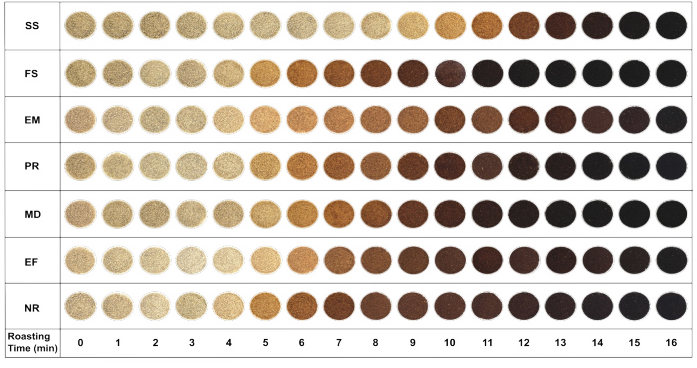
UC DAVIS

COFFEE CENTER



Overview for the Kona Coffee Farmers Symposium

Asst. Prof. Irwin R. Donis-González, February 2026

UC DAVIS COFFEE CENTER

2013 — Design of Coffee Freshmen Seminar (18 students)

2014 — UC Davis Coffee Initiative established

2015 — Coffee Lab begins serving 500 students / quarter

2016 — Peet's Coffee provides a founding gift

2017

2018

2019 — Donations from many more forward-thinking companies and individuals from the coffee industry… & generous alumni!

2020

2021

2022 — $6M Coffee Center renovation commences!

2023

2024 — Grand Opening!

Major Research Projects

- Brewing Control Chart (Breville)
- Cold Brew (Toddy)
- Roasting Kinetics (Probat)

Specialty Coffee Association

UC DAVIS COFFEE CENTER

Main goal: to create a world-class facility for coffee research and advanced education, under one roof

- Pilot roastery
- Brewing & espresso lab
- Green bean storage lab
- Sensory / tasting lab
- Chemical analytical lab
- Innovation space
- Classroom and office space

Renovation of an existing building!

$4.35M raised to date for renovation to create a world-class, state-of-the-art facility

Our supporters:

Peet's Coffee
la marzocco handmade in florence
PROBAT
TODDY cold brewed. simply better.
Curtis
Folgers
BENCAFÉ
BARATZA
BEHMOR
JOSUMA COFFEE COMPANY
MERCON COFFEE GROUP
RL RIZO-LOPEZ FOODS, INC.
BRIDGE COFFEE CO.
ROYAL
cropster

+ many individuals!

UC DAVIS
COFFEE CENTER

Media Alcove

Cropster Corridor

Behmor
Office
Space

Folgers Chemical
Analytical Laboratory

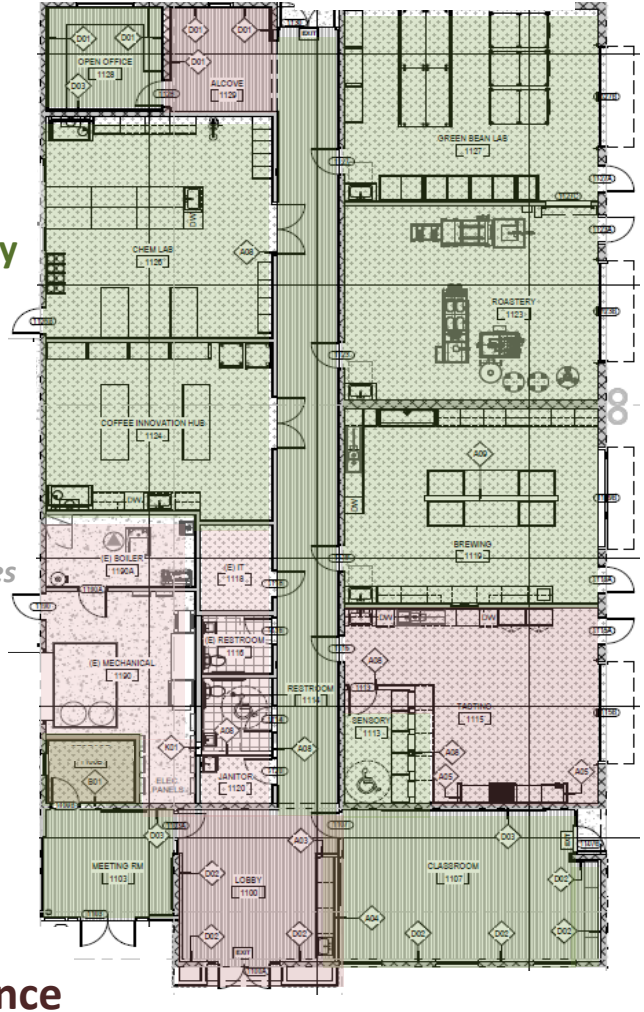
Toddy
Innovation
Laboratory

Utilities

Kent Bakke &
Moira Kennelly
Director's
Office

Josuma
Meeting
Room

**Lobby &
Grand Entrance**



Nicaraguan Coffees
Green Bean Storage
Laboratory

Peet's Coffee
Pilot Roastery

La Marzocco
Brewing & Espresso
Laboratory

Sensory & Cupping
Laboratory
& Sensory Suite

Wasson Classroom

Grand Opening! May 3, 2024

The Washington Post
Democracy Dies in Darkness

NATIONAL Climate Education Health Innovations Investigations National Security Obituaries Science

New coffee center in Northern California aims to give a jolt to research and education

A university in Northern California has launched a specialized center devoted to coffee education and research

By Haven Daley and Sophie Austin | AP
June 21, 2024 at 1:03 p.m. EDT

Latest Local News Live Shows ••• CBS NEWS

SACRAMENTO | News Weather Sports Video Your County •••

LOCAL NEWS

The science of coffee: UC Davis now home to first coffee research center at a U.S. university

By Ashley Sharp
May 24, 2024 / 11:34 PM PDT / CBS Sacramento

sactown MAGAZINE

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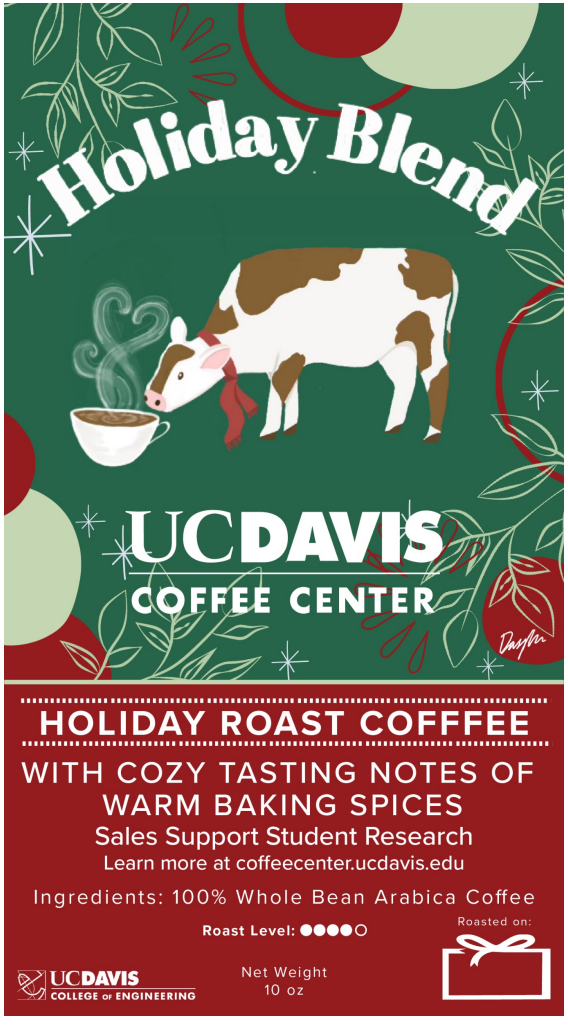
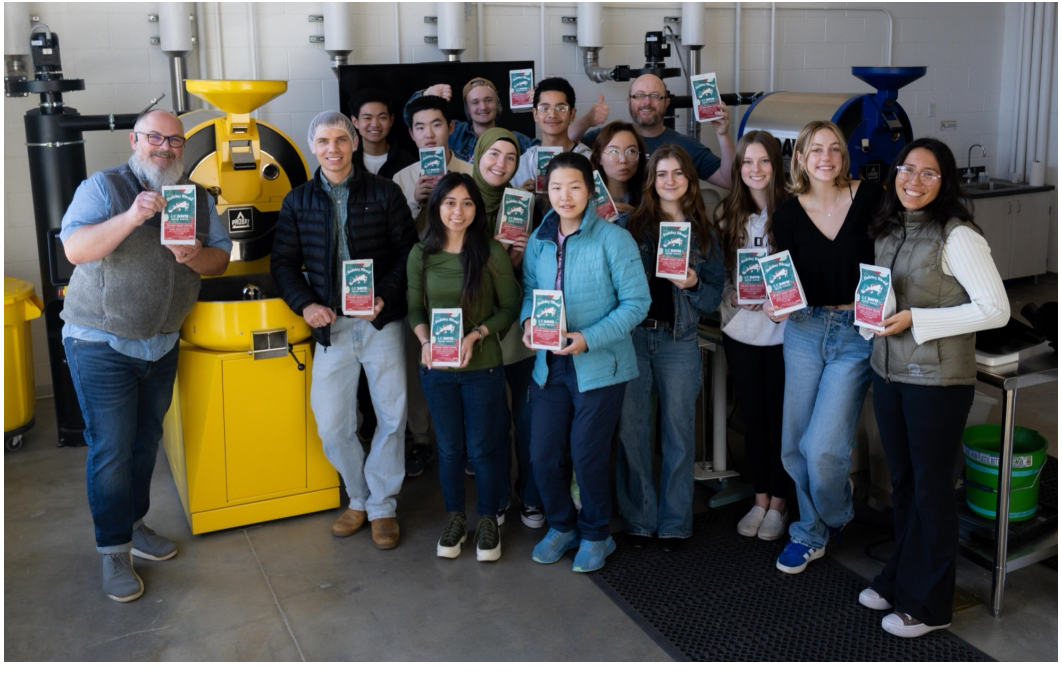
UC Davis Turns to the (Deliciously) Dark Side

Something's brewing at the University of California at Davis. Already a global leader in wine and beer studies, the school is setting out to conquer yet another of our collective liquid loves. In May, UCD launched America's very first academic facility dedicated entirely to the research of coffee. And with a multibillion dollar industry awaiting, the sky's the limit.

BY HILLARY LOUISE JOHNSON



Coffee Roastery Operations & Product Development (Importance of branding!)



Fall 2024 class, holding the coffee we developed to sell in the bookstore!
Sold out Xmas 2024 ☺

AGGIE BLEND

MEDIUM ROAST
WHOLE BEAN COFFEE

UCDAVIS
COFFEE CENTER

AGGIE BOLD

DARK ROAST
WHOLE BEAN COFFEE

UCDAVIS
COFFEE CENTER

AGGIE BRIGHT

LIGHT ROAST
WHOLE BEAN COFFEE

UCDAVIS
COFFEE CENTER

Critical Steps in Coffee Production and Processing: How to Achieve the Highest Quality

Irwin R. Donis-González

UCDAVIS
COFFEE CENTER

100 YEARS 1915 - 2015
UCDAVIS
BIOLOGICAL AND AGRICULTURAL ENGINEERING

UCDAVIS
UNIVERSITY OF CALIFORNIA

Coffee quality and its importance

- Quality is a unique attribute or feature of a product that defines its degree of excellence or superiority.
- Coffee beans' intrinsic properties, including chemical composition and physical characteristics, are precursors to the final beverage quality.
- The quality of coffee is judged and priced by the sensory properties of the final beverage, mainly through subjective measurements of its flavor, color, and aroma, a process known as "cupping".

Genetics

Edaphoclimatic conditions

Crop management

Harvest and Postharvest processes

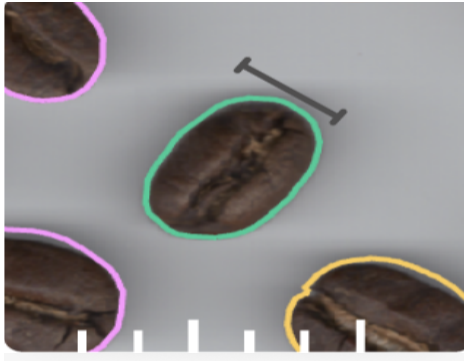
Green coffee handling

Roasting

Beverage

At the UC Davis Coffee Center, how are we enhancing our understanding and contributing to improving coffee quality?

UC DAVIS
COFFEE CENTER



Uganda Sip Falls 2021 >

30 Apr 2022, 7:56:40 PM

Size
17.8 ± 0.2 >

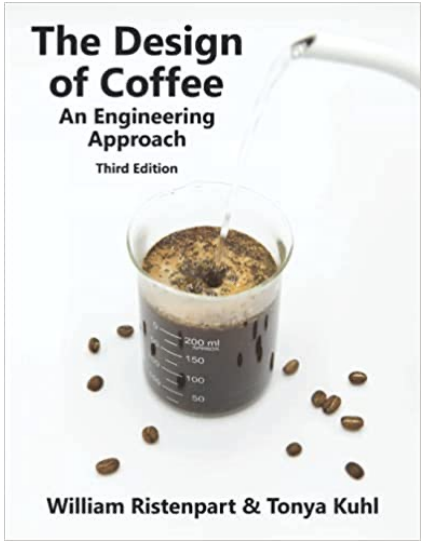
Color
Bluish green (65%) >

Defects
3% (2 of 60) >

Teaching

Research and Outreach

Tech Incubator



(Book available at Amazon for $29)

Lab Experiments in *The Design of Coffee*

Analysis

- Lab 1 – Reverse Engineering a Drip Coffee Brewer
- Lab 2 – Process Flow Diagram and Mass Balances for Coffee
- Lab 3 – The pH of Coffee and Chemical Reactions
- Lab 4 – Measuring the Energy Used to Make Coffee
- Lab 5 – Mass Transfer and Flux during Brewing
- Lab 6 – Coffee as a Colloidal Fluid and the Effect of Filtration

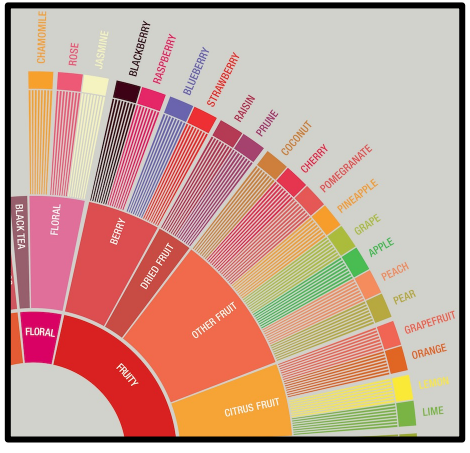
Design

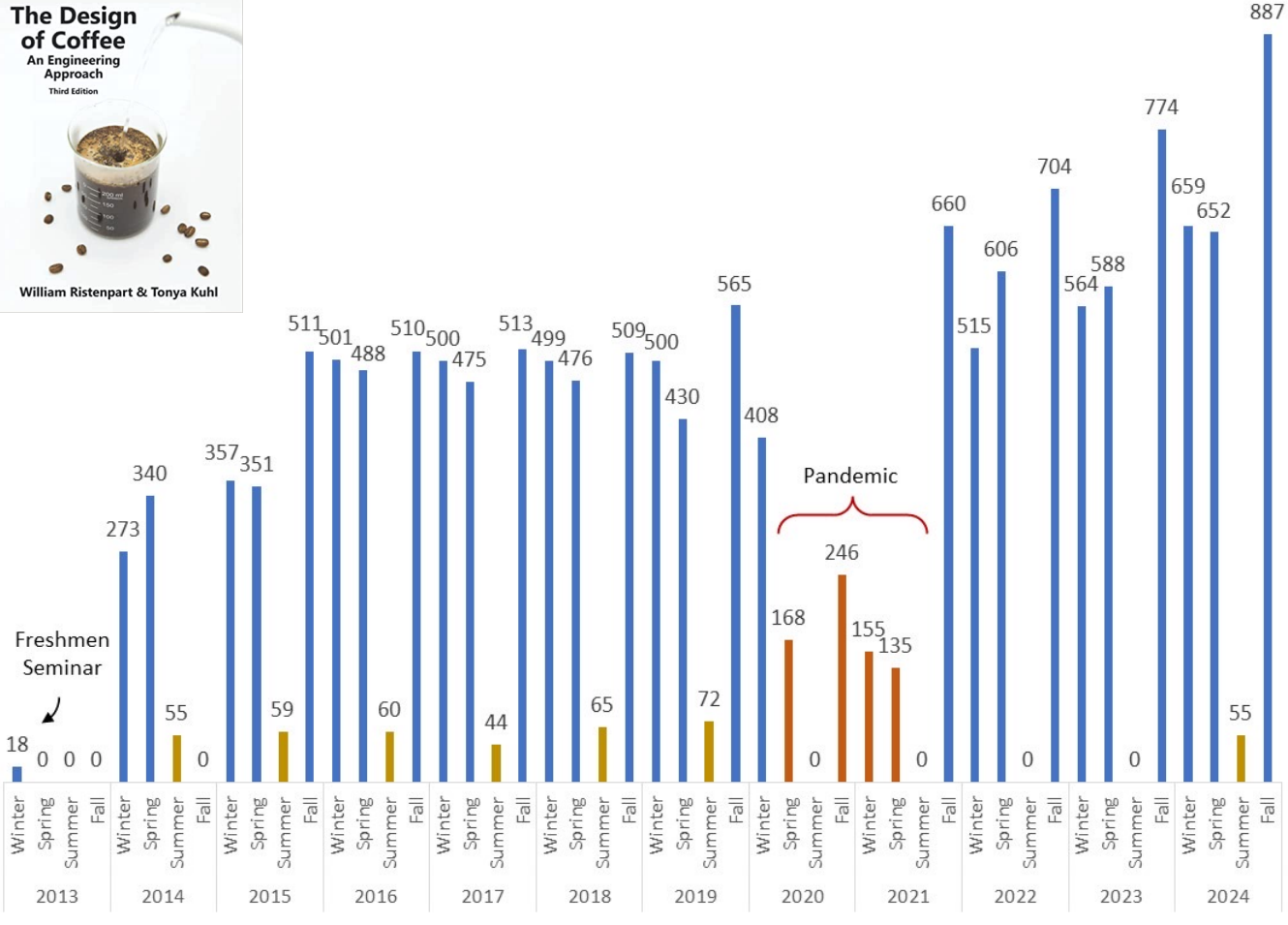
- Lab 7 – First Design Trials: Optimizing Strength & Extraction
- Lab 8 – Second Design Trials: Scaling Up to 1 Liter of Coffee
- Lab 9 – Design Competition and Blind Taste Panel

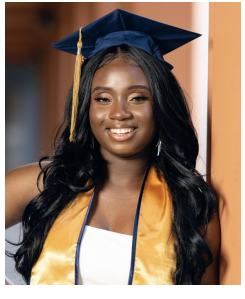
Tonya Kuhl William Ristenpart

The goal of the coffee engineering design project is to make the **best tasting coffee**, using the **least amount of energy**!

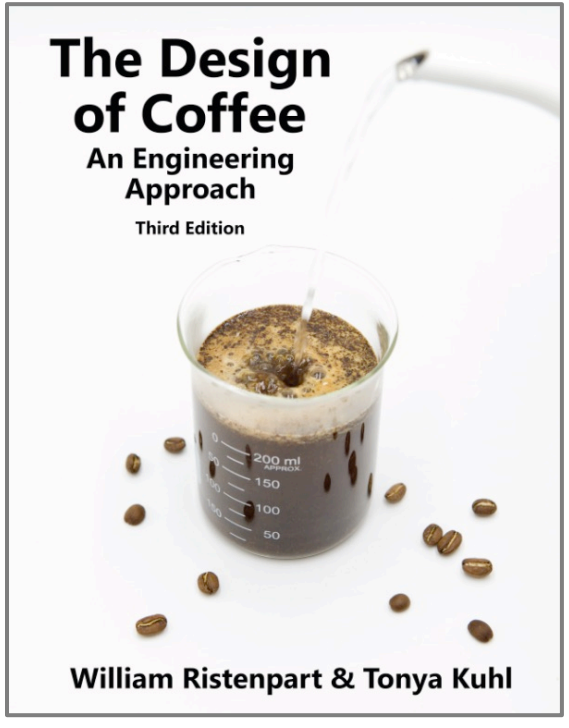
$$\text{Final Score} = \frac{\text{Blind Taste Test Score}}{\text{Total Electrical Energy}}$$



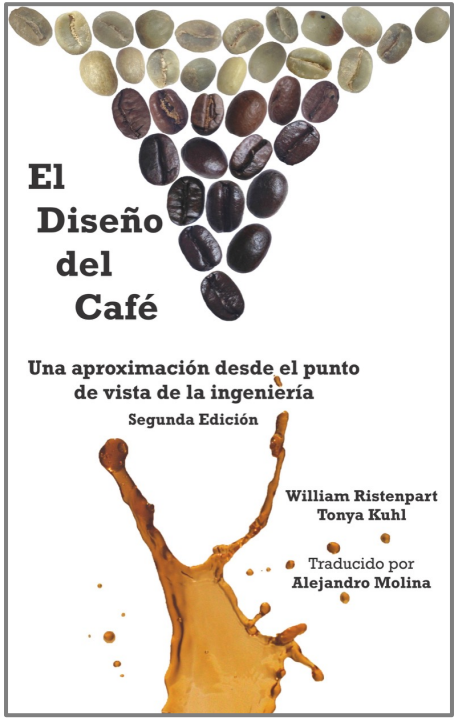




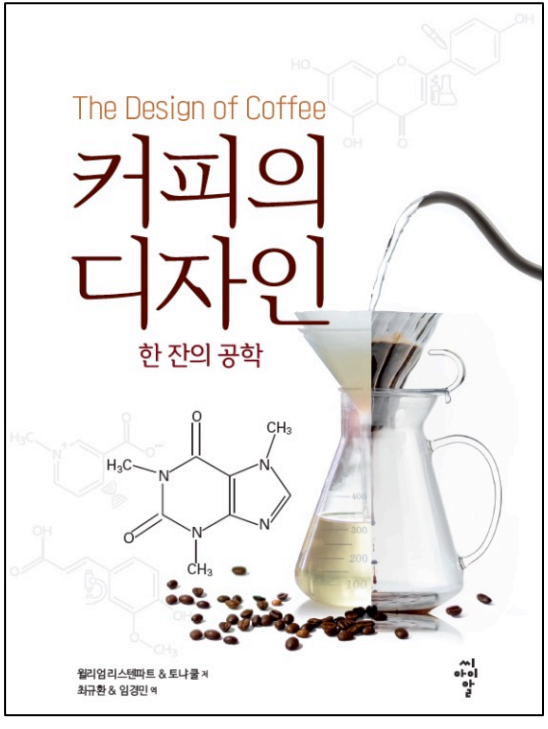
Laudia Anokye-Bempah, Head TA



English



Spanish



Korean
(just published!)

Another class in development:

World Coffee Cultures

A collaboration between Middle Eastern / South Asian studies & Engineering with a global focus

Understanding the product and its needs: What is coffee?

skin
exocarp

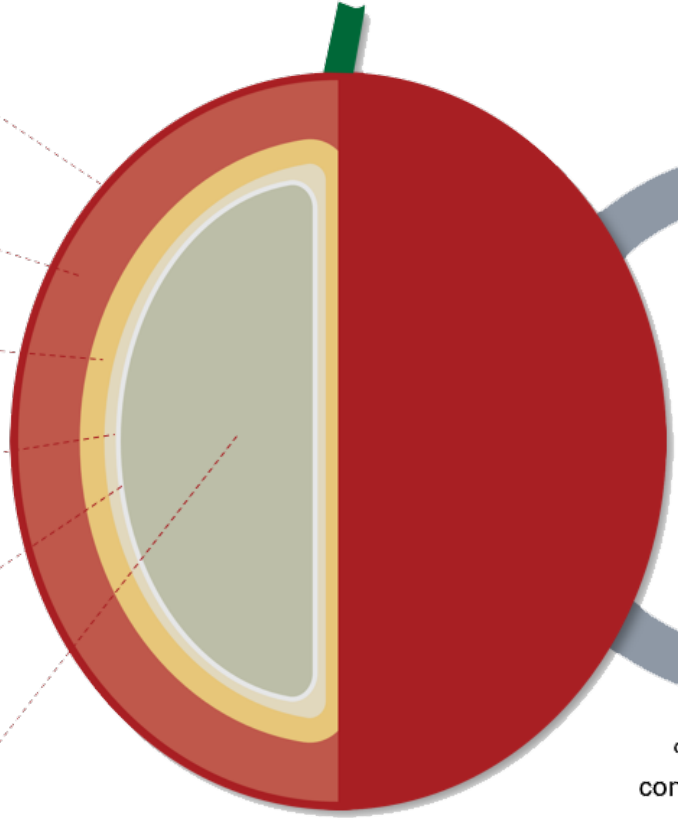
pulp
mesocarp

mucilage
mesocarp

parchment
endocarp

silver skin
epidermis

bean
endosperm



Water
65.3%

Skin + Pulp
9.9%

Mucilage
1.7%

Parchment +
Silver skin
4.1%

Bean
19.0%

Coffea arabica
An evergreen shrub grown primarily at high altitudes in the tropics. It produces the fruit, commonly known as a "cherry" from which the seed is used to make the coffee beverage.

% mass of coffee cherry components, dry weight basis

Coffea arabica
10-18 mm long
6.5-9.5 mm wide

millimeters

Once dry and packaged, no further energy costs

Dried products

GOOD

DRY

Long-term storage

BEST

Excellent for seeds or germplasm storage

DRY CHAIN

WARM

DRY and COLD

COLD

COLD CHAIN

Fresh produce

Infrastructure, refrigeration and energy costs

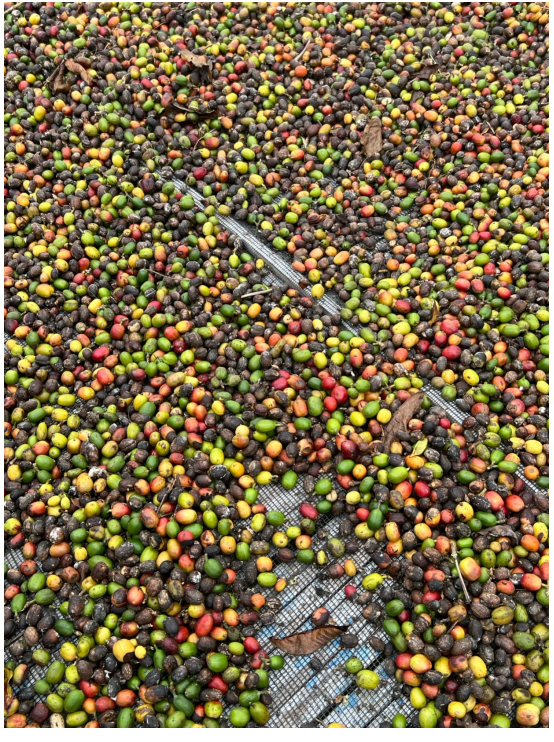
Most fruits begin wet and warm

POOR

WET

How important is harvesting?

Best Good Bad



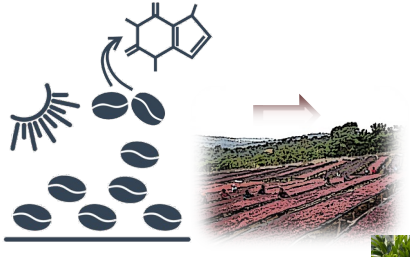
Can I control coffee quality with processing?

Natural Processing

Coffee cherries are dried intact as fresh fruit. The dried cherries are depulped to remove the skin and pulp, and hulled to remove the mucilage, parchment, and silver skin, yielding green coffee. This results in a **fruity**, **juicy**, and **syrupy** coffee beverage with **notes of deep fruit and complex sweetness**.

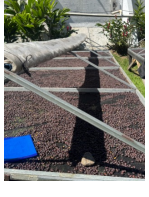
Sorting

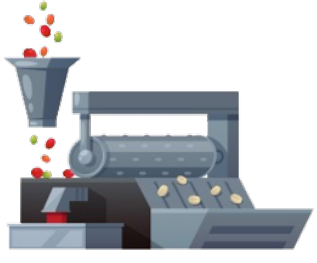
Harvested coffee cherries are sorted by hand based on ripeness, appearance, color, and size.



Drying & Fermenting

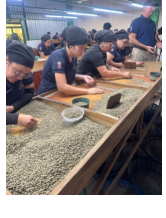
Coffee cherries are sun-dried on raised beds and constantly raked to prevent spoilage, reaching 11 to 12% moisture content.

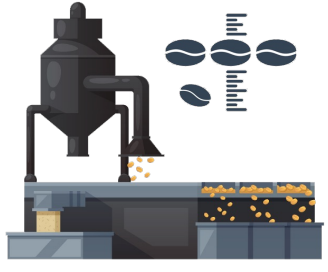




Depulping

Depulper machines mechanically remove the skin and pulp from the coffee cherry.





Hulling & Sorting

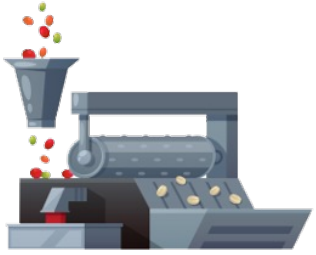
Parchment, mucilage, and silver skin are removed from the parchment coffee to produce green coffee. The green coffee is sorted by size, color, and defects.

Honey Processing

Coffee skin and pulp are removed from the cherry, and the resulting cherry is then dried to produce parchment coffee. The parchment, along with its remaining mucilage and silver skin, is then removed to obtain green coffee. The result is a **syrupy**, **sweet**, and **juicy** coffee beverage with subtle **notes of brown sugar and chocolate**.

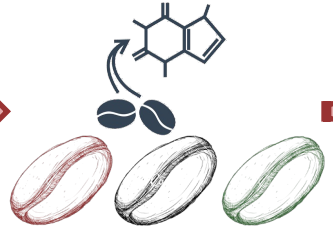
Floating & Sorting

Harvested coffee cherries are submerged in a water reservoir and sorted by density and size.



Depulping

Depulper machines mechanically remove the skin and pulp from the coffee cherry. The mucilage is either left on the wet parchment or partially removed mechanically.

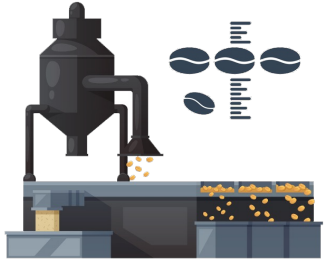


Fermenting

Honey coffee is classified into white and yellow honeys, which have less mucilage, depending on the amount of mucilage remaining in the parchment. In contrast, gold, red, and black honeys contain significantly more mucilage.

Drying

Wet coffee parchment with remaining mucilage is sun-dried on open-air patios, raised beds, or in mechanical driers until reaching 11 to 12% moisture content.



Hulling & Sorting

Parchment with residual mucilage and silver skin are removed from the parchment coffee to produce green coffee. The green coffee is sorted by size, color, and defects.

Washed Processing

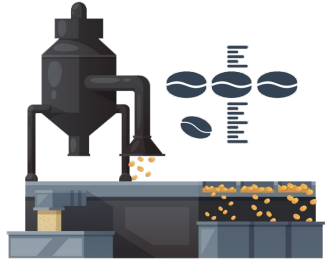
Coffee skin and pulp are removed from the cherry, washed of its mucilage, and then dried to produce parchment coffee. The parchment and silver skin are then removed to obtain green coffee, resulting in a **crisp**, **uniform**, and **clean-tasting** coffee beverage with **pronounced acidity**.

Floating & Sorting
Harvested coffee cherries are submerged in a reservoir of water and sorted by density and size.

Depulping
Depulper machines mechanically remove the skin and pulp from the coffee cherry, leaving the mucilage on the wet parchment.

Fermenting, Washing & Sorting
The wet parchment is fermented in tanks with water, and then the residual mucilage is washed off and/or mechanically removed. The wet parchment is also sorted by density.

Drying
Wet parchment is sun-dried on open-air patios, raised beds, or in mechanical dryers until it reaches 11 to 12% moisture content.



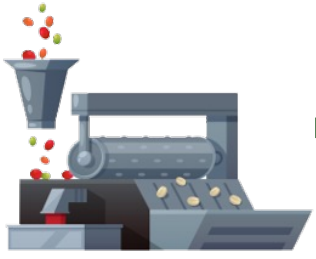
Hulling & Sorting
Parchment and silver skin are removed from the parchment coffee to produce green coffee. The green coffee is sorted by size, color, and defects.

Wet-Hulled Processing

Coffee skin and pulp are removed to produce wet parchment coffee, which is fermented, then hulled and dried as green coffee. This yields a **heavy-bodied**, **earthy** beverage with **mossy**, **nutty**, and **herbal** flavors.

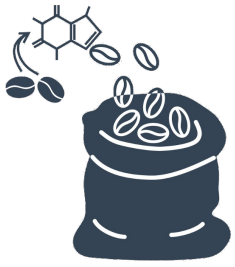
Floating & Sorting

Harvested coffee cherries are submerged in a reservoir of water and sorted by density and size.



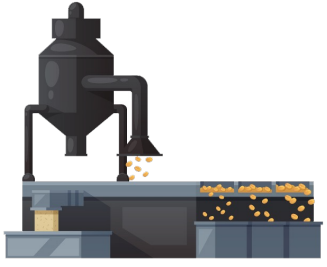
Depulping

Depulper machines mechanically remove the skin and pulp from the coffee cherry, leaving the mucilage on the wet parchment.



Fermenting

The wet parchment, with all its mucilage, is fermented in tanks.



Hulling & Sorting

Parchment with remaining mucilage and silver skin are removed from the parchment coffee to produce green coffee.

Drying

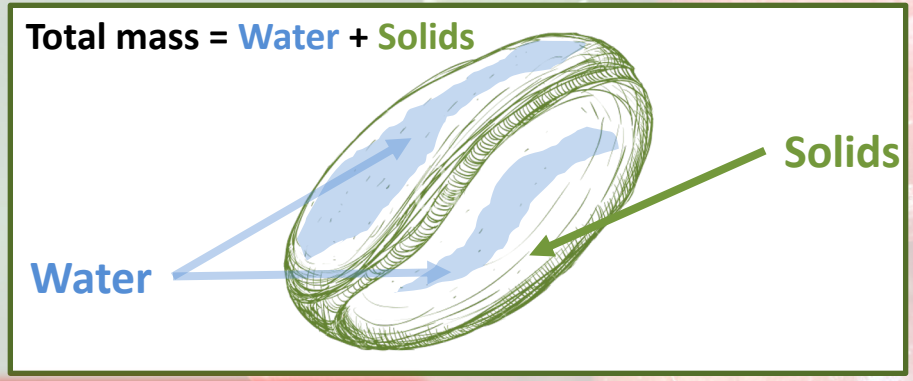
Wet green coffee is sun-dried on open-air patios, on raised beds, or in mechanical driers until it reaches 11 to 12% moisture content. The green coffee is sorted by size, color, and defects.

After processing, which attribute is most important?

Dryness

Moisture Content (MC)

- Amount of water contained in the moist coffee bean.



Wet-basis (MC_{wb})

Dry-basis (MC_{db})

Direct estimation of water content - Oven drying method (Standard)

- Most used, including the Brazilian Agriculture Ministry: Thermogravimetric method (loss of water mass on drying) in which the coffee sample (5-100g) is dried at 105 ℃ (220 ℉) in a convection oven for 24 hours or until a constant weight is achieved.

$$MC_{wb}(\%) = \frac{W_i - W_f}{W_i} \times 100 \qquad MC_{db}(\%) = \frac{W_i - W_f}{W_f} \times 100$$

$W_i = Initial\ weight$
$W_f = Final\ weight$




ASAE/ASABE S352.2 (1988,R2017)
Moisture Measurement-Unground Grain and Seeds

ISO 1447:1978 (67.140.20)
Green coffee – Determination of moisture content (Routine method - 130 ℃, 5g, ~4h)

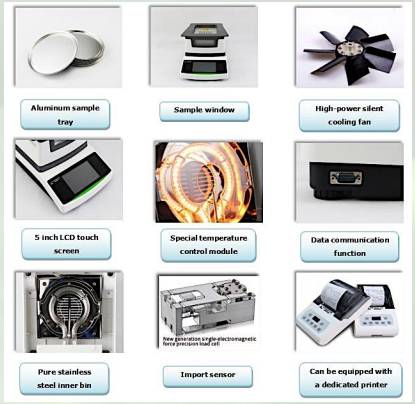
ISO 1446:2001 (67.140.20)
Ground green coffee – Determination of water content (Basic reference method – Phosphorous pentoxide (P_2O_5, 2kPa, 48 ℃, ~150-200h)

ISO 6673:2003 (67.140.20)
Green coffee – Determination of loss in mass at 105 ℃ (10 g, ~16h)

Alternative methods

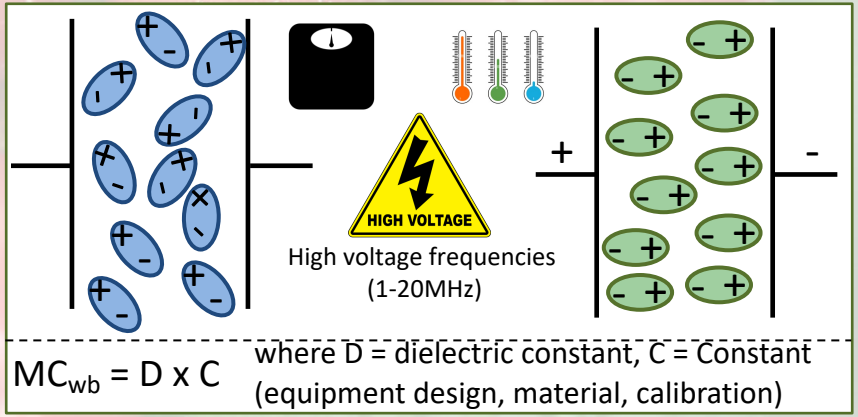
Halogen Moisture analyzers (Direct method - loss of water mass on drying)

Ohaus
Torbal
A&D weighing
Mettler Toledo
Sartorius



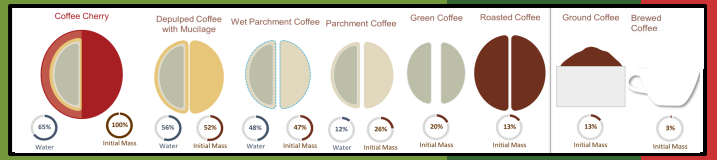
Dielectric method – Measured capacitance of a capacitor or 2 plates (Indirect method)

Dickey-john GAC 2500
AgraTronix - Coffee
AMTAST



$MC_{wb} = D \times C$ where D = dielectric constant, C = Constant (equipment design, material, calibration)

Weight loss during coffee drying?



- During drying, coffee will lose weight due to loss of moisture.
  - Example: 1000 kg of wet parchment coffee is at 55% MC_{wb}. If it is dried down to 12% MC_{wb}, what is the final weigh of the dried parchment coffee?

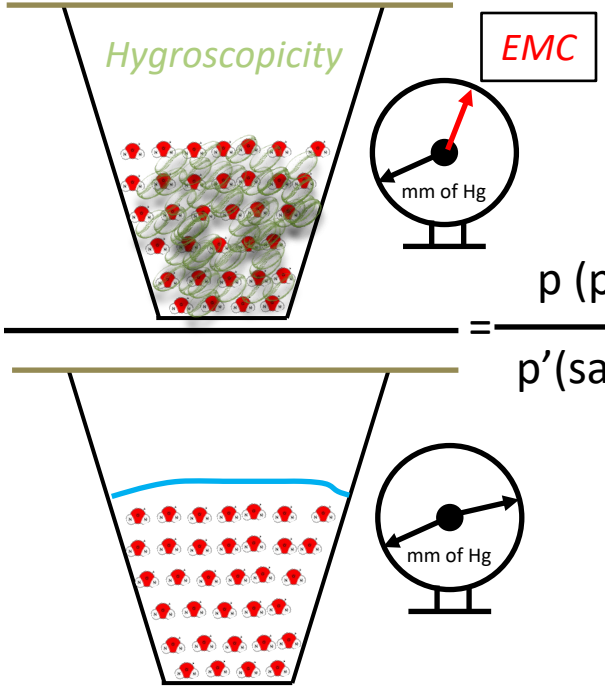
$$W_f = W_i \times \frac{100 - I_{MC_{wb}(\%)}}{100 - F_{MC_{wb}(\%)}} = 1000\ kg \times \frac{100 - 55}{100 - 12} = 511.4\ kg$$

$W_f = Final\ weight$
$W_i = Initial\ weight$
$I_{MC_{wb}(\%)} = Initial\ moisture\ content\ wet - basis\ (\%)$
$F_{MC_{wb}(\%)} = Final\ moisture\ content\ wet - basis\ (\%)$

Water activity (A_w)

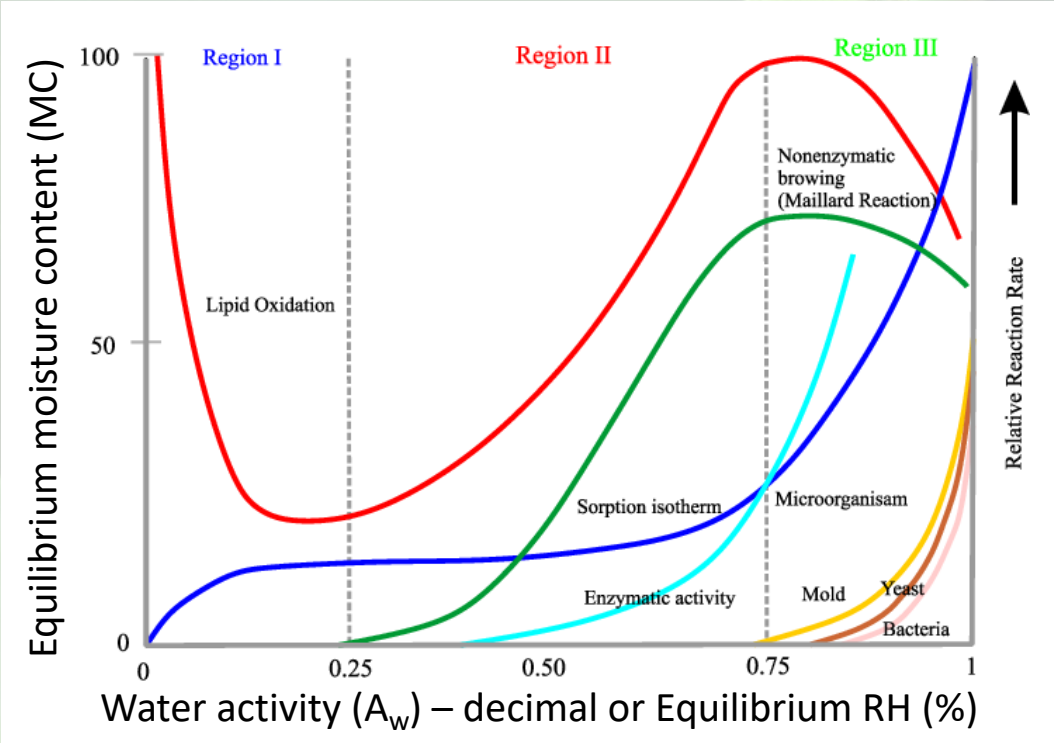
- Defined as the ratio of partial vapor pressure of water above a food product (i.e. coffee beans) to the vapor pressure of pure water at the same temperature and pressure.

$$A_w = \frac{P_{\text{water above coffee beans}}}{P_{\text{pure water}}} = \frac{p\ (\text{partial water pressure})}{p'(\text{saturation vapor pressure})} = \frac{\text{ERH (\%)}}{100}$$



- A_w is a thermodynamic parameter defined as the "chemical potential" of the water in the coffee beans, referring to the state of energy of the molecules in the system. It expresses the potential availability of water ("free") to participate in chemical and biochemical reactions.

Relationship between EMC and A_w (Moisture sorption isotherms [constant temperature]) – Labuza (1970)



Many biochemical reaction (including the Maillard reaction – browning during roasting) and microorganisms that affect the quality and stability of coffee have Aw dependent reactions rates.

Region I

1. MC and A_w are low.
2. Water molecules are tightly held by coffee beans with limited mobility.

Region II

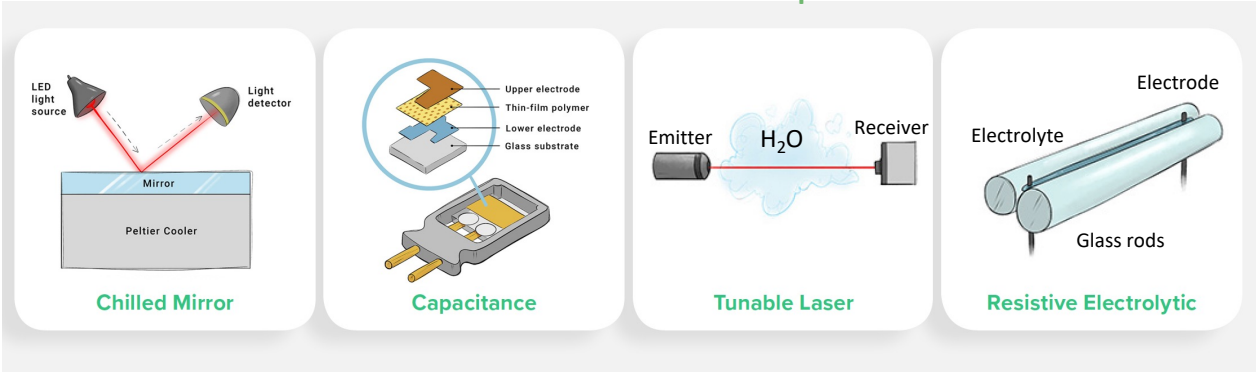
1. MC is relatively low, but A_w increases rapidly with small increases in MC.
2. Water molecules interact with food, but have some mobility.

Region III

1. MC and A_w are high.
2. Water molecules have high mobility.

Measuring water activity (A_w)

Measurement technique



METER/AquaLab

Rotronic

METER/AquaLab

NOVASINA

Sample Read Times

→ High accuracy (±0.003), $8,000 [Foods, No Volatiles]

→ Mid accuracy (±0.007), $14,000 [Volatiles]

→ Low accuracy (±0.01), Aw>0.7, $5,100 [Portable]

→ Low accuracy (±0.05), $3,000 [Portable], low durability

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http://www.aimspress.com/journal/agriculture

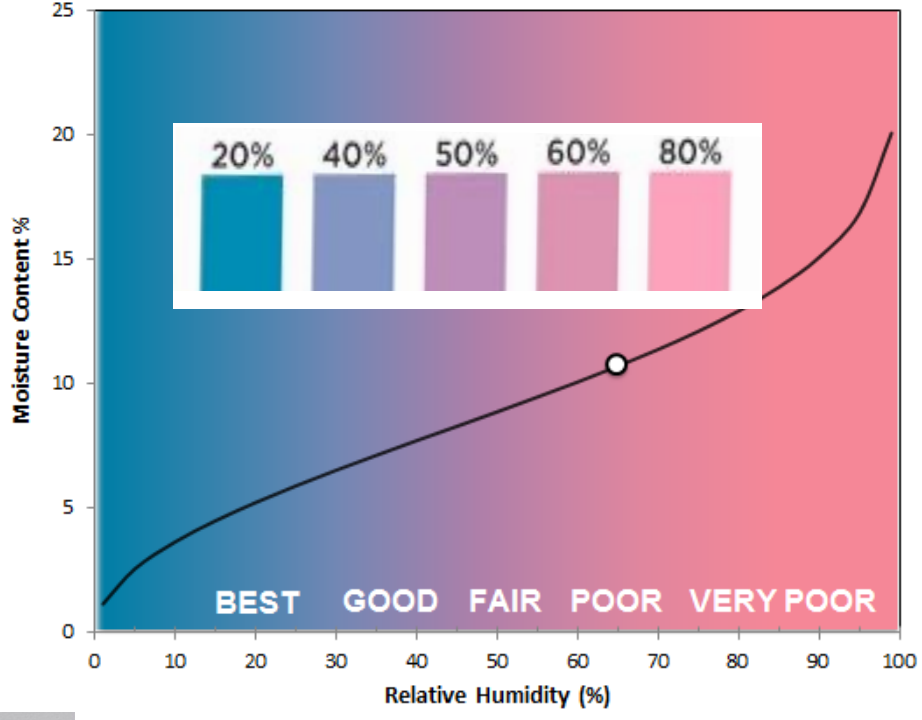
Research note

DryCard™ — A Low-Cost Dryness Indicator for Dried Products

James F. Thompson[1,*], Michael S. Reid[2], Lucia Felix[1], Irwin Donis-Gonzalez[1], Bertha Mjawa[3], and Jane Ambuko[4]

[1] Department of Biological & Agricultural Engineering, University of California, Davis, One Shields Ave, Davis, CA 95616, USA.
[2] Department of Plant Sciences, University of California, Davis, One Shields Ave, Davis, CA 95616, USA.
[3] Prime Minister's Office, Marketing Infrastructure, Value Addition and Rural Finance Support Programme, P.O. Box 14416, Arusha, Tanzania
[4] Department of Plant Science and Crop Protection, University of Nairobi, University Way, Nairobi, Kenya.

Aw Values Directly Indicate Potential Storability

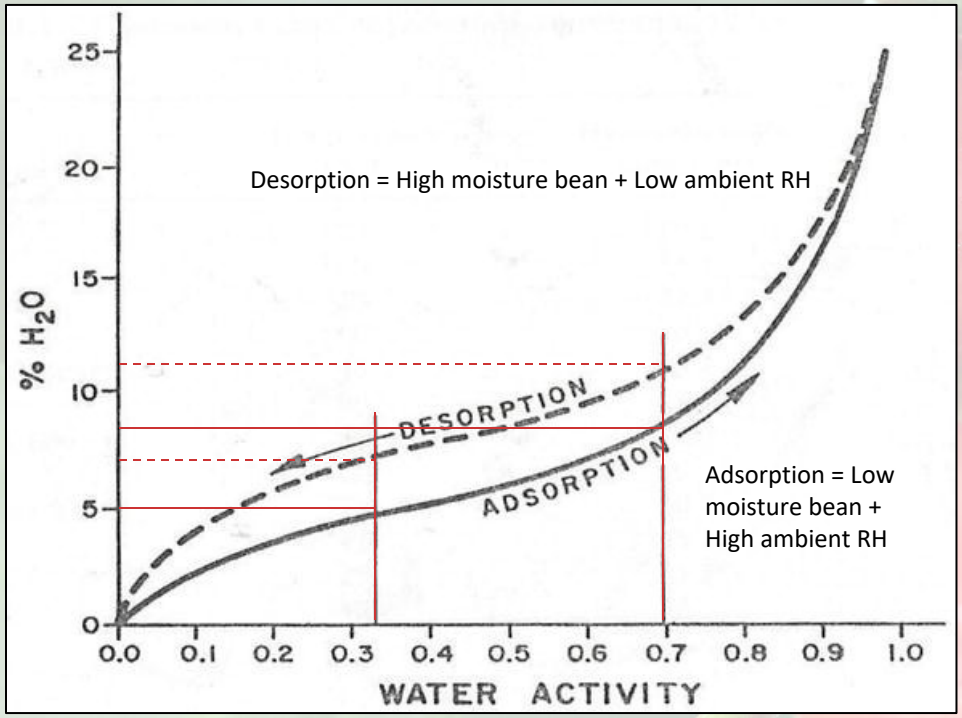


www.microessentiallab.com

Equilibrium Moisture Content (EMC)

- EMC depends on air vapor pressure, which in turn depends on air temperature and RH.
- Changes in the chemical composition of coffee beans can affect EMC.
  - For example, coffee beans with high lipid/oil content will adsorb less moisture from the surrounding air.
- The previous moisture adsorption/desorption history will affect EMC (hysteresis).
- Coffee beans will…
  - Exert a characteristic vapor pressure or Aw at a certain ambient pressure, temperature, and MC.
  - Often adsorbs or desorbs water molecules very slowly, thereby attaining EMC over several days or weeks.
  - Release moisture if exposed to ambient air with low RH or to heated air due to the differential vapor pressure.
  - Gain moisture in humid air.

Hysteresis (Aviara, 2020) – Problems with Aw fluctuation



A product reaches moisture equilibrium with its surroundings by losing moisture at a given temperature, called desorption EMC. When dry material absorbs moisture from high humidity, it reaches adsorption EMC. Isotherm plots may show differences between desorption and adsorption EMC values at certain Aw and temperatures, with desorption higher, known as moisture sorption hysteresis.

Moisture preservation

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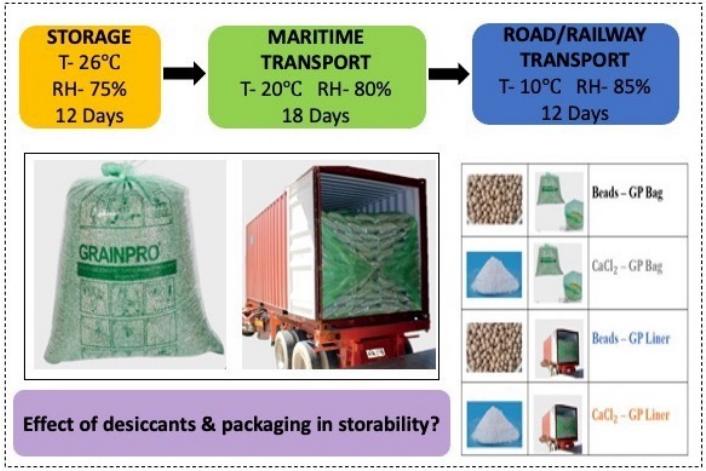
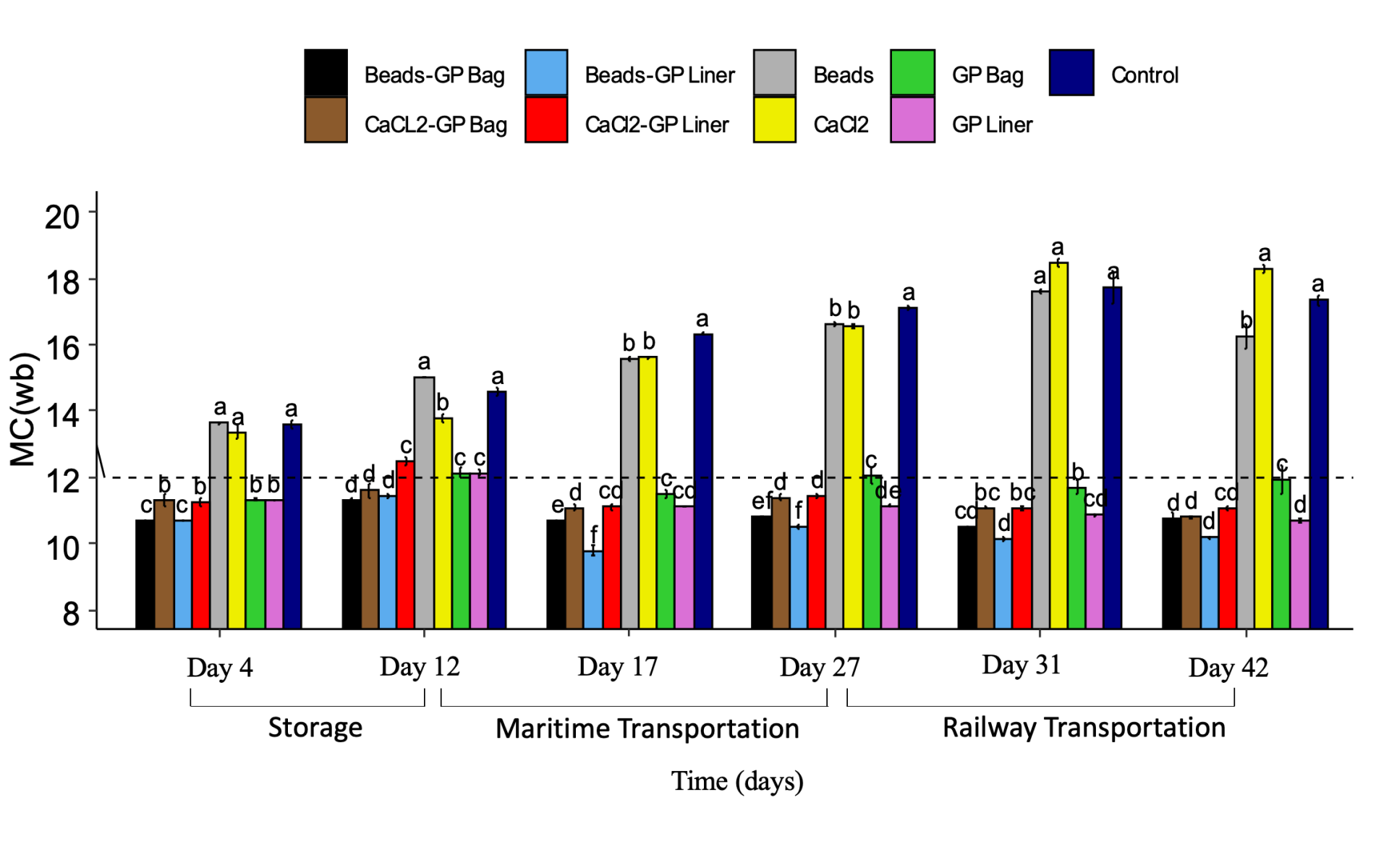
journal homepage: www.sciencedirect.com/journal/journal-of-agriculture-and-food-research

The use of desiccants for proper moisture preservation in green coffee during storage and transportation

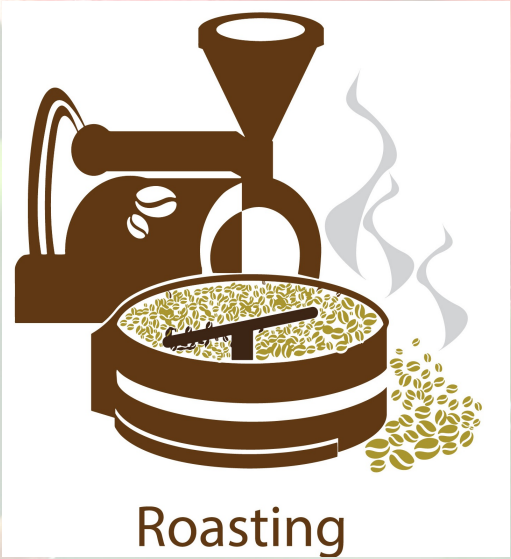
Laudia Anokye-Bempah [a], Juliet Han [b], Kurt Kornbluth [a], William Ristenpart [c], Irwin R. Donis-González [a,*]

[a] Department of Biological and Agricultural Engineering, University of California, Davis, CA, 95616, USA
[b] Department of Plant Sciences, University of California, Davis, CA, 95616, USA
[c] Department of Chemical Engineering, University of California, Davis, CA, 95616, USA




Beads-GP Bag
CaCL2-GP Bag
Beads-GP Liner
CaCl2-GP Liner
Beads
CaCl2
GP Bag
GP Liner
Control
MC(wb)
20
18
16
14
12
10
8
Day 4
Day 12
Day 17
Day 27
Day 31
Day 42
Storage
Maritime Transportation
Railway Transportation
Time (days)

Can I control coffee quality during roasting?



Roasting dynamics & acidity

nature scientific reports

nature > scientific reports > articles > article

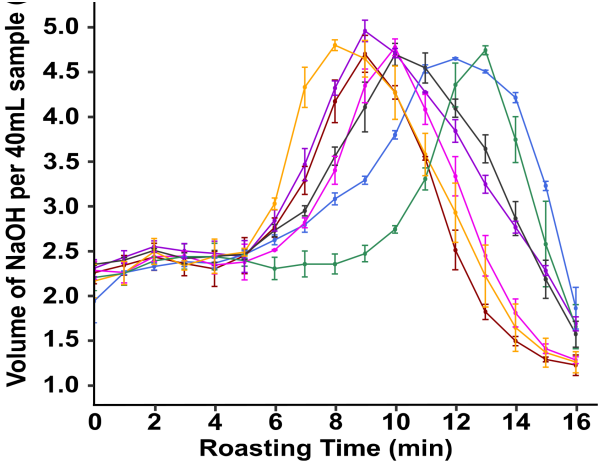
Article | Open access | Published: 08 April 2024

The effect of roast profiles on the dynamics of titratable acidity during coffee roasting

Laudia Anokye-Bempah, Timothy Styczynski, Natalia de Andrade Teixeira Fernandes, Jacquelyn Gervay-Hague, William D. Ristenpart & Irwin R. Donis-González

Scientific Reports **14**, Article number: 8237 (2024) | Cite this article

53 Accesses | Metrics



Experimental Design

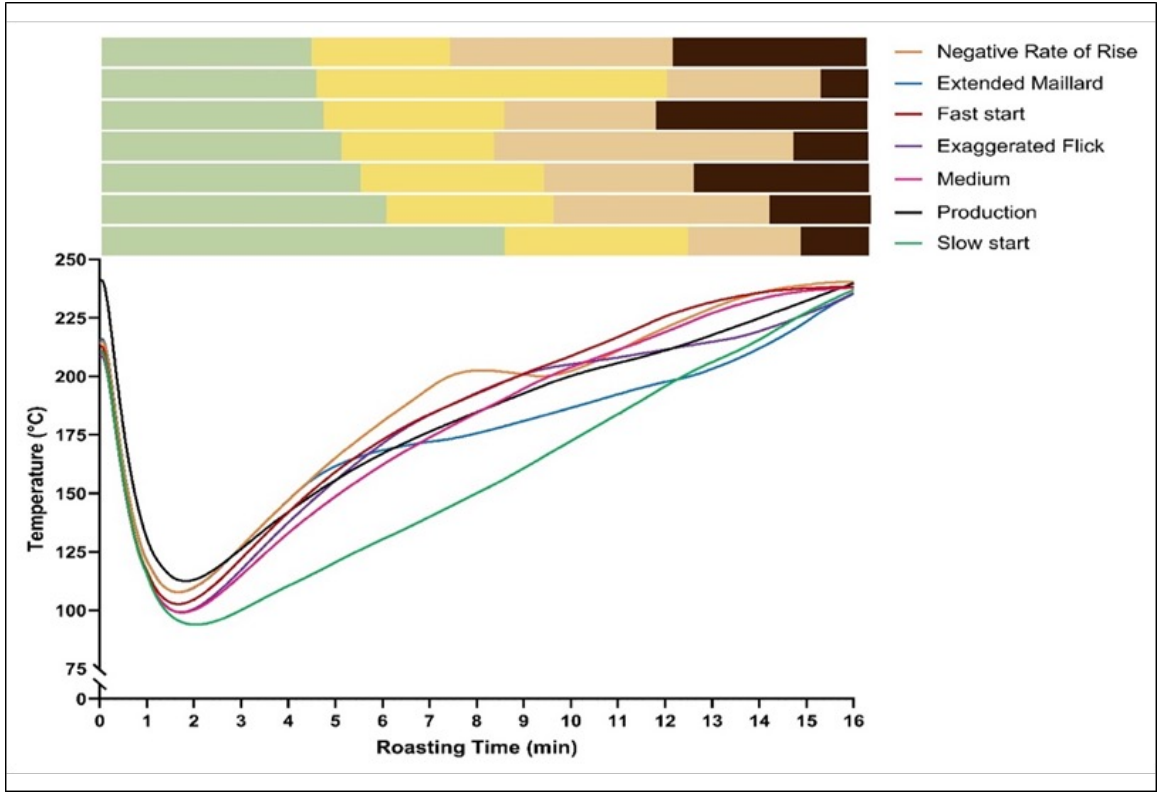
Green Coffee
Uganda Sipi falls (USF)
El Salvador Honey (ELS)
Sumatra washed (SUM)

Roasting
7 Roast Profiles
16-minute roasts
Sampling per minute

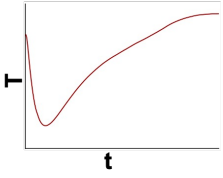
15⁺ Physical and Chemical Measurements

Water Activity
Titratable Acidity (TA)
Lipids
Bulk Density
Protein
Moisture Content
pH
s
TDS
Chlorogenic Acids (CGA)
Size Distribution
NIR spectroscopy
Color

Roast Profiles

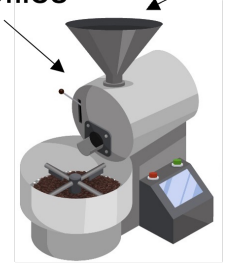


Methodology



Roast profiles

Green coffee

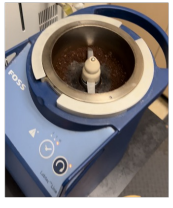


Roasting
(16 minutes)

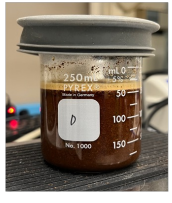
≅ 13 g
Sampling per minute
(min 0 to 16)

Freezing in Liquid N_2

Grinding



Brewing (R_{brew} 1:18)



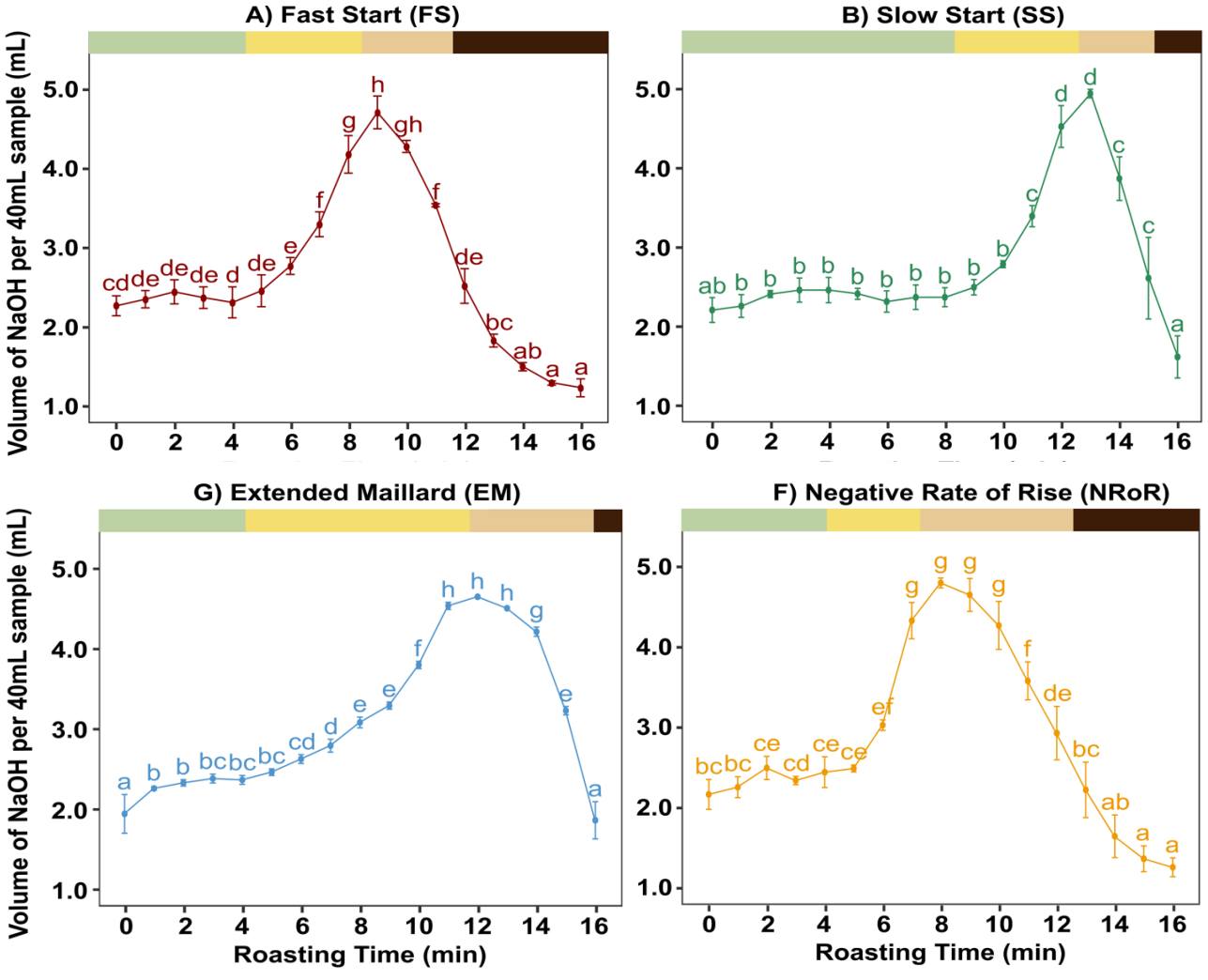
TDS measurement

TA and pH measurements

1. There was a similar trend in Titratable Acidity for all roast profiles

Roast phase:

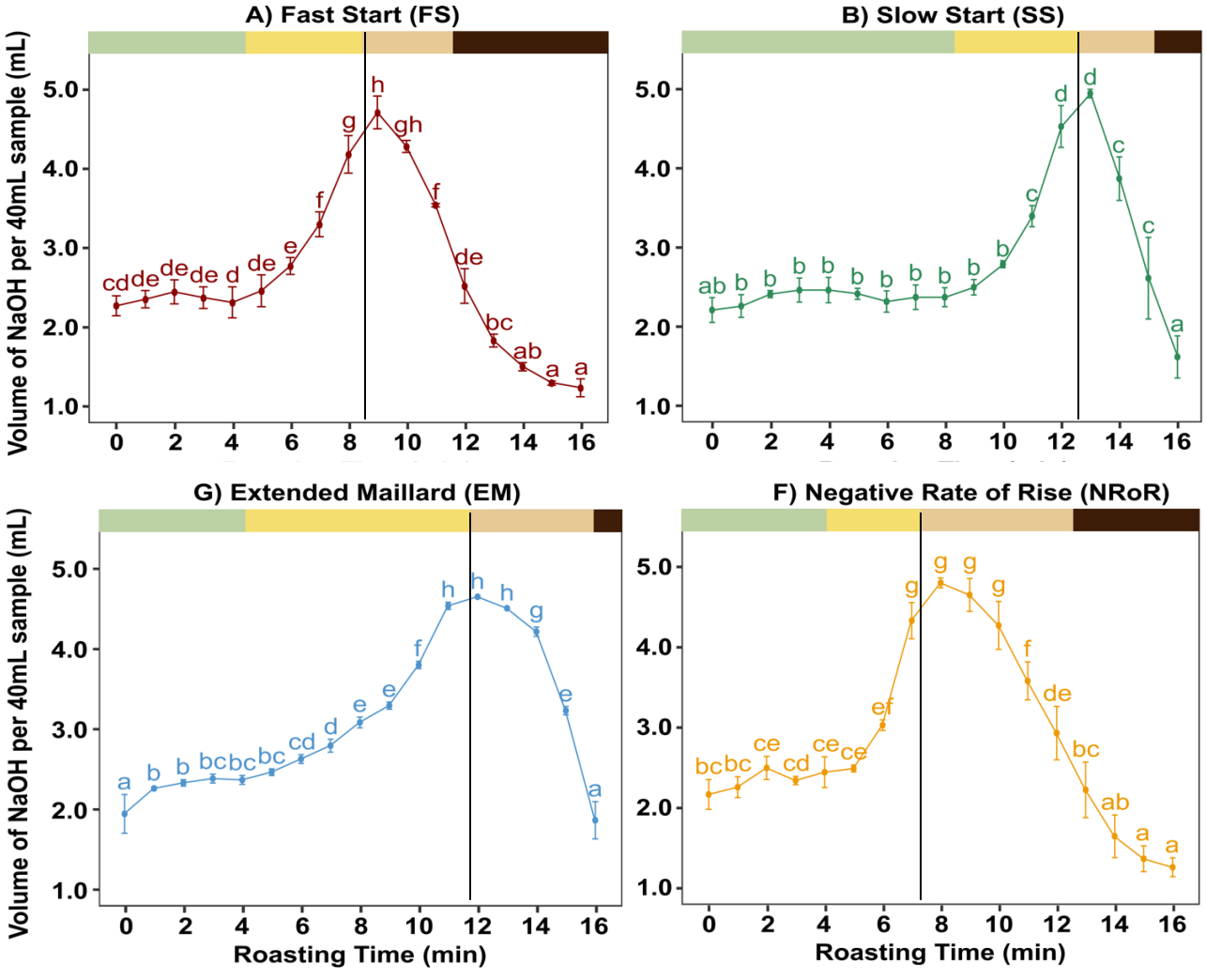
- Pre-color change
- Color change to First crack
- First to Second crack
- Post second crack



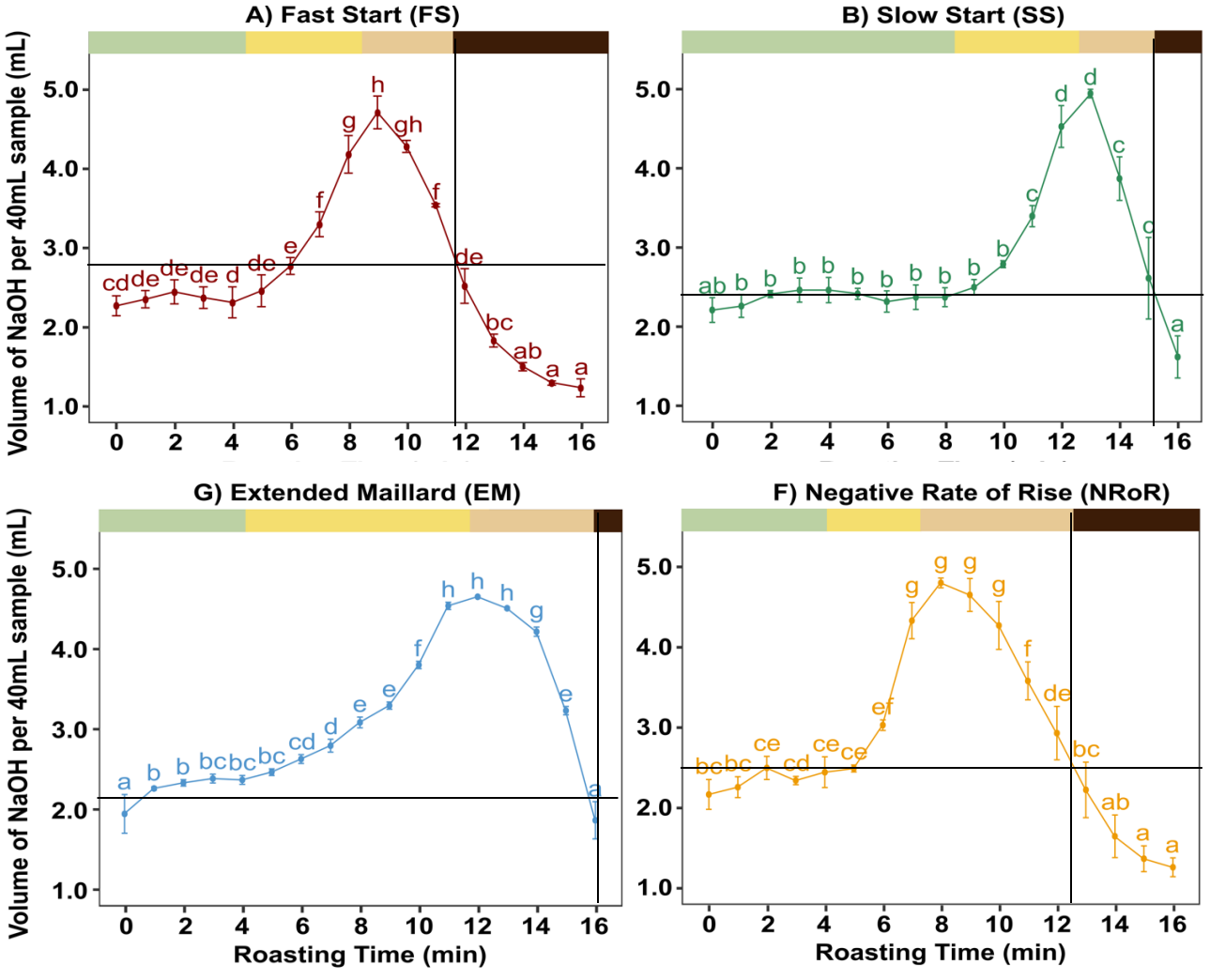
2. Titratable Acidity peaks during first crack

Roast phase:

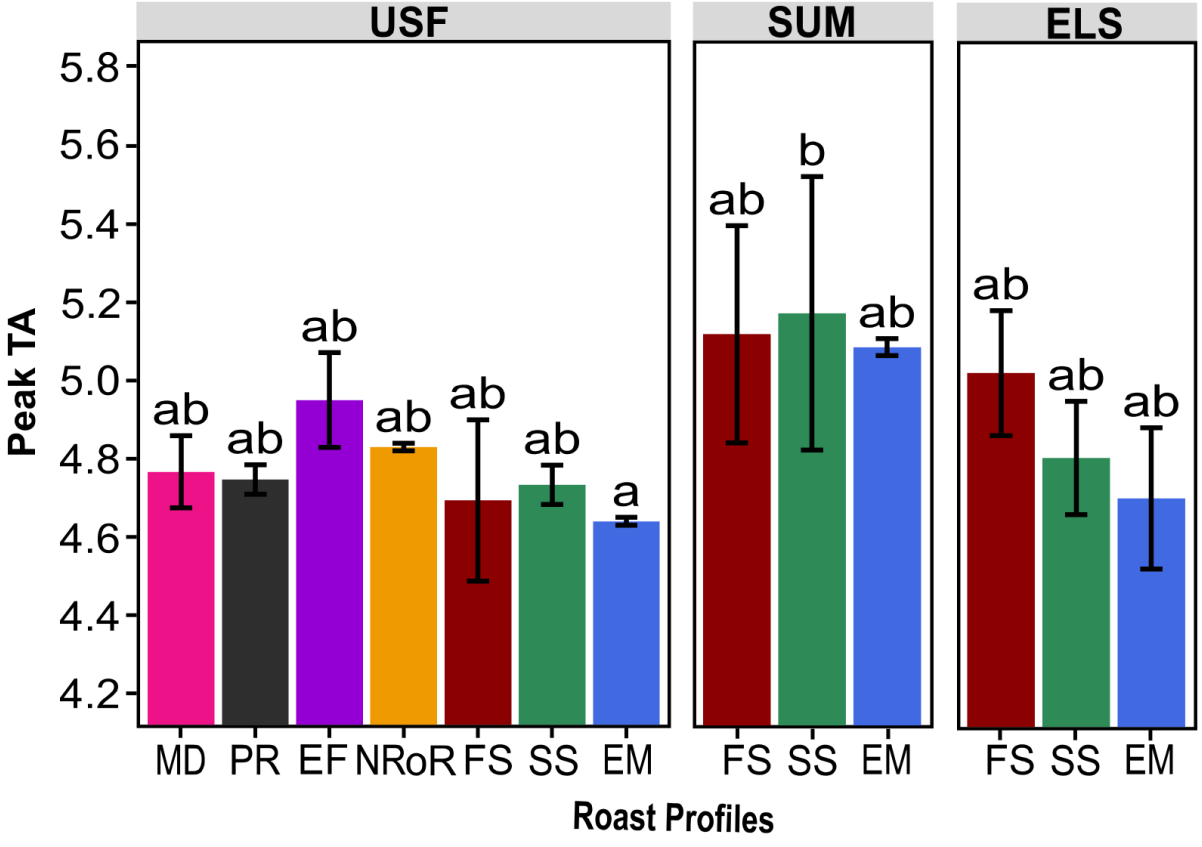
- Pre-color change
- Color change to First crack
- First to Second crack
- Post second crack



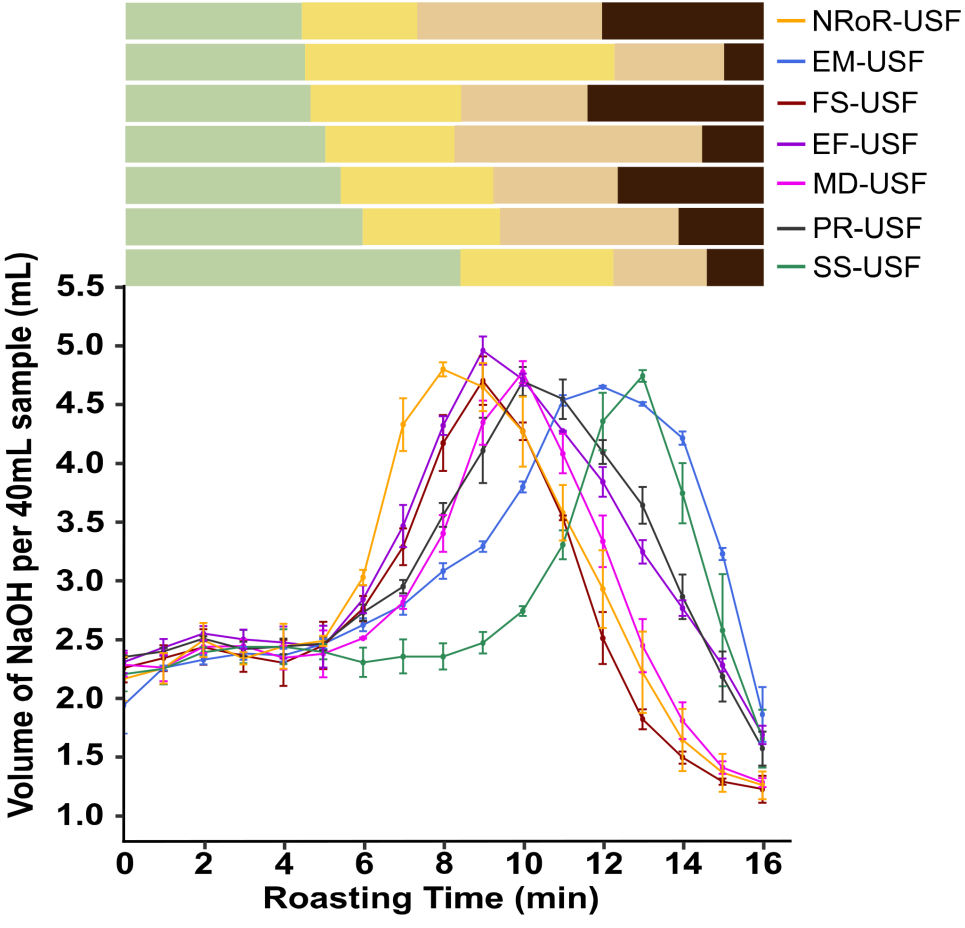
3. Titratable Acidity returns to its initial value by second crack



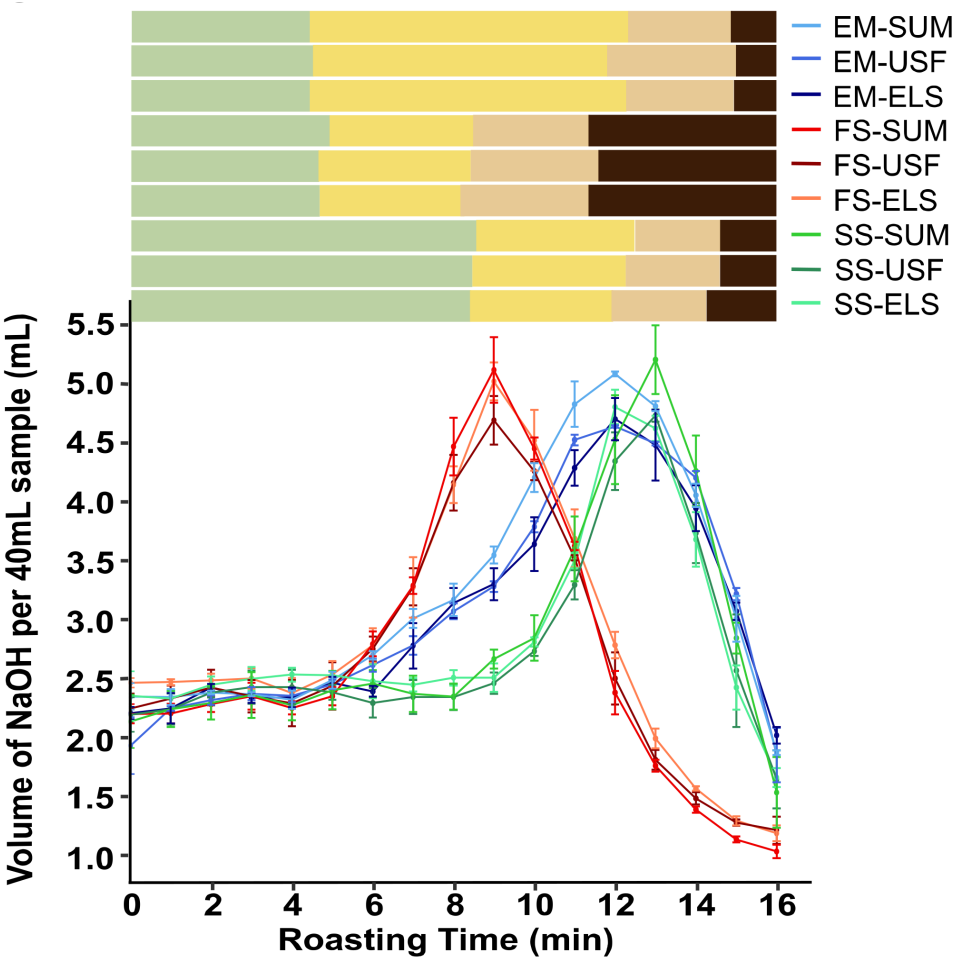
4. The maximum Titratable Acidity values were similar for all roast profiles



5. Yes, roast profiles affect the behavior of Titratable Acidity during roasting



6. There were no significant differences in the behavior of TA among the green coffee origins

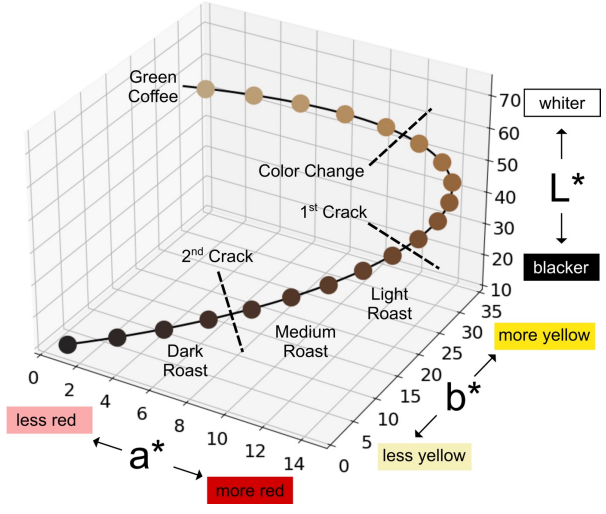


A “universal coffee color curve”

What Color is Your Coffee? | 25, Issue 21

University of California Davis Coffee Center scientists **LAUDIA ANOKYE-BEMPAH, IRWIN R. DONIS-GONZÁLEZ,** and **WILLIAM D. RISTENPART** describe research undertaken in 2023 with a goal of developing new roast color standards for the coffee industry.

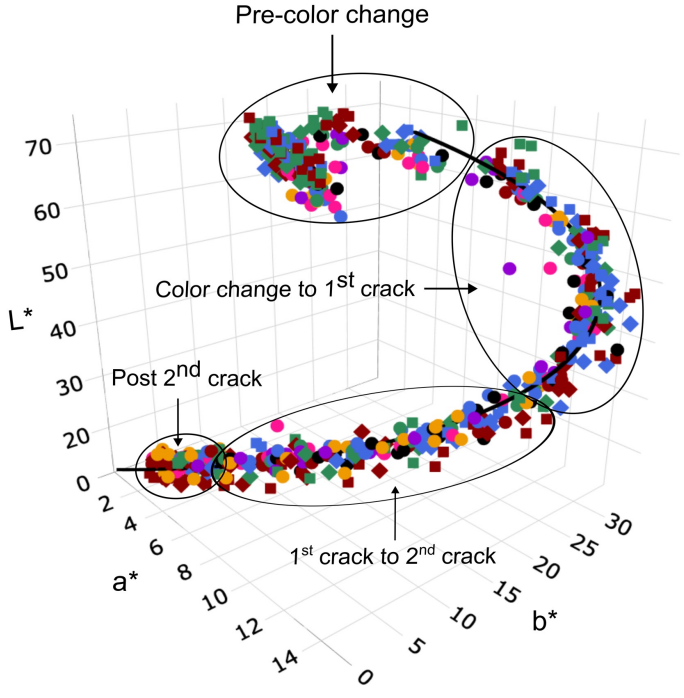
Apr 4, 2024



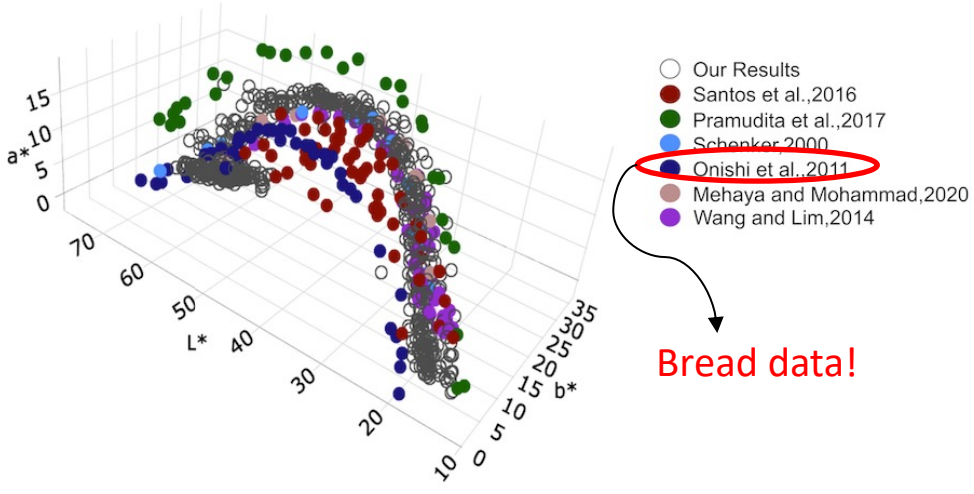
Why is color important, and how does it relate to coffee?

Color indicates roast level (light, medium, dark), and affects the quality of coffee

A Universal Coffee Color Curve

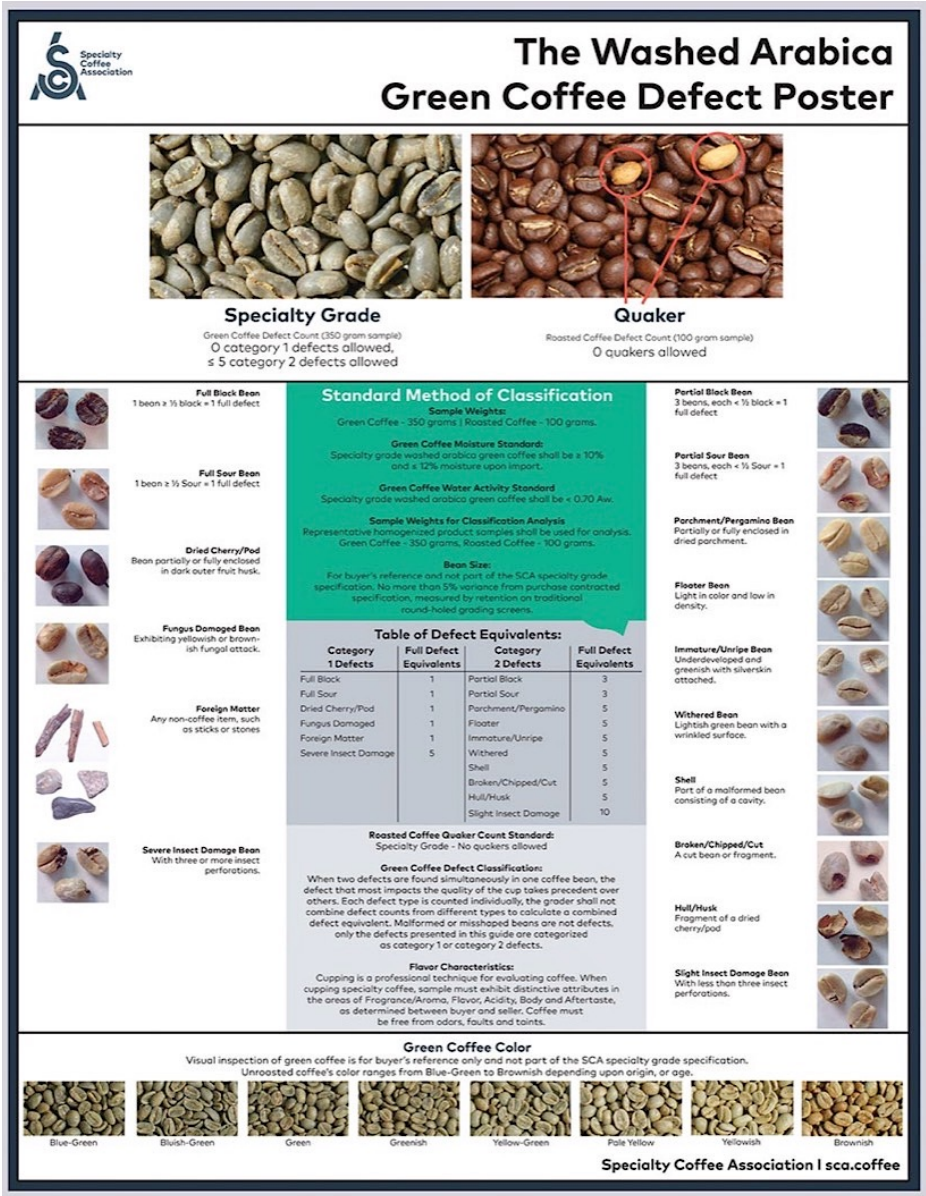


Our Data



Our Data + Other Authors

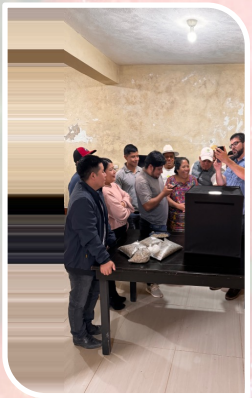
Do defective beans affect the quality of the coffee beverage?



Guatemala Sample Collection

Roasteries

Farms



Cooperatives

135+ Vacuum-Sealed Samples

Wet mills

Dry mills

Preliminary Findings

Under current test conditions

i. Full Sour DT: 20–30% (≈230–350 beans per 350g)

ii. Full Black DT: <5% (≈60 beans per 350g)

iii. Defect Equivalence: **1 Full Black ≈ 4–6 Full Sour**

1 Full Black bean

≈

4-6 Full Sour bean

UC DAVIS
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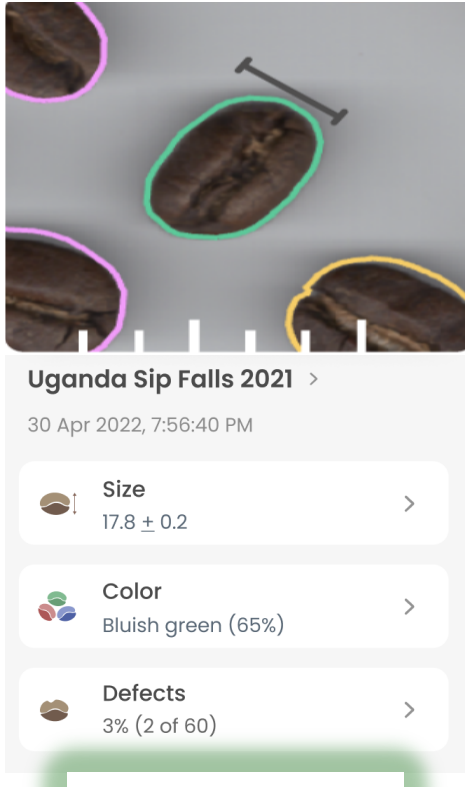
Teaching

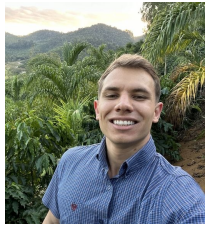
Research and Outreach



Tech Incubator

Development of tools to measure quality and modify coffee attributes?

ROASTPIC



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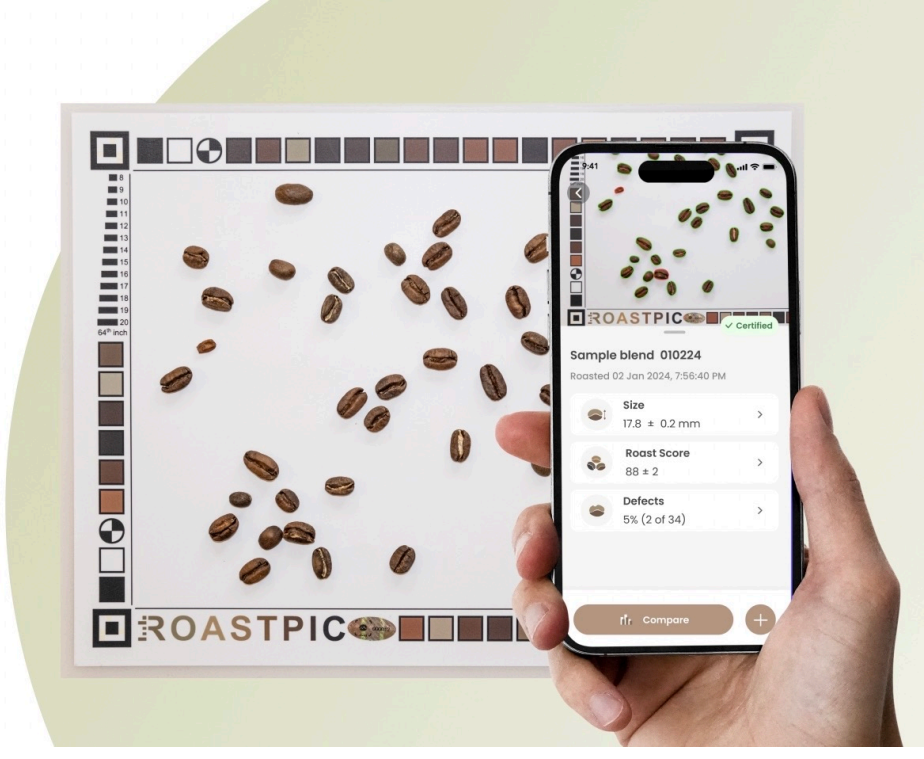
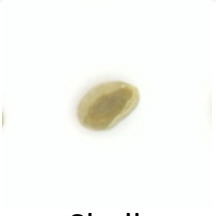
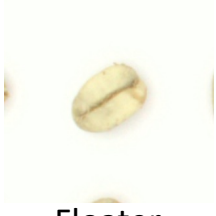
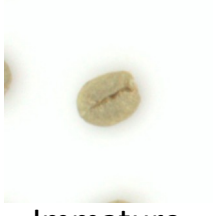
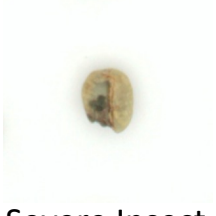
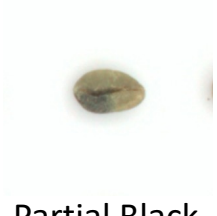
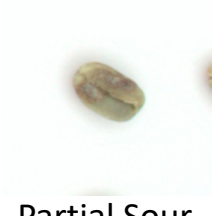
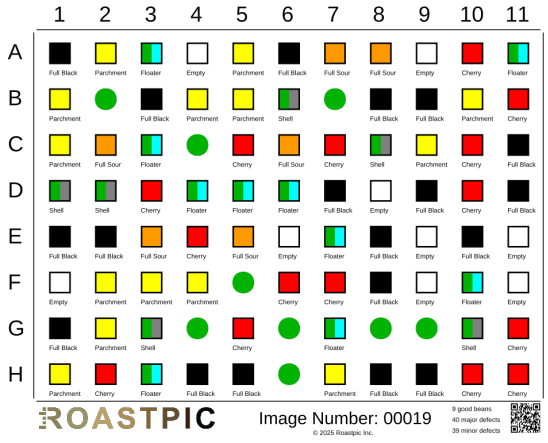
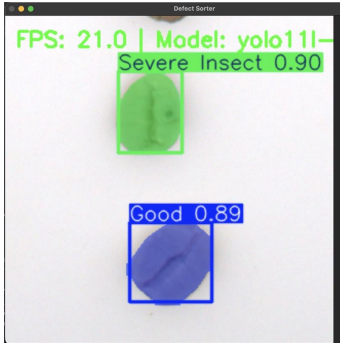


The Types of Arabica green coffee beans

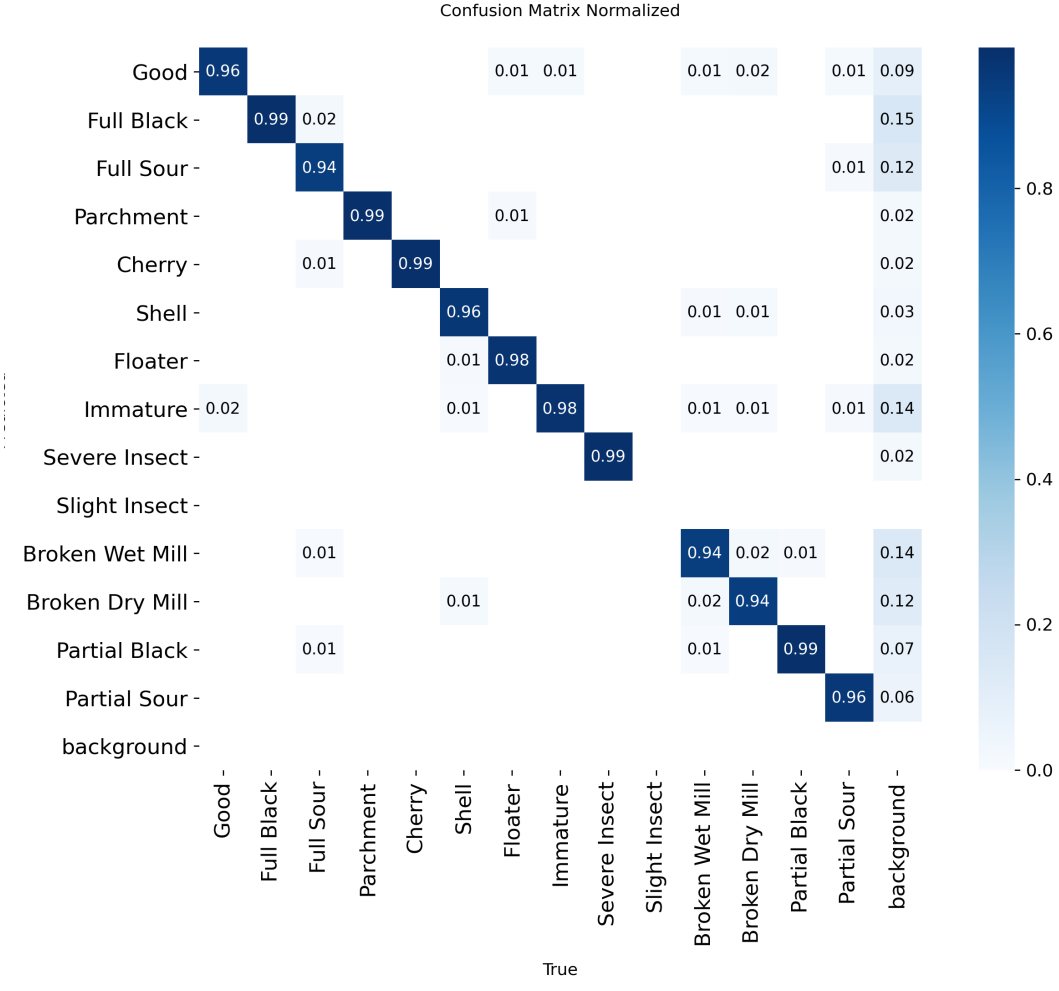
 Good	 Full Black	 Full Sour	 Parchment	 Cherry	 Shell
 Floater	IN PROCESS Withered	 Immature	 Severe Insect	IN PROCESS Slight Insect	IN PROCESS Broken Wet Mill
IN PROCESS Broken Dry Mill	IN PROCESS Hull	IN PROCESS Husk	 Partial Black	 Partial Sour	IN PROCESS Foreign Matter

Training AI models to classify defects





Confusion Matrix – YOLO11 implemented



THANK YOU!

CONTACT INFORMATION:

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Director | Postharvest Research and Extension Center
Co-Director | Coffee Center
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