Master Beekeeper Certification Course: Category #8
By: Louis Matej
Date: 1 May 2004
Name: Pollen and Pollination

Subject: The nutritional value and chemistry of pollen from various sources, both for colony management and human consumption, to include the assessment of a colony for pollination.

PROPOSAL

1. Discuss the chemistry of pollen.
2. The utilization of pollen by the honeybee for brood production and metabolism.
3. Assessment of a colony fit for commercial pollination.
4. An analysis of pollen substitutes.
5. The nutritional values of various types of pollen for human consumption.
6. Written paper and to be included as part of an oral presentation of the chemistry of bees.

REFERENCES

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Saffari, Abdolreza M.; Devan, Peter G. and Atkinson, James L. "A Promising Pollen Substitute for Honey Bees"

"Nutritional Value of Bee Collected Pollens", Publication, Rural Industries Research and Development Corporation, NSW Agriculture

Mussen, Eric C., Extension Apiculturist, UC Davis, "Feeding Bees Pollen Substitutes"

Spear, Lloyd; "Golden Harvest, Part I", Bee Culture Magazine, Feb 2001, pages 29-31.

Burgett, D. M[1].; Fisher, Glenn C. [1]; Mayer, Daniel F. [2]; and Johansen, Carl A. [2], "Evaluating Honey Bee Colonies for Pollination", Oregon State University Extension[1] and Washington St. Unversity Extension[2] Publication

ABSTRACT

Pollen and Pollination

While carbohydrates provide the honey bee with necessary energy for heat, metabolism and movement, pollen provides the bee with essential nutrients for brood rearing, synthesis of needed metabolites, and maintenance of honey bee viability. Not only does pollen contain all the 23 essential amino acids needed for protein production, it also contains at least 18 vitamins, 25 minerals, 59 trace elements, 11 enzymes or co-enzymes, 14 fatty acids, and 11 carbohydrates. Pollen predominantly contains 25% protein, 48.5% carbohydrates, 9.9% fatty acids, 14.2% fiber and 3.5% ash. Since it varies from one plant species to another, it is important for the beekeeper to understand the needs of the hive in terms of the availability of all nutrients for a healthy colony.

Pollen is a very elemental source of rich protein but also it is very low in fat while being easily obtained by the honeybee. Since it is such a high protein source, body builders use honey to provide a rich source of protein with a low fat content. Also, not only is pollen essential to the bee, it provides valuable vitamins, minerals, and other nutrients for building strong healthy bodies. This makes it very profitable for the bee as well as for human consumption.

When pollen is scarce during the time of brood rearing, because of location or weather, the beekeeper has the option to move his bees to a pollen rich area or to provide a pollen substitute to the bees to allow for maximum build-up for the honey flow. A pollen substitute or pollen supplement will not provide the same nutrition and brood rearing capability as normal incoming pollen, but it will provide needed nutrients to prevent a total shutdown of brood rearing and colony viability.

The value of honey bee pollination of agricultural crops amounts to around $6 billion. It is extremely important for the beekeeper who engages in commercial pollination to manage his colonies to meet the minimum standards required by the particular state where the hives are located. Oregon and Washington have regulations which must be met in order to legally engage in commercial pollinations services. The beekeeper must be aware of the quality of the queen, the health of the colony, the amount of brood present and the number of foraging bees available for each hive he wishes to hire out for pollination.

Master Beekeeper Certification Course: Category #8
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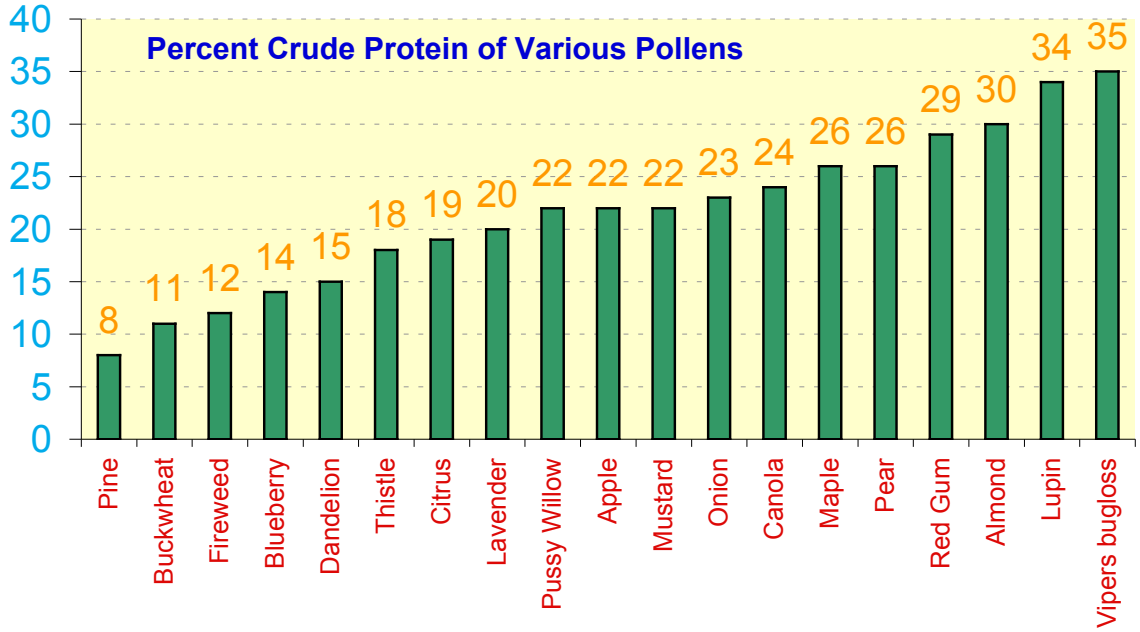
Date: 10 June 2004
Category: Pollen and Pollination

The Nutritional Value and Chemistry of Pollen from Various Sources, both for Colony Management and Human Consumption, to include the Assessment of a Colony for Commercial Pollination

The Chemistry and Composition of Pollen

Pollen is a very interesting and valuable food, providing a source for both energy production and protein synthesis for many insects. It is estimated that one colony needs a minimum of around 66 lbs. of pollen per year or in other words, one pound of pollen is needed to rear and support approximately 4,000 bees. Pollen consists of 8-40% protein, 15-45% carbohydrates, 1-15% lipids, minerals, vitamins, ash and other minor components. As opposed to anemophious (wind-borne) pollen, entomphious (insect-transferred) pollen is heavier, stickier, and more colorful coming in shades of yellow, brown, orange and red. The honey bee (*apis melifera*), obtains virtually 100% of it's protein as well as many nutrients and vitamins from pollen. As we can see from the chart below, not all pollen contains the same amount of crude protein.



Pear nectar is very low in sugar content, however it's pollen is relatively rich in protein. On the other hand, fireweed is a very high honey producing plant here in the northwest, yet it's pollen is of poor quality. Alternatively, just because the percent crude protein of a particular pollen is high doesn't mean it is of high quality. Pollen is classified into

four main groups depending upon the quality in providing longevity and broad development: Highly nutritious, Less nutritious, Fairly nutritious, and Poorly nutritious. In addition to proteins which are broken down into amino acids, pollen contains a variety of vitamins and minerals as well as some lipids. Here is a chart listing the average amounts of substances contained in various pollens:

	%		ppm
Protein	23.7	Iodine	Trace
Carbohydrates	27.0	Fluoride	Trace
Lipids	4.8	Selenium	Trace
Phosphorus	0.53	Thiamine	Trace
Potassium	0.58	Niacin	Trace
Calcium	0.23	Riboflaven	Trace
Magnesium	0.15	Pyridoxine	Trace
Sodium	0.04	Pantothenate	Trace
	ppm	Folic Acid	Trace
Iron	140	Biotin	Trace
Manganese	100	Vitamin B12	Trace
Zinc	78	Vitamin C	Trace
Copper	14	Vitamin A	Trace
Nickel	4.5	Carotenes	Trace
Boron	Trace	Vitamin D	Trace
Chromium	Trace	Vitamin E	Trace
Molybdenum	Trace	Vitamin K	Trace

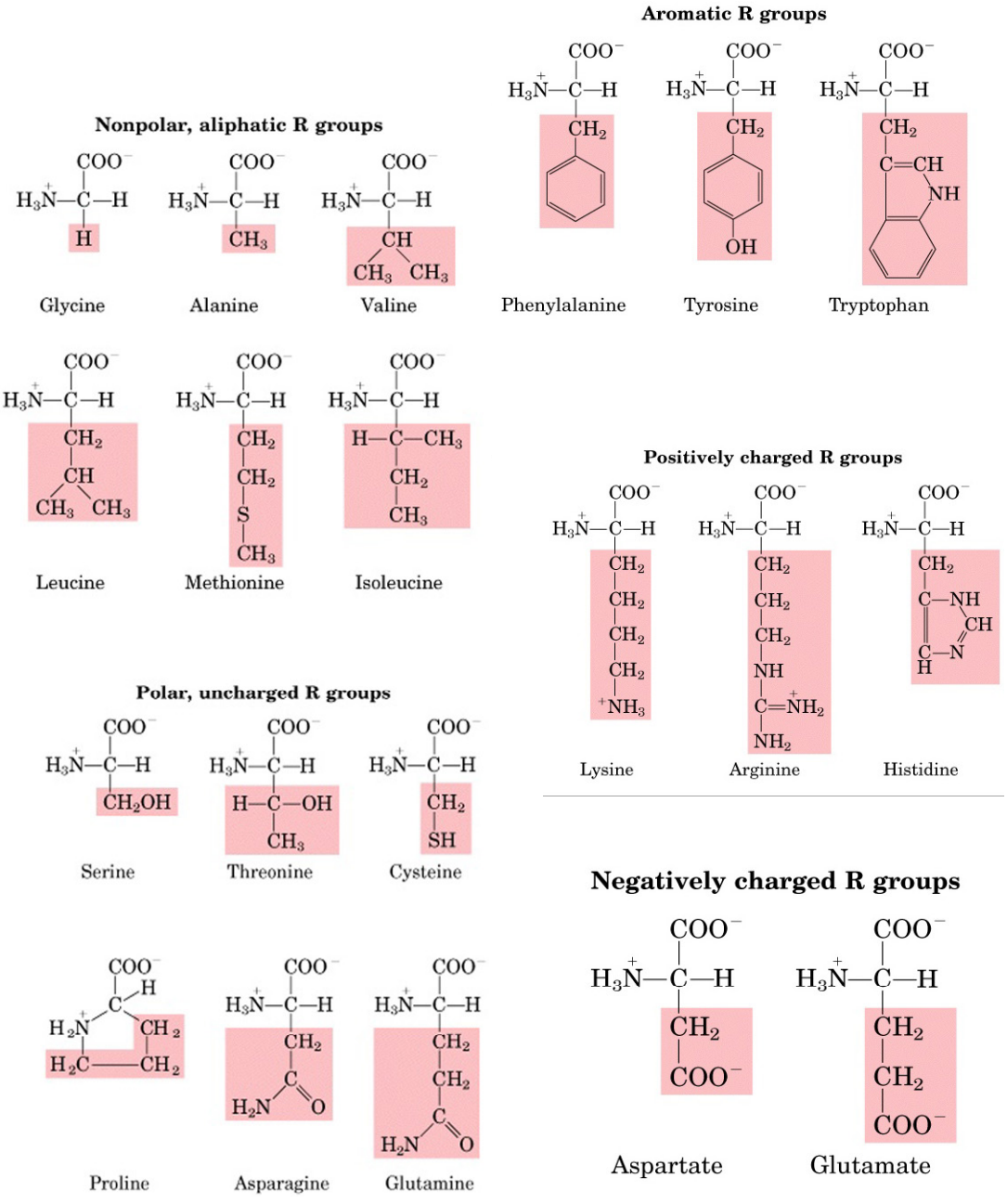
Vitamins and minerals are used by the bees to produce enzymes, pheromones, venom, and a variety of catalysts which aid in biochemical reactions involved in metabolism.

Since bees do not store fat as humans due, lipids are metabolized immediately. Some make their way into the biochemical pathways leading to the production of bees wax.

Having all of the essential amino acids available to the bees at all times and especially in the spring when brood rearing is in full gear is necessary for proper growth and survival of a colony. Amino acids and glucose are equally necessary for bee and if we feed sugar syrup to the bees in the spring we should also be aware of their need for a total essential amino acid supply.

Proteins are synthesized in the ribosomes of cells and consist of chains of amino acids. There are 22 known amino acids. Although honey bees need all 22, especially for growing brood, 10 of these are highly essential to the honey bee for survival. How is a pollen analyzed for it's nutrition? Two factors are important in a good pollen: 1. High in percent crude protein and 2. High in quantity of the 10 essential amino acids necessary to the bee. They are: Arginine, Histidine, Lysine, Tryptophane, Phenyalanine, Methionine, Threonine, Leucine, Isoleucine, and Valene.

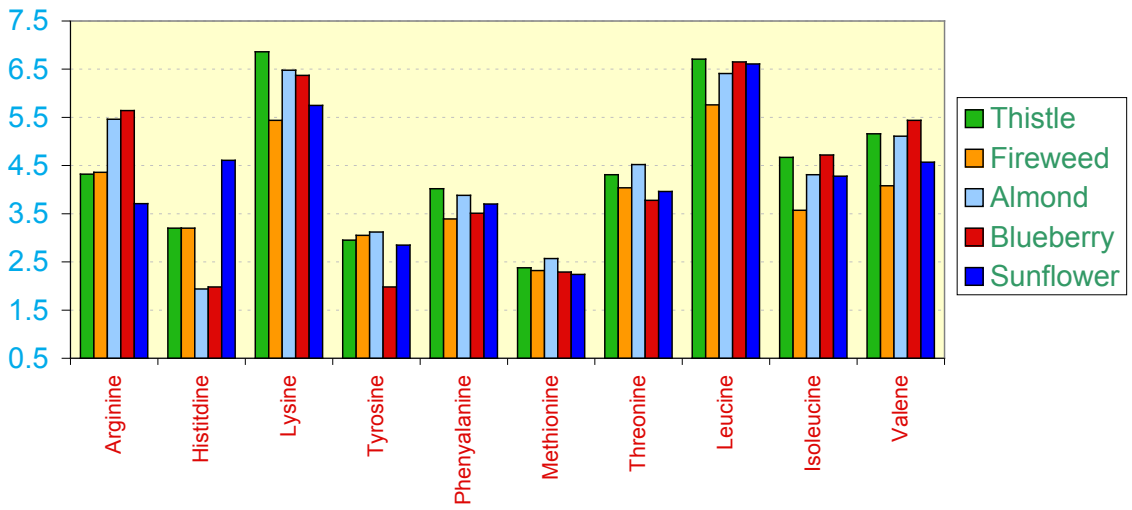
Here is a chart showing the chemical structures and differences of 20 amino acids:



When assessing a natural pollen source, the beekeeper should be aware of the quality of the pollen. If the bees do not have access to other pollens, one source of pollen may not provide adequate nutrition for the bees. Bees generally prefer a mixture of many different pollens because not all pollens are equal.

From the chart below you can see that pollen from blueberry flowers are sufficient in providing Arginine, Leucine and Valine, but are deficient in Histidine and Tyrosine. On the other hand, Sunflower is sufficient in Histidine and Leucine, but deficient in Arginine:

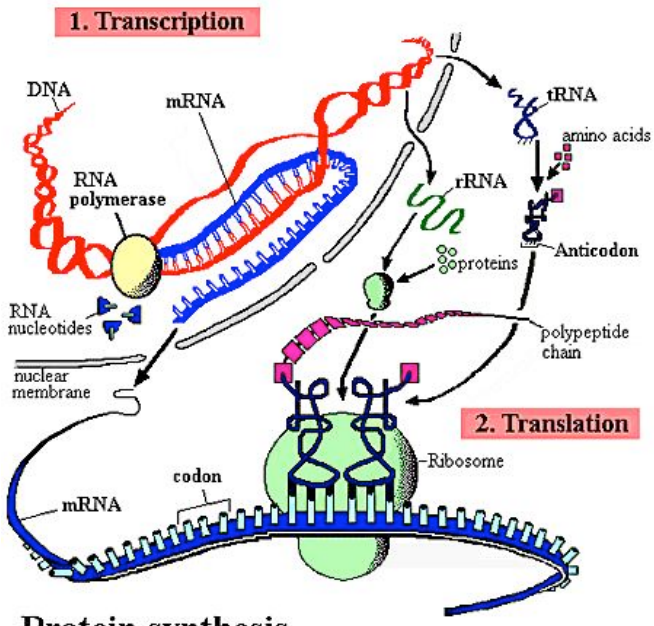
Chart:
% of each Amino Acid (Arginine, Histidine, Lysine, Tyrosine, Phenylalanine, Methionine, Threonine, Leucine, Isoleucine and Valine) to Total Amino Acid Content in Thistle, Fireweed, Almond, Blueberry and Sunflower Pollen



The utilization of pollen by the honeybee for metabolism and brood production

Protein Production

Why is it important for bees to have access to all amino acids? This is because when protein synthesis occurs in the ribosomes of cells, all amino acids and especially the 10 most important amino acids must be randomly available or protein synthesis will not occur or it will be slowed down. Honey bee larva grow at a very fast rate and protein synthesis is occurring rapidly. A lack of available amino acids will slow or even stop brood growth and survival. Below is a diagram of the protein synthesis on a cellular level. Transcription of genetic information occurs in the nucleus of cells. Messenger RNA (mRNA) carries this information to the ribosomes where translation occurs and proteins are produced. Proteins are chains of amino acids. Pollen is the only source of these amino acids for honey bee protein synthesis. Notice the random amino acids needed for protein synthesis to occur:



Protein synthesis

<----- Here all 22 amino acids are needed randomly to allow needed proteins to be synthesized in the cells of honey bees and brood. Millions of different proteins are synthesized from the amino acids derived from pollens.

<----- Proteins are synthesized by connecting amino acids through polypeptide bonds. The sequence is derived from messenger RNA (mRNA) transcribed from the DNA sequence in the nucleus. This protein synthesis is called Translation and happens in the ribosomes of all honey bee cells.

So you can see without pollen or a pollen substitute, bee brood cannot grow since translation cannot occur.

Amino Acid Metabolism (Catabolism)

Amino acids from pollen, like nectar, are also used by the honey bee to produce energy. The metabolism of amino acids involves 2 basic step common to all the different amino acids:

1. Transamination of Amino Acids

   In this step amino acids are converted to glutamate and Keto acids. Keto acids are used up to produce energy and for the synthesis of carbohydrates.

$$\text{Amino Acid} + \text{a-ketoglutarate} \xrightarrow{\textit{transaminase}} \text{Keto Acid} + \text{Glutamate}$$

2. Oxidative Deamination of Glutamate

   This final step converts glutamate to a-ketoglutarate which enters the Kreb Cycle (Tricarboxylic Acid Cycle) and is utilized for the production of stored chemical energy (NADH), which the bee needs for movement and heat. NADH is transported to the mitochrondria of various cells (such as the bee wing cell) and through oxidative phosphorylation is converted to energy to provide movement and heat. You will also notice that a-ketoglutarate is recycled for use in the above reaction.

$$\text{Glutamate} + NAD^{+} \xleftrightarrow{\textit{Glutamate dehydrogenase}} \text{a-ketoglutarate} + \text{NADH} + NH_3$$

Even though honey is used as the major source of energy, we can see that the honey bee also uses pollen for energy and heat production in addition to it's main use in protein production.

<u>An Analysis of Pollen Substitutes</u>

When pollen is scarce, pollen substitutes aid honey bees in providing the needed protein, vitamins, minerals, some carbohydrates and fatty acids for survival and growth of the colony. It is important to know that a pollen substitute enhanced with pollen itself becomes what is termed a pollen supplement. A pollen supplement adds to the nutrition as well as the attraction of honey bees. These supplements should be given 6 to 8 weeks prior to the honey flow and have been shown to increase honey production up to 38%.

Depending on how much a beekeepers is willing to spend, there are a number of pollen substitutes which vary in nutrition, ease in use and availability.

Over the years, brewer's yeast has been used as a pollen substitute. More recently soybean flour and wheast (a combination of low-lactose whey and yeast) have been used. These are made by adding 3 parts brewer's yeast, soybean flour or wheast and 3 parts of sugar to 2.5 parts of water forming a patty. When adding pollen you should use a 3:1 mixture of brewer's yeast or wheat flour to fresh natural pollen. Add this to 2 parts of a sucrose syrup (for brewer's yeast 6:1 sucrose/water; for wheat flour 2:1 sucrose/water).

There are currently available at various prices commercial brands such as Bee-Pro and Feed-Bee. These are more expensive but they have been formulated to give maximum nutrition for honey bees.

It was determined that the effectiveness of pollen substitutes was attributed to their high attractiveness to the bees, which means that if you add natural pollen to any of the above, their effectiveness is increased.

A good pollen substitute should contain all amino acids and the B vitamins: thiamin, riboflavin, niacin, pyridoxine, pantothenic acid, folate, biotin and vitamin B-12. Many trace minerals including chromium and selenium must be present. Para-aminobenzoic acid and myo-inositol are other important ingredients necessary for a good substitute.

Remember that no pollen substitute or pollen supplement can take the place of pure natural pollen in providing necessary nutrition for the bees during brood rearing. They are used to help bridge the gap in times of initial and heavy brood production when good pollen sources are not available.

Evaluation of a Colony fit for Commercial Pollination

Although it is important for the farmer to determine how many bee colonies to use to adequately pollinate his crop, it is also important that he be provided by the beekeeper with strong hives. This is important not only for the crop pollination itself but also for legal reasons since the beekeeper is receiving pay for providing pollination.

It is interesting to note that Washington and Oregon have different regulations on the requirements for a colony used for pollination. This is because Oregon has 2 grades of colonies due to 2 different types of pollination requirements: Grade B: Field and Grade A: Orchard. Since fruit trees bloom early the requirement is less; this is because hives are not at their peak and are still building up from the winter.

A good hive for pollination should have lots of brood. This is because brood needs to be fed and maintained. Furthermore, the more bees that are born, the more bees can be transitioned into foragers.

1. Amount of Comb:
   Although a one deep-hive body hive meets the minimal requirement in Washington State., it does not meet the requirements in Oregon. Typically in both states a colony should contain 2 standard deep hive bodies or one deep and an additional western hive body.
2. Amount of Brood:
   The very minimum amount of brood necessary is 750 square inches, which is about 4 frames; however, for a Grade B colony there must be 1,000 square inches of brood. This amounts to around 5 or 6 frames of filled brood.

3. Amount of Worker Bees
   The number of worker bees needed to qualify as meeting the requirements in Oregon for commercial pollination is 6 (Grade A) to 10 (Grade B) frames full of well covered frames. This equates to around 15,000 to 24,000 bees. Notice that the Grade B Field colony is stronger than the Grade A Orchard colony. In Washington you must have 6 frames which are 2/3rd covered with bees at 65º F. This equates to around 10,000 bees. However, at 65º F there would be about 1/3 of the bees foraging so the number of total required bees would be around 15,000 per hive.
4. Food Requiremnt:
   There should be about 10 pounds of honey in each hive to provide the bees with food to maintain healthy bees and queen.

In conclusion, it is very important for the beekeeper and the commercial grower to know the requirements of a colony fit for pollination. The commercial grower has the right to be shown frames from random colonies to insure proper minimum requirements are met.

In Washington State a colony which meets the minimum requirements must have at the very minimum 1 deep hive body with about 15,000 bees and having at least 6 frames which are 2/3rd covered with bees at 65º F and containing about 10 lbs. of honey.