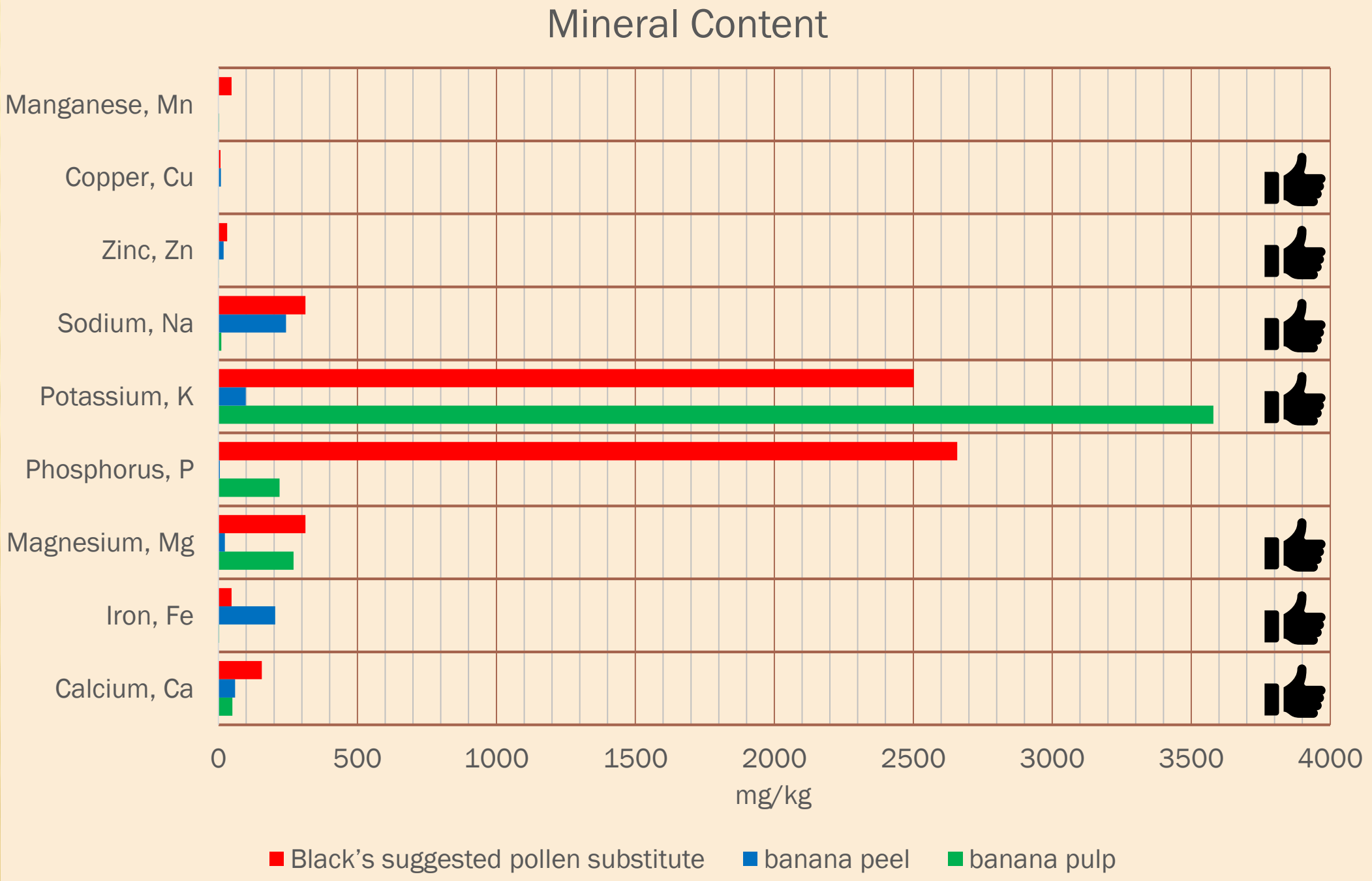
MINERAL CONTENT



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LIPIDS

- Lipids are part of the bee's diet and is usually satisfied by pollen consumption. Lipid quantity varies by pollen sources from 1-20 percent (Lunden, 1954).
- Lipid digestion by honey bees increases during days 3-8 after emergence and decreases with age from there. Queens have their cell membranes mostly made up of mono-unsaturated fatty acids. Worker bees are similar after emergence but change to polyunsaturated fatty acids over time. This plays a major factor in the shortening of the worker's life span over that of a queen.
- Cholesterol and sterols also pay part in a bee's diet, since they are not able to metabolically make them. Neither is present in bananas.
- Lipids remains almost constant at 1% during the ripening process (Mohapatra, Mishra, & Sutar, 2010).
- Lipids found in banana are in very small quantities and most likely do not provide much nutritional value to honey bees.

Lipids in banana pulp	Banana pulp	Banana peel	Black's suggested pollen substitute
Fatty acids, total saturated	0.112g/100g	1.7g/100g	
Fatty acids, total monounsaturated	0.032g/100g	No data available	
Fatty acids, total polyunsaturated	0.073g/100g	No data available	
Linoleic acid	460mg/kg	No data available	1218mg/kg
Linolenic acid	270mg/kg	No data available	4264mg/kg
Fatty Acids, total trans	0g/100g	No data available	
Cholesterol	0mg/100g	No data available	
Phytosterols	16 mg/100g	No data available	

Source: (USDA, 2018); (Mohapatra, Mishra, & Sutar, 2010); (Black, 2006)

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AMINO ACIDS

- Amino acids play a vital role in bee health. In simple terms they are the building blocks of all life forms. De Groot published his extensive study on amino acids in 1953. Much of his research is still today's standard (De Groot, 1953).
- A pollen deficiency or shortage decreases colony population. Royal jelly depends on amino acids brought into the hive via pollen foragers. Pollen influences physiological metabolism, immunity, and bee health. The insect's fat body depends on it. Fat body is high in larvae, and directly influences the metamorphism into an adult bee. It decreases as the bee ages and make the bee more susceptible to disease and other environmental factors. Pasquale tested the influence of pollen nutrition on honey bee health and showed a connection between bee health and pollen quality (Pasquale, et al., 2013).
- Pollen stress during larval development had physical and behavioral effects on adult bees. Workers on an inadequate diet were lighter, shorter lived, poor waggle dancers, and poor foragers (Scofield & Mattila, 2015).
- Schmickl and Crailsheim showed cannibalism and early capping of brood in colonies voided of pollen (Schmickl & Crailsheim, 2001).
- Amino acids have a direct influence on the lifespan of a honey bee (Paoli, Wakeling, Wright, & Ford, 2014).
- In lab testing they found that 12mg/g tryptophan increases the bee's lifespan (Fengkui, Boahua, Ge, & Hongfang, 2015).
- Tryptophan can be catalyzed into serotonin, and tyrosine into dopamine.

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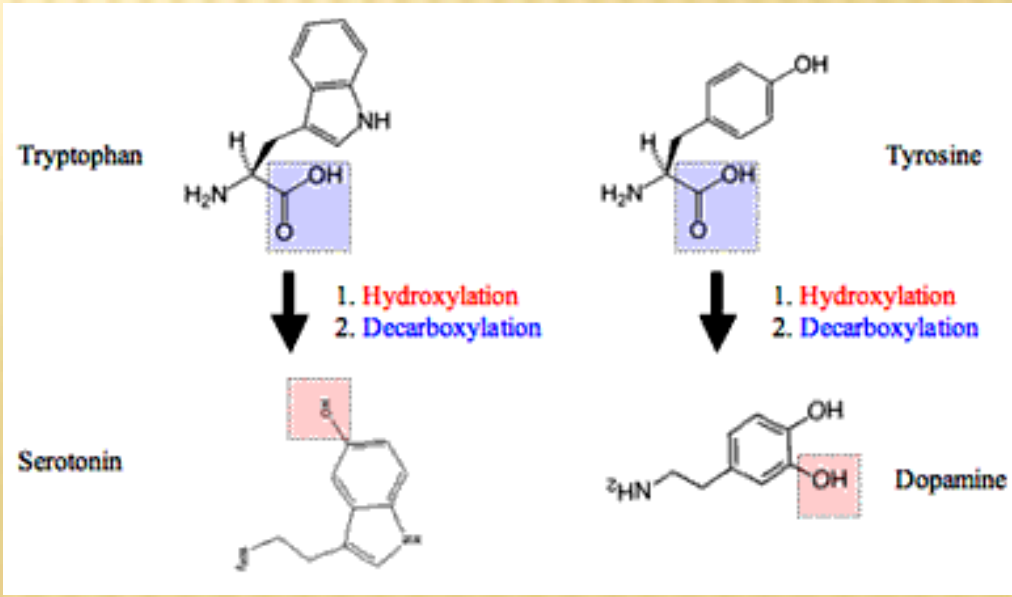
AMINO ACIDS

- Natural pollen provides better overwinter survival over colonies fed on protein supplements. Protein titers were the same in natural pollen and pollen substitutes fed bees. However, bees on substitute pollen showed more queen losses and more problems with diseases. This indicates natural forage may be better for honey bee winter survival (DeGrandi-Hoffman, et al., 2016).
- Proteins increase during the ripening process of bananas (Mohapatra, Mishra, & Sutar, 2010).
- Amino acids are simply not high enough for bees when compared to the Black's Honeybee Nutrition table (Black, 2006). This suggests adding a pollen substitute during banana feeding.

Amino Acids	banana pulp mg/kg	banana peel mg/kg	Black's suggested pollen substitute mg/kg
Tryptophan	90		3,250
Threonine	280	181.9	10,000
Iso-leucine	280	75.0	13,250
Leucine	680	150.0	19,250
Lysine	500		16,750
Methionine	80	138.8	4,750
Phenylalanine	490	230.6	10,250
Valine	470	165.0	16,750
Tyrosine	90		ND
Arginine	490		12,750
Histidine	770	521.3	5,500



Source: (USDA, 2018); (Sharaf, Sharaf, Hegazi, & Sedky, 1978); (Black, 2006)

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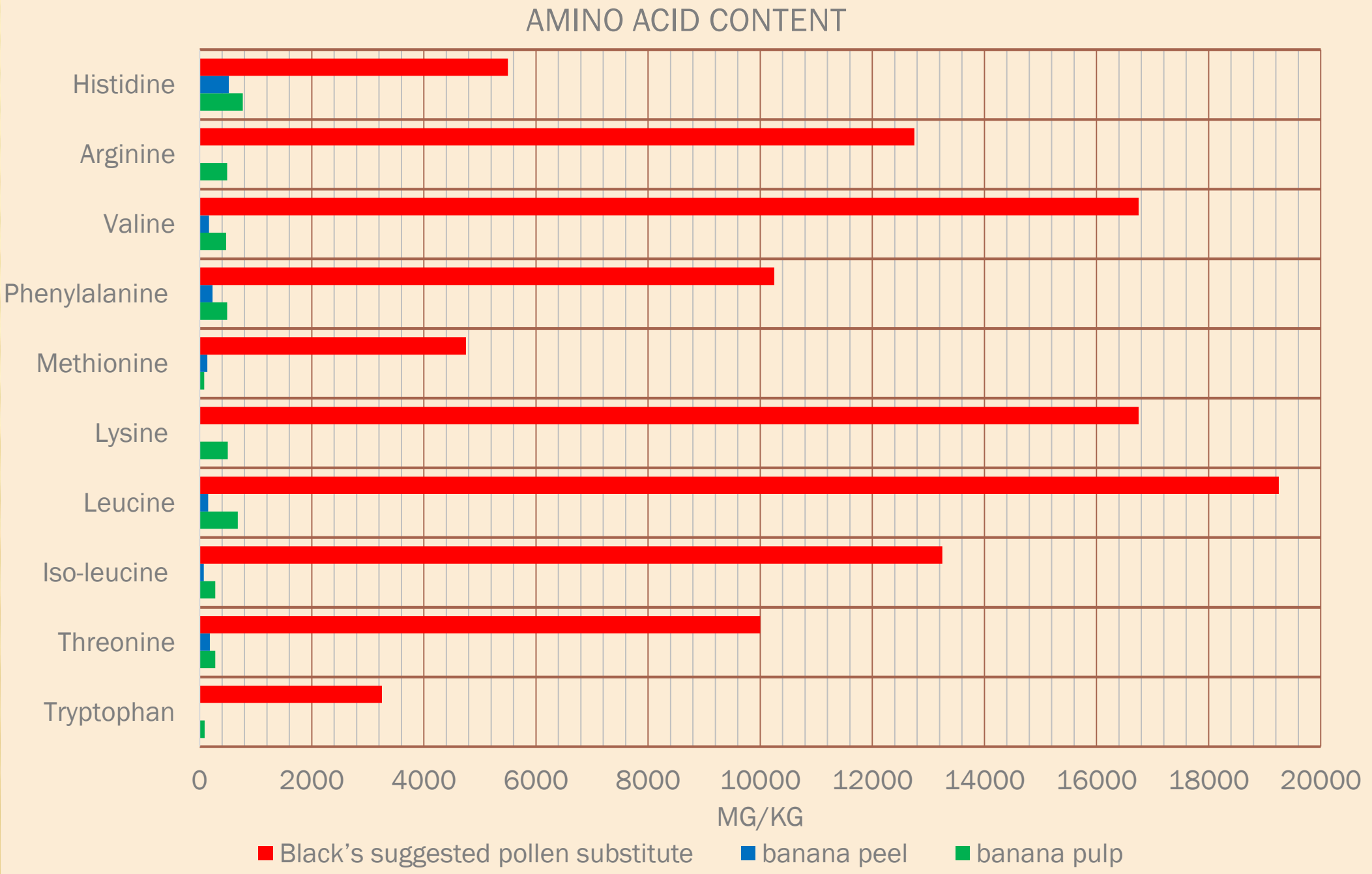
AMINO ACIDS



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VITAMINS

- Vitamins play a role in bee nutrition. Hives deficient of vitamins fail to rear brood (Haydak, 1970).
- Adding the inositol, gibberellic acid, vitamin B group, vitamins A and K increases brood rearing success. The addition of vitamin C increased brood rearing capacity (Herbert & Shimanuki, 1978).
- Bees fed vitamin C had 33% less winter losses (Farjan, Dmitryjuk, Lipinski, Biernat-Lopienska, & Zoltowska, 2012).
- B vitamins are essential for the development of the hypopharyngeal glands with the pantothenic acid B5, thiamine B1 and riboflavin B2 been established (Herbert & Shimanuki, 1978). Larval food was rich in pantothenic acid B5, niacin B3, and pyridoxine B6 content, but decreased with the age of the nurse bee. However, there was no change in ascorbic acid (C) in aged nurse bees (Herbert & Hill, 2015).
- Vitamin E prevents lipid oxidation and affects reproduction in insects (Cheng, Zhang, Shen, & Li, 1993).
- Supplementing vitamin E in syrup increased royal jelly production in colonies (Sahinler, Gül, & Sahin, 2005).
- Pollen is rich in water-soluble vitamins C and the B group, but is low in fat-soluble vitamins A and K (Herbert & Hill, 2015).
- Banana pulp is rich in vitamin C, vitamin A, B-vitamins, and vitamin K. We could not discover information regarding vitamin content in banana peel. Bananas vitamins may aid honey bees but are not high enough concentrations.

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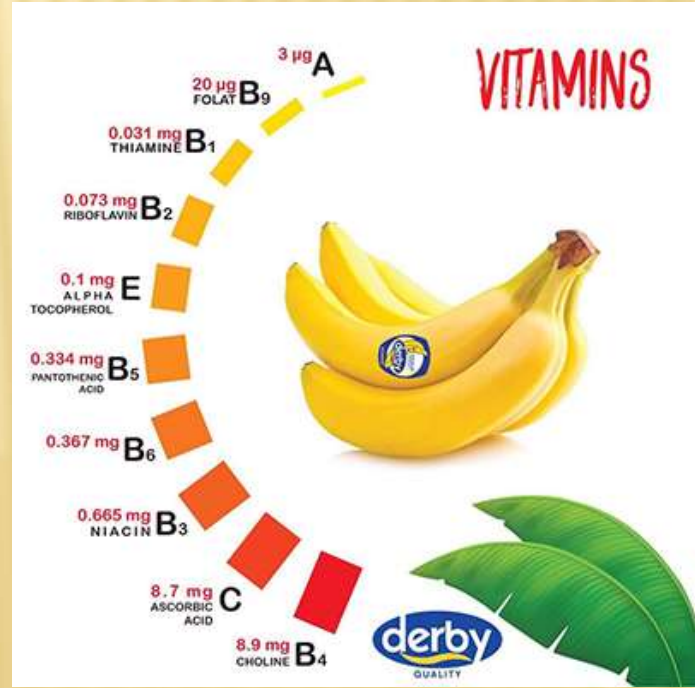
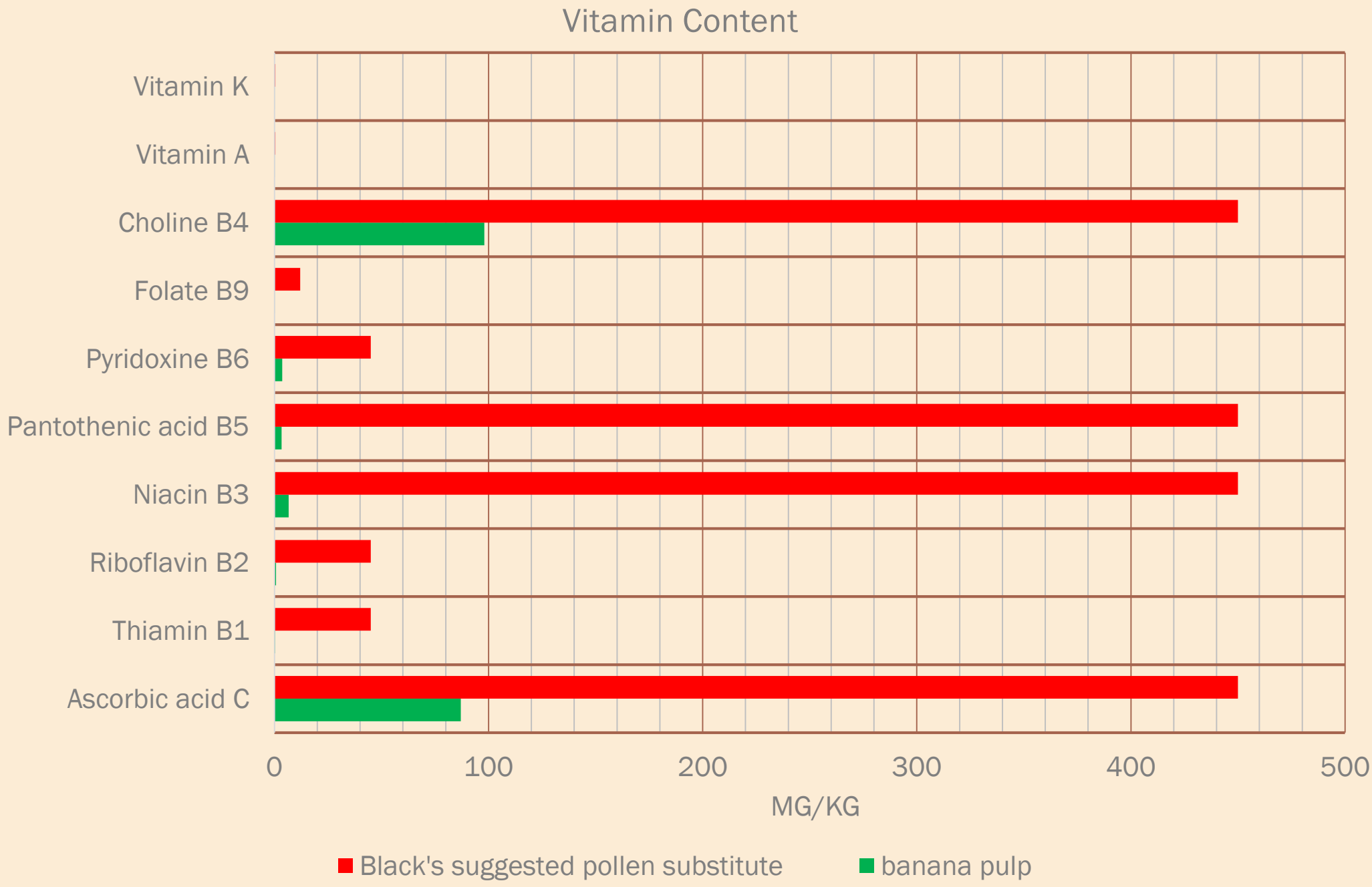
VITAMINS

Vitamins	Banana pulp mg/kg	Banana peel mg/kg	Black's suggested pollen substitute mg/kg	Water or Fat Soluble
Ascorbic acid C	87.0000	-	450.0	water
Thiamin B1	0.3100	ND	45.0	water
Riboflavin B2	0.7300	ND	45.0	water
Niacin B3	6.6500	ND	450.0	water
Pantothenic acid B5	3.3400	ND	450.0	water
Pyridoxine B6	3.6700	ND	45.0	water
Folate B9	0.0240	ND	12.0	water
Choline B4	98.0000	ND	450.0	water
Vitamin A	0.0040	-	0.4	fat
Vitamin K	0.0006	ND	0.4	fat
Vitamin E	0.0001	ND	ND	fat

Source: (USDA, 2018); (Mohapatra, Mishra, & Sutar, 2010); (Black, 2006)



VITAMINS



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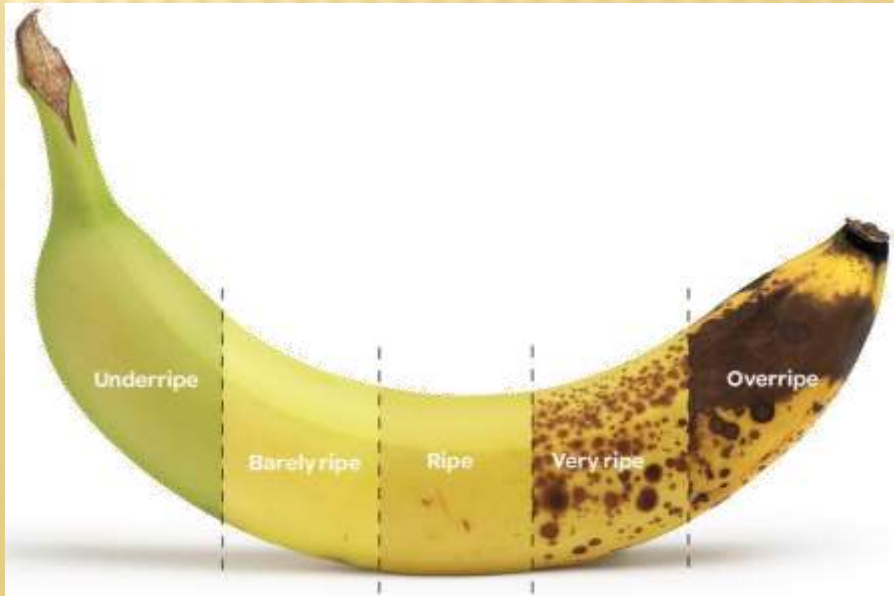
PHENOLIC COMPOUNDS AND FLAVONOIDS

- Phenolic compounds are directly related to botanical resources, such as pollens, nectars, resins and oils that bees collect (da Silva & all., 2013).
- Bananas are rich in phenolic compounds and flavonoids, which have antioxidant properties (Mohapatra, Mishra, & Sutar, 2010).
- Phenolics within banana peels have been found to have potent antioxidant and antimicrobial properties. Total phenolic content was found to decrease with the ripening process. (Vu, Scarlett, & Vuong, 2018).
- Phenolics are more abundant in peel than in pulp. The peel extract showed 2.2 times stronger antioxidant activity than the pulp (Someya, Yoshiki, & Okubo, 2002).
- More research is needed to understand their roles in honey bee health.
- **Dr. Dale Hill:**
  "There has been very little good scientific information about phenolics for honey bees. Most of the information that I've used in the past has come from the human food industry regarding the various phenolic compounds/sources and their modes of biological activity. One of the more significant uses of phenolics is their role as antioxidants in foods. We don't really know that much about whether this biological role also occurs in the body, but it does appear to do so at some level."



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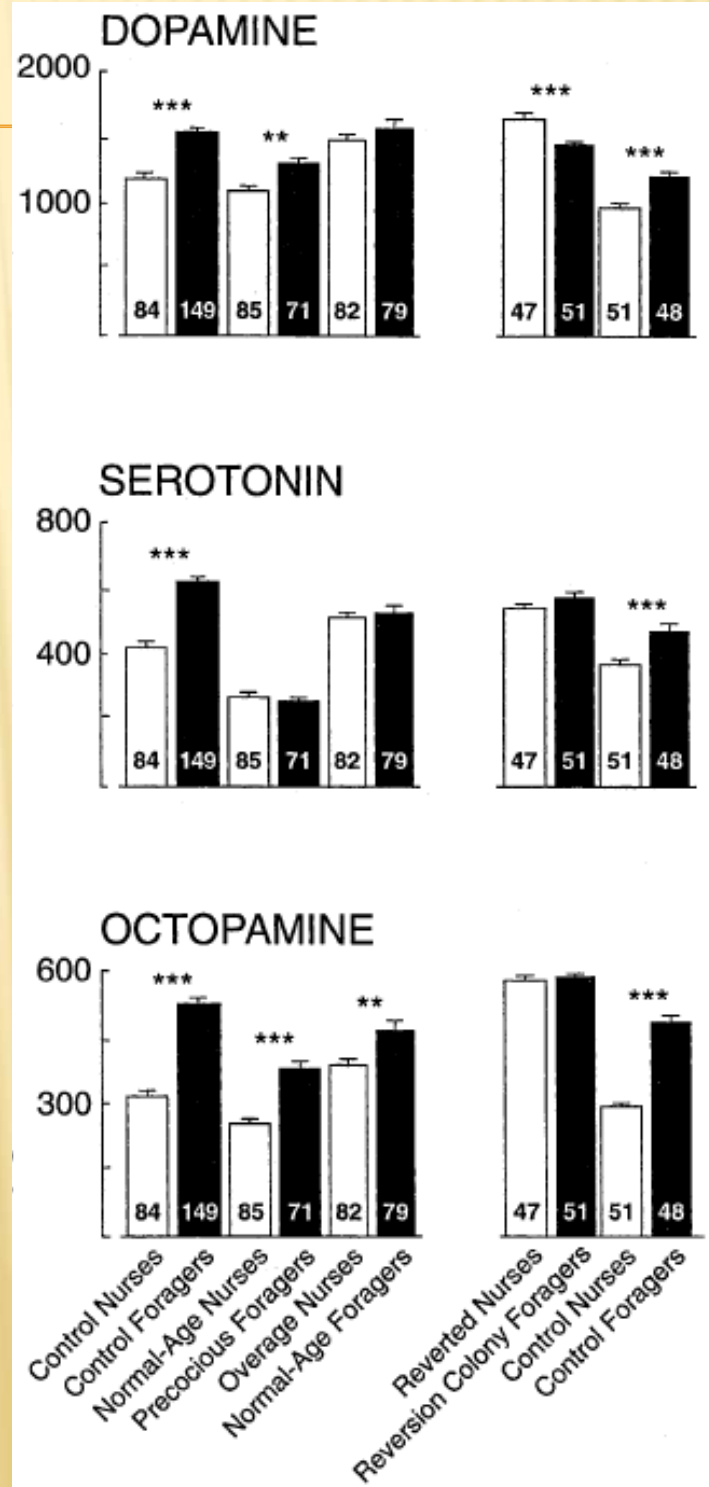
AMINES

- Amines are known neuromodulators that influence behavior like aggression, foraging, feeding, sexual, learning and memory. Dopamine, serotonin and octopamine are found in the brain of the honey bee.
- Amines levels vary with age suggesting its involvement in colony division of labor. **Dopamine** for nectar foragers. **Serotonin** for guard bees, pollen and nectar foragers. **Octopamine** for pollen and nectar foragers. Foragers had 10-37% higher levels of dopamine, 23-35% higher levels of serotonin, and 21-51% higher levels of octopamine than nurse bees (Wagener-Hulme, Huehn, Schulz, & Robinson, 1999).
- Dopamine is found in juvenile hormones. Banana fed colonies were able to sustain continuous and rapid growth. Akinwande suggests that feeding amines to bees has a role in inducing foraging behavior. (Akinwande & Badejo, 2009) (Akinwande & Badejo, 2009).
- Nectar foragers had 10-37% higher dopamine levels, suggesting that it made them more productive (Wagener-Hulme, Huehn, Schulz, & Robinson, 1999).



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AMINES

- Serotonin decreases responsiveness to Isopentyl acetate IPA (Harris & Woodring, 1999).
- Serotonin can affect worker bee behavior, lifespan, reproductive cycle, antioxidant function and levels of aggression (Tierney, 2001).
- In lab testing they found that feeding 12mg/g serotonin in sugar syrup increases the bee's lifespan (Fengkui, Boahua, Ge, & Hongfang, 2015).
- Scheiner found that feedings of octopamine and tyramine increased sucrose responsiveness but feeding dopamine did not (Scheiner, Plückhahn, Öney, Blenau, & Erber, 2002).
- Wright found that dopamine is associated with food aversions and learning. Dopamine was associated with the avoidance of bitter substances (Wright, 2011).
- Banana contains large amounts of dopamine in the peel. The amount decreases with ripening within the pulp and increases within the peel (Kanazawa & Sakakibara, 2000).
- The table shows that dopamine stands out in large quantities within banana peels, and our hypothesis is that it stimulates honey bees.

Amines	Banana pulp, ripe mg/100g	Banana pulp, overripe mg/100g	Banana peel, ripe mg/100g	Banana peel, overripe mg/100g
Dopamine DA	2.5-10	0.72-6.1	50-560	235-930
Serotonin 5HT	3.6	3.5	6.7	16.55
Tryptamine	0	ND	0	ND
Tyramine	6.5	ND	0.7	ND
Norepinephrine	12.2	ND	0.2	ND

Source: (Kanazawa & Sakakibara, 2000); (Udenfriend, Lovenberg, & Sjoerdsma, 1959)

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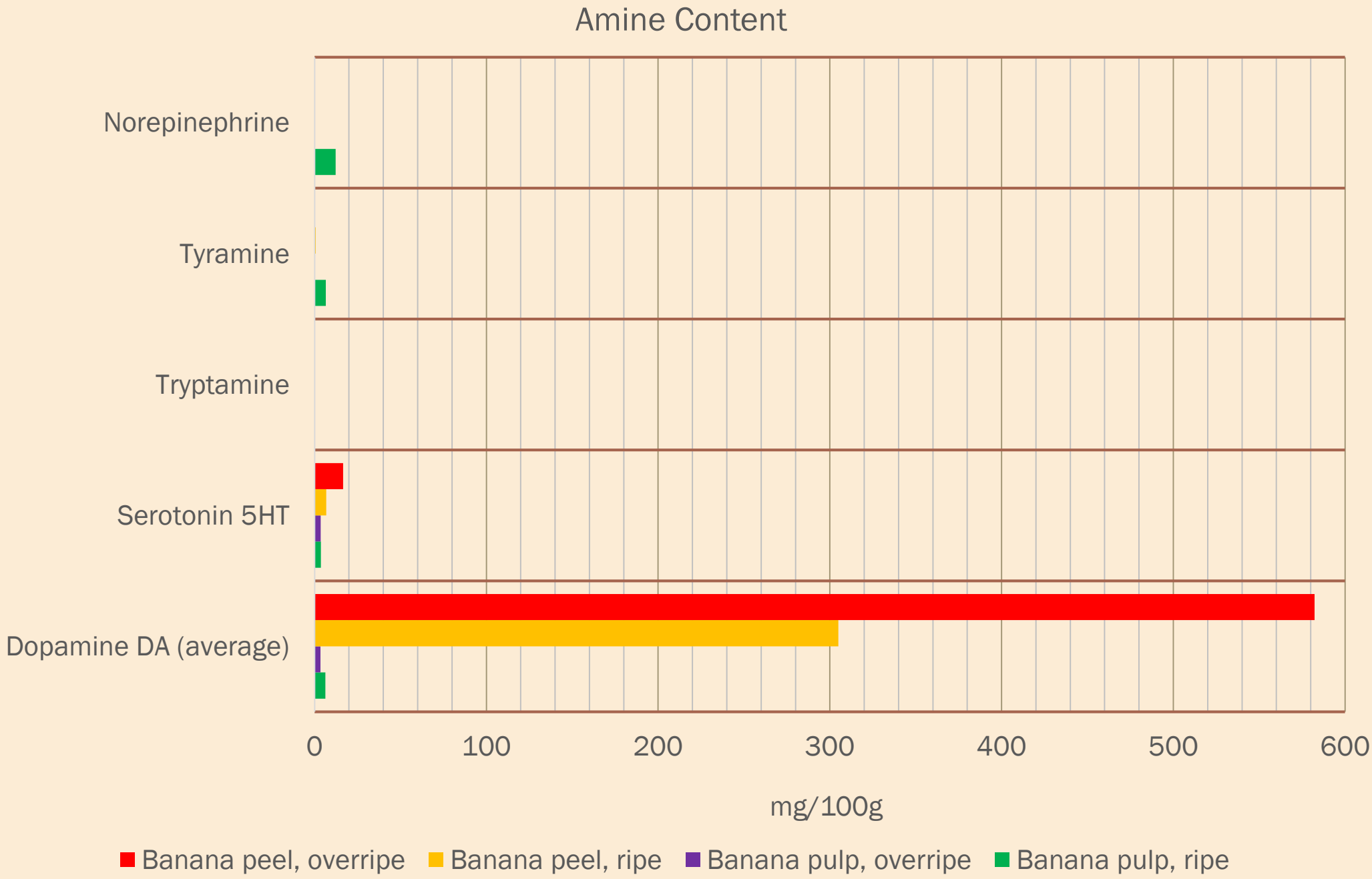
AMINES



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FUNGICIDES

- Bananas are grown in humid climates with plenty of rain, and many fungi thrive in such condition. Pesticides are used to combat fungi on bananas. Most fungicides are in/on the peel, but some can be detected in the pulp itself. A list of known banana diseases and their treatment is available online (Kumar, 2012). http://agropedia.iitk.ac.in/content/banana-diseases-their-control
- We know that some fungicides will affect honey bees (Hooven, Sagili, & Johansen, 2016) (Connelly, 2012).
- We could not find studies showing impact on honey bees foraging bananas due to fungicides. Perhaps it is best to wash the peel prior to introduction to the hive.

Aerial spraying of fungicides on a banana plantation.
Image Credit: GHJ Kema.

Indian banana grower develops a way to grow bananas without pesticides

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COMMERCIALLY AVAILABLE POLLEN SUBSTITUTES

- We have tried to find the composition of commercially available pollen substitutes and found that many are proprietary. This makes it almost impossible to make a smart decision on which one to buy.
- Most will list total protein and the amino acids based on De Groot's recommendation. Some state the protein source, probiotics, and that minerals/vitamins have been added.
- We have also found evidence that some are based on Wesson's Salt for invertebrates, containing excessive amounts of calcium and sodium (Herbert & Hill, 2015).
- Some supplements are soy based and others are not. Gregory reports that Feed-Bee and Bee-Pro contained stachyose, which is toxic to honey bees unless it is under 4% with 50% sucrose (Gregory, 2006).
  Bee-Pro® is soy-based, and Feed-Bee® and MegaBee are non-soy-based.
- Commercially available products do increase brood area and population size (DeGrandi-Hoffman, Wardell, Ahumada-Sedura, Rinderer, & Danka, 2008).
- We cannot directly compare bananas with pollen substitutes, due to bananas not containing enough amino acids, but feel that it may benefits honey bees if supplied in addition to pollen substitutes. Further testing is needed.

Ingredients: Plant Protein Products, Processed Grain By-Products, Roughage Products, Canola Oil, Lemongrass Oil, Sodium Chloride, Vitamin A Supplement, Vitamin D_3 Supplement, Vitamin E Supplement, Ascorbic Acid Stabilized, Zinc Sulfate Monohydrate, Menadione Sodium Bisulfite Complex, Riboflavin, Pyridoxine Hydrochloride, Folic Acid, Biotin

Sample of a pollen substitute product.

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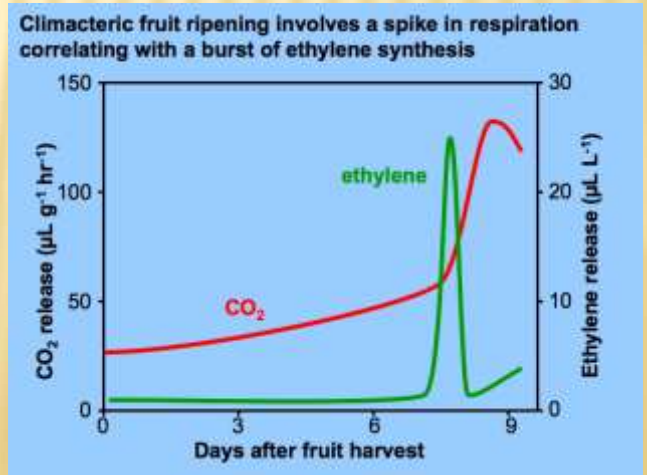
CHALKBROOD IN BEES

PLAUSIBLE

- Australian beekeepers have been putting banana peel into their hives to suppress chalkbrood disease (Hornitzky, 2001).
- Banana peel contains at least 200 individual volatile components, and fermentation produces ethanol, ethylene, and acetaldehyde. These were shown to inhibit mold growth in oranges (Yuen, Paton, Hanawati, & Shen, 1995).
- Some people have suggested that the banana entices the bees to perform hygienic behavior and overcome chalkbrood that way.
- We have not found a single study showing that banana peel cures or suppresses chalkbrood, nor could we find any study showing that banana induces hygienic behavior.
- To the contrary, we found that bees do not discard the peel and digest it when put into a hive in during our 2018 tests.

Credit: iStockphoto



http://plantphys.info/plant_physiology/ethylene.shtml

http://beeaware.org.au/archive-pest/chalkbrood/

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BEE BEHAVIOR AND BANANAS

- Isopentyl acetate aka isoamyl acetate (IPA) is the main active component of the alarm pheromone mix.
- IPA is naturally present in many fruits; it is used in food aromas, fragrances in the cosmetic industry, many cleaning products and air fresheners (PubChem, 2019).
- IPA is present in bananas and does not cause defensive stinging behavior by itself. Pankiw describes alarm behavior as being distinguished by the absence of stinging (Pankiw, 2004).

- Bortolotti and Costa identified 40 compounds in the worker sting apparatus. Among these are 15 components that stimulate one or more alarm behaviors like biting, stinging, and pursuing. They describe IPA's main function to alerting and eliciting defensive responses (Bortolotti & Costa, 2014).
- We conducted several tests in 2018 to monitor bee behavior in the presence of banana pulp and peel. One thing that became apparent was that bees are not interested in Cavendish bananas if openly fed, put on top a hive, or at the hive entrance. It is unclear why, but most likely due to their sugar content not to be in their preferred concentration. There are banana cultivars that are sweeter, and it has been reported that bees are willing to take those in an open feeding environment.

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BEHAVIOR TESTS OF HONEY BEES WITH BANANAS

- All three tests were done with same method.
- We took ripe store-bought Cavendish bananas.
- Each unpeeled banana was sliced in half and cut into half giving us 4 quarter pieces. The average piece weight was 50 grams.
- Banana pieces were placed into hives over the top bars with peel and pulp.
- They were squished down to accommodate the inter cover fit.
- We used 8 colonies for each test.


Photo: Anthony Azzariti

Watch Anthony Azzariti feeding bananas to his bees. No protective gear! Anthony lives in Thailand where he utilizes a different variety of dessert banana called Latundan or Apple Banana. He has been experimenting with bananas in his colonies since 2018.

https://www.youtube.com/watch?v=MCSvRF7PgOE

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BEHAVIOR TESTS OF HONEY BEES WITH BANANAS

- **Test 1 Stinging Behavior**
- Will banana presence entice stinging behavior?
- Bananas contain IPA, which is an active component of the sting pheromone. We tried to figure out if honey bees will aggressively sting when bananas were placed into hives.
- We observed normal behavior as we placed the banana over the bars, but got their attention the moment we squished them down. No stinging behavior was observed, but we noticed some bouncing behavior on our veils. Bouncing behavior stopped once the hive was closed. No pursuing behavior was observed.
- We repeated this feeding in 4 weekly intervals on our 8 hives and consistently observed the same behavior.
- We would not suggest doing this without proper protective gear. Smoker was not always necessary but was used to clear areas of bees before we applied the banana piece.

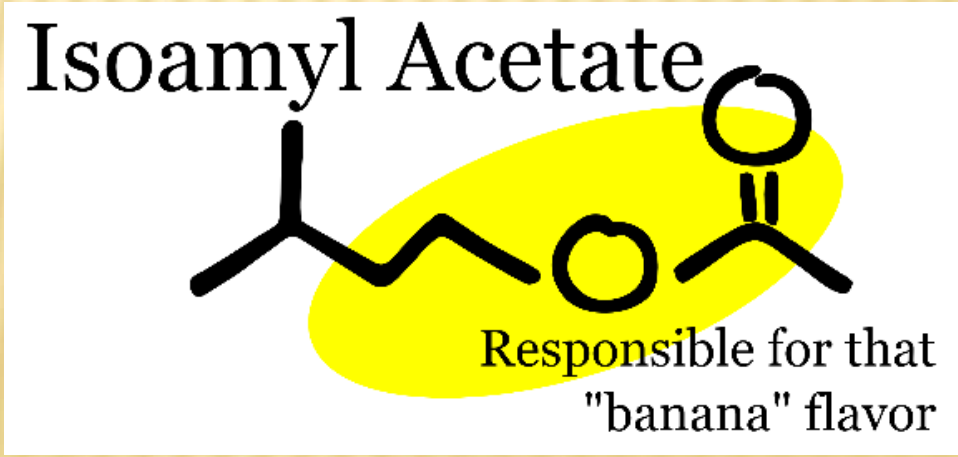

Image: Science and Food

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BEHAVIOR TESTS OF HONEY BEES WITH BANANAS

- **Test 2 Banana Consumption**
- Will honey bees accept banana as an alternative feed before and during the first nectar flow? Or will they just remove it from the hive?
- We used bananas with peel in spring during rear up on 8 colonies to see if the bananas were removed from the hive and discarded. For this experiment we again we placed weekly 50g banana pieces inside of the hive squishing down onto the bars.
- We have noticed that all colonies needed one week to consume the amount given. We found no evidence of discarded banana parts in front of the hives or on the bottom board. The peel was mostly consumed, but we sometimes found about 1-2 cm^2 peel left behind.
- Our 8 colonies of honey bees readily took the banana supplement until the first nectar flow. After that they refused to touch the banana and simply left it where we put it. A few of them removed some of the banana pulp. We observed some mold growth on the banana after a week. We offered 3 more banana feedings over the following weeks with the same results.

http://www.greatstems.com/2009/11/war-peace-and-bananas.html

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BEHAVIOR TESTS OF HONEY BEES WITH BANANAS

- **Test 3 Nectar Death**
- A final test was done in late summer after Rabbit brush was done blooming and we were going into nectar dearth. We had some early cold snaps in summer, which is not uncommon in our high elevation and desert climate in the Klamath Basin of Oregon.
- Again, we offered 4 weeks of banana feeding to our colonies. We placed 100g of banana into the strong populous summer colonies.
- This time they took it again with the same results we had during rear up before the first flow - they consumed it all.
- After 4 weeks we stopped and applied our fall mite treatment and prepared the hives for winter as usual.

Photo: Katharina Davitt

Feeding your hive is one way to help them survive a dearth.
(Photo: shoot4pleasure/Shutterstock)

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CONCLUSION

- We conclude that honey bees may benefit from banana supplementation during off-seasons, like in spring for rear-up, during pollen and nectar dearth, and in fall for winter preparation.
- Bananas by themselves are not enough nutritionally and are best used as an additive. Making a patty or sugar syrup; containing sugar, a dry pollen sub and bananas can improve bee health.
- In our review we found minerals and amines of particular interest. The question is can these be added to existing pollen substitutes instead?
- Bananas are being used in tropical climates as an alternative feed and do improve bee health by strengthening hives. They are a free or cheap solution to such nations.
- In the US it would be more of a novelty idea. We found 3 studies showing that bananas increase brood and honey production in tropical climates. No studies have been done in temperate climates.
- We have found beekeepers to say that it only makes bees aggressive and causes hygienic behavior without any studies to prove these statements. More studies are needed, and this topic will remain controversial to some.
- We plan on doing a rear up study of packages in spring of 2019.

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SPRING MANAGEMENT RECOMMENDATION

- Bananas have positive effects on honey bees as they rear up in spring.
- According to Akinwande not only do they rear up faster producing 10% more brood, but they will also produce 20% more honey.
- Winter bees start to rear summer bee brood before the first flow comes on. As a guideline keep an eye on the willows budding out. Start feeding bananas at that point.
- To feed cut the banana lengthwise and cut one more time in half. Feeding a quarter banana at a time is advised or you my may find left over banana covered in mold. Add more as needed on a weekly basis.
- We have found that the bees will eventually stop taking it. Usually when the dandelions start to bloom and the first flow is on. At that point they find all their nutrient requirement from floral sources.

Photo: Katharina Davitt

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FALL MANAGEMENT RECOMMENDATION

- Floral sources are rich in nutrients in fall for insects to make it through the winter.
- Honeybees start to rear winter bees before the first frost. In our region it is with the onset of the rabbit brush blooming. That can be mid August to mid September. At that time all supers should be off, so bees can back fill empty hive cells with honey and bee bread for winter.
- Pollen is extremely important to them since it provides the protein, fat, and minerals the winter bees need to live longer than the summer bees.
- This is the time we suggest to offer bananas to the bees and follow your normal winter preparation.

Photo:
Katharina Davitt

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RESULTS AND DISCUSSION

- Are Cavendish bananas suitable as honey bee feed? We have investigated carbohydrate, protein, lipid, vitamin, mineral, and amine contents. We compared those to John Black's book "Honeybee Nutrition: Review of Research and Practices" by the Australian Government Rural Industries Research and Development Corporation. His feeding recommendations for supplemental honey bee feeding are rather comprehensive for what we know at this point.
- Bananas contains contain sucrose, glucose and fructose sugars in modest concentrations. These levels go up as the fruit ripens. Cavendish bananas are naturally low in starch, and almost free of starches when overripe. Banana lacks toxic bee sugars like mannose, lactose, galactose and raffinose. Adding sucrose will make the feeding of bananas more attractive to honey bees.
- The mineral content is suitable for honey bees. Various levels are found within the pulp and the peel. Iron, sodium, zinc and copper are highest in the peel. Magnesium, phosphorus, and potassium are high within the pulp. This suggests that both should be fed to the honey bees. Total calcium is 1/3 of what has been recommended by Black, and Somerville found excess amounts can cause paralysis. Bees seek calcium, magnesium and potassium sources in fall, suggesting that these are needed for winter survival. Potassium stands out exceeding Blacks suggestion. We feel that this may be important for the winter preparation of the hive when the long-lived winter bees are being raised. Bananas are a rich sources of ash (peel) and potassium (pulp).

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RESULTS AND DISCUSSION

- Amino acids, lipids, cholesterol and sterols are not enough within the banana suggesting the supplementation of such when feeding bananas.
- Vitamins found within the banana are insufficient within the pulp, and no data on the peel was available. Choline and vitamin C supplied in the pulp were about 15% of the bee's requirements.
- Phenolic compounds and flavonoids are present in bananas and they do provide antioxidant and antimicrobial properties. Phenolic content was found to decrease with the ripening. Overall, more research is needed to make a recommendation.
- Dopamine and serotonin levels were present in the peel and twice as high in overripe banana peel. Dopamine stood out with very high levels. These neuromodulators affect the bee's behavior. Dopamine and serotonin are associated with foraging. Dopamine is also found in juvenile hormones and colonies fed dopamine were able to sustain continuous and rapid growth. Serotonin also increases the lifespan of bees. We suspect that amines within the banana have a major impact on honey bee colonies.
- Commercial pollen substitutes have shown to increase brood and population size. Most are of proprietary mixes and generally only the amino acid contents are listed. Some have the addition of minerals and vitamins. We suggest feeding them in addition to the banana.

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RESULTS AND DISCUSSION

- Ethylene acetaldehyde is being released as the banana peel decomposes. We could not find any studies supporting that it cures or suppresses chalkbrood, nor could we find anything supporting that it entices hygienic behavior. In our tests we found that bees eat the peel and do not dispose of it.
- Bananas are grown in humid climates and are sprayed for fungi. We suggest washing the peel prior to feeding them to colonies.
- Further, we conducted some basic experiments to see how honey bees will respond to banana exposure, their behavior, feeding quantities, and seasonal feeding responses. IPA within the banana does not induce stinging behavior. It does cause alarm behavior when squished over hive frames. We have also established that a spring colony will consume about 50 g of banana per week, while a fall colony will consume twice as much. Cavendish bananas will only be consumed via internal feeding. Honey bees will not consume banana when there is plenty of natural forage present. Therefore, banana is most beneficial during spring, nectar dearth, or fall-winter preparation of the colony.

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