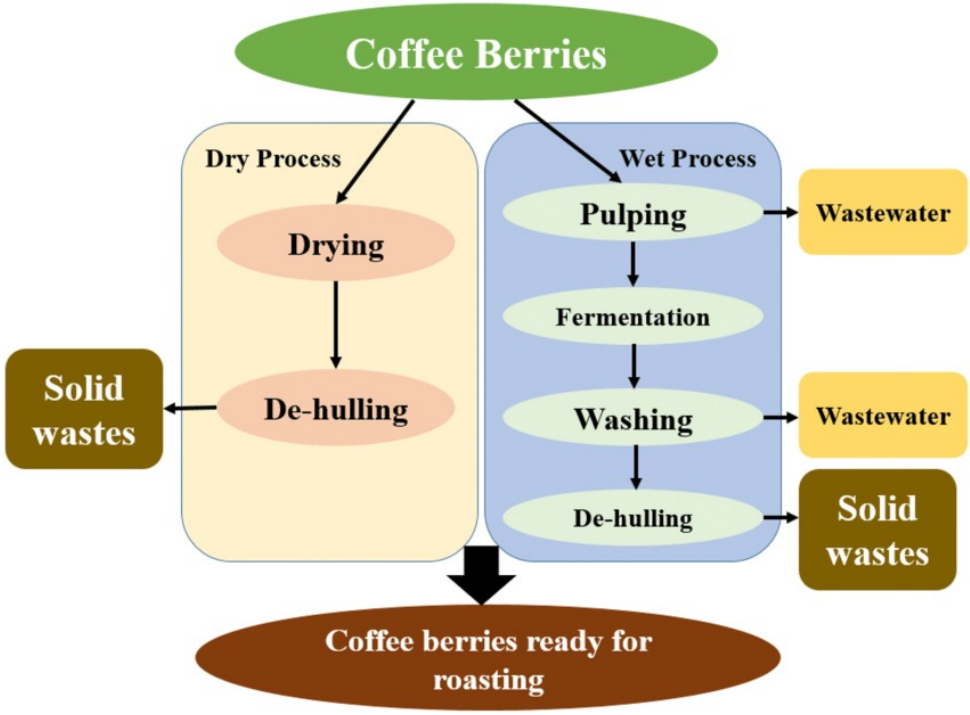
Coffe aroma:

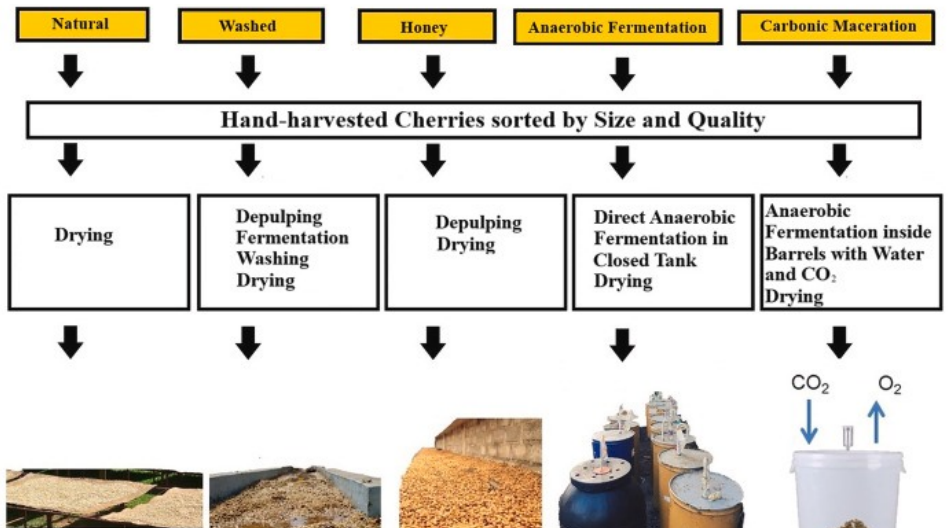
Heat reactions, Molds, Fermentation

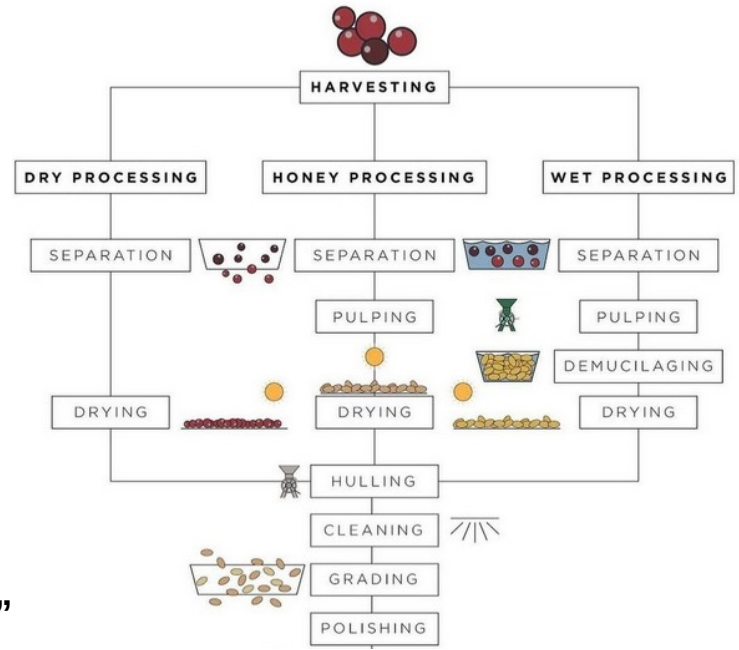
Non-confidential
Dr. Peter HANTZ

Introduction

Our R&D





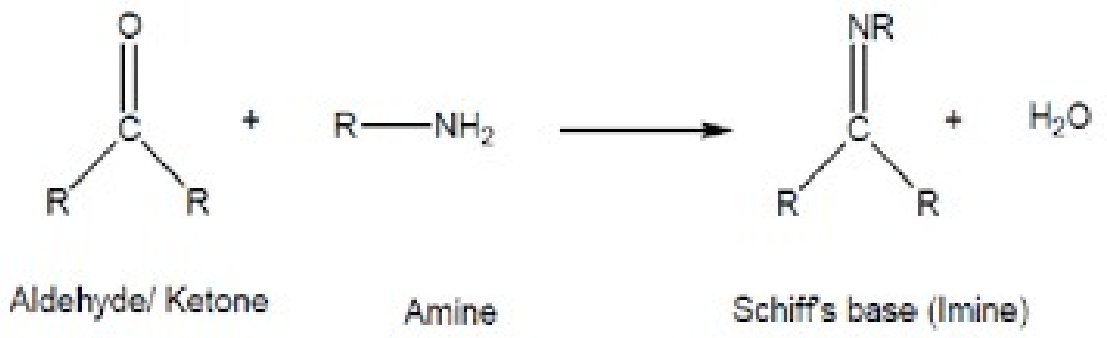


Terminology marketing / mismatch: always ∃ some biotransformation

“Carbonic maceration” =
whole cherry anaerobic fermentation
“Honey” =
pulped (skin removed) **with some or all mucilage left @ “fermentation”**

Maillard reactions: first step

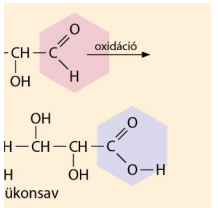
$$R–C(=O)H + H_2N–R' \rightarrow R–C(=N–R')H + H_2O$$



R–C(=O)H = carbonyl @ reducing sugar
$H_2N–R'$ = amino group of an AA

WA 0.6-0.8
pH around neutral
RT(ripening)…. Cca. 120-180 oC (fast)

Reducing sugar

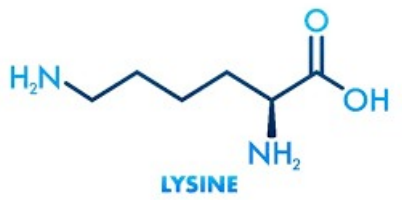


NOT
sacharose

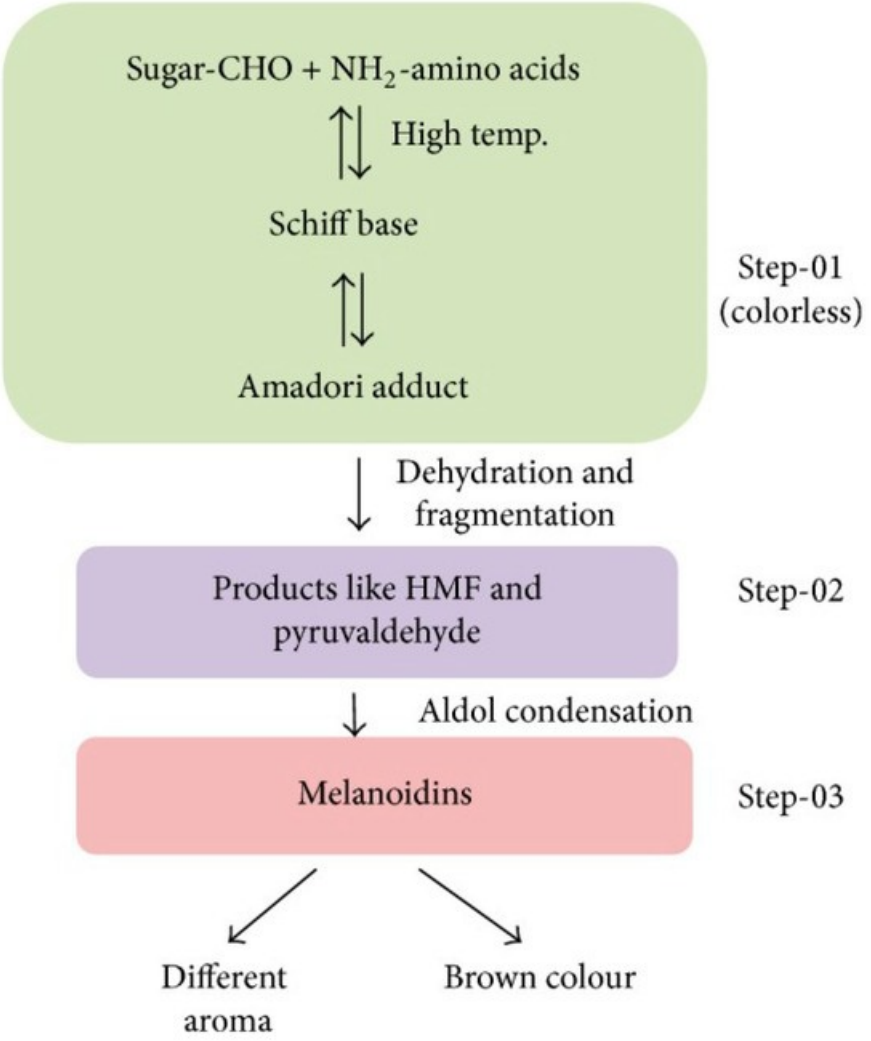
YES
glucose, fructose, tagatose
lactose (glu+gal)

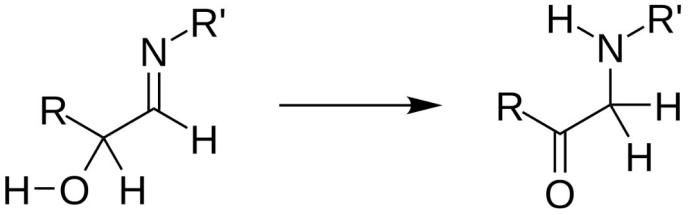
Any AA

Especially extra amino:
Lysine
Arginine, Hystidine



Maillard: later





Amadori rearrangement - more stable

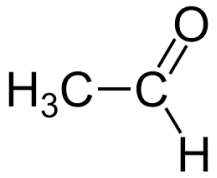
Pyrolysis

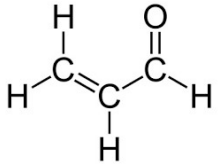
Thermal decomposition of organic matter in the absence of oxygen.

Occurs at high temperatures (typically >200 °C)
Leads to smoky, burnt, bitter notes
Often destroys previously formed aroma compounds

Sugars

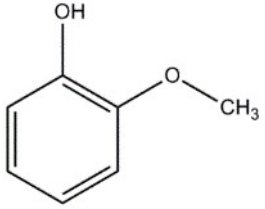
Small carbonyls (acetaldehyde, acrolein - harsh)

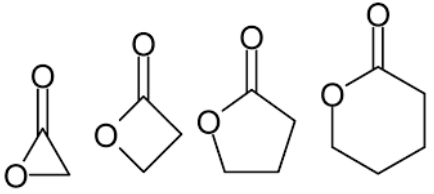




Chlorogenic acids (CGA)

Phenols (guaiacol, - harsh), lactones (bitter)





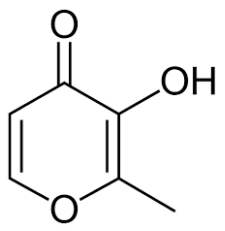
Caramelization

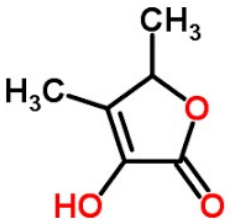
Mild thermal reactions of sugars. Not pyrolysis. Oxygen: may be present.

Temperature: ~110–200 °C
- fructose ~110–130 °C
- sacharose ~160 °C

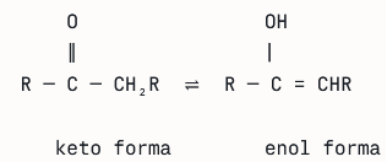
Mechanism: dehydration, enolization, rearrangement, polymerization

Products: furans, maltol, caramel compounds, phenylacetaldehyde
Sensory: sweet, caramel, toffee

maltol 



furaneol



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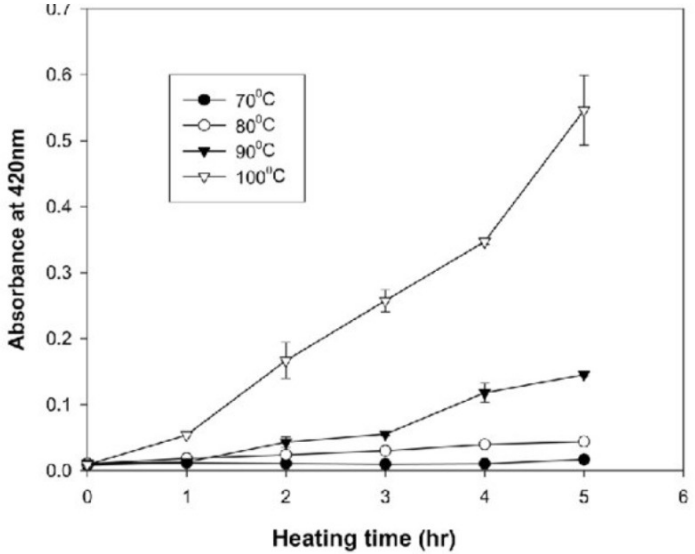


Effect of temperature on the rate of Maillard browning reaction of 0.2 M tagatose and 0.2 M glycine mixture with respect to absorbance at 420 nm

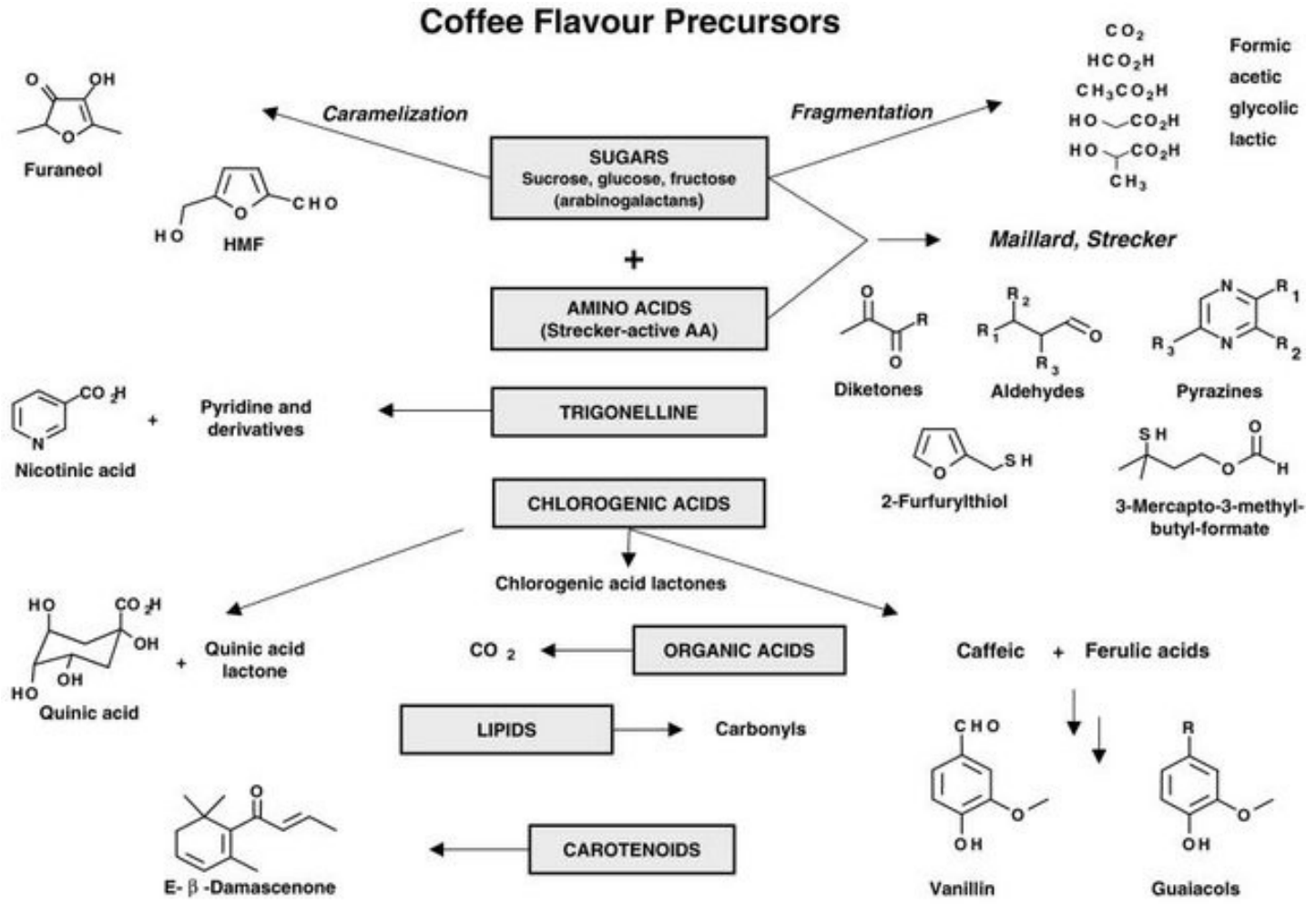
Temp (°C)	Maillard rate (relative)	Caramelization rate (relative)	Pyrolysis rate (relative)
20	1	~0	~0
40	6	~0	~0
60	40	~0	~0
80	250	~0	~0
100	1.5×10^{3}	~0	~0
120	1×10^{4}	1	10^{-6}
140	7×10^{4}	10	10^{-4}
160	4×10^{5}	10^{2}	10^{-2}
180	2×10^{6}	10^{4}	10^{1}
200	1×10^{7}	10^{5}	10^{4}–10^{5}
220	6×10^{7}	10^{6}	10^{7}

Approx. rates

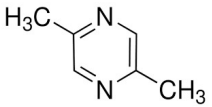
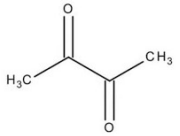
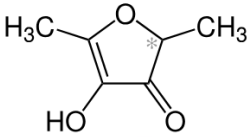
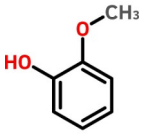
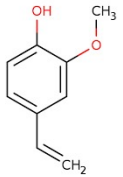
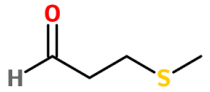
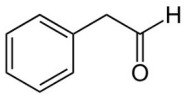
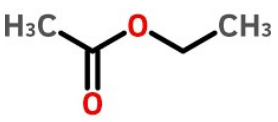
Maillard, Caramelization, Pyrolysis, etc.

Temperature (°C)	Dominant chemistry	What happens
<120	Drying	Water removal
120-160	Maillard	Browning, aroma precursors
160-180	Advanced Maillard + Caramelization	Flavor development, caramel notes
180-200	Transition (Caramelization continues)	First crack, sweet-bitter balance
>200	Pyrolysis dominates	Smoke, bitterness, carbonization

Reduce chlorogenic acid in Robusta – USA preference



https://www.researchgate.net/publication/225389834_From_the_green_bean_to_the_cup_of_coffee_Investigating_coffee_roasting_by_on-line_monitoring_of_volatiles

Compound	Typical aroma	Common flavor application	Origin
2,5-Dimethylpyrazine	Nutty, roasted	Cocoa	Maillard reaction
Diacetyl (2,3-butanedione)	Buttery, creamy	Butter	Maillard reaction
Furaneol	Caramel-like, sweet	Caramel	Maillard reaction
Guaiacol	Smoky	Smoke	Pyrolysis
4-Vinylguaiacol	Smoky, spicy	Spiced sweets (like clove)	Pyrolysis
Methional	Malty, cooked	Roasted meat flavoring	Maillard reaction
Phenylacetaldehyde	Floral, honey-like	Honey flavoring	Caramelization
Ethyl acetate	Fruity, sweet	Artificial fruit flavorings	Fermentation/ Esterification

Microbi

Usually: bacs+yeasts

Fermentation:

Lactic Acid Bacteria

homofermentative

mainly LA

EMP / glycolysis pathway, more special, 2 ATP

heterofermentative

LA + other products incl. CO_2

”phosphoketolase pathway”, more diverse, 1 ATP

usually more flavors

Levilactobacillus brevis, hetero
Lactiplantibacillus plantarum, homo
Leuconostoc mesenteroides, hetero

Yeasts:

some strains can degrade pectin
may inhibit toxic molds

Hanseniaspora uvarum – fruity, floral
Candida spp. (humilis, quercitrusa)
Saccharomyces cerevisiae - alcohol

AABs during drying:

Acetobacter and *Gluconobacter*

LAB



SIAF - self-induced-anaerobic fermentation
coffee (cherry or pulped) @ closed container/bioreactor

WHOLE CHERRY
- > 1 week
- Less uniform

PULPED
- ~ 2 days
- touch sugars fast

NO pasteurization
- Natural LABs and yeasts
- ctrl temperature, time

Trends:
- co-ferment w other fruits
- added starters to bias
- “multi-stage” /see: oolong complexity


Animals

Eat & don't chew: civet, elephant, some monkeys

general biotransformation

good amount of marketing

gut microbiome:

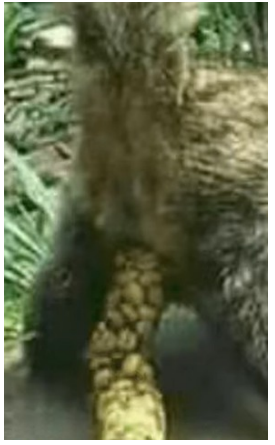
civet:

Gluconobacter – (!) H2S

L. plantarum – common! /pectinase

elephant:

Acinetobacter /cellulase



Gluconobacter dominates the gut microbiome of the Asian palm civet _Paradoxurus hermaphroditus_ that produces kopi luwak

Hikaru Watanabe[1], Chong Han Ng[2], Vachiranee Limviphuvadh[3], Shinya Suzuki[1] and Takuji Yamada[1]

Preliminary study of gut microbiome influence on Black Ivory Coffee fermentation in Asian elephants

Nodoka Chiba[1], Vachiranee Limviphuvadh[2], Chong Han Ng[3], Ryuto Koyagi[1], Yuta Kino[1], Yuya Nakamura[1,6] & Takuji Yamada[1,4,5,6]

Our R&D

Koji

Aspergillus oryzae

Koji @ cherries, Paavolainen protocol:
reproducibly failed + food safety issues

Koji @ cleaned beans:
reproducibly failed

New protocol developed @ fresh/dry cherries

Carbohydrate-active enzymes (CAZymes) ~ 500

Starch-degrading ~ 150
a-amylase,
glucoamylase
a-glucosidase

Proteases ~ 120
acidic, neutral, alkaline

R&D: Rehydration Koji

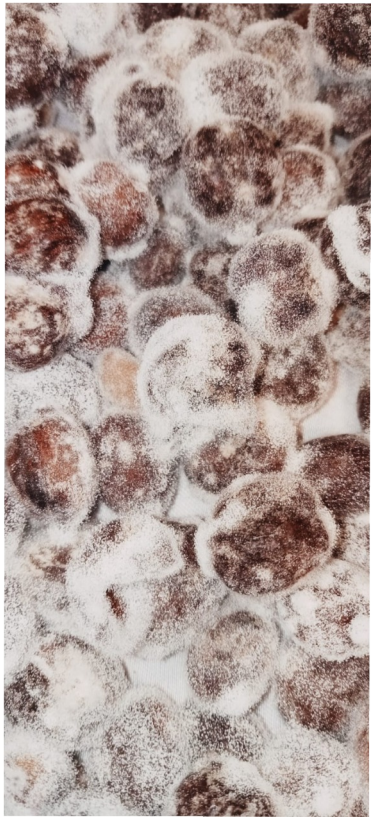
Re-hydrate DRY cherries @special protocol

Importance:

storage/transport

freedom @ expts: space & time

Koji: successful

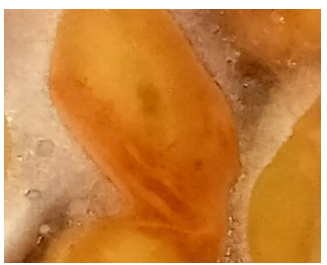


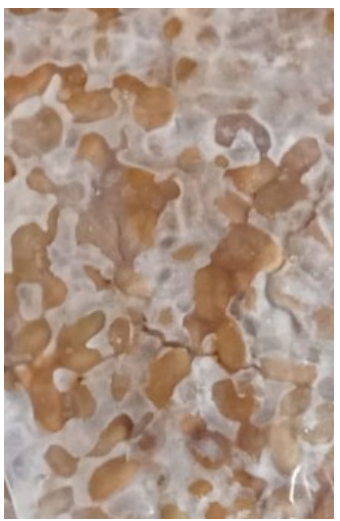
R&D: Tempeh

Rhizopus oligosporus
Massive mycelium building

Micro-aerophilic
@ depulped fresh beans
preliminary results @ dry beans
pored plastic bag / banana leaf

Most important enzymes:
proteases, amylases




R&D: Rehydration Tempeh

Cherries: conditions
Beans: Hydrogel trick needed

R&D: Maillarding

Proprietary Maillard precursor solutions
Enhanced Maillard reactions during roasting

Cascara upcycling

Various LAB fermentation w/wo salt

- Tapai starters
- Sauerkraut starters

Cascara (coffee cherry pulp) — dry basis

Component	Typical range (% dry weight)
Carbohydrates (total)	**60–75**
├─ Sugars	15–25
├─ Starch	0–2
└─ Dietary fiber	30–40
Protein	**8–11**
Fat (lipids)	**0.5–2**
Caffeine	**0.2–1.3**
Ash (minerals)	**3–5**

Instant coffee: aroma extraction(s)

Methods:

-hot water
-pressurized hot water (PHWE) / subcritical
-supercritical extraction
-cold brewing

Realistic alternative solvent:

-water-ethanol mixes

classical countercurrent
ultrasound-assisted
microwave-assisted

Caffeine:
Coffee beans: 1–3%
Guarana powder: 2-8%

Biotech: polysaccharide-specific enzymes

Ongoing R&D

Sensory evaluation + feedback

Mixed fermentation, other molds /N – “gut”

Fine-tuning @ Tempe, Koji, Maillarding

Smoking, Mofetta

Molds on tea / mix