A Discussion on the Science of Coffee Staling

Coffee Freshness System, LLC

Who we are: ***Coffee Freshness System, LLC***

Keeps Coffee Fresh by removing Oxygen & storing in Pressurized CO2. Info: Visit our Booth

www.coffeefreshness.com

The Science of Coffee Staling

Course Outline:

1. Coffee Bean Chemistry
2. Roasting Chemistry
3. Mechanisms of Coffee Staling
    a. Parameters affecting Coffee Staling
4. Model of Coffee Staling
5. How to reduce the rate of Coffee Staling
6. Conclusion / Questions

Some Examples of Stale Coffee

https://www.youtube.com/embed/w8_jpQXUyA?autoplay=1&start=56&end=70

https://www.youtube.com/embed/Rfp7eWDIt2c?autoplay=1&start=6&end=20

First, let’s review what is in the Coffee Bean

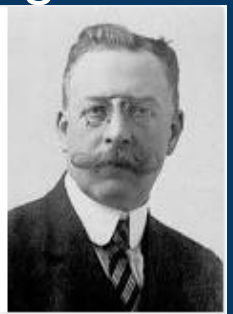
- To understand staling, we need to understand the chemistry fundamentals of the Roasted Coffee Bean
- A coffee bean contains over a thousand chemical compounds, such as:
  - Aromatic Flavor compounds
  - Melanoidins
  - Lipids (Oils)
  - CO_2 gas

How do all those chemicals get into Coffee?

- Answer: Roasting, The Maillard Reaction and Pyrolysis
  - The heat from roasting causes chemical reactions that:
    - Result in the wonderful smelling and tasting Aromatic Flavor compounds in Coffee
    - And CO_2 gas within the Coffee Beans
  - Quite a lot of CO_2 in fact, 6 - 10 liters/Kg of Beans

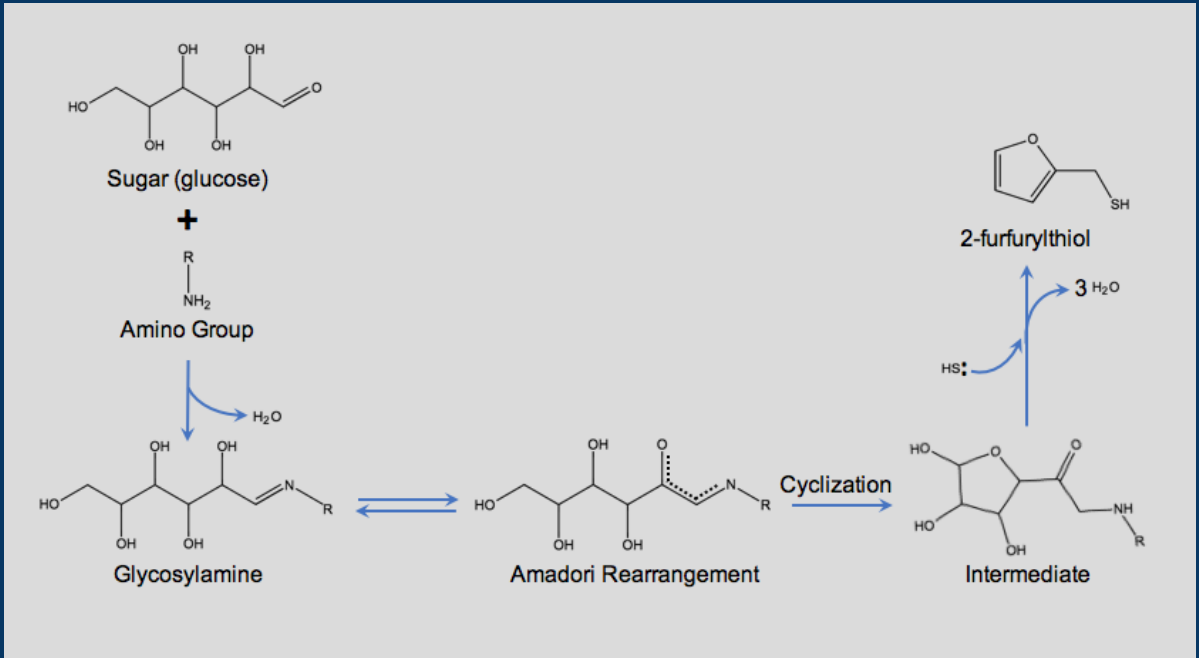
Louis Camille Maillard

French physician



Example of Maillard reaction

- Maillard reaction forming 2-furfurylthiol



Why does Coffee go Stale?

- First - two interesting observations on Coffee Staling
  - Coffee staling takes its origin from roasting
  - Maillard reaction and Pyrolysis… transform the beans into a very unstable and reactive system

Ref. M.C. Nicoli, Espresso Coffee The Science of Quality, Pg. 232

Why does Coffee go Stale?

- Staling of coffee beans is mainly due to two actions
  - 1) Oxidation - *From Oxygen in the air! Causes stale taste*
  - 2) Volatilization - *Evaporation/Loss of flavor chemicals*

- Other Parameters affecting coffee Staling are:
  - 3) Moisture - Delivers heat and oxygen to aromatics
  - 4) Heat - Increases rates of Oxidation and Volatilization
  - 5) Light - catalyzes auto-oxidation of fatty acids

What is Oxidation?

- Chemical reaction where a compound 1) loses electrons, 2) gains Oxygen
  - For Example: Methanethiol to Dimethyl disulfide
    - $4\ H_3C\text{-}SH + O_2 \rightarrow 2\ H_3C\text{-}S\text{-}S\text{-}CH_3 + 2\ H_2O$
- What Oxidation are we concerned with in Coffee?
  - Aromatic Flavor compounds and Lipids
- *Why is this a concern*
  - *Oxidation of Aromatics creates off-flavors [Stale]*
  - *Oxidation lowers the amount of anti-oxidants*

How much does Oxidation/Oxygen affect staling?

- *Oxygen is the most critical factor in coffee staling*
- Degradation of coffee increases with oxygen by:
  - 10 times from 0.1% to 1.1% oxygen concentration
  - 20 times over real world test range of 0.5 - 21%

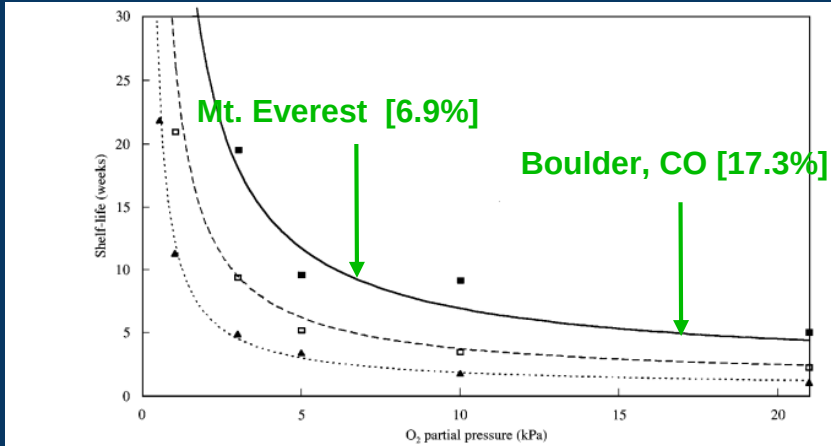


Fig. 3 Sensory shelf life of R/G coffee at 22 °C, a_w: ■ 0.106, □ 0.248, ▲ 0.408

Ref. Cardelli and Labuza (2001)

Staling comparison Oxygen, Moisture, Heat

- Relative effects in staling:
  - Oxygen = 20, Moisture = 1.8, Heat = 0.6

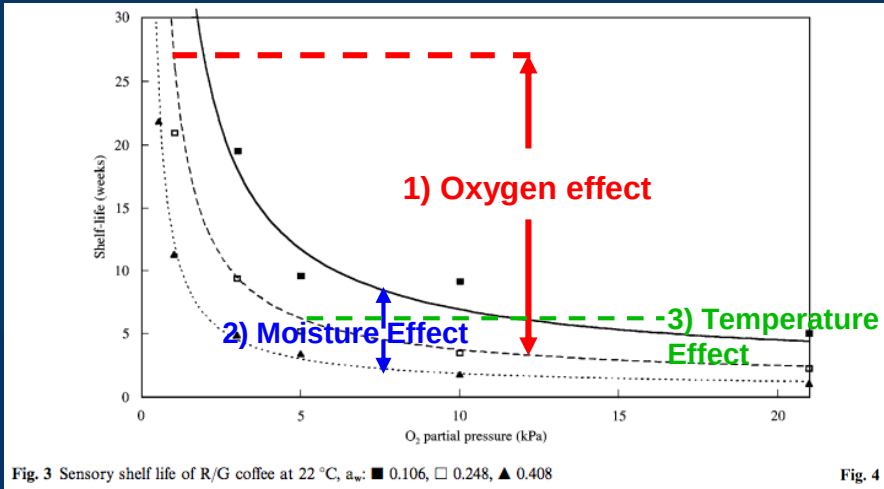


Fig. 3 Sensory shelf life of R/G coffee at 22 °C, a_w: ■ 0.106, □ 0.248, ▲ 0.408

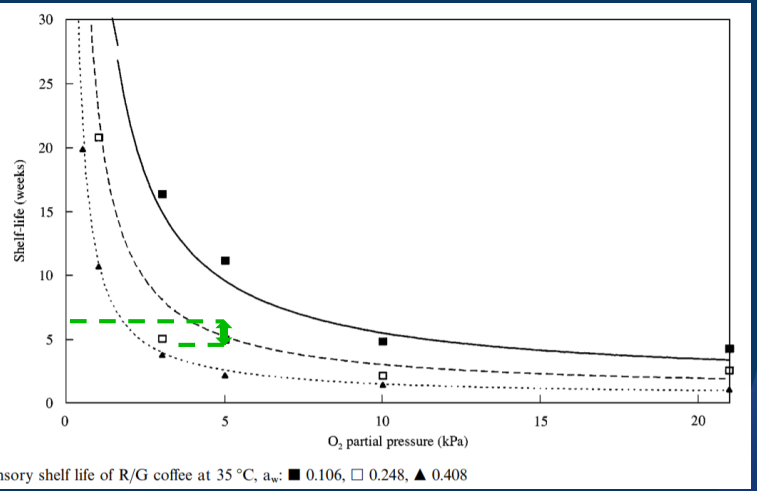


Fig. 4 Sensory shelf life of R/G coffee at 35 °C, a_w: ■ 0.106, □ 0.248, ▲ 0.408

Ref. Cardelli and Labuza (2001)

Summary: Oxygen, Moisture and Heat Effects

- In a consumer test, the decrease in Coffee shelf life when measured over a range of ‘real world’ use was:
  - 20 times when Oxygen increased from 0.5 - 21%
  - 60% per 0.1 point increase in Water activity (a_w)
  - 20% per 10℃ increase in Temperature
- (a_w) range was .3 and Temp was 30℃

Relative staling effect: Oxygen 20, Moisture 1.8, Heat 0.6

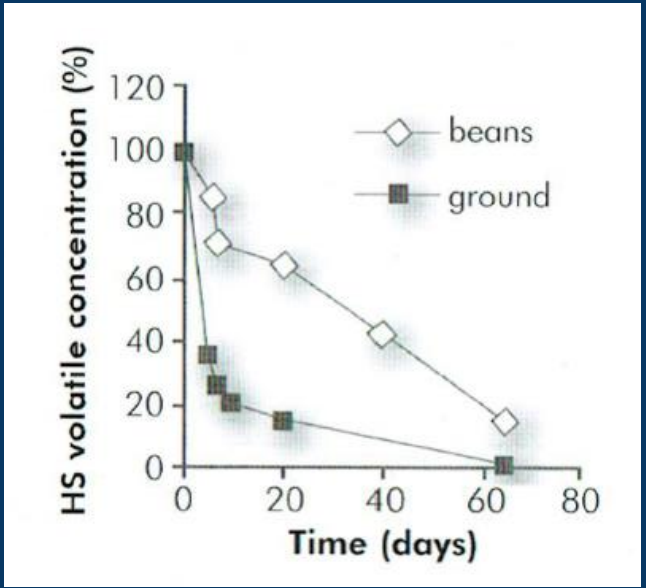
Ref. Cardelli and Labuza (2001)

Volatilization Effects

- What is Volatilization?
- Converting a chemical substance from a liquid or solid state to a gaseous or vapor state
  - For Example:
    - 2-furfurylthiol$_{(\ell)}$ ↑ 2-furfurylthiol$_{(g)}$
- What Volatilization is of concern in Coffee Staling?
  - Aromatic Flavor compounds and CO2

Volatilization of Aromatics

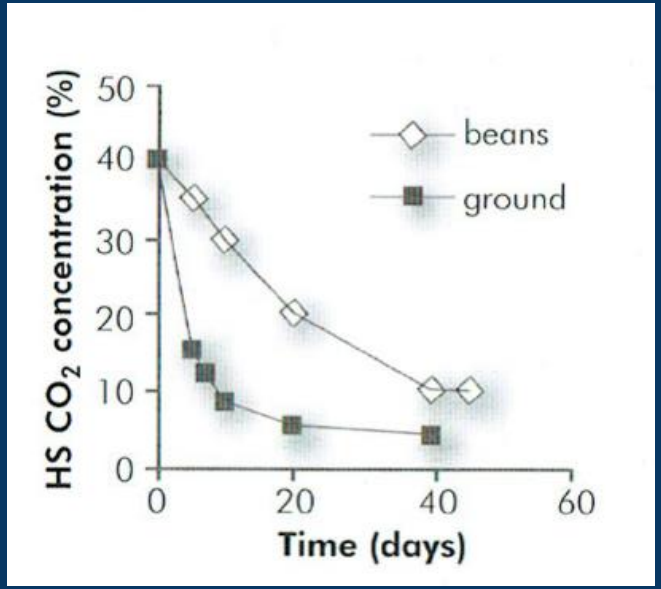
- Aromatics outgas continuously, starting right after roasting
- This results in the loss of flavor aspect of staling



Ref. Espresso Coffee The Science of Quality, Fig 6.3 Pg. 237

Volatilization of CO2

- CO2 outgasses continuously starting right after roasting
- This allows oxygen to enter and oxidize flavor compounds



Ref. Espresso Coffee The Science of Quality, Fig 6.3 Pg. 237

Diagram of Coffee Staling

- Fig-1: Oxygen attacks Aromatics and Lipids, also Aromatics and CO2 volatilize

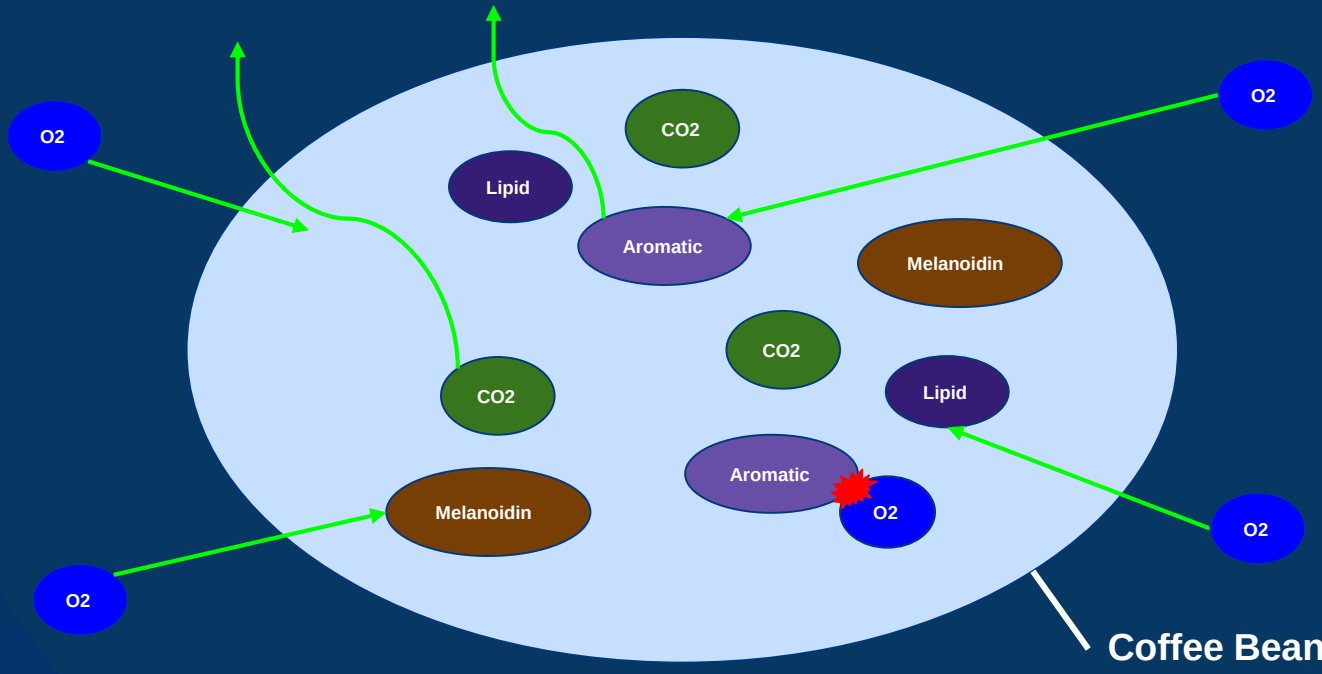
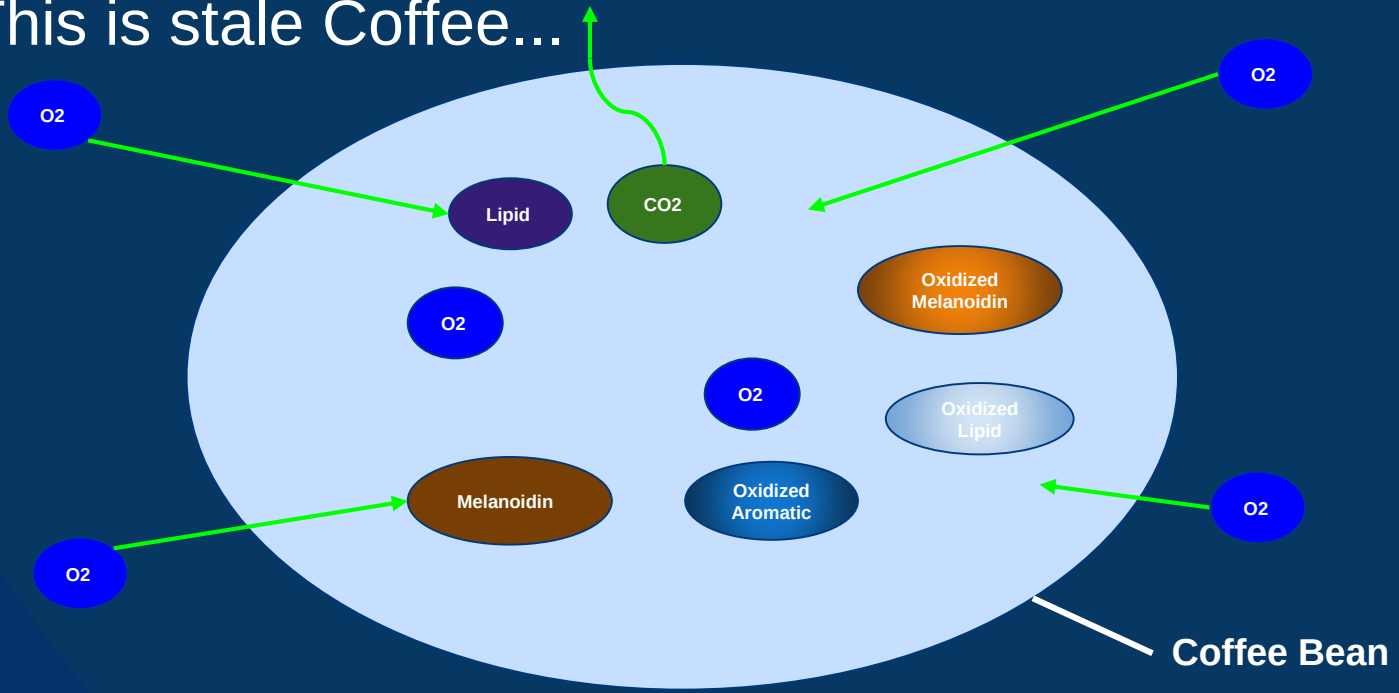


Diagram of Stale Coffee

- Fig-2: Over time, we are left with oxidized flavour compounds and have lost Aromatics and CO2
- This is stale Coffee...



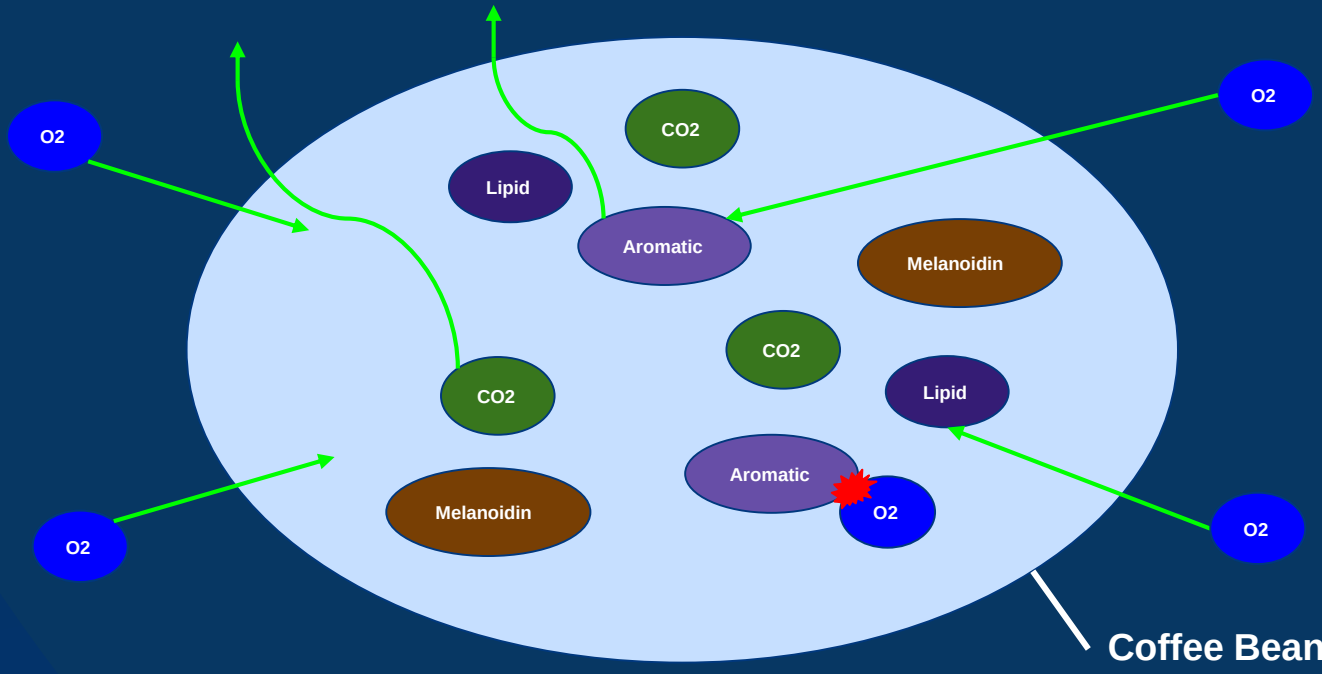
Can Coffee Staling be Prevented?

- Not completely, however the *rate* of staling can be *significantly slowed* by *counteracting* the causes of staling

- For example,
  - By removing oxygen and replacing with inert gas or CO_2
  - By increasing pressure to reduce the volatilization rate

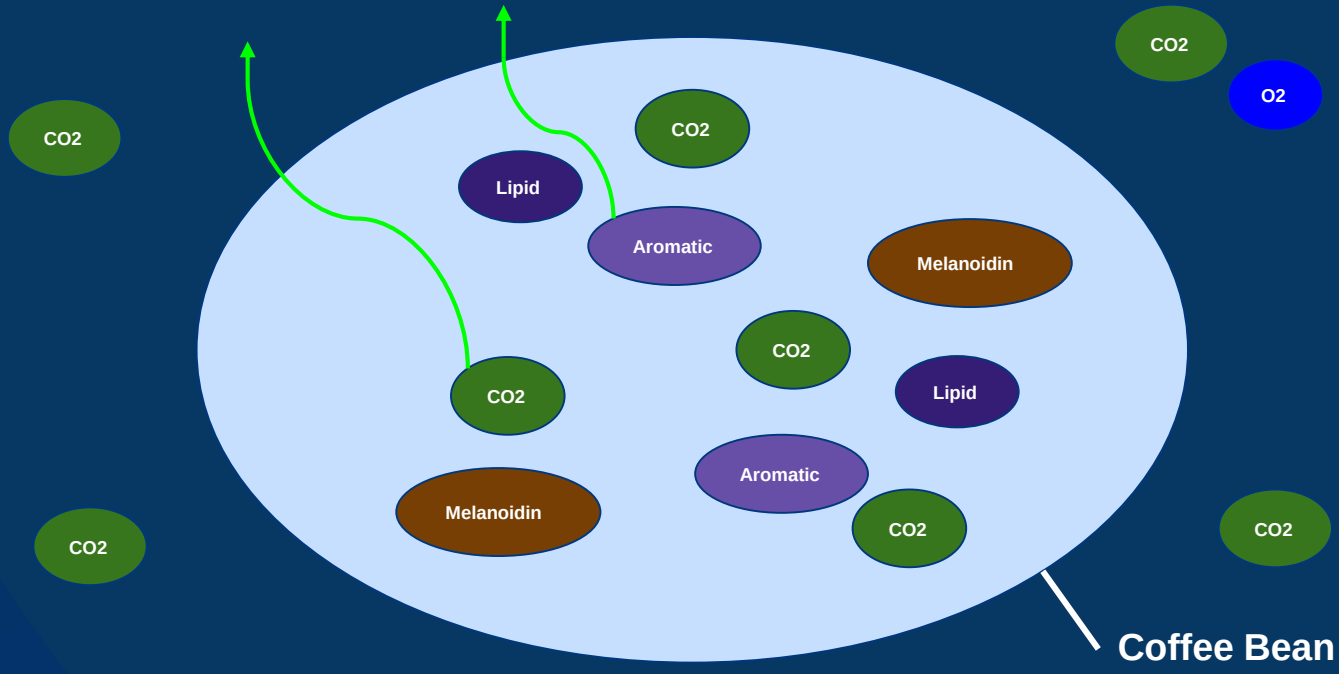
Counteracting Coffee Staling

- Fig-3: Replacing oxygen



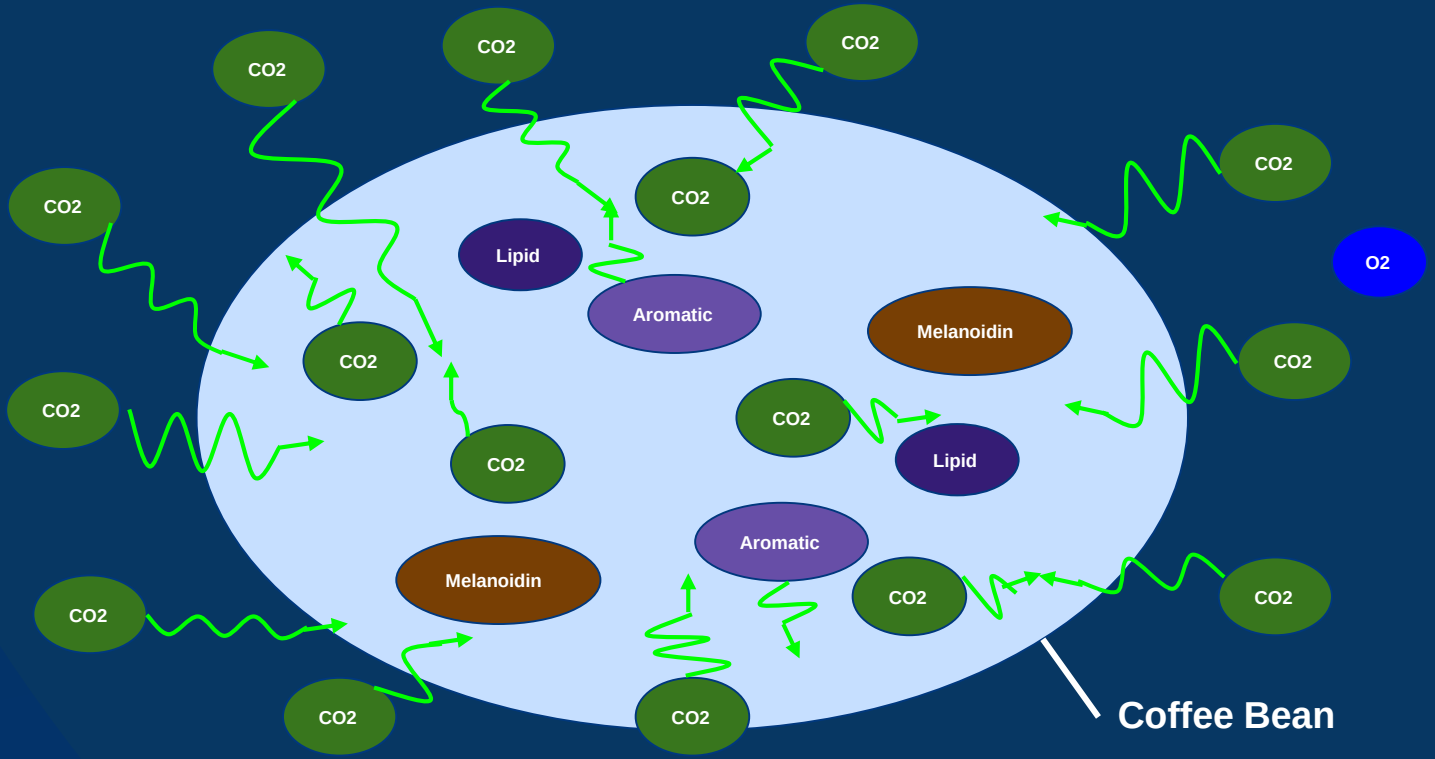
Counteracting Coffee Staling

- Fig-3: Replacing oxygen with CO2



Counteracting Coffee Staling

- Fig-3: Replacing oxygen with CO2 and increasing pressure



Counteracting Coffee Staling

- The best techniques to slow the rate of staling are:
  - Low Oxygen - Inert gas
  - Pressurization

Table 6.6 Packaging parameters

Technique	Residual O_2(%)	Shelf life (mth)	Absolute P_{int} (Atm)	Material
In air:				
tight	16–18	1	nRT/V	Rigid
with valve	10–12	3	1.01*	Indifferent
Under vacuum	4–6	4–6	0.3	Better flexible
Under inert atmosphere	1–2	6–8	1.01*	Indifferent
Under pressure	<1	>18	Up to 2.2	Rigid

*Pressure at which the valve opens.

Ref. Espresso Coffee The Science of Quality, Table 6.6 Pg. 253

Conclusion

- Roasting creates coffee flavors by Maillard reaction
- Staling is caused by 2 main mechanisms
  - Oxidation of flavor compounds
  - Volatilization of flavor compounds
- Staling can’t be completely stopped, but the rate of staling can be *significantly* slowed by storing under optimized conditions

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Thank you!

Questions?

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Back-up -

Oxidation in Fresh Roasted Coffee

A Question of Freshness

By Paul Songer

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Inevitably, coffee is in contact with oxygen for a certain period before packaging. A common myth is that coffee is not able to take on oxygen immediately after roasting due to carbon dioxide degassing. However, Michael Sivetz estimates that instead of 21%, about 10% oxygen surrounds degassing coffee –certainly enough to initiate oxidation.

Oxidation in Fresh Roasted Coffee

THE LEGEND OF CARBON DIOXIDE HEAVINESS

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Abstract: The false legend of carbon dioxide traps resulting from the weight of carbon dioxide gas is disproved. In spite of water-vapor lightness in comparison with air, no water-vapor trap exists on cave ceilings. In fact, underground atmospheres with specific compositions are not related to gravity, but to the absence of any air movement around the gas sources. The process of double diffusion of oxygen and carbon dioxide during

Table 1 shows that, depending on molar mass, gas density changes significantly with water vapor, with methane and hydrogen being less dense than air, while carbon dioxide and radon are much denser. If stratification really does occur, according to the meaning adopted by those who state that heavier gases accumulate in depressions, then we would live in a carbon dioxide atmosphere just a few meters above sea level, in oxygen at the top of mountains, in nitrogen above the mountains, and finally, in water vapor (and rain) in the stratosphere. The Dead Sea and the Caspian Sea would exist in pure radon atmospheres whereas hydrogen would be concentrated in the ionosphere (incidentally, where it actually is, but due to reasons other than stratification). This is an unrealistic scenario.