

Coffee Processing and Quality

Grain Technology
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Summary

1. History
2. Economic Relevance
3. Coffee plant
4. Main pathogens
5. Fruit/grain
6. Harvest and post-harvest processing practices
7. Quality
8. Main products

1. History

- Coffee originated in Ethiopia
- Taken by slaves from Sudan into Yemen and Arabia, through the port of Mocha
- 1615 in Europe
- 1668 in North America
- 1688 in England
- 1699 in Indonesia

Cultivars in Brazil

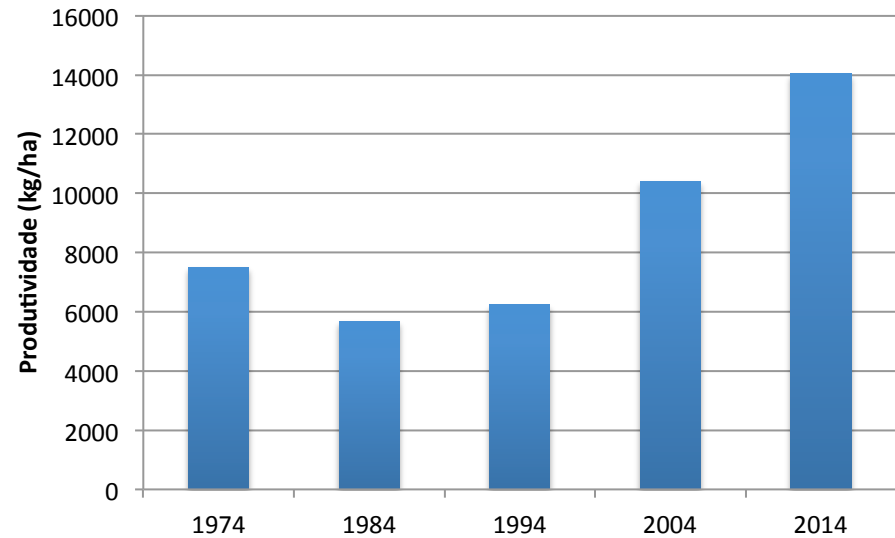
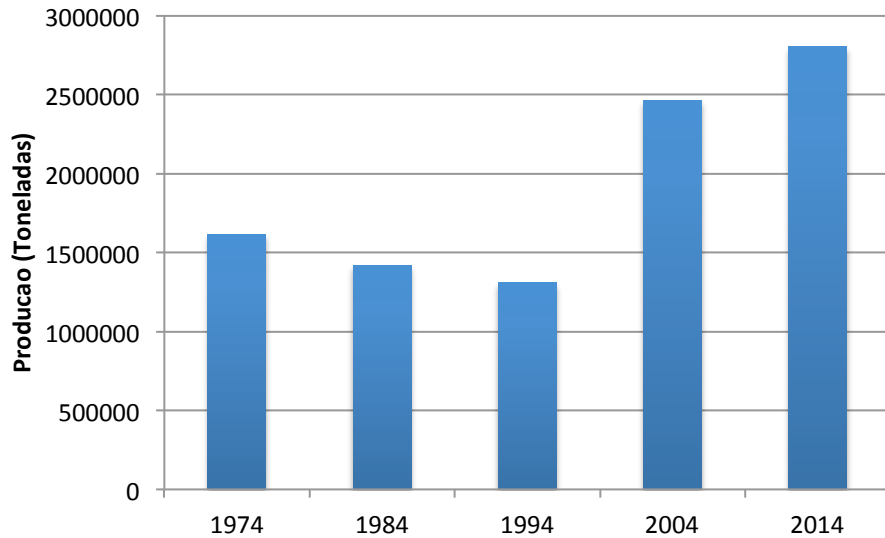
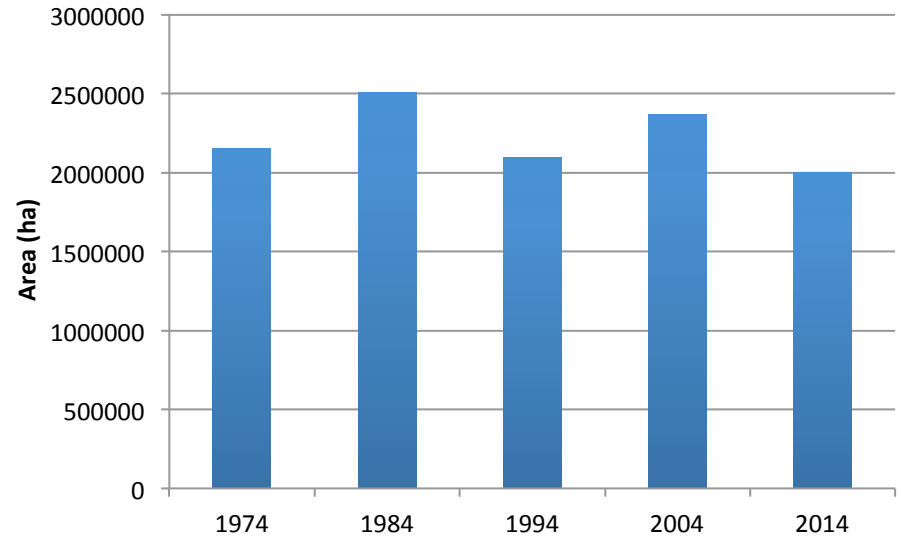
- 1727 seeds from Guiana
 - 100 years progenies with genetic variability
 - Mutations produced different types
- 1896 seeds from Sumatra
 - Natural hybrids
- 1931 cv Mundo novo
- 1980 "Kouilou" river in Congo – "Conilon"
- cv Acaia (larger seeds)
- cv Caturra (shorter plant size)
- cv Catuaí (Caturra x Mundo Novo)
- Strong breeding program
- Increased crop yield

2. Economic Relevance

- Coffee production (FAO)
- Brazil 1.997.827 ha
- Indonesia 1.230.500 ha
- Colombia 795.563 ha

- Since 2012 consumption has increased 1.3%/year
- Production is below demand

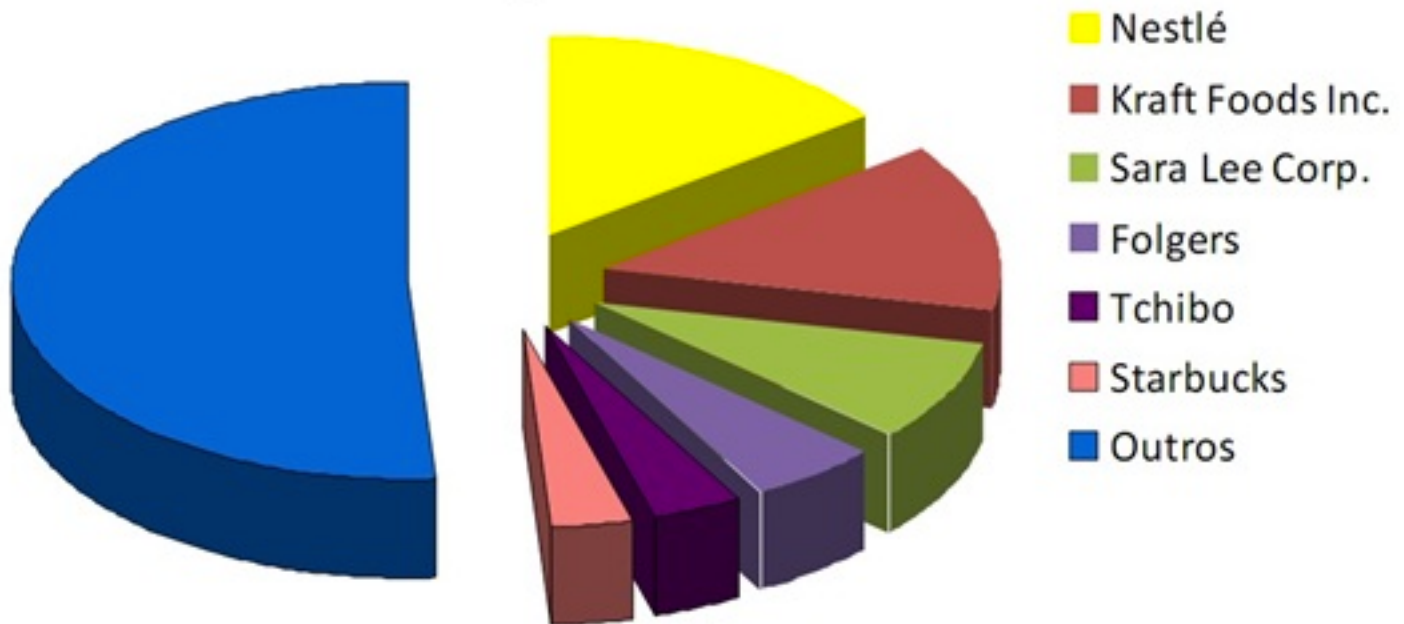
National historic series



2. Economic relevance

- Secretaria de Comércio Exterior, 2016
- US\$ 5.4 bi em exportações
- Café cru em grão - Nono principal produto de exportação (US\$ 4.84 bi)
- Café solúvel (US\$ 0.57 bi)
- Extratos, concentrado de café (US\$ 41 mi)
- Café torrado (US\$ 12 mi)

Torrefação no Mundo



Cadeia produtiva

- **25 milhões de famílias** em 60 países e representa um mercado que movimenta cerca de **100 trilhões de dólares** no mundo
- Fornecedores de insumos, máquinas e equipamentos
- Produção primária
- Processamento (maquinistas e cooperativas, empresas de torrefação e moagem, empresas de café solúvel e cooperativas)
- Vendedores nacionais (exportadores, cooperativas e atacadistas)
- Compradores internacionais (empresas de café solúvel, empresas de torrefação)
- Varejo nacional e internacional (supermercados, pequeno varejo, mercado institucional, lojas de café e bares e restaurantes)

Estados produtores

- MG 55%
 - ES 20%
 - SP 10%
 - BA 7%
 - RO 4%
-
- 40 sacas/ha de arábica
 - 23 sacas/ha de conilon
-
- 2016
 - 43 milhões de sacas beneficiadas de arábica
 - 8 milhões de sacas beneficiadas de conilon

Estados produtores

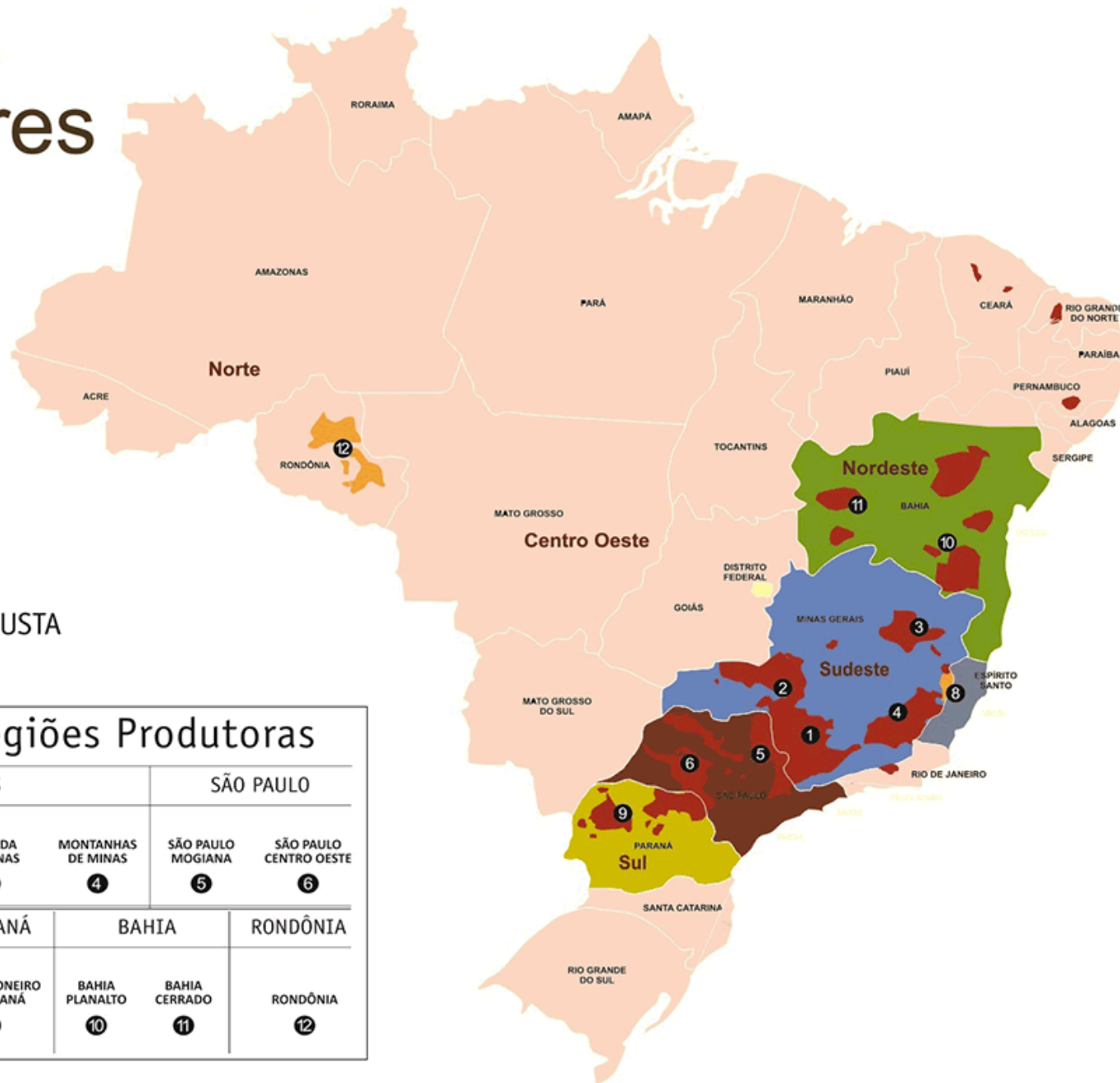
TIPOS DE CAFÉ



ARÁBICA



CONILON / ROBUSTA



Principais Regiões Produtoras

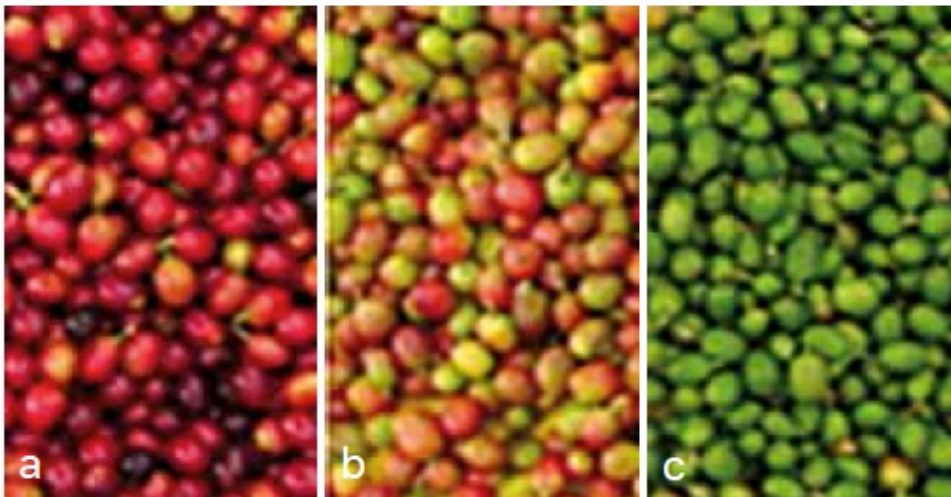
MINAS GERAIS				SÃO PAULO	
SUL DE MINAS 1	CERRADO 2	CHAPADA DE MINAS 3	MONTANHAS DE MINAS 4	SÃO PAULO MOGIANA 5	SÃO PAULO CENTRO OESTE 6
ESPÍRITO SANTO		PARANÁ	BAHIA		RONDÔNIA
MONTANHAS DO ESPÍRITO SANTO 7	CONILON CAPIXABA 8	NORTE PIONEIRO DO PARANÁ 9	BAHIA PLANALTO 10	BAHIA CERRADO 11	RONDÔNIA 12

3. Coffee plant

- Família Rubiaceae
- 600-2000m altitude
- 15-25°C
- Mantidos a 2-2,5m
- reach maturity after 3 to 4 years
- Pico produtivo em 10-15 anos mas produzem até 40 anos
- 8-12 meses da antese ao fruto maduro



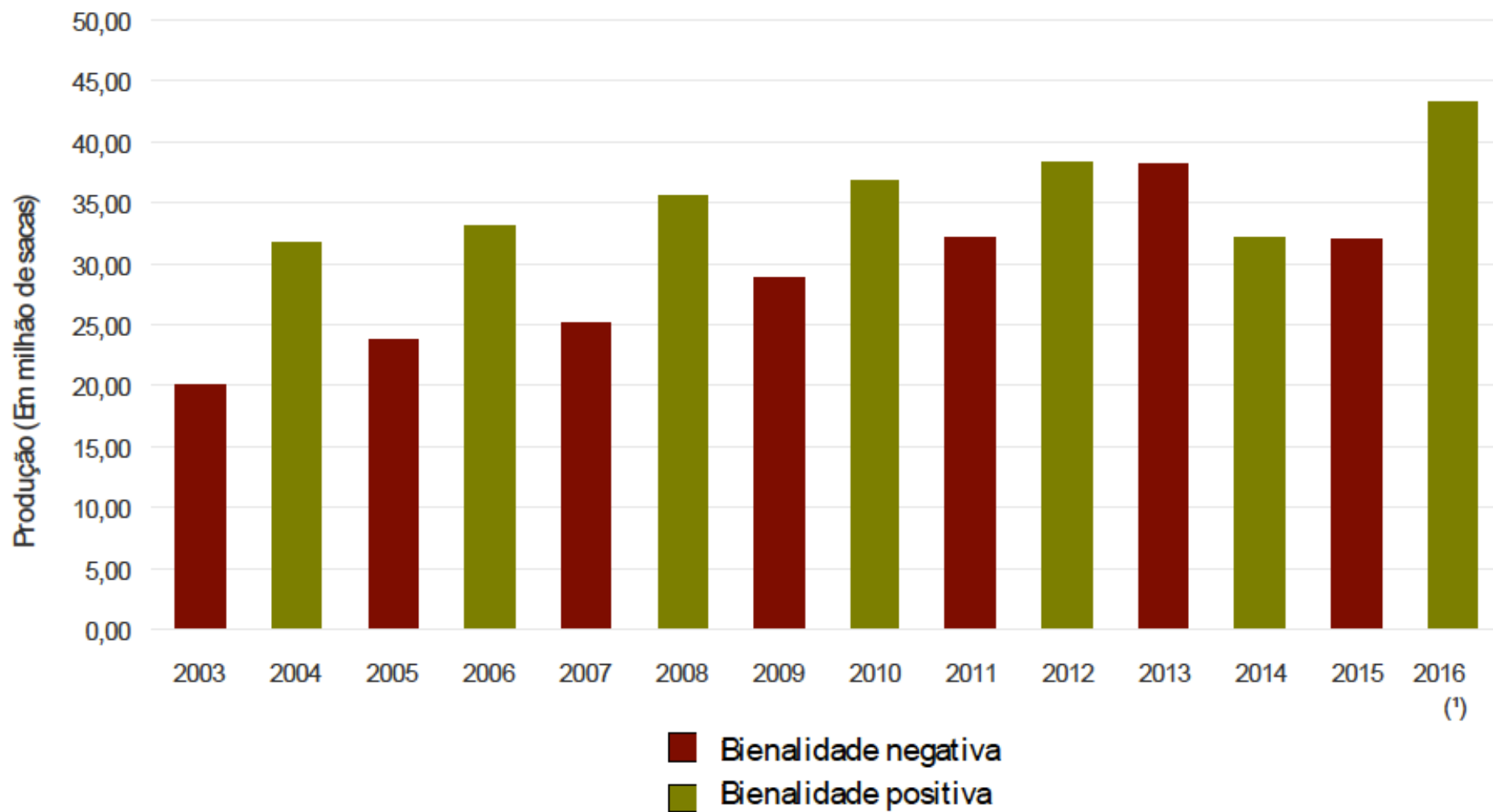
- *Coffea arabica*
- *C. canephora* (robusta)
- Fruto 1,5 cm diâmetro
- Verde → Amarelo → Vermelho
- Verde → Amarelo



Bienalidade

- **Cultivo a pleno sol**
- floração abundante
- baixa abscisão
- dreno forte
- crescimento vegetativo prejudicado
- seca de ramos e morte de raízes

Bienalidade



Fonte: Conab.
Nota: Estimativa em 2016.

Management practices

- Shade and altitude influence air temperature, and their positive effects have been mostly attributed to cooler climatic conditions.
- Low temperatures have been suggested to slow down the ripening process, which in turns leads to higher accumulation of aroma precursors.

Altitude

- the mean air temperature during seed development greatly influenced the sensory profile.
- Positive quality attributes such as acidity, fruity character and flavour quality were correlated and typical of coffees produced at cool climates.
- Bertrand et al., 2012 Food Chem

- In Brazil
- 18 °C and 22 °C
- high temperatures lead to faster coffee bean ripening, which leads to smaller seeds

Shade

- In Costa Rica 45% shade decreased coffee tree productivity by 18%
- Shade positively affected bean size and composition as well as beverage quality by delaying berry flesh ripening by up to 1 month
- Elevation and shade improved coffee quality owing to cooler climatic conditions and probably a longer ripening period of coffee berries
- (Vaast et al., 2006 Journal of the Science of Food and Agriculture)

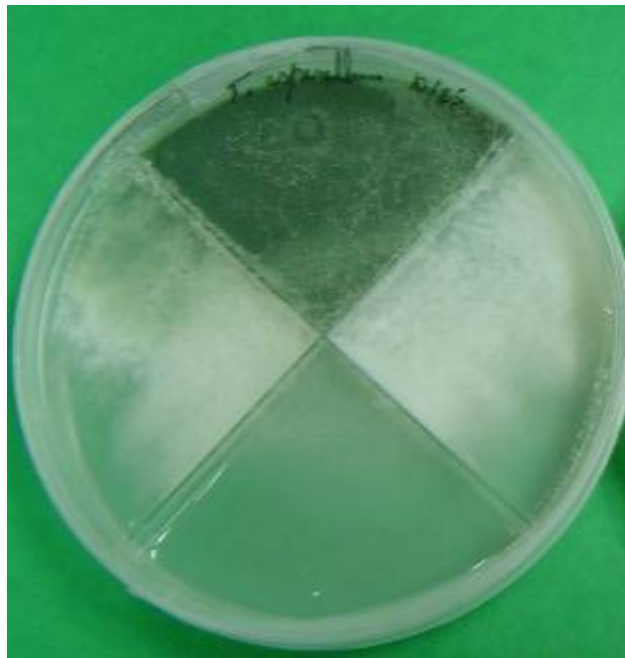
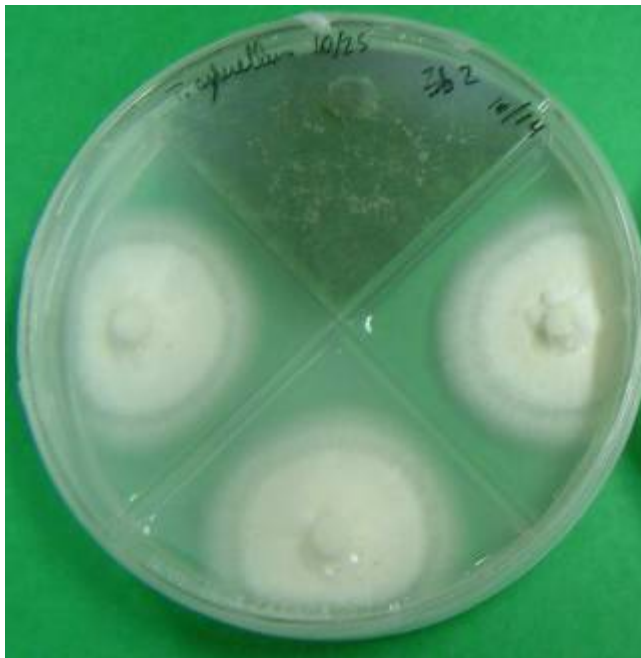
4. Main Pathogens

- Ferrugem das folhas
- Antracnose
- Cercosporiose
- Phoma
- Bicho-mineiro
- Acaro-vermelho
- Broca



Controle biologico da broca

- Entomopathogenic fungi - *Beauveria bassiana*
 - Colonization efficiency and persistence



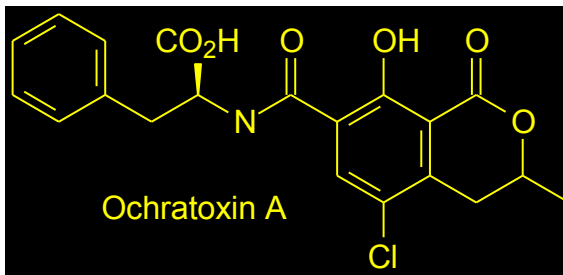
Coffee berry borer biological control

- Wasp – *Prorops nasuta*

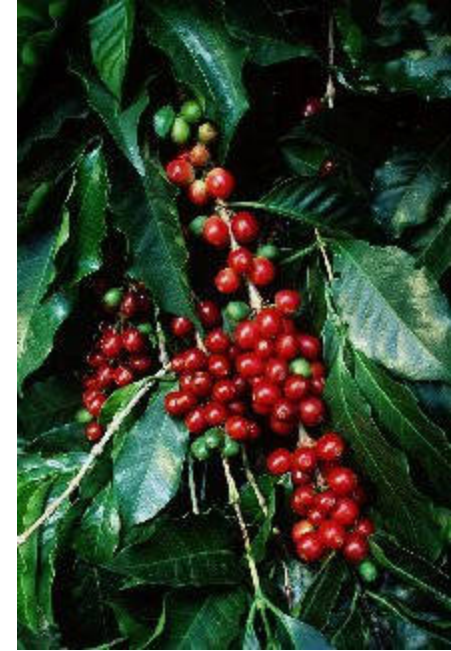
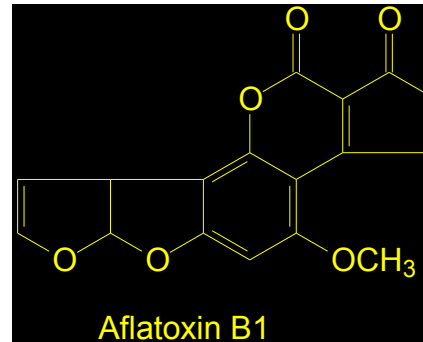


Micotoxinas

- Ochratoxinas



- Aflatoxinas



- *Aspergillus and Penicillium* spp

- Vega FE, Posada F, Peterson SW, Gianfagna TJ, **Chaves FC**. *Penicillium* species endophytic in coffee plants and ochratoxin A production. *Mycologia* **2006**,98(1):37-48.
- Vega FE, Posada F, Gianfagna TJ, **Chaves FC**, Peterson SW. An insect parasitoid carrying and ochratoxin producing fungus. *Naturwissenschaften* **2006**,93:297-299.

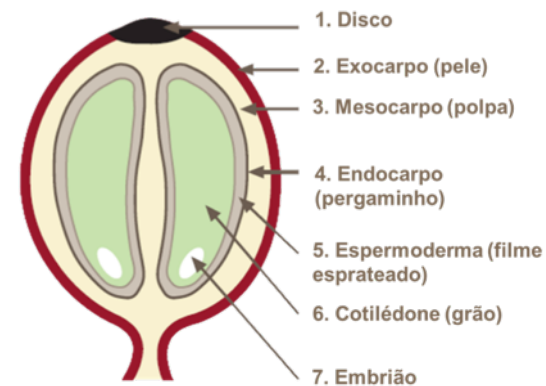
5. Fruit/Grain

PERICARPO

- Exocarpo (casca, pele)
- Mesocarpo (polpa)
 - Mucilagem
- Endocarpo (pergaminho)

SEMENTE

- Espermoderma (tegumento, pele prateada)
- Endosperma (semente, grão)
- Embrião





Pergaminho do verdeengo



Pergaminho do maduro



Café beneficiado (Green coffee – grão cru)

6. Harvest and postharvest practices

Harvest

- Dezembro a Fevereiro – Equador ao tropico de câncer
- Maio a Agosto – Equador ao tropico de capricórnio
- Arruação
- Derrixa
- Varrição
- Recolhimento
- Abanação
- Transporte



Derrça





Soprador e rastelo



Enleirador de frutos



Coletora

Processamento pós-colheita - Café natural (coco)

- Via seca - o fruto é seco na sua forma integral
- Pode ou não passar pelos lavadores para a separação dos grãos maduros dos verdes e dos brocados (boia)
- Volume 50% maior que o descascado
- Seco ao sol em terreiros ou secadores



Processamento pós-colheita - Café cereja descascado

- Pré-limpeza
- Lavador
- Descascador de café “cereja madura”
- Desmucilador (degomagem)
 - Mecânica
 - Biológica (fermentação) – 4 dias
- Lavagem
- Secagem

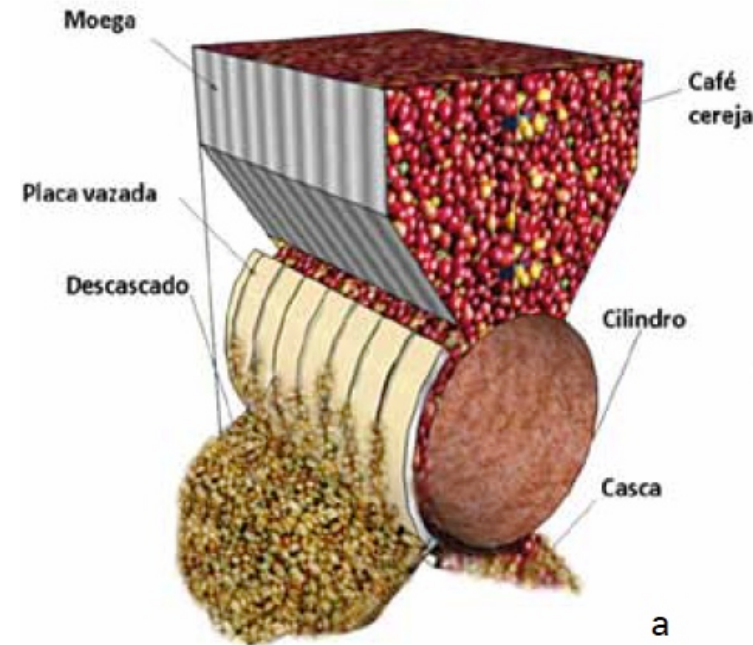


Table 1
Description of the wet post-harvest processing treatments used

Treatment	Pulping	Mucilage removal	Water used ^a
1	Disc pulper	Fermentation in water	13
2	Disc pulper	Dry fermentation	10
3	Vertical drum	Dry fermentation	5
4	Vertical drum	Mechanical mucilage removal	1.25

^al/kg of green coffees obtained.

Gonzales-Rios 2007

Fermentation

- Mucilage sugars and pectic substances
- Acidic 5.3 ± 3.5
- Decomposition by acidification
- Mucilage can also be eliminated using NaOH or enzymes pectinases but fermentation is the least expensive method.
- A textural change is observed and washing can finally eliminate this mucilage.

Fermentation

- Incomplete fermentation lead to mucilage remnants consumed by micro-organisms in secondary fermentation during drying and storage
- 16 to 80 h (3.3 days)
- Over-fermentation and bad fermentation, with butyric or propionic acids production, would be, respectively, responsible for the `alcoholic' and `stinker' coffee tastes

CAFÉ DE CIVETA (Kopi Luwak)



Kopi Luwak sensory attributes

- earthy, musty, syrupy, smooth, and rich with both jungle and chocolate undertones
- more red and darker in color
- possess surface micro-pitting caused by the action of gastric juices and digestive enzymes making them harder and more brittle

Buy Kopi Luwak

Kopi Luwak tastes smooth, and it's not bitter, like other types of coffee.

The balanced flavour is incomparable.

Smooth, delicious, one-of-a-kind.

Order today to taste it yourself - Free shipping over \$50.

1kg (2.2 lbs) - \$659.00



CAFÉ DO JACU

- Espirito Santo
- “Pé-de-moleque”
- “a galinha do café de ouro”





Jacu Bird – 1.1 pound (500 grams)

\$189.50

Hand-gathered in the wild, washed and dried, and then shipped to Vienna, where it's hand ro

Price is per **1 pound, 2 ounces (500 grams)** packed in 2 pouches.

Price includes shipping directly from Vienna, Austria, via Austrian Post Express International

-

1

+

Add to cart

SKU: RE-03 Category: Rare Coffees & Exotic Coffees

- Jamaican Blue Mountain and Hawaiian Kona
- US\$ 65 / 500g US\$ 60 / 500g



Black ivory coffee

- Elefante
- US\$1500/kg



TABELA 8 ACEITAÇÃO SENSORIAL DAS BEBIDAS DE CAFÉ DE DIFERENTES CATEGORIAS

Categoria	Valor hedônico
Tradicional	6,3 ^{ab}
Premium	6,0 ^{ab}
Gourmet	5,6 ^b
Jacu	6,0 ^{ab}
Civeta	6,5 ^a

1: desgostei muitíssimo; 5: nem gostei/nem desgostei, 9: gostei muitíssimo.

Valores médios de 76 consumidores.

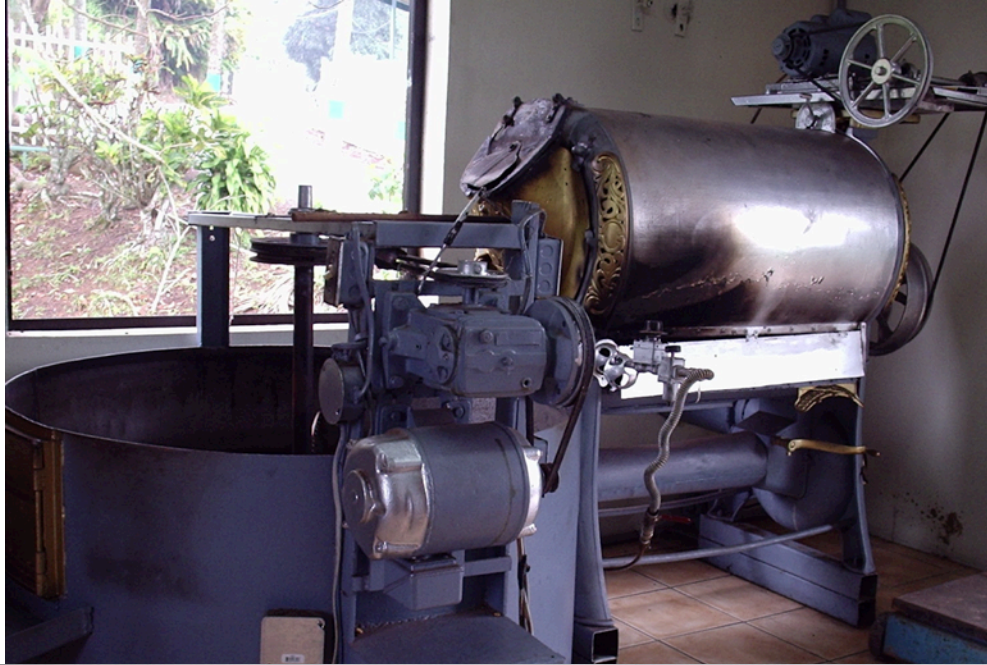
Médias na mesma linha acompanhadas de letras minúsculas iguais não diferem de $p \leq 0,05$. Escala de 9cm.

Moisture content

- If the beans are too wet (above 12.5 % moisture), they will mould easily during storage.
- If the beans are too dry (below 8 % moisture), they will lose flavour.

Torrefação

- Grãos verde
- Temperaturas 100-200°C
- Aumentam de tamanho
- Mudam estrutura, cor e aroma
- 4 fases:
 - Secagem
 - Desenvolvimento
 - Decomposição
 - Torrefação completa (1.5 a 3.5% umidade)



Degree of roast

- external color varying from light to dark brown
- Flavor (> 850 compounds) – key quality parameter
- amount of dry matter loss
- light, medium, or dark degree of roast
- light roast - 30 min roasting at 200°C
- dark roast - 2 h roasting at 200°C

Main products

- Café torrado
- Café torrado e moído (Mercado interno – mais de 1200 empresas – 50% em SP)
 - Classificação:
 1. café torrado e moído **Tradicional** – sem restrição
 2. **Superior** ou **Premium** – máx. 15% de conilon
 3. **Gourmet** – 100% arábica
- Café solúvel

7. Quality

Coffee quality

- inherent or distinguishing characteristic
- the ability of a set of inherent characteristics of a product, system or process to fulfill requirement of customers and other interested parties

Quality

- at the farmer level: coffee quality is a combination of production level, price and easiness of culture;
- at the exporter or importer level: coffee quality is linked to bean size, lack of defects, regularity of provisioning, tonnage available, physical characteristics and price;

Quality

- at the roaster level: coffee quality depends on moisture content, stability of the characteristics, origin, price, biochemical compounds and organoleptic quality. It should be noted that each consumer market or country may define its own organoleptic qualities;
- at the consumer level: coffee quality deals with price, taste and flavour, effects on health and alertness, geographical origin, environmental and sociological aspects (organic coffee, fair trade, etc).

- ISO (2004a) International Standard ISO 9116: 2004. Green coffee – Guidelines on methods of specification, 4 pp.
- geographical and botanic origins of the coffee
- harvest year
- moisture content
- total defects
- proportion of insect-damaged beans
- bean size

Physical quality for export

- Limits
- for Arabica, 86 defects per 300 g
- for Robusta, 150 defects per 300 g

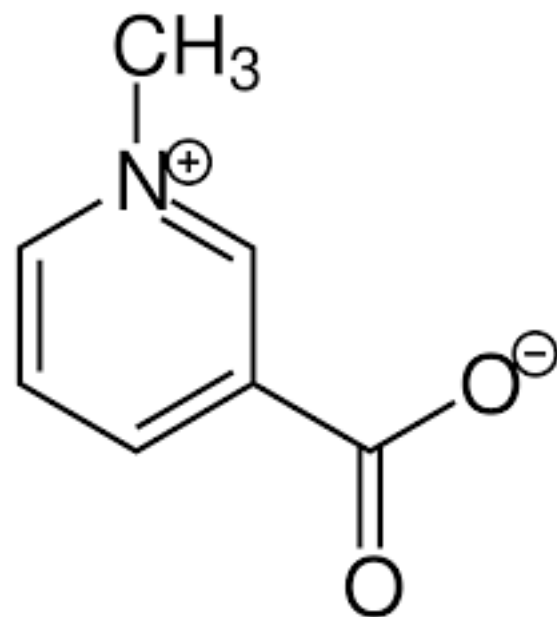
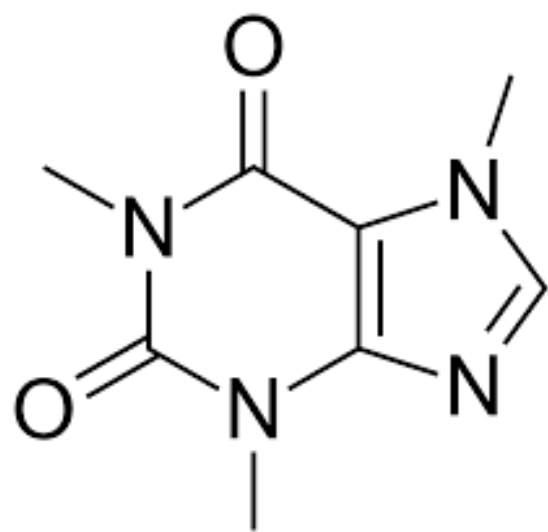
- Defects
- Foreign materials of non-coffee origin;
- Foreign materials of non-bean origin, such as pieces of parchment or husks;
- Abnormal beans for shape regularity/integrity;
- Abnormal beans for visual appearance, such as black beans;
- Abnormal beans for taste of the cup after proper roasting and brewing.

Bean size

- When unevenly sized beans are roasted, the smallest tend to burn and the largest tend to be under-roasted, affecting the visual appearance of the beans and, more importantly, the cup quality

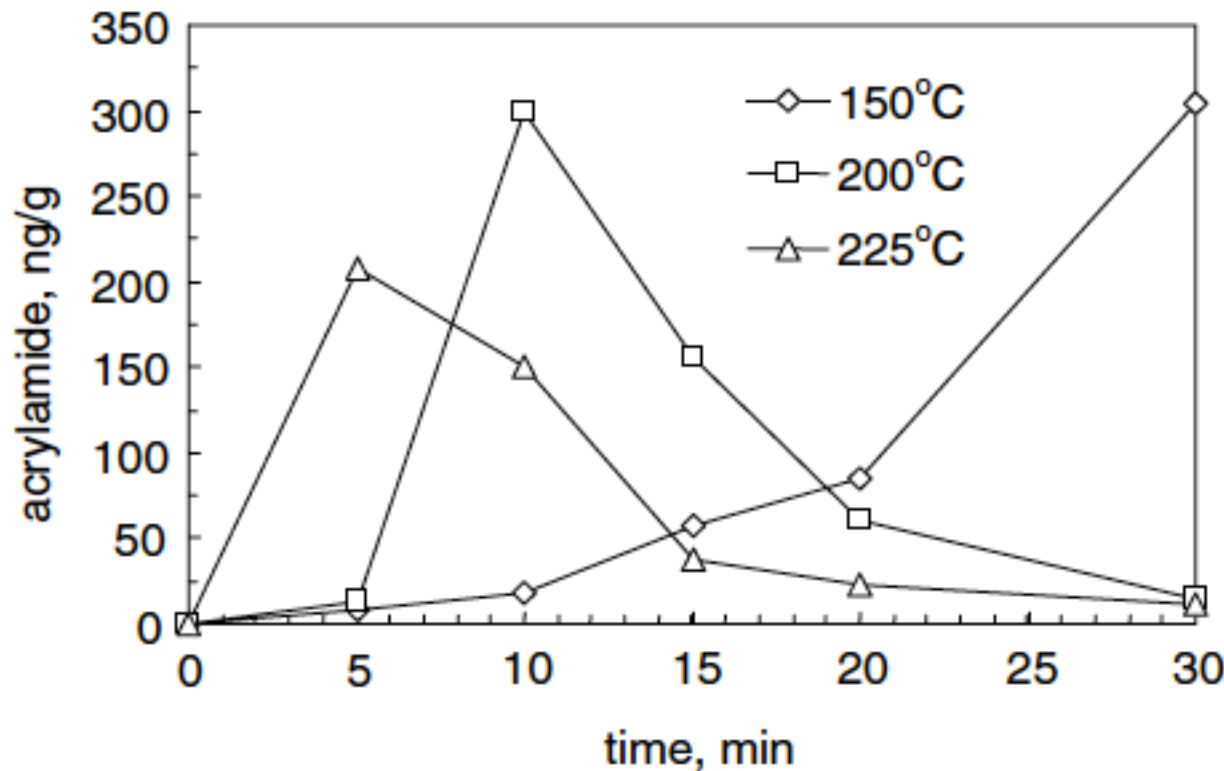
Roasting reactions

- Maillard and Strecker reactions
- Sugars, particularly sucrose as the most abundant, will act as aroma precursors, originating several substances (furans, aldehydes, carboxylic acids, etc.) that will affect both flavor and aroma of the beverage.
- Degradation of proteins, polysaccharides, trigonelline and chlorogenic acids
- Trigonelline contribute to the formation of desirable aromas during roasting
- Caffeine presents a characteristic bitter taste



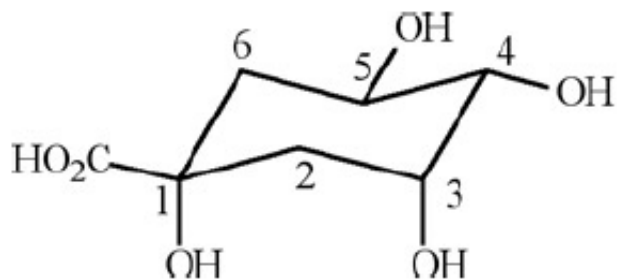
Acrilamida

- Reducing sugars with asparagine at temperatures above 120°C

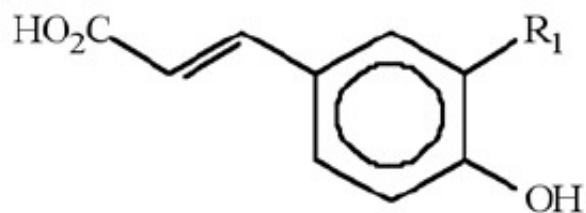


Roasting reactions

- Chlorogenic acids (CGA), a group of phenolic compounds that represent 6–12% of coffee constituents in mass are known to be responsible for coffee pigmentation, aroma formation, and astringency
- Thermal degradation of chlorogenic acids during roasting will result in phenolic substances that contribute to bitterness.
- Caramelization, oxidation, and Maillard reactions

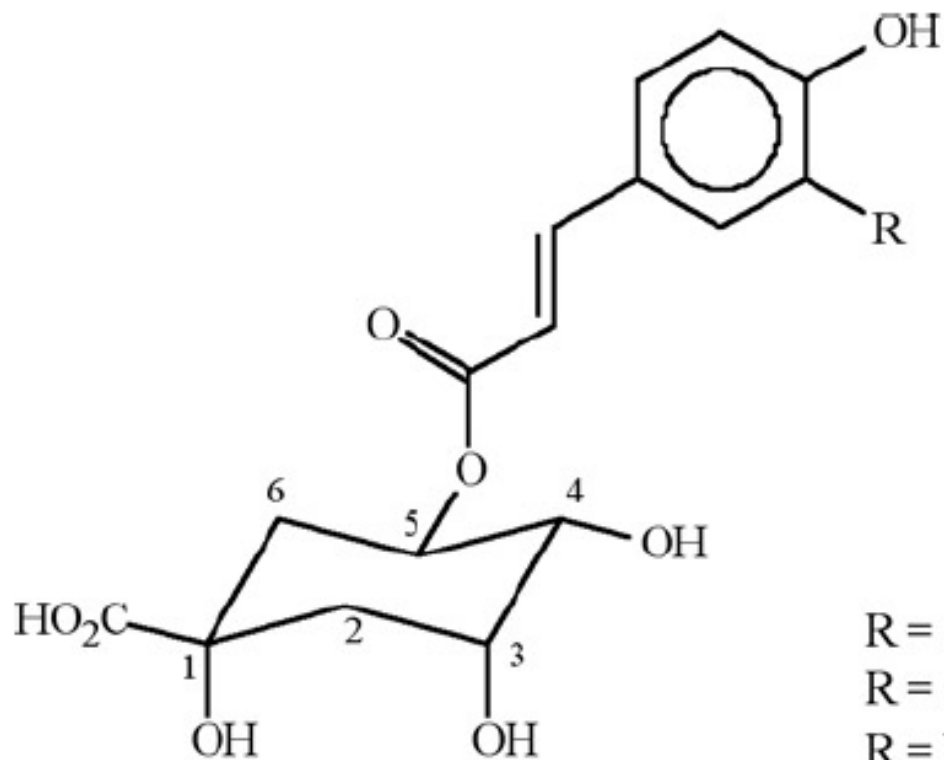


quinic acid

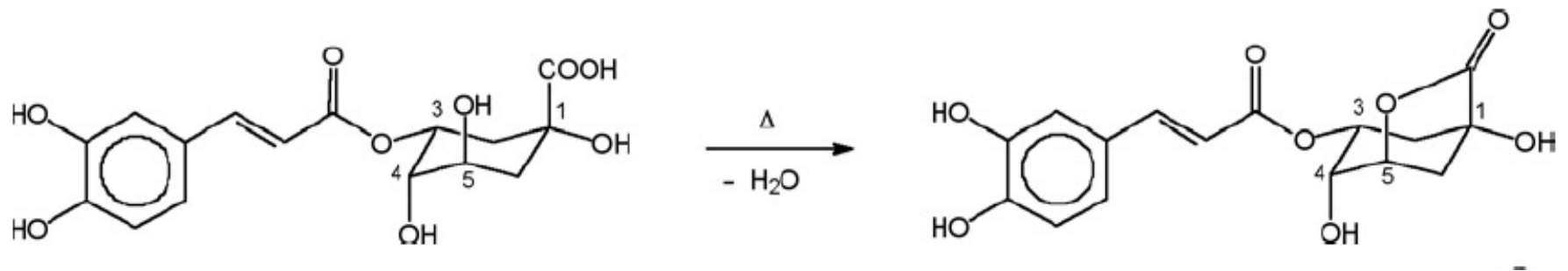


Caffeic acid
Ferulic acid
p-coumaric acid

$R_1 = \text{OH}$	CA
$R_1 = \text{OCH}_3$	FA
$R_1 = \text{H}$	<i>p</i> CoA



$R = \text{OH}$	5-CQA
$R = \text{OCH}_3$	5-FQA
$R = \text{H}$	5- <i>p</i> CoQA



Quinolactona Formada na torrefacao

- Chlorogenic acid content
- 4 to 8.4 % for *Coffea arabica*
- 7 to 14.4 % for *Coffea canephora* (dw)

- Low caffeine or caffeine free coffee species also possess low CGA

Aroma

- The character impact odor compounds of the powder and brew of Arabica coffee are different.
- The contributions of thiol odorants (e.g. 3-mercapto-3-methylbutylformate, 2-furfurylthiol) and (E)-B-damascenone are stronger in the flavour of the powder than to that of the brew.
- The reverse effect was found for methional, sotolon, 4-hydroxy-2,5-dimethyl-3(2H)-furanone and vanillin.
- **2-Ethyl-3,5-dimethylpyrazin** plays an important role in the flavours of both the powder and the brew.

(Blank et al. 1992)

Quality measured upon Brewing

- Steeping
- Pouring boiling water (150 mL) directly onto roasted and ground coffee (10 g; mild roast; fine grind) contained in a small cup and performing sensory (smell, flavor) evaluation
- after a few minutes

- **Fragrance:** the smell of the dry roasted and ground coffee
- **Aroma:** smell in the cup a few minutes after pouring hot water on the ground coffee
- **Acidity:** a pleasing taste of the beverage, from low (sweet) to high (fruity/citrus)
- **Body:** mouth feel of the beverage
- **Flavour:** a combination of taste and aroma.

Table 1

Official classification of Brazilian coffee beverage (Bartholo & Guimarães, 1997)

Classification	Characteristics
Strictly soft	Very smooth flavor; slightly sweet; low acidity
Soft	Smooth flavor; slightly sweet
Barely soft	Smooth flavor, but with slight astringency
Hard	Astringent flavor; rough taste; lacks sweetness
Rioysh	Slight taste of iodoform or phenic acid
Rio	Strong unpleasant taste, reminding iodoform or phenic acid
Rio zona	Intolerable taste and smell

Low quality

- Rio off-flavor - pungent, medicinal, phenolic or iodine-like flavor associated with a musty, cellar like odor (2,4,6-trichloroanisole and 2,4,6-trichlorophenol)
- Defects
 - **Black beans** are those from over-ripened fruits
 - **Sour beans** are from fruits that are fermented on the ground
 - **Immature beans** come from immature fruits (2-methylbutyraldehyde and 3-methylbutyraldehyde)
 - **Immature- black** are beans from immature fruits in which the skin is oxidized
 - **bored beans** are those damaged by insect action.

Cup quality

- trigonelline and 3,4-dicaffeoylquinic acid and, to a lesser extent, caffeine, showed association with **good cup quality**, for both green and light roasted coffee
- caffeoylquinic acids (predominantly 5-CQA), feruloylquinic acids (to a lesser extent), and their oxidation products were associated with **poor cup quality**
- Farah et al. 2006 Food Chem.

Vida de prateleira

- Café verde pode ser armazenado por 1 a 3 anos
- O café torrado empacotado permanece fresco por até 3 meses
- O café moído empacotado a vácuo pode ser armazenado por até 8 meses
- Uma vez aberto em 2 semanas perde a qualidade

- When green coffee is stored for a prolonged time, its quality decreases distinctively, expressed by a typical flattening and slackening of the cup quality
- 6 months of storage, coffee beans stored within the parchment remained viable for >1 year
- Glucose and fructose decreased slightly in the course of storage and glutamine content declined significantly.
- bluish-green colour developed, putatively due to the oxidation of chlorogenic acids

(Selmar et al., 2008 *Annals of Botany*)

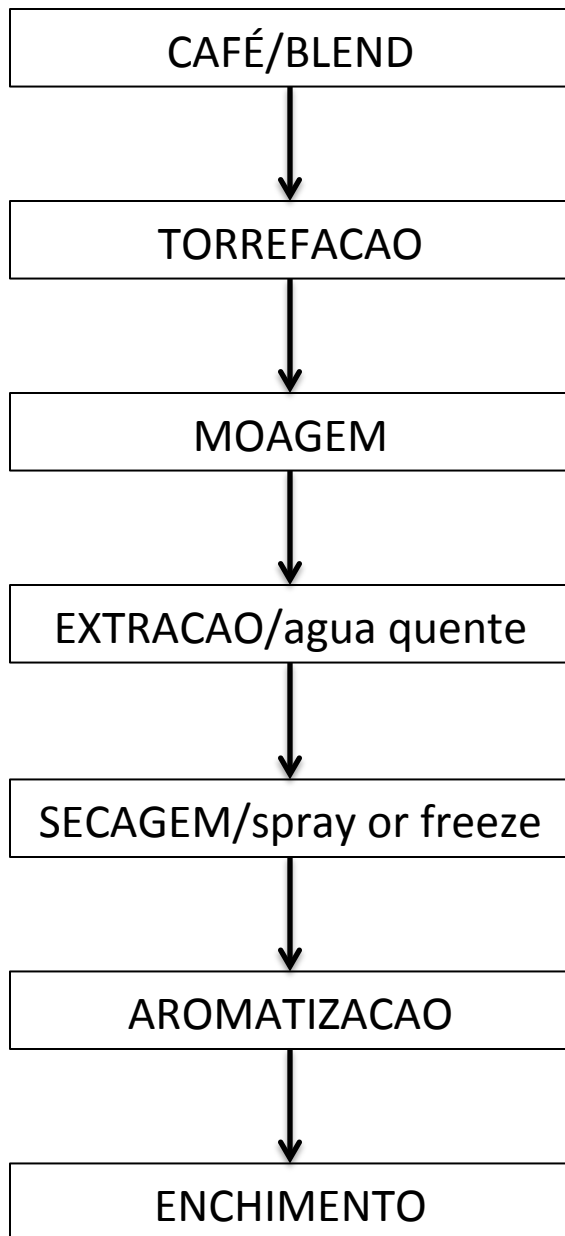
8. Products

Café descafeinado

- Cultivares sem cafeína
- Descafeinação
 - Encharcamento
 - Extração com solvente (diclorometano, acetato de etila)
 - ver o solvente (desodorização)
 - Secagem

 - Alternativamente extrai com agua quente, o extrato é então extraído com solvente e a fase aquosa é adicionada de volta ao café

 - Tratamento com vapor para remoExtração com fluido supercrítico CO₂ liquido



Café solúvel

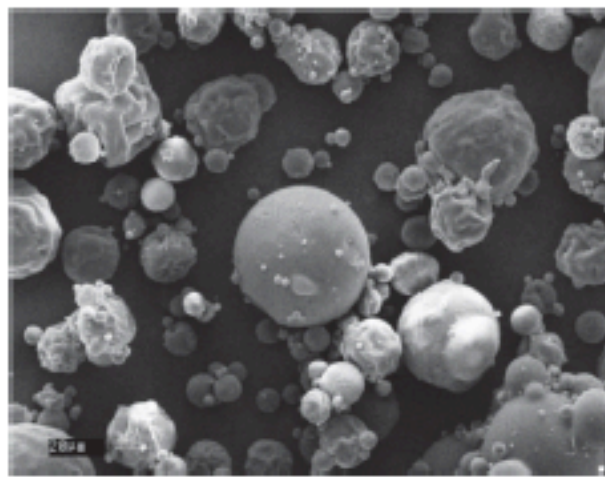
- SD is more economical
- FD provides superior aroma quality
- < 4% moisture

SD x FD

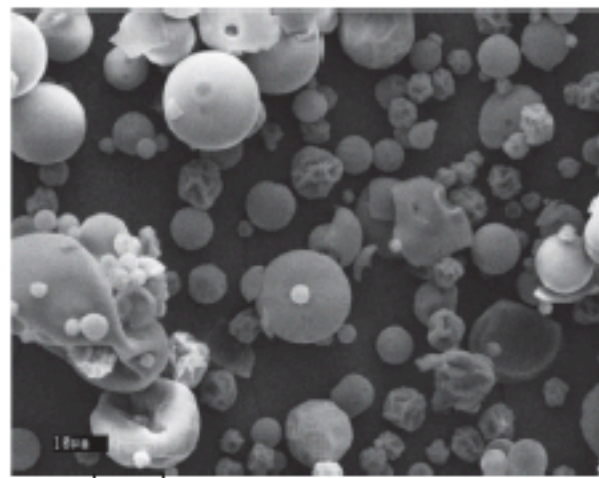
- **Spray drying (SD)** – due to high temperatures loses low-boiling aromatic compounds in coffee
- **Freeze drying (FD)** - energy intensive and expensive owing to the low-temperature and low pressure operation employed to avoid loss of flavours and the development of off-flavours in the dried product. Freeze drying of aqueous coffee extract requires longer drying time (8–16 h).

Spray-Freeze-Drying (SFD)

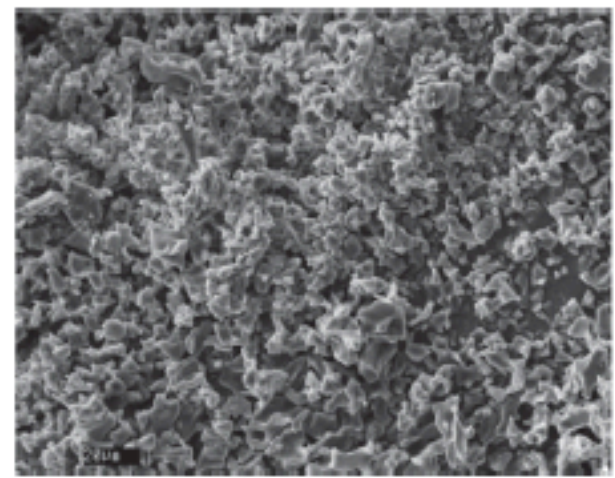
- SFD involves atomization, freezing and drying of the feed solution
- The minute droplets resultant from atomization offer more homogeneous temperature field for heat transfer during the spray freezing step, which leads to uniform nucleation and formation of fine ice crystals.
- In the freeze drying step, an enhanced sublimation rate is facilitated by reduced product dimension. The consequent increase in surface mass transfer coefficient leads to a reduction in total drying time and eventually results in fine and free flowing powder.



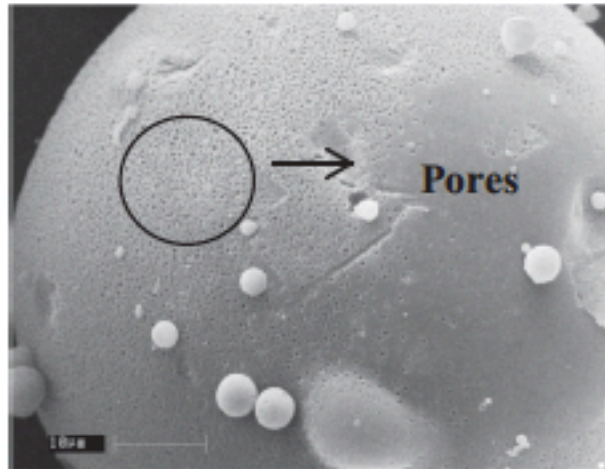
20 μm



10 μm

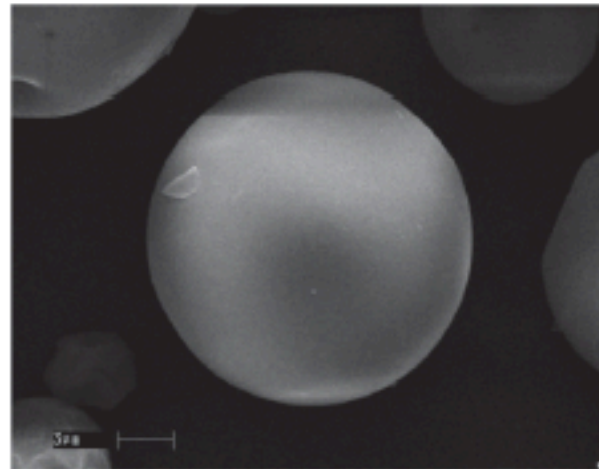


20 μm



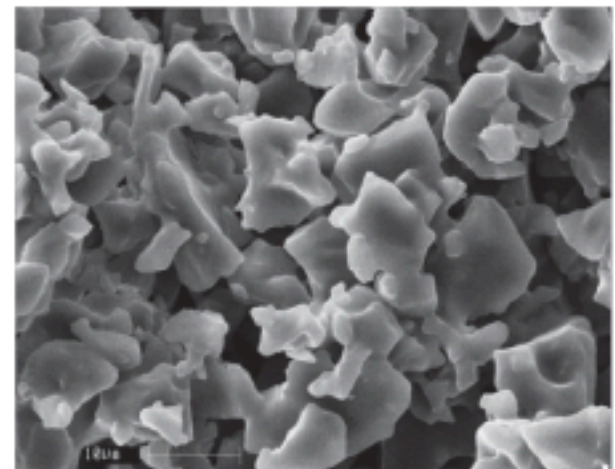
10 μm

(a) SFD



3 μm

(b) SD



10 μm

(c) FD

Fig. 4 SEM micrographs of (a) spray-freeze-dried (SFD), (b) spray dried (SD) and (c) freeze dried (FD) coffee samples.

- SFD showed better aroma quality by retaining the characteristic low-boiling aromatic compounds of coffee, that were lost during the initial stages of FD and SD.
- SFD was found to have a competitive edge over its counterparts in terms of the product's end application, i.e. instant solubility along with good flow characteristics and high bulk density that can confer good packaging and transportation characteristics.

Table 1. Variation of chemical components of green beans in *Coffea arabica* and *Coffea canephora*.

Component	<i>C. arabica</i>	<i>C. canephora</i>
pH	5.26-6.11	5.27-6.13
Mineral content *	3.5-4.5	3.9-4.5
Fat content *	13-17	7.2-11
Caffeine content *	0.7-2.2 (average 1.4)	1.5-2.8 (average 2.2)
Chlorogenic acids content *	4.80-6.14	5.34-6.41
Trigonelline*	1- 1.2	0.6-1.7
Oligosaccharides*	6 - 8	5 - 7
Total polysaccharides*	50 - 55	37 - 47

* % dry matter (dm)