Vanilla Life Cycle: Cultivation, Harvest, and Curing

FEMA

June 15th, 2023

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Bakto Flavors

Edison, NJ

Bakto Flavors®

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The Prized Vanilla Flavor

The prized flavor of cured vanilla beans is considered the world's most popular and consumed flavor.

It is used in foods, beverages and cosmetics, and in ice cream.

Vanilla is a common ingredient in baked goods.

It is also used to enhance the flavor of chocolate, custard, caramel, coffee and other foods.

Vanilla History

- 1520, Hernan Cortes conquered the Aztecs
- 1602, Hugh Morgan introduced vanilla as a flavoring by itself
- 1836, Charles Morren Belgian botanist
- 1841, Edmond Albious of Reunion

The Conquest of the Aztec Empire: Hernán Cortés

Diego Rivera: Totonac Civilization, 1950, National Palace, Mexico City

Vanilla Facts

- Vanilla is a clone propagated by cuttings: 2 nodes per cutting
- Only 2 species are permitted to be used in food
- V. planifolia and V. tahitensis
- Growing methods need to be similar across the producing countries
- Greenhouse with total weather controls
- Poly houses with shading control and fogging
- The best support system is artificial/plastic poles
- Soil mix in detached pots
- Plant Nutrition
- Universal diseases and pest control

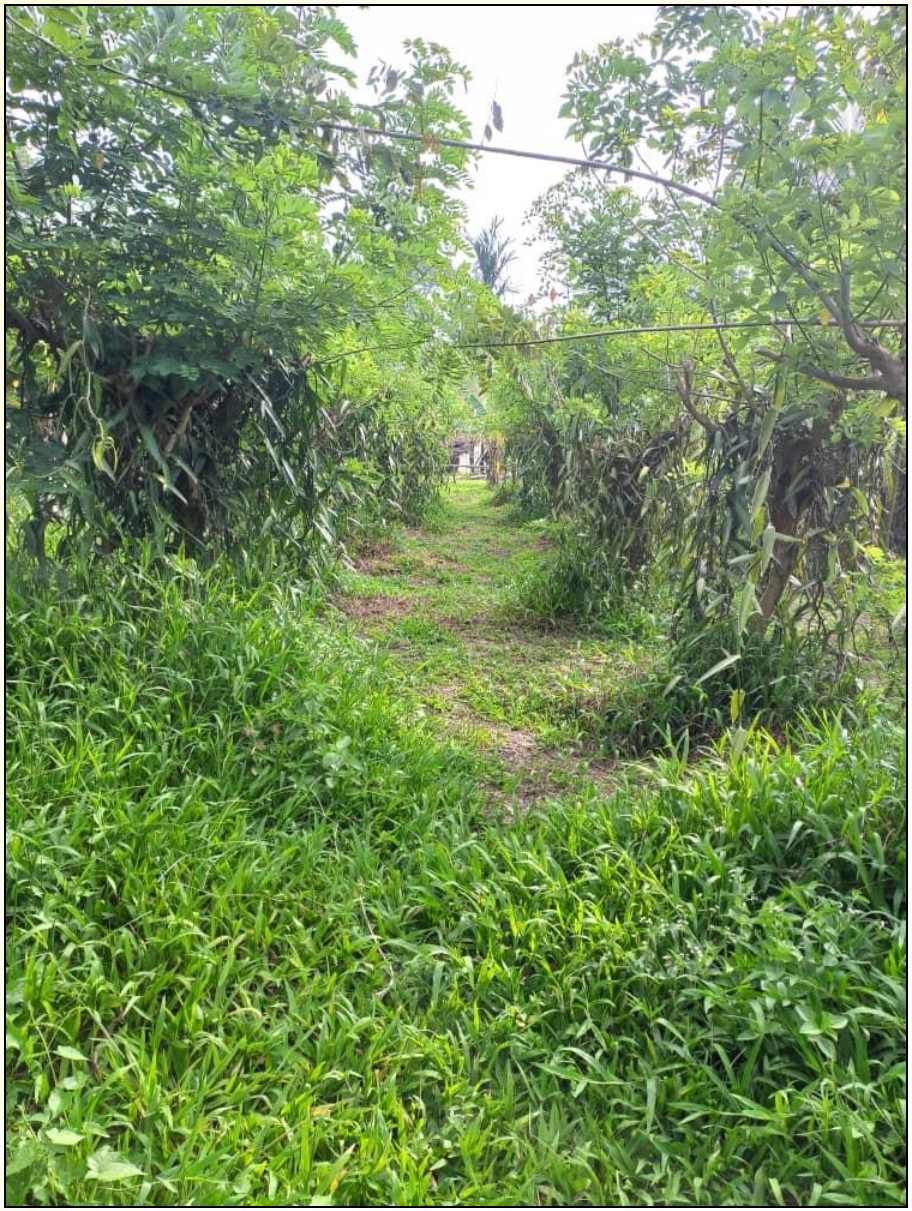
World Vanilla Production

Traditional Vanilla Cultivation

- **Cuttings**
- **Tutor Trees & Co-Cultivation**
- **Flowering**
- **Pollination-Hand Pollination, Bee Pollination**
- **Harvest**

Vanilla Plant

Vanilla Plantation In Mexico



The Life Cycle of Vanilla

1. Propagation: Seeds, Micropropagation (Tissue Culture), and Cutting
2. Plant Growth
3. Flowering, Pollination, and Fruiting
4. Flavor Production and Accumulation
5. Harvesting, Curing, and Storage
6. Extraction and Products from Vanilla (Vanilla Beans, Extract, Concentrate, Paste, Flavor, Seeds, Sugar, Liquor)
7. Vanilla Application to Food
8. Vanilla Standard of Identity

Propagation

- Seeds Germination
- Micropropagation -Tissue Culture
- Cutting

Plant Growth Requirements

- Soil
- Support
- Water: Irrigation and fogging
- Nutrients
- Light
- Disease control: Fungi, Viruses, etc.
- Insects control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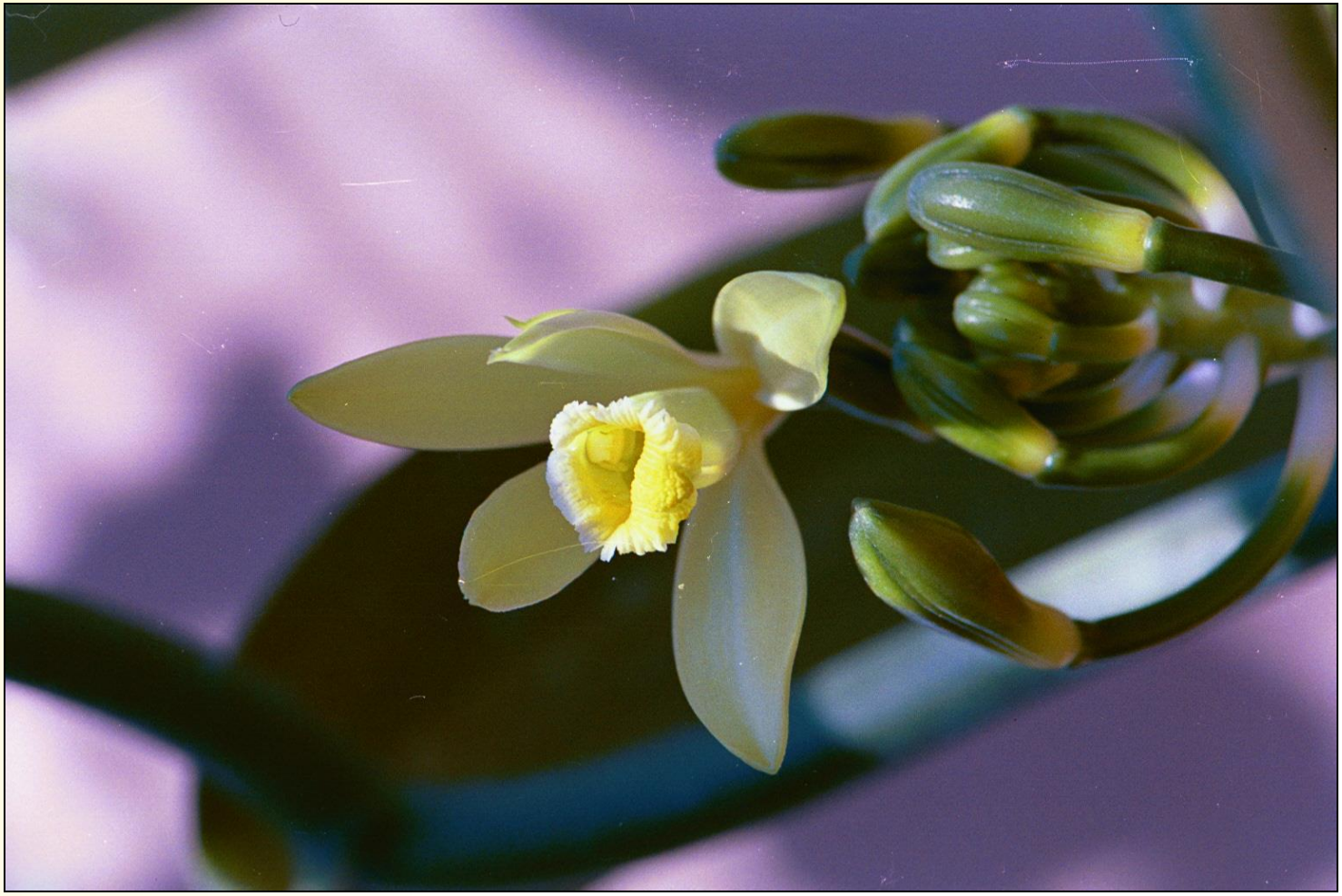
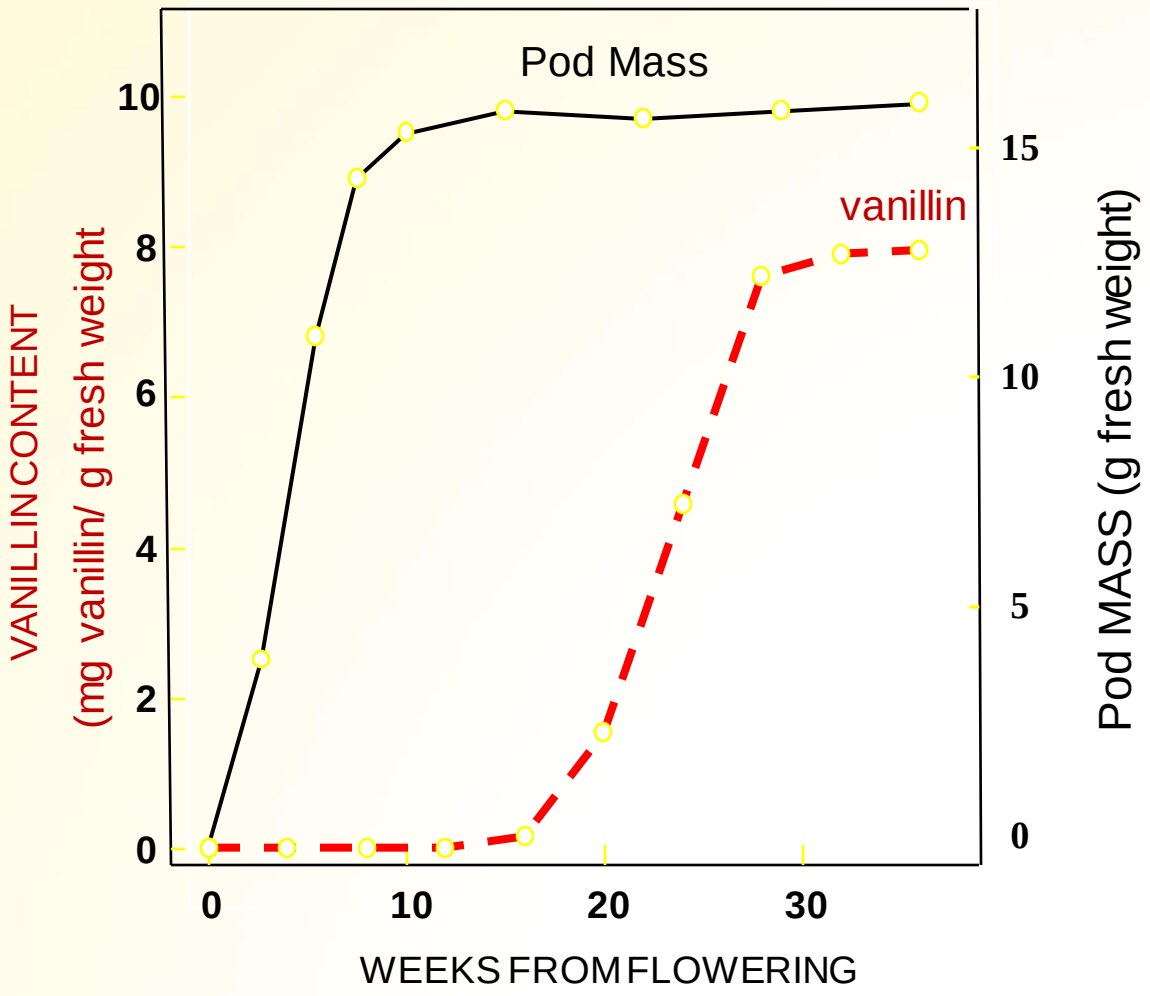
Flowering

- Flowering: Age of the Vine & Inducing Flowering for 1-3 months
- Hand Pollination, and Fruit Set
- Flavor Production and Accumulation



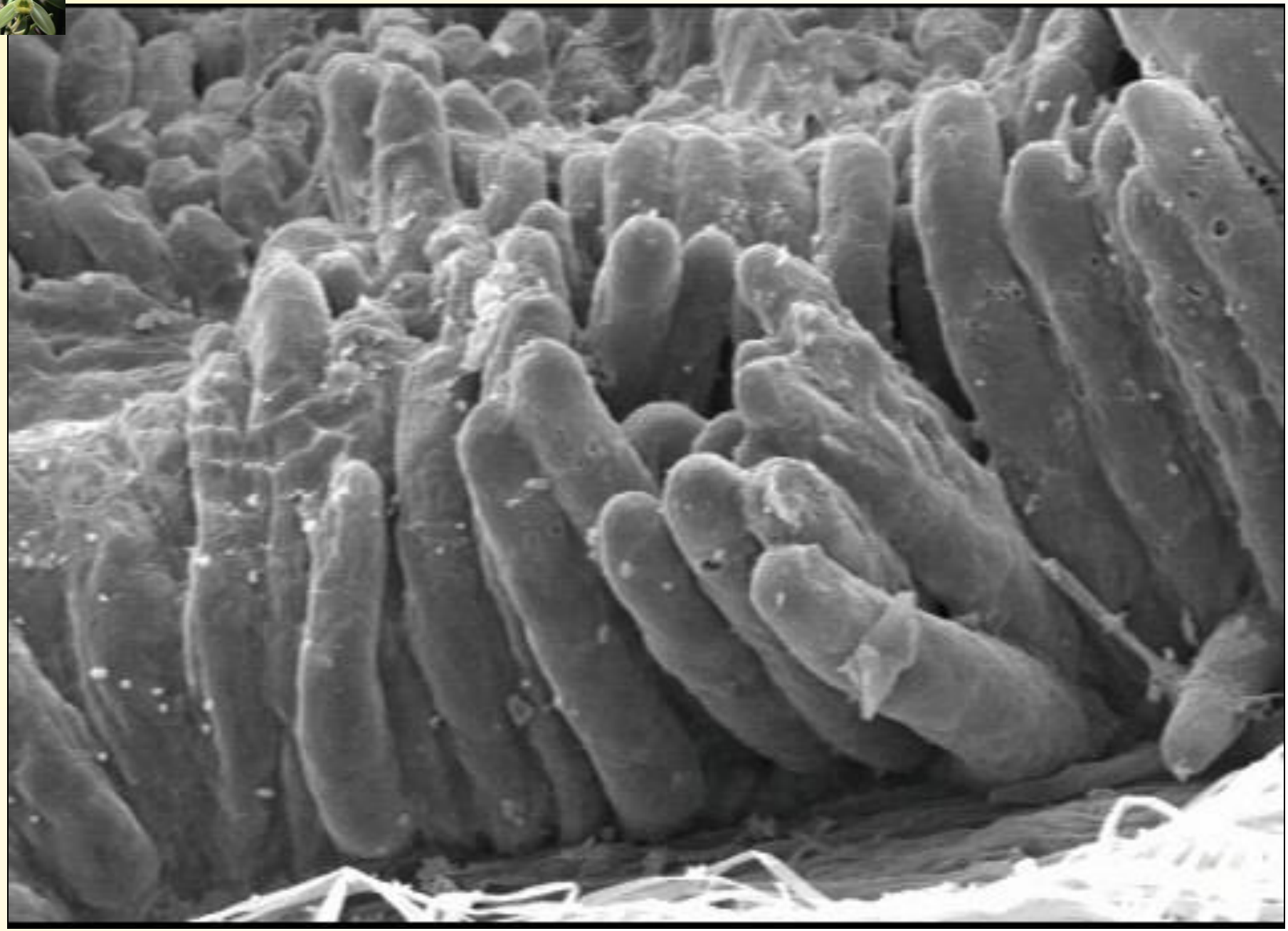
Vanilla Hand Pollination

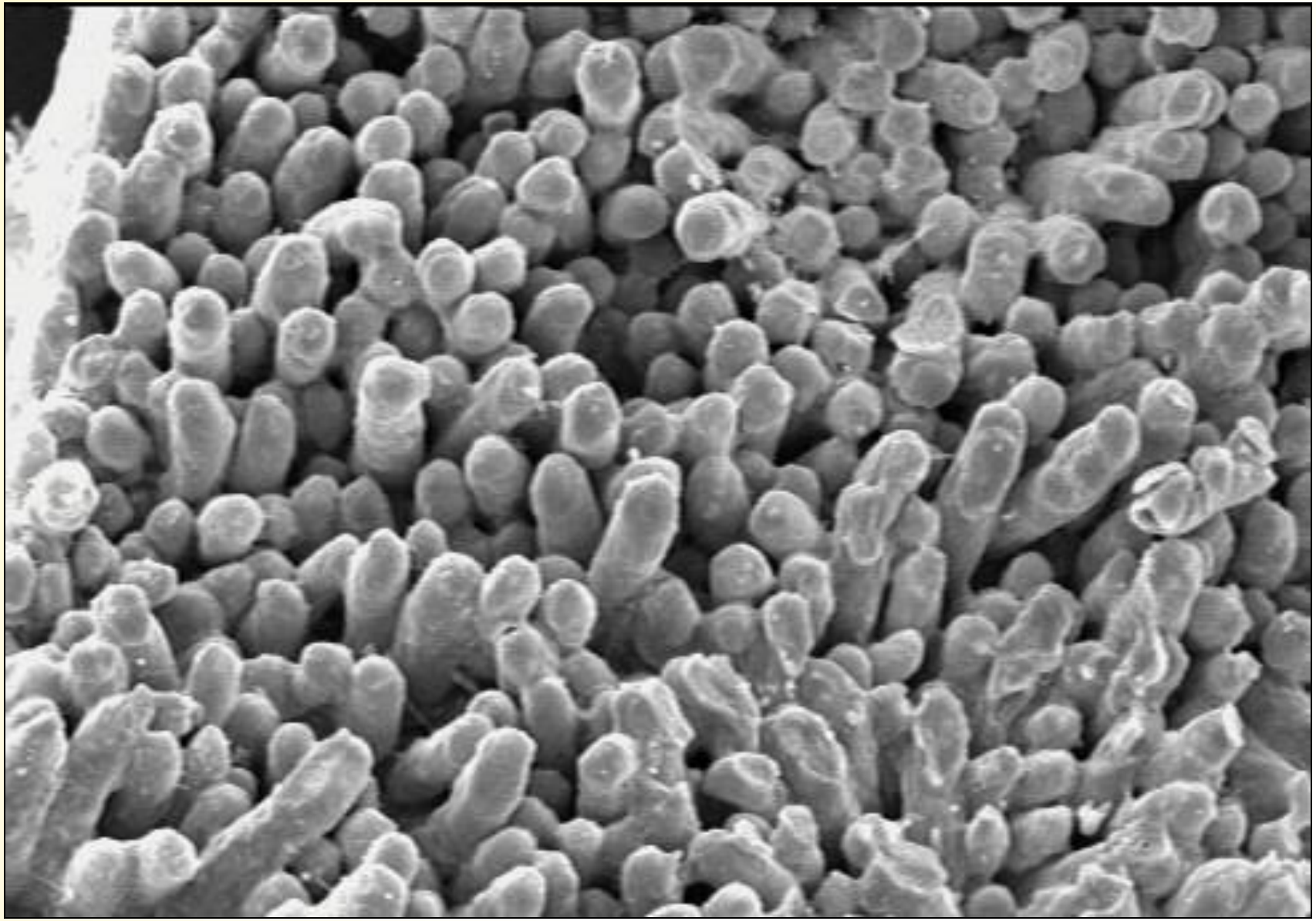
Time-Course Accumulation of Vanillin in Developing Mexican Vanilla Pod



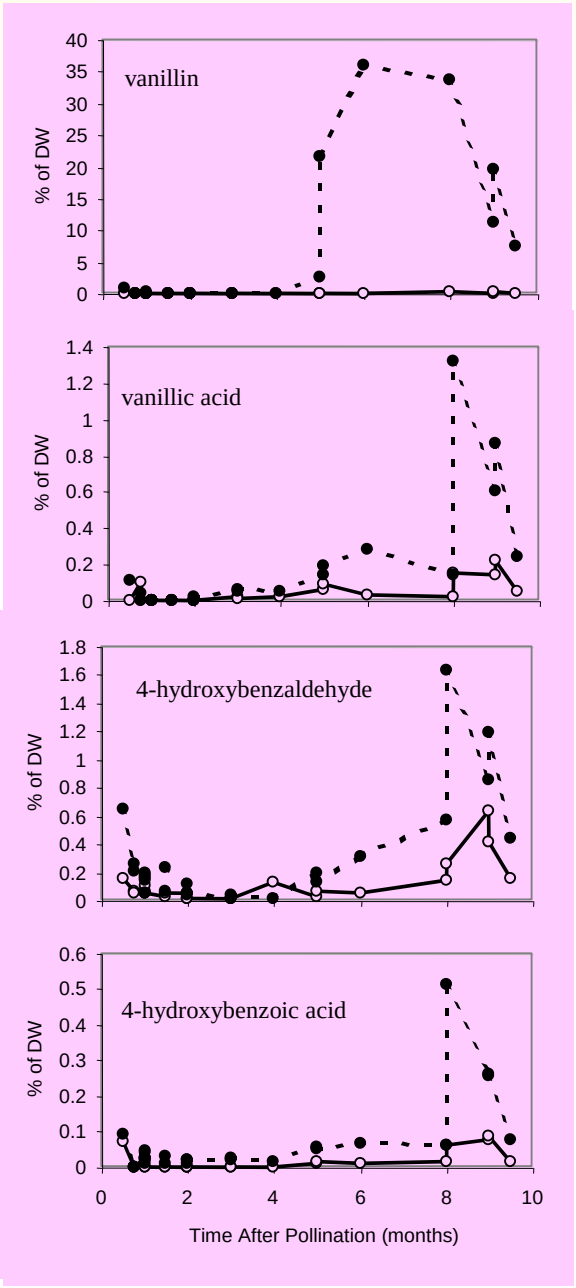
A graph showing time-course change in vanilla pod mass and corresponding accumulation of vanillin during vanilla pod development on the vine.

Vanilla Secretory Hair Cells



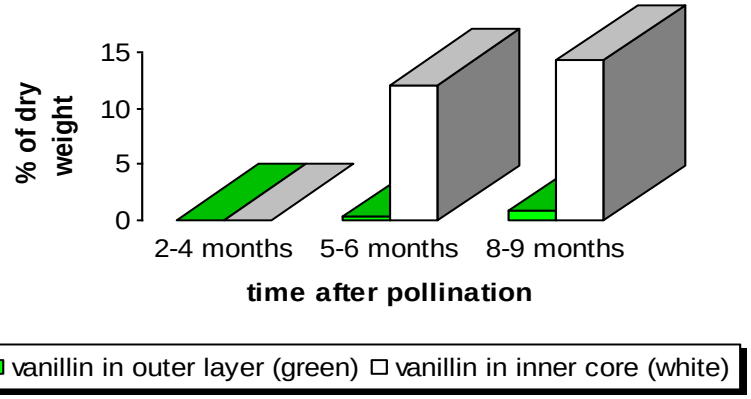


Time course change in the content of various metabolites in the green outer tissue (solid lines) and the inner white tissue (dashed lines) of vanilla bean during pod development on the vine. Beans were harvested green at various stages of development. The various metabolites, present as glucosides, were hydrolyzed and the resulting aglycons determined as described previously (Podstolski et al., 2002).

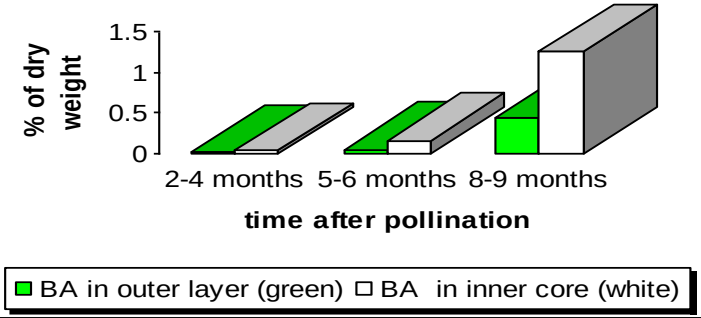


Joel et al 2003

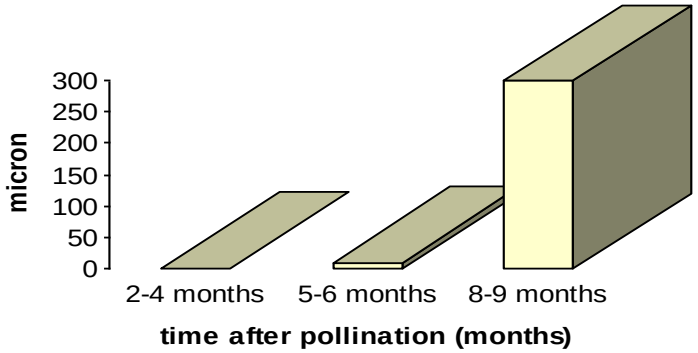
Vanillin in inner core (white) and outer part (green)



4-Hydroxybenzaldehyde (BA) in inner core (white) and outer part (green) of the bean



cell size



12 months 15 months 18 months 20 months

Vanilla beans that have cured naturally on the vine, for 12, 15, 18 and 20 months after pollination.

Green Beans Harvesting

- One Time Harvest: All Beans Sizes
- Multitime Green Beans Picking: based on size

Stages of Vanilla Production

- Cultivation: growing, flowering, fruiting
- Curing process
- Extraction of cured beans

The purpose of the curing process is:

- **To transform green beans, without flavor or aroma into cured beans with the prized vanilla flavor**
- **To reduce the water (moisture) content of the green beans from 85% to 25%-30% (or below) as a method of preservation:**

a. To increase the shelf life of cured vanilla beans

b. To obtain vanilla beans free of molds and bacteria

Green Vanilla Beans

Vanilla Curing Process

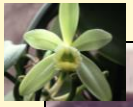
- **Killing**
- **Sweating**
- **Drying**
- **Conditioning**

Recent Changes in Vanilla Curing

- Over the last few years there has been a gradual decline in the quality of cured vanilla beans
- This is reflected primarily in decreased levels of vanillin; a good indicator of green bean quality & curing performance
- Best practices of vanilla curing have declined as indicated due to partial curing by farmers along with vacuum packing of part-cured beans
- Harvesting of immature (young) beans became common practice, resulting in a lower ratio of Cured-to-Green
- There is a need to revisit the total curing operation and take control of the process from start to finish

Three Type of Curing

1. Traditional
2. Improved Traditional
3. Quick Curing Madagascar/Indonesian style
4. Technology-Based Curing- Short and Effective



Traditional curing

Advantages

- Produces a “traditional”, familiar flavor
- Limited capital equipment requirement

Disadvantages

- Generally low vanillin yield related to poor glucovanillin conversion
- Lack of control of temperature for all process steps
- Variability in product quality
- Labor-intensive operation
- Dependent on local weather conditions for drying

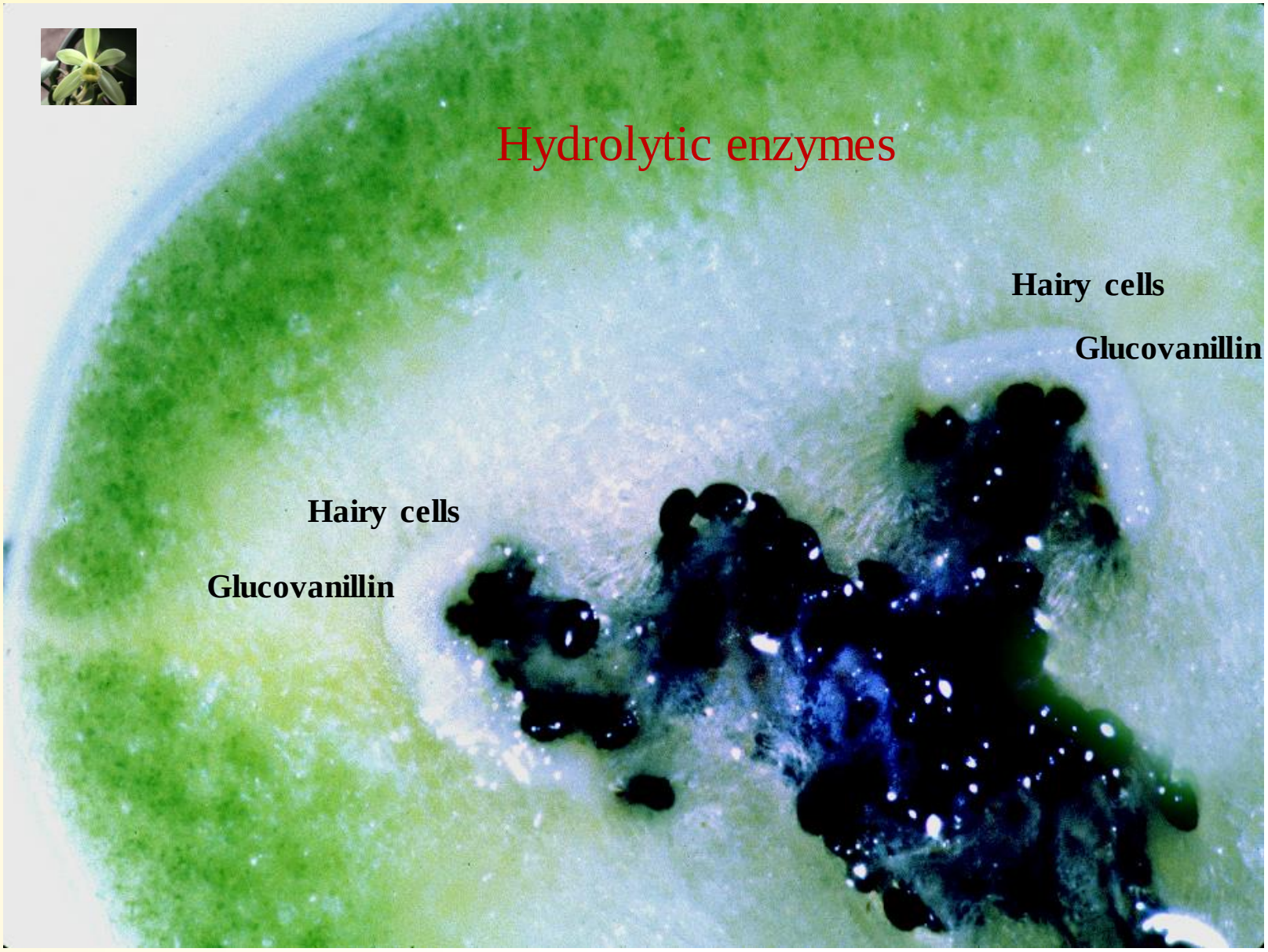
Technology Based Curing

- Not labor intense
- Mechanized the process
- Shorter time and better quality beans
- Require skilled workers and investment

Vanilla Curing Process

- **Killing**
- Sweating
- Drying
- Conditioning

Killing voids the spatial separation between hydrolytic enzymes and glucovanillin, initiating the hydrolysis of glucovanillin to vanillin and glucose

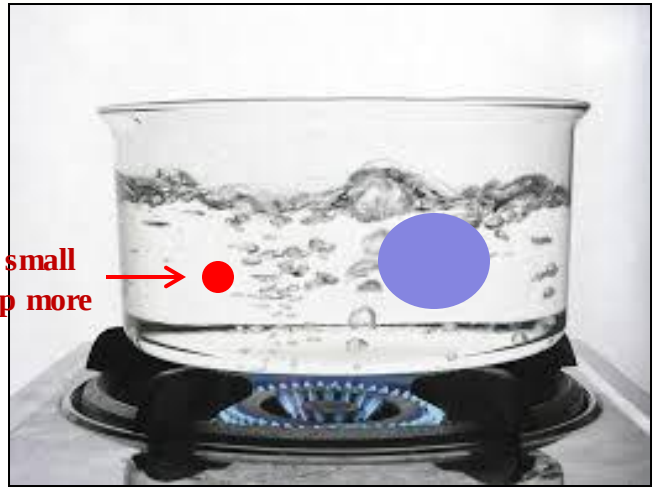


Preparation for Killing

1 Killing is preferably carried out immediately after harvest, to avoid uncontrolled curing processes occurring naturally

a. It synchronizes enzymes for catalyzed flavor production
b. In harvested beans the flavor forming enzymes have short life

2. Vanilla pods should be sorted by size or weight, to ensure an even distribution of heat or cold shock.



3 . Harvested green vanilla pods should be washed with food-grade detergent, to minimize contamination by microorganisms.


© Carolyn Lochhead

Purpose of Killing

1. To stop all organized cellular activity

2. To allow contact between enzymes and substrates, previously compartmentalized in different fruit regions

3. To release the activity of hydrolytic enzymes

4. To access oxygen for flavor forming oxidative reaction

Methods of Killing

1. By mechanical damage:
   a. Scratching
   b. Chopping
   c. Homogenizing

2. Temperature-induced damage:
   a. Sun killing (Irradiation)
   b. Dry heat (oven)
   c. Hot water scalding
   d. Freezing

Vanilla Curing Process

- Killing
- **Sweating**
- Drying
- Conditioning

Sweating

Sweating is a condition that allows the formation of vanilla flavor by enzymatic and non-enzymatic processes (Similar to fermentation).

Enzymes Involved in the evolution of vanilla flavor during the Sweating Process

Hydrolytic enzymes:

β-glucosidase, catalyze the breakdown of glucovanillin to vanillin and glucose.

glycosyl hydrolases, catalyze hydrolysis of glycosidic bonds in complex sugars.

Cellulases, degrades cell wall cellulose.

Pectinases, degrade cell wall pectin.

Esterases, breaks ester bonds abundant in cell wall.

Lipases, esterases that hydrolyze lipids to fatty acids.

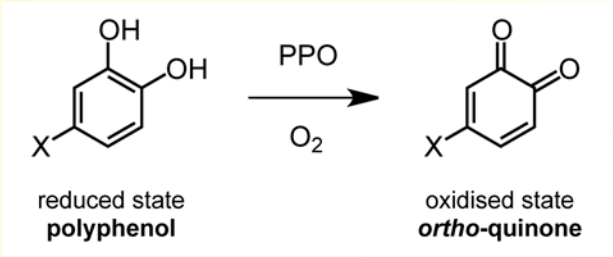
Proteases, breaks down the structure of proteins and enzymes. Proteases liberated by Killing attack flavor-forming enzymes putting time limit on the Sweating process.

β-glucosidases, glycosyl hydrolases, cellulases, pectinases and estrases degrade the cell wall. Cell wall dissolution facilitate the migration and contact between flavor precursors and enzymes.

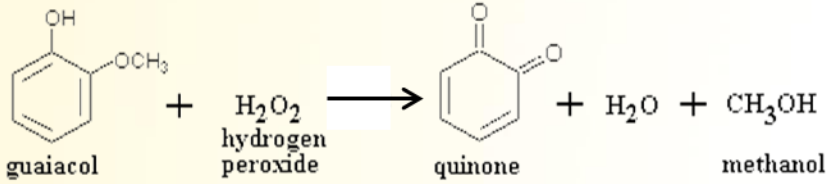
Oxidative enzymes:

Oxidases -Polyphenol oxidase (PPO) catalyze the oxidation of phenolic compounds by
oxygen.

Peroxidase, stimulate the oxidation of phenolic compounds by hydrogen peroxide.



An oxidative reaction using molecular oxygen, catalyzed by polyphenol oxidase (PPO).



An oxidative reaction utilizing hydrogen peroxide, catalyzed by peroxidase

Oxygen-dependent processes contribute to the formation of vanilla flavor:

The curing process appears to be associated with robust oxidative metabolism.

Many aroma and flavor compounds in cured vanilla appear to arise from lipid oxidation.

Oxidation of phenolic compounds accounts for the browning of cured vanilla beans.

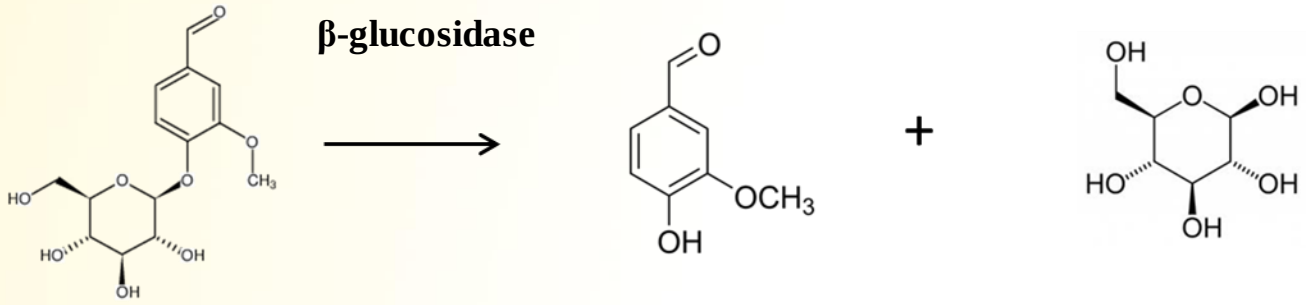
Molecular oxygen (O_2) and hydrogen peroxide (H_2O_2) a reactive oxygen form, might be involved in oxidative reactions in curing vanilla bean.

An example of the catalytic action of hydrolytic enzymes in the formation vanilla flavor

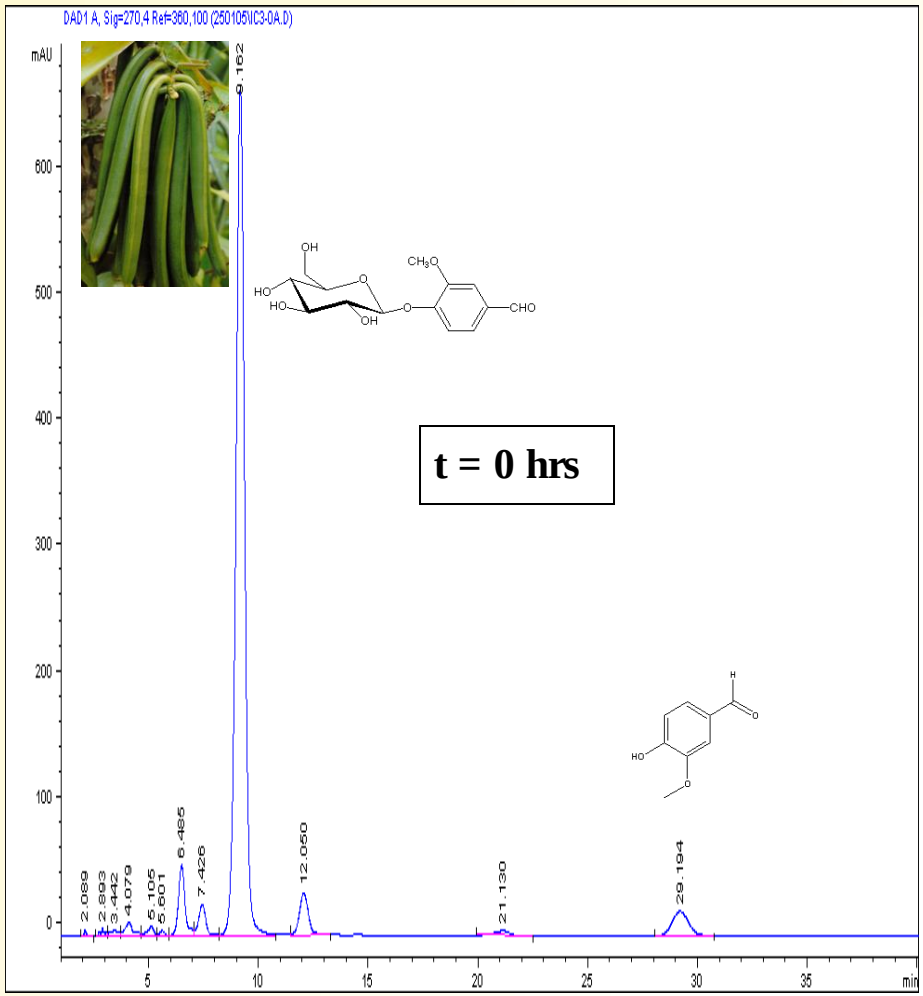
β-glucosidases

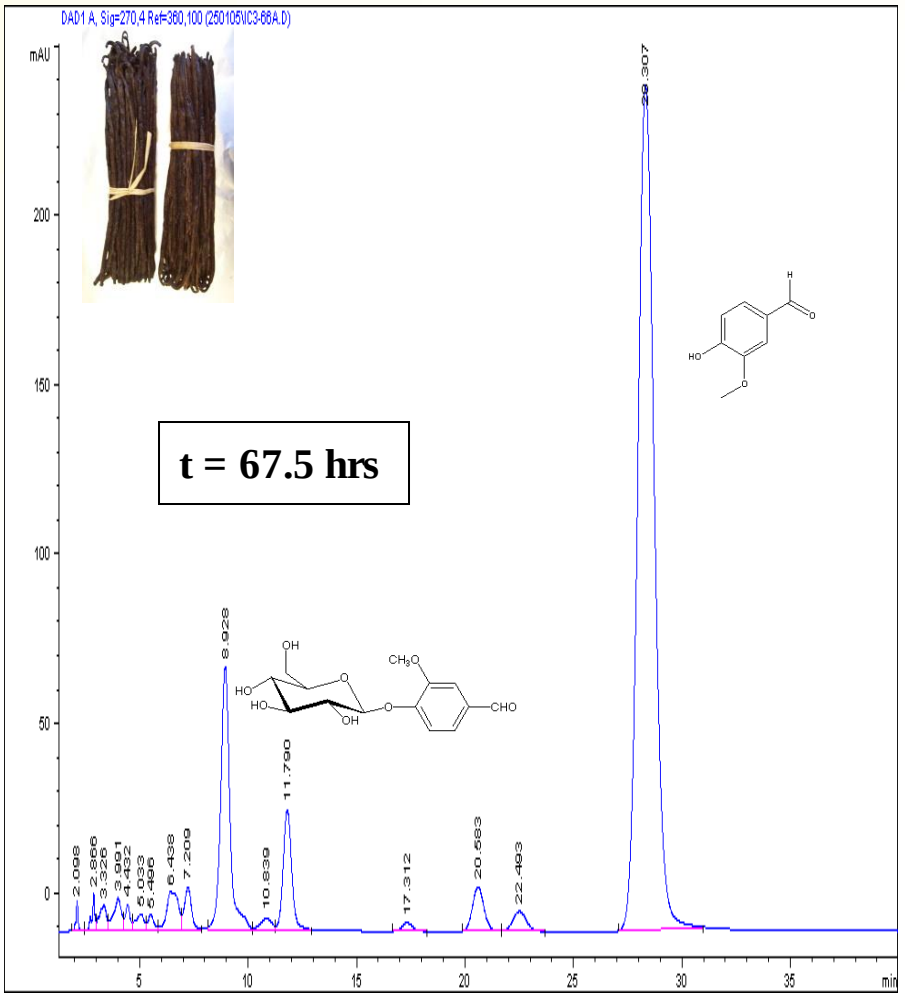
This enzyme family breaks glucosidic bond between a sugar molecule, glucose for example, and an aglycone molecule, such as a phenol.

It will, therefore, hydrolyze glucovanillin to vanillin (the aglycone) and to glucose.



Determination of gluco-vanillin and vanillin: HPLC chromatogram of incubated green vanilla beans @ 50° C:





Conditions Required for Sweating

1. Contact between enzyme and substrate
2. Temperature
3. Moisture
4. pH
5. Oxygen

Why 50^{O} c?

Maximum conversion of glucovanillin to vanillin.
Fastest rate of conversion.

These conditions were determined empirically.

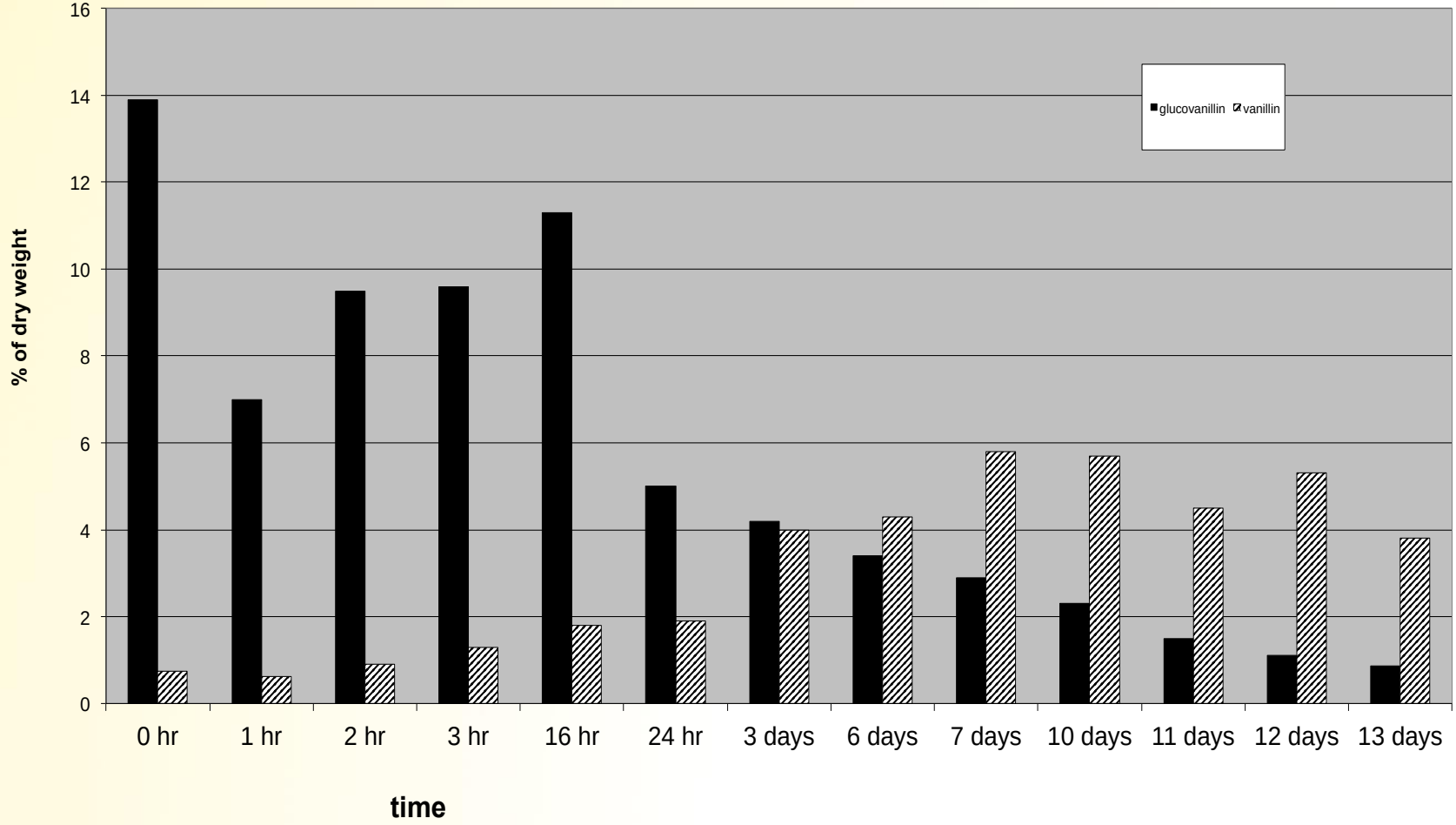
Enzymes Involved in the Sweating Process

β-glucosidase
glycosyl hydrolases
cellulase
pectinase
protease
polyphenol oxidase (PPO)
peroxidase
lipases
esterases

β-glucosidase

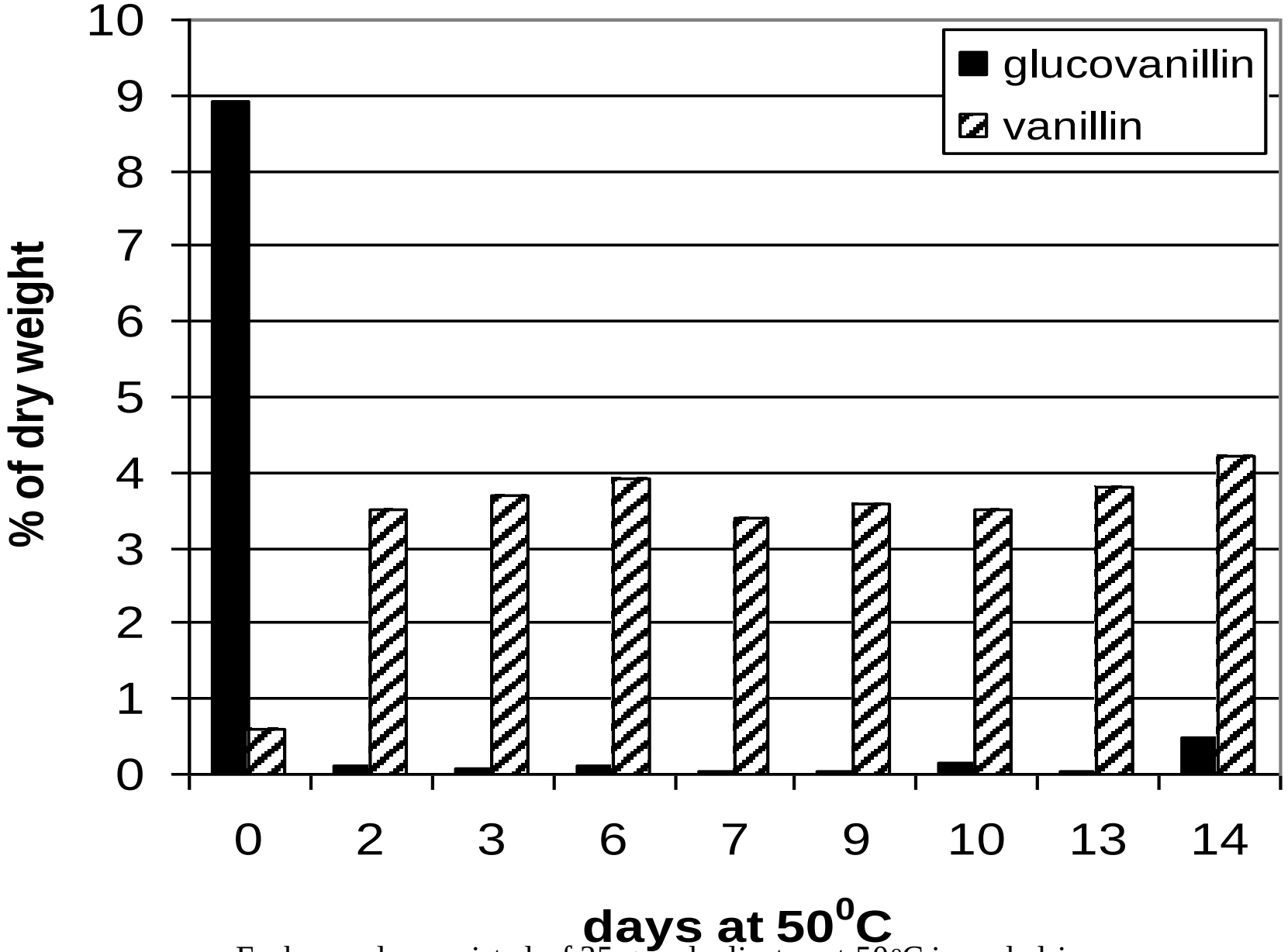
This enzyme breaks the bond between a sugar molecule, glucose for example, and an aglucone molecule, such as a phenol. It will, therefore, hydrolyze glucovanillin to vanillin and glucose.

Conversion of Glucovanillin to Vanillin in whole green vanilla beans (Havkin-Frenkel et al 2002)



Each sample represent 35 gram of green beans in duplicates in a sealed Jar at 50^{0}C

Conversion of Glucovanillin to Vanillin in chopped beans (Havkin-Frenkel et al 2002)



Each sample consisted of 35 g in duplicates at 50^{o}C in sealed jars

Proteases

Proteases are enzymes, which break down proteins by cleaving a peptide bond.

Proteases represent a large family of enzymes, usually with specificity toward a defined protein composition. Importantly, proteases tend to attach proteins that have become denatured, occurring during the curing process of vanilla beans.
The action of proteases limits the duration of the killing process. Vital enzymes will be destroy

Cellulases

Cellulases are a group of enzymes, which break bonds between two sugar molecules in the polymer structure of cellulose, the plant cell wall material.

Cellulases become active during stress episodes or during senescence. It removes the barrier to the migration of enzymes and their substrates.
Only plants and some microorganisms contain cellulases.

Pectinases

This is a group of enzymes that catalyze the breakdown of pectine, a plant cell wall material.

Pectin is broken down to galactose, trehalose and other exotic sugars found in the polymeric structure of pectin.

Peroxidase

Peroxidases are a large family of enzymes, which catalyze the transfer of oxygen from hydrogen peroxide (H_2O_2) to phenolics and other compounds.

Peroxidases becomes active during stress episodes and during senescence in plants. It is one of the oxidative enzymes that lend dark color to a cured vanilla bean.

Peroxidases are very stable even under extreme temperature conditions.

Peroxidase may aid in lipid oxidation and, therefore, contribute to the flavor of cured vanilla beans.

Polyphenol oxidase (PPO)

PPO is an oxidative enzyme requiring oxygen, which catalyze the addition of a hydroxyl group to aromatic rings.

PPO becomes active during stress episodes and during senescence in plants. It is one of the oxidative enzymes that lend dark color to a cured vanilla bean.

PPO is very stable even under extreme temperature conditions. The role of this enzyme in the development or perhaps destruction of flavor is unknown.

Aroma and flavor compounds in extract from cured vanilla beans

- Color-marked compounds might be products of lipid hydrolysis and oxidation

Phenols

Guaiacol
4-Methylguaiacol
Phenol
p-Cresol
4-Vinylguaiacol
Vanillyl methyl ether
4-Vinylphenol
Vanillin
Acetovanillone
Vanillyl alcohol
Vanilloylmethyl cetone
p-Hydroxybenzaldehyde
p-Hydroxybenzyl alcohol
Vanillic acid
p-Hydroxybenzoic acid

Aromatic acids

Benzoic acid
Benzene propanoic acid
Cinnamic acid (isomer 1)
Cinnamic acid (isomer 2)
Anisic acid

Aliphatic acids

Acetic acid
Propanoic acid
Isobutyric acid
Butyric acid
Isovaleric acid
Valeric acid
Hexanoic acid
Heptanoic acid
Octanoic acid
2-Heptenoic acid
Nonanoic acid
Dodecanoic acid
Myristic acid
Pentadecanoic acid
Hexadecanoic acid
9-Hexadecanoic acid
Heptadecanoic acid
Stearic acid
Oleic acid
Linoleic acid

Aldehydes

2-Heptenal
(E)-2-decenal
(E,Z)-2,4-decadienal
(E,E)-2,4-decadienal

Ketone

3-Hydroxy-2-butanone

Esters

Methyl salycilate
Methyl cinnamate
Anisyl formate
Ethyl linolenate
Hydrocarbons
Tricosane
Pentacosane

Alcohols

1-Octen-3ol
2,3-Butanediol
1-Octanol
2,3-Butanediol
1,2-Propanediol
Benzyl alcohol
2-Phenylethanol
Benzene propanol
Anisyl alcohol
Cinnamyl alcohol

Heterocyclics

Furfural
c-Butyrolactone
Pantolactone
1H-pyrrole-2,5-dione, ethyl-4-methyl

A Perez-Silva et al (2006) Food Chemistry 99:728-735

Importance of Lipid Oxidation in Cured Vanilla Bean

Oxidation of lipids leads to the formation of aroma and flavor compounds (It is a major process in aroma formation in plants).

However, lipid hydro-peroxides can react spontaneously or enzymatically with phenolic compounds in the vanilla bean. These reactions might lead to alteration in phenolic flavor constituents, vanillin or 4-hydroxybenzaldehyde for example.

Vanilla Curing Process

- Killing
- Sweating
- **Drying**
- Conditioning

Methods of Drying

- Sun drying can lower moisture content to about 15%, however, it is too slow to maintain the high quality of some foods
- Oven drying- heat apply- no control of RH
- Beans dehydration: Artificial drying under controlled conditions (RH) ideally causes minimal changes in product properties
- Dehumidification under specific temperature

Drying Rate is Dependent on:

Surface area: particle size/shape - smaller pieces, liquid films. Greater surface areas allow faster drying.

- **Increase surface for**

1. heat transfer
2. moisture to escape from food

- **Decrease distance**

1. heat must travel to food center
2. moisture must travel from food center to food surface.

Temperature-

- a. >temperature gradient, >rate of heat transfer to food

Dehydration Principle:

- Apply Heat / Remove Water
- Enhanced by:
  - Increased surface area
  - Increased temperature
  - Increased air velocity
  - Reduced humidity
  - Reduced pressure (vacuum)

Drying Process

In this process the water content of sweated bean is reduced form 80% to around 25-30% moisture content.

Purpose of Drying

A method of preservation (employed also in other foods) to protect cured beans from microorganism and from continued chemical changes.

This stage determines the quality and the shelf-life of the cured beans.

The drying stage is the one in need of improvement, over the traditional drying.

Principles of Drying

To create conditions in the environment of cured beans that will force migration of moisture from the bean tissue to the surrounding air.

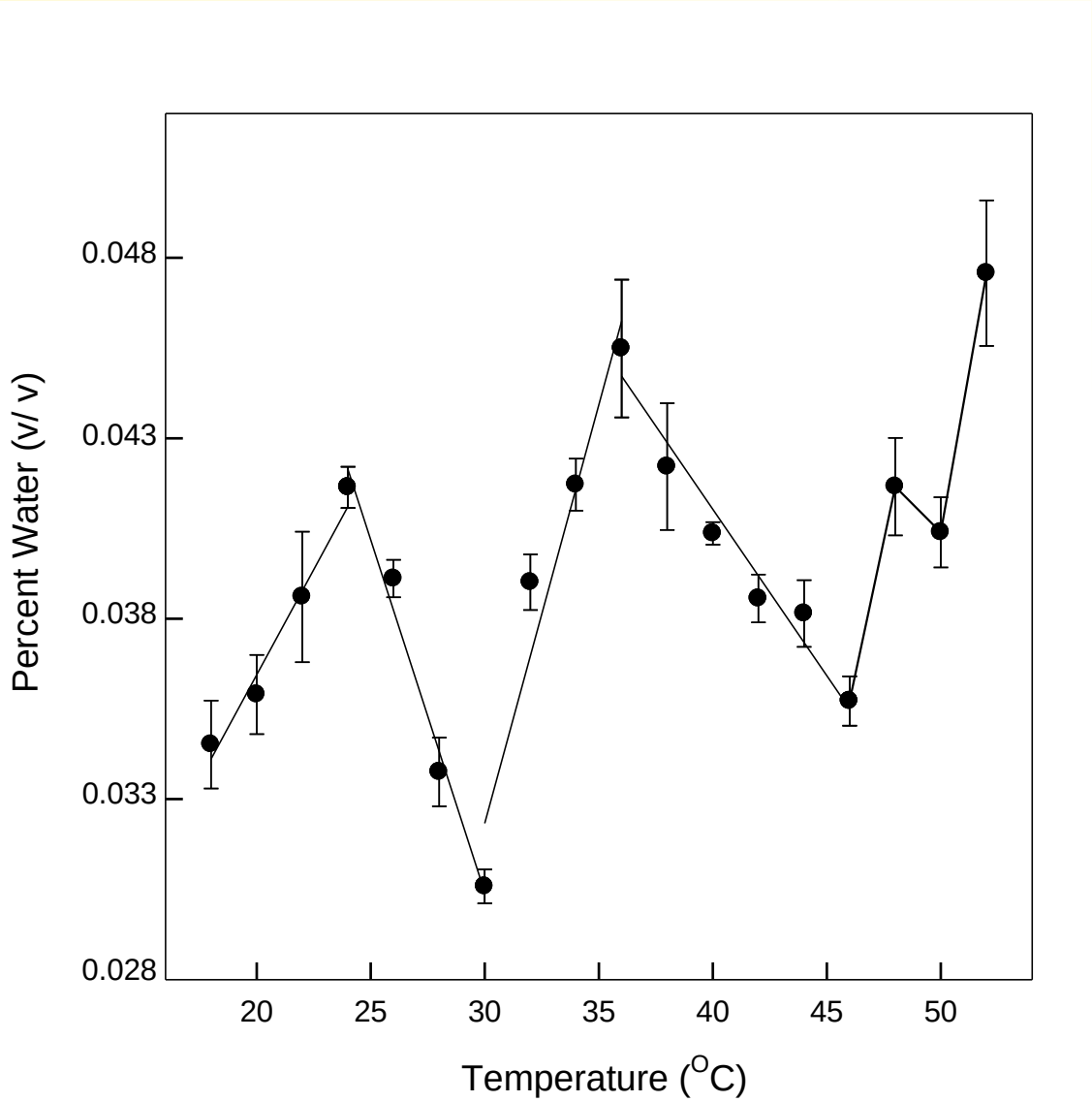
World Vanilla Production

Selection of Drying Conditions

1. Periodic intervals of 1^{O}C, from 0^{O} to 100^{O}C and intervals from 0 % to 100 % RH.

2. Combining these two one obtains 10, 000 combination, which is impossible to do.

3. One can do some of these combinations and apply mathematical modeling to find the optimal temperature that will preserve the maximum amount of vanillin with the minimum content of water (in this case around 25% moisture content).



Temperature-dependent periodicity in water content of oleic acid methyl ester (Frenkel et al 2003)

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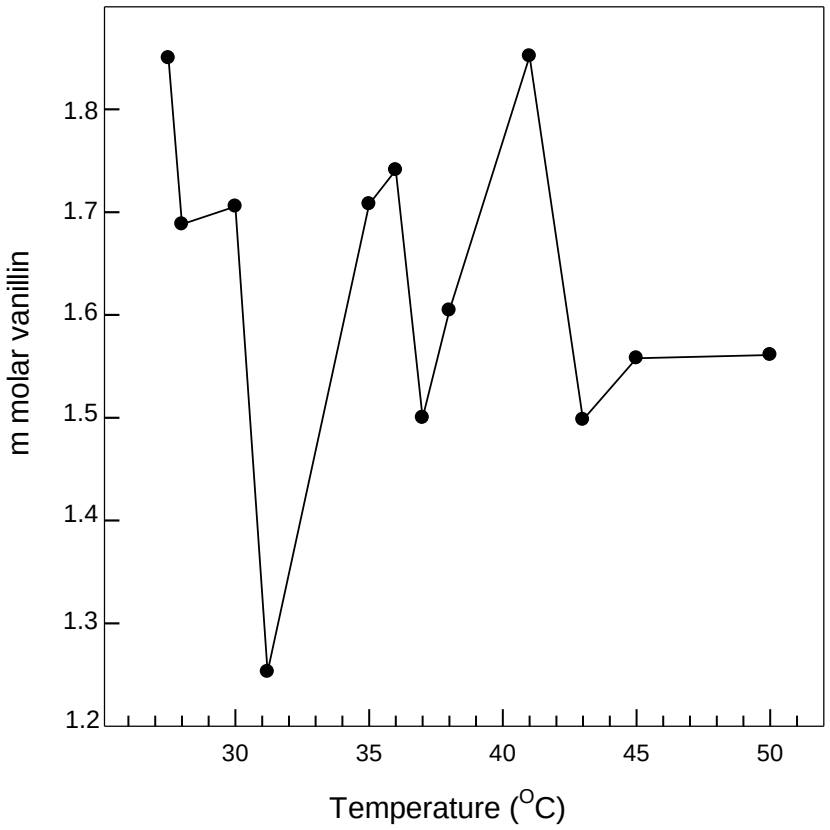

Periodicity in water solubility of vanillin at different temperatures (Frenkel et al 2003)

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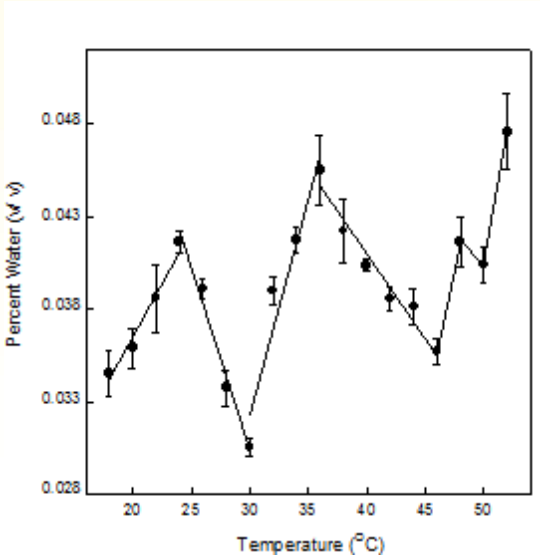
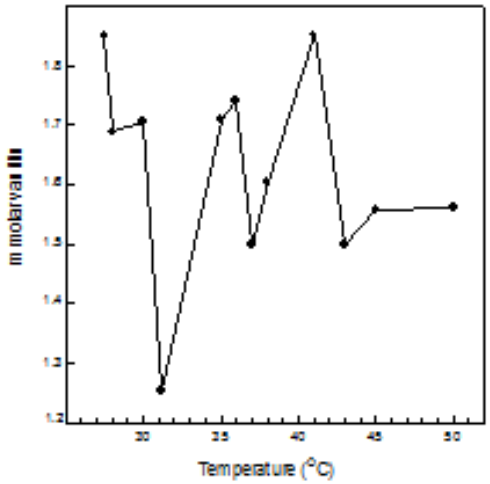
Temperature control of the Drying stage

The graph show the water-affinity of a lipid compound (oleic acid methyl ester) as function of temperature.

Water affinity of lipid, a hydrophobic compound, manifest temperature periodicity with minima at around 31° and 45° C.



Vanillin, also non-polar compound manifest similar temperature-dependent periodicity in solubility, showing minima at around 30C and 45° C.



At 31° C (and 45° C) vanillin is the least soluble. We reasoned that at 31° C vanillin is conserved, because it is not prone to react or migrate with the escaping water.

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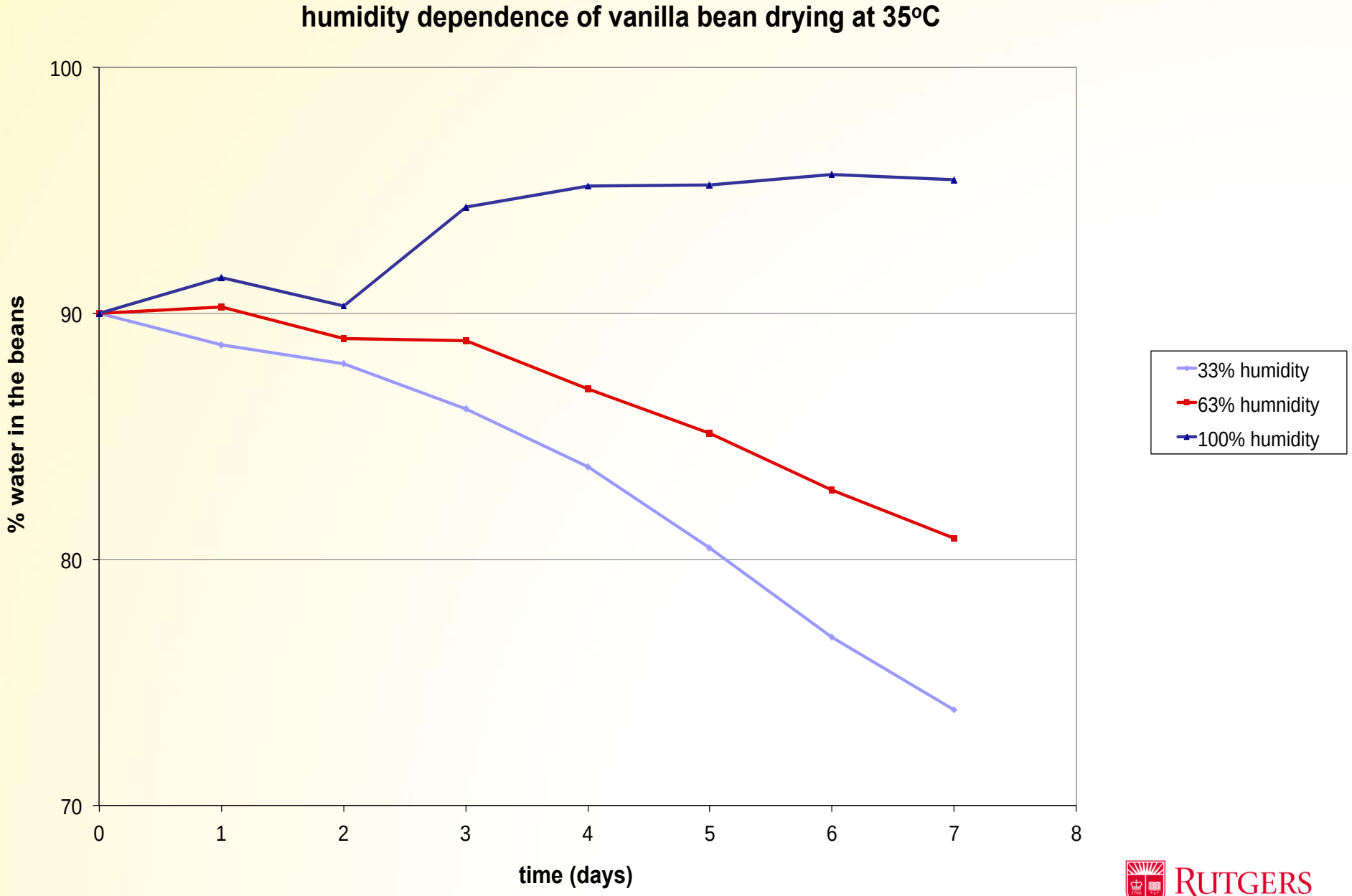

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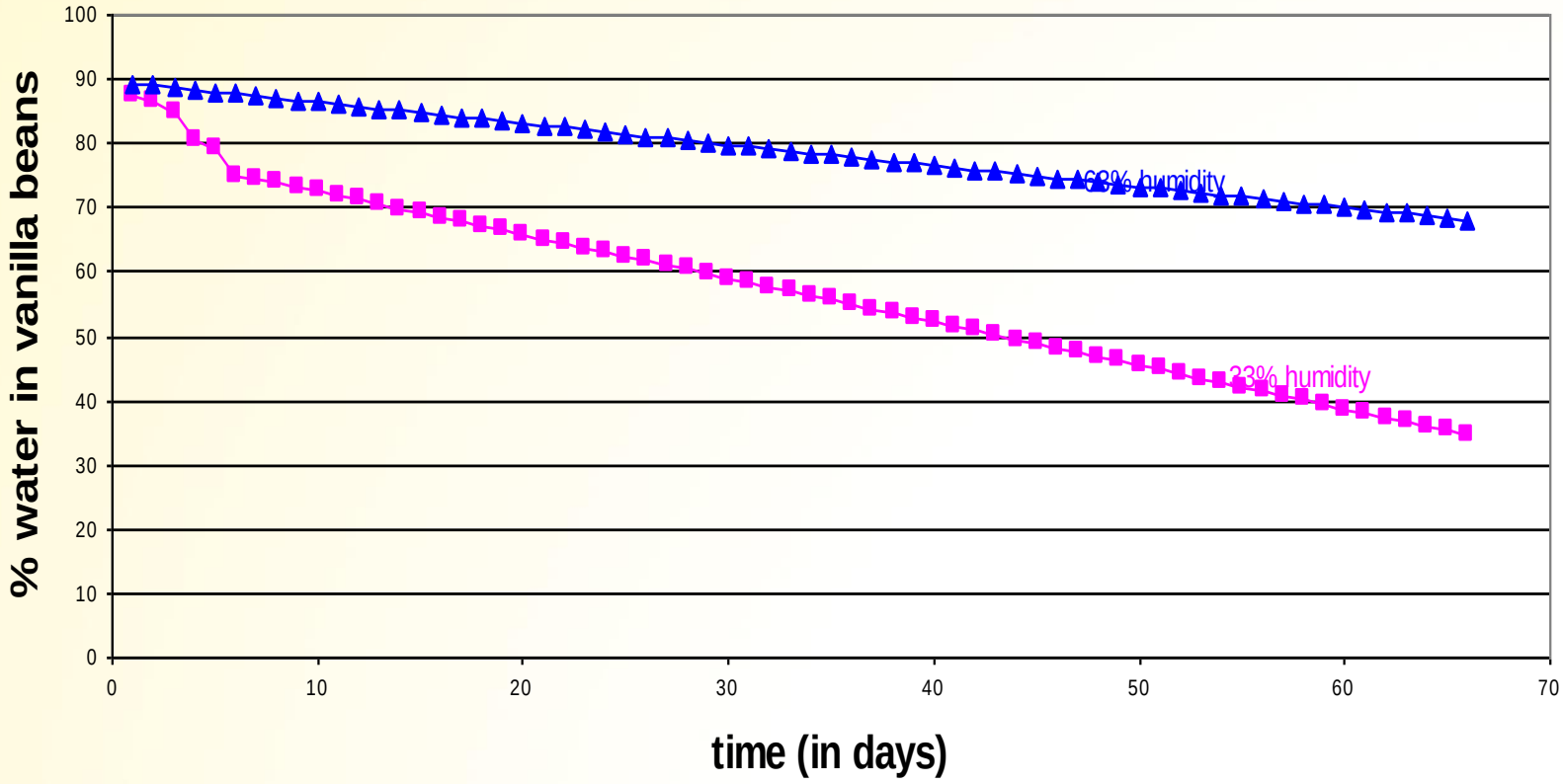
linear model for drying curve of vanilla beans at 35°C



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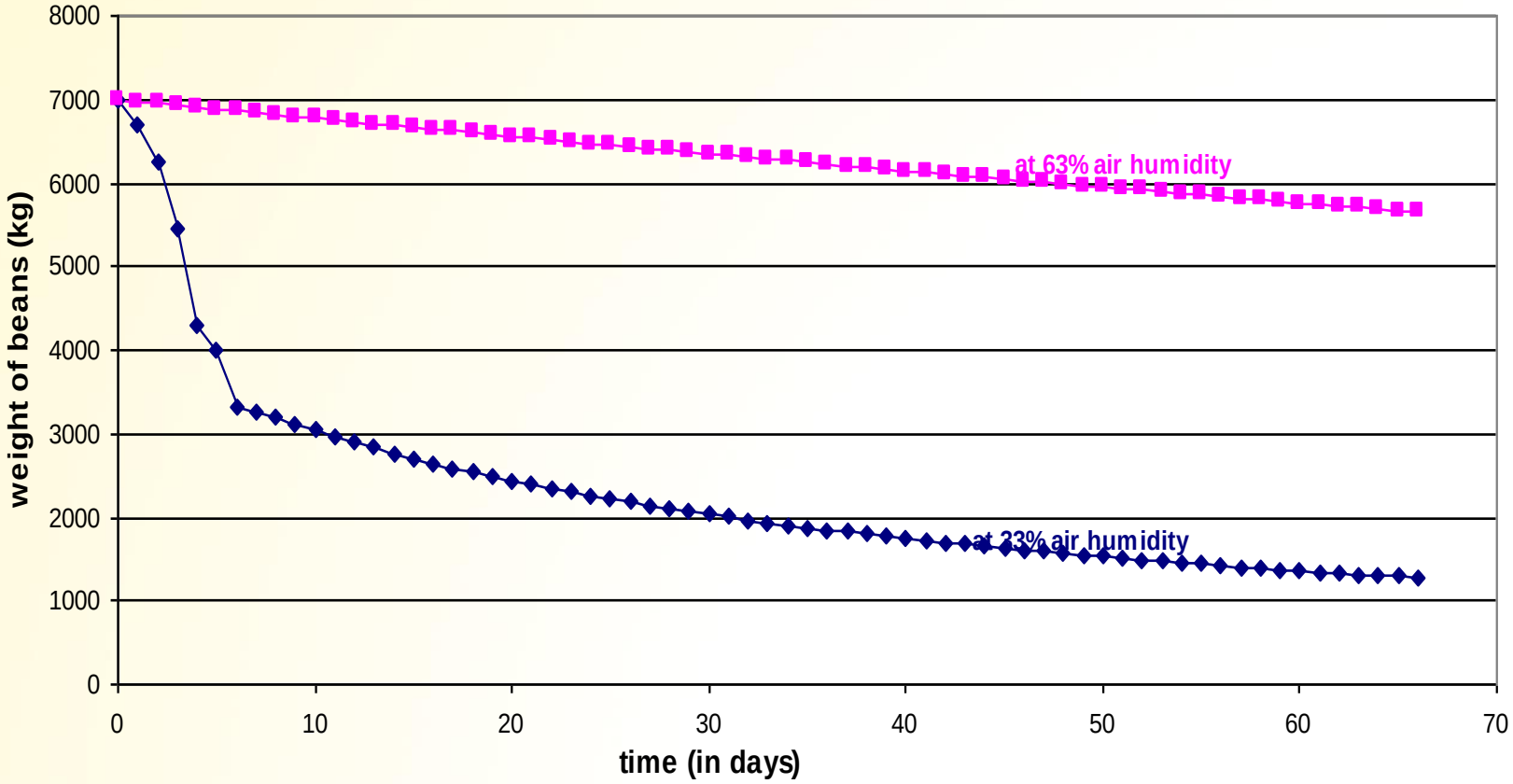
linear model for large scale drying of green vanilla beans



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A scheme describing steps in the process of Mechano-Curing of vanilla beans

Harvest mature beans → Mechanical sorting by size → Wash beans to remove soil and dirt. Dry. → Killing. Hot water (63 ° C) → Sweating (50 ° C) → Drying Dehumidification at optimal temperature 31C

Protocol for Tech-Curing of Harvested Vanilla Beans

1. Harvest. Vanilla beans are harvested at the mature stage, to ensure full flavor complement.

Harvest is 'one time', yielding beans of different sizes.

2. Washing. Vanilla beans are then washes, to remove soil, particles and dirt.

3. Sorting. Beans are sorted by size, because each size has different Killing requirements.

4. Killing. Beans are 'Killed' by dipping in hot water (63 ° C), found empirically as best temperature.

5. Sweating. Killed beans undergo sweating at 50 ° C for few days.

6. Drying. The final drying step is of major importance:

Drying is by dehumidification (rather than heating) at an optimal temperature, usually at 31 C.

At this temperature the water-solubility of vanillin is the least. Therefore, the escaping water would carry little or no vanillin, thus minimizing loss in vanillin observed in prolonged and heat-dependent drying protocols.

Our method of Tech-Curing offers the following advantages:

a. It shortens the entire curing process from months to several days.

b. It helps preserve flavor and aroma constituents, vanillin for example, lost during prolonged drying in the traditional curing process.

c. The process is mechanized and, therefore, not labor-intensive.

d. The process is controlled, thus ensuring consistency in product quality. Consistency is an attribute that is much appreciated by the industry.

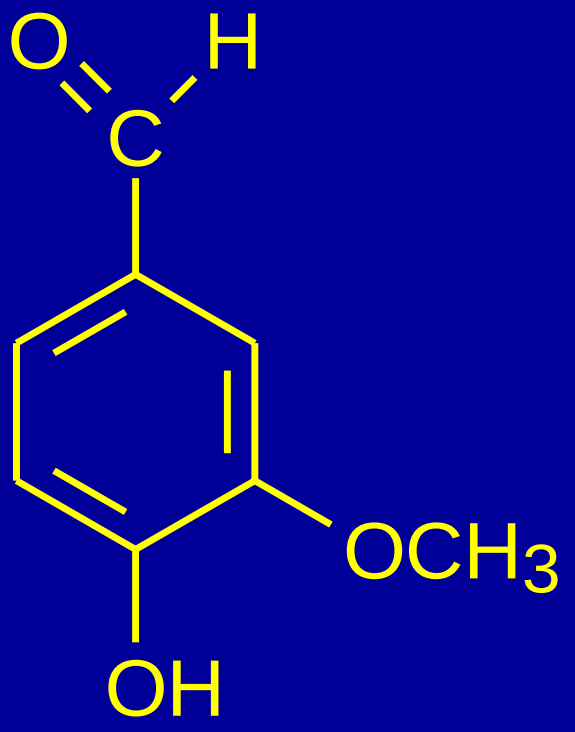
Disadvantages:

The new process requires an investment.

Tech-curing of green vanilla beans is an effective, consistent and economical process. Extracts obtained from these beans comply with top industry standards.

Vanillin

- Molecular Weight 152
- CAS 121-33-5
- FEMA-GRAS 3107
- Classification: A monocyclic aromatic aldehyde-phenol containing a methoxy group, found in a number of natural products in low levels.



Pure Vanilla Extract - Standard of Identity

- **Total flavor and odor principles of properly cured vanilla beans**
- **Bean species:** *V. planifolia* **Andrews or *V. tahitensis* Moore**
- **Bean weight: 13.35 ounces per gallon, per fold**
- **Beans no more than 25% moisture content**
- **Alcohol content: minimum 35% by volume**
- **Optional ingredients permitted including sugar, corn syrup, dextrose, glycerin and propylene glycol**

Vanilla Product Range

- **Vanilla Extract**
- **Vanilla Flavor**
- **Concentrated Vanilla Extract**
- **Concentrated Vanilla Flavor**
- **Vanilla - Vanillin Extract**
- **Vanilla Powder**
- **Vanilla Sugar**