Roasting
Foundation | Intermediate | Professional
Roasting
Professional
## ROASTING CURRICULUM: Professional

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<tr>
<th><strong>Title of module</strong></th>
<th>Roasting</th>
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<tr>
<td><strong>Level</strong></td>
<td>Professional</td>
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<tr>
<td><strong>Recommended course hours</strong></td>
<td>24 hrs</td>
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<tr>
<td><strong>Course aim</strong></td>
<td>Advanced skills in profile development and sensory evaluation of different profiles are tested. Knowledge of the fundamental chemistry of coffee is tested as well as the chemical reactions happening during coffee roasting. Roastery management include principles of manufacturing efficiency and capital expenditure decision making is tested.</td>
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<th><strong>Information for trainer</strong></th>
<th>Prerequisites for this module are:</th>
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<td>• Roasting Intermediate</td>
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<td>• Sensory Intermediate</td>
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<td></td>
<td>• Green Coffee Intermediate</td>
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<td>Maximum students per roaster: 2 for mandatory activities and 1 for test</td>
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### Specific Objectives:

- Ability to control and match color within different and specified time limits.
- Identify by visual assessment different roast colors.
- Identify by sensory analysis different roasting profiles of the same color with varying development time and rate of change by using the official roasting evaluation form.
- Create, discuss, and analyze profiles using terminology from keyword list.
- Configuration and use of roast profile software
- Perform calculations on rate of change on a known roast curve.
- Understand and analyze roasting operations using workflow optimization methods including LEAN production and PIC concepts.
- Describe the two main browning reactions in terms of sequence and flavor development and which basic molecules are involved in the different browning reactions.
- Explain the principles of heat transfer, how the heat enters and distributes inside the bean and how they are generally applied to the roasting process.
- Describe how/which types of heat transfer are adjustable during the roasting process including different roasting technologies.
- Visual identification of roasting defects on beans and/or pictures: Scorching, Tipping and Facing.
- Blending. Pre/post considerations, bean selection, number of components, product purpose (espresso, filter, milk, sugar)
- Cupping
  - Green coffee selection
  - Roast profile evaluation. Roast profile evaluation form.
  - Quality control methods (In/out, triangulation)
  - Downstream quality control
- Chemical and physical transformation
  - Describe Green coffee chemistry and the relevant transformations during roasting.
  - Describe the chemical differences of processing methods during roasting and how they impact color and flavor profile
  - Gas formation
  - Acid degradation and formation
  - Physical reasons for solubility
  - Chemical reasons for solubility
  - Chemical causes of roast color and its importance
<table>
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<tr>
<th>Code/subject</th>
<th>Sub code</th>
<th>Knowledge</th>
<th>Skills</th>
<th>References</th>
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<tbody>
<tr>
<td>1.01 GREEN COFFEE</td>
<td>1.01.01</td>
<td>Anatomy of the cherry. Skin, pulp, parchment, pergamino, silverskin, bean. Density, size, moisture level</td>
<td>Analyze green coffee with respect to bean size, density and moisture level and design roast profiles</td>
<td>(Illy &amp; Viani 2005; Clarke &amp; Vitzthum 2001) p. 938 Gonzalez-Rios &amp; Suarez-Quiroz 2007 Illy &amp; Viani 2005) p. 87-102</td>
</tr>
<tr>
<td>Chemistry of Green Coffee</td>
<td>1.01.02</td>
<td></td>
<td></td>
<td>(Gonzalez-Rios &amp; Suarez-Quiroz 2007 Jansen 2006) page 8-11 Illy &amp; Viani 2005; Belitz et al. 2009) page 941, table 21.2</td>
</tr>
<tr>
<td>Physical properties of green beans (moisture, density, size):</td>
<td>1.01.03</td>
<td>Moisture level depends on proper drying in the production country in the first place and later in proper transportation and storage conditions. 8-12% moisture is normal for specialty coffee although around 12% is the ideal. Higher than 12% and there is risk for mold formation. Lower than 8% and the tissue starts to get damaged and important substances can evaporate even at room temperature. Density is correlated with growth height</td>
<td>Be able to measure moisture, density and size of beans and use the information to design roast profiles</td>
<td>(Illy &amp; Viani 2005; Jansen 2006) page 8-11 Guenther et al. 2007; Belitz et al. 2009) page 941, table 21.2 (Suarez-Quiroz &amp; Gonzalez-Rios 2004; Bertrand et al. 2012 Illy &amp; Viani 2005) p. 149-150 Bean size: (Clarke &amp; Vitzthum 2001; Illy &amp; Viani 2005) p. 103, 135-136</td>
</tr>
<tr>
<td>Chemical properties of different processing methods</td>
<td>1.01.04</td>
<td>Small sugars are washed out with the washed process so it appears more acidic and with a lower body.</td>
<td></td>
<td>(Jansen 2006; Illy &amp; Viani 2005) p. 99 (Huschke 2007; Gonzalez-Rios &amp; Suarez-Quiroz 2007a)</td>
</tr>
<tr>
<td>Health related issues of green coffee. Ochratoxins, Achrylamide</td>
<td>1.01.05</td>
<td>Ochratoxins are potential health risk factors developed by fungi during processing in the production countries. The concentration of Ochratoxins will be reduced yet not eliminated during the roasting process. The better grade of green coffee beans will contain less Ochratoxins. At the moment, dietary exposure to OTA is considered low enough to not cause significant risk. Achrylamide is another cancer risk factor developed during the roasting process yet also degraded by time so slow roasted coffee contains almost nothing whereas flash roasted coffee contains a considerable amount</td>
<td>Ability to discuss these topics with customers as well as authorities. It is a normal requirement to get this analyzed and documented when either starting a roastery (the authorities) or when exporting coffee or selling to big institutions</td>
<td>Ochratoxins: (Toci et al. 2009; Illy &amp; Viani 2005) p. 209 Achrylamide: (Huschke 2007; Illy &amp; Viani 2005) p. 368f Plenty info on the internet if these concepts are googled so the following scientific articles are not necessary to read: (Huschke 2007; Guenther et al. 2007) (Clarke &amp; Vitzthum 2001; Suarez-Quiroz &amp; Gonzalez-Rios 2004)</td>
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<tr>
<td>Heat transfer:</td>
<td>2.01.01</td>
<td>Building on the knowledge from Intermediate on Contact, convection and radiation in this section there is a bigger focus on the dynamics of heat transfer</td>
<td>Ability to analyze and explain a given technology in term of scientific understanding of heat transfer</td>
<td>Rivera et al. 2011; Clarke &amp; Vitzthum 2001) page 90-100 (Meste et al. 2002; Toci et al. 2009) (Illy &amp; Viani 2005; Huschke 2007) page 18-24</td>
</tr>
<tr>
<td>Heat transfer between materials (hot to cold)</td>
<td>2.01.02</td>
<td>Heat as molecular vibration diffuses between material and internally in material as soon as there is a temperature difference where heat diffuses from higher temperature to lower temperature</td>
<td>Explain visualize and explain 'diffusion' of heat</td>
<td>Wiki:Heat_transfer</td>
</tr>
<tr>
<td>Transfer of heat from roaster to bean</td>
<td>2.01.03</td>
<td>As consequence of heat transfer between materials, conductive heat will diffuse from the heating element of the roaster and onto the bean surface</td>
<td>Analyze the temperature difference between air and bean at any given point of a roast and understand how the temperature difference drives the speed of the roast at any given point.</td>
<td>(Jansen 2006; Huschke 2007) p. 27-39 (Clarke &amp; Vitzthum 2001) p. 101-104 (Clarke &amp; Vitzthum 2001; Illy &amp; Viani 2005) p. 184-187 Wiki: Diffusion</td>
</tr>
<tr>
<td>Transfer of heat from bean surface to bean center</td>
<td>2.01.04</td>
<td>When the conductive heat reaches the surface of the bean it is up to the conductivity coefficient to diffuse the heat towards the center of the bean. The temperature difference between hot air and bean will drive the speed of the diffusion of heat from the hot air to the colder bean</td>
<td>Understand and avoid extreme temperature differences because an unfortunate roast degree gradient will be formed in the beans</td>
<td>(Jansen 2006; Clarke &amp; Vitzthum 2001; Illy &amp; Viani 2005) p. 183-184</td>
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<td>3.0 PHYSICAL CHANGES IN BEANS</td>
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<td>Glass transition temperature</td>
<td>3.01.01</td>
<td>Green beans at room temperature are 'glass like' in their structural appearance but polymeric material like green beans will become 'leathery' when the glass transition temperature is reached so they are leathery during the roasting process but becomes glass like again soon after reaching the cooling tray</td>
<td></td>
<td>(Huschke 2007; Jansen 2006) p. 32-34 (Belitz et al. 2009; Rivera et al. 2011) (Clarke &amp; Vitzthum 2001; Meste et al. 2002) Wiki:Glass_transition</td>
</tr>
<tr>
<td>Topic</td>
<td>Section</td>
<td>Description</td>
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<td>Roast gasses</td>
<td>3.01.02</td>
<td>First water (8-12% moisture of the green bean) will turn into vapor when heated. Later the Maillard reaction, Strecker degradation, Caramelization and decarboxylation of organic acids will create organic roast gasses like CO2 and other small organic gasses.</td>
<td>(Hertz-Schünemann, Dorfner, et al. 2013a) (Hertz-Schünemann, Streibel, et al. 2013b)</td>
<td></td>
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<tr>
<td>Expansion (spongy)</td>
<td>3.01.03</td>
<td>The 'leathery' material with developing gasses (vapor, CO2 and organic gases) will expand and the dense material will become a spongy structure with many small gas pockets and channels. Oils can travel through these channels so if a careful roast profile and roast degree is not used oils will migrate to the surface and will get rancid when O2 from the air reaches the oils.</td>
<td>Ability to avoid oils migrating to the surface of the roasted beans (Belitz et al. 2009; Illy &amp; Viani 2005) p. 182 (McGee 2004; Jansen 2006) p. 23-26, 30-44 (Ill &amp; Viani 2005; Clarke &amp; Vitzthum 2001) p. 94</td>
<td></td>
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<tr>
<td>Loss of water</td>
<td>3.01.04</td>
<td>Water will leave the material in a opposite direction of the heat going in and it is a prerequisite for the pyrolysis to take place. This is the major contributor to roast loss.</td>
<td>(Clarke &amp; Vitzthum 2001) p. 93-94 (Jansen 2006) p. 33-34</td>
<td></td>
</tr>
<tr>
<td>Physical reason for increased solubility of dark roasted coffee</td>
<td>3.01.05</td>
<td>The darker the roast the more spongious the bean material with bigger internal channels that the water can run through and harvest the soluble molecules. The less spongious and small channels the less able the water is to harvest the soluble molecules in the more dense material. Instruct and explain to customers to extract for a longer time in order to obtain enough bitterness and body in a light roasted coffee if it is lacking in a given brew.</td>
<td>(Clarke &amp; Vitzthum 2001) p. 94-95 (Jansen 2006; Huschke 2007) p. 23</td>
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### 4.0 CHEMISTRY OF COFFEE ROASTING

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<tr>
<th>Section</th>
<th>Description</th>
<th>Reference</th>
<th>Notes</th>
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<tbody>
<tr>
<td><strong>Color</strong></td>
<td>4.01.01</td>
<td>The brown color of coffee is primarily caused by the Maillard reaction and to a lesser extent by Caramelization. Since there is such an intimate relationship between the aroma chemistry and color, color is an important macroscopic indicator followed closely by the roast master during roasting.</td>
<td>(Illi &amp; Viani 2005; Belitz et al. 2009) p. 940, 284 (Jansen 2006; McGee 2004) p. 779 (Clarke &amp; Vitzthum 2001; Illy &amp; Viani 2005) p. 193 (Belitz et al. 2009; Jansen 2006) p. 64 Wiki: Melanoidin</td>
</tr>
<tr>
<td><strong>Chemical reason for increased solubility of dark roasted coffee</strong></td>
<td>4.01.02</td>
<td>Hydrolysis of carbohydrate makes the big polysaccharides more soluble (polar) and smaller so they easier move through the coffee-water matrix. The di- and mono saccharides are cleaved into acids and other smaller polar compounds which makes them move quicker in the coffee-water matrix</td>
<td>Wiki: Hydrolysis</td>
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<tr>
<td></td>
<td>4.01.03</td>
<td>Use the sensory level of acidity to evaluate roast degree. Analyze the quality of acidity to determine optimum roast profile.</td>
<td>(Clarke &amp; Vitzthum 2001) p. 18-30 + 59 (Bhumiratana et al. 2011; Jansen 2006) p. 46-67, 52-53, 57-61 (Illi &amp; Viani 2005) p. 194 Fig 4.11</td>
</tr>
<tr>
<td>Acids developed during roasting</td>
<td>Some acidic compounds are derivatives of carbohydrate (acetic, formic, lactic, glycolic...) and are developed very early in the roasting process and later degraded as the coffee becomes darker around and after 1st crack.</td>
<td>(Morgan &amp; Brenig-Jones 2012; Jansen 2006)p. 58 fig 33 (George et al. 2005; Clarke &amp; Vitzthum 2001) p. 22-25 (Illy &amp; Viani 2005) p. 196-197</td>
<td></td>
</tr>
<tr>
<td>Bitterness</td>
<td>4.01.04 Bitterness is primarily developed by the products of the Maillard reaction, breakdown of chlorogenic acids and products of caramelization so a darker roast leads to higher bitterness. Ability to control the level of bitterness by controlling end color.</td>
<td>Bitterness (Morgan &amp; Brenig-Jones 2012; Clarke &amp; Vitzthum 2001) p. 53</td>
<td></td>
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<tr>
<td>Aroma of roasted coffee</td>
<td>4.01.05 On a crude level flavor of coffee changes with roast degree but on a more subtle level even the same color could express many different sensory properties depending of the specific temperature profile applied. Thousands of aromas are present in roasted coffee but on a basic level 28 aromatic substances can largely approximate 'coffee aroma'. Skills in expressing different characteristics of the same coffee at the same roast color but with different roast profiles.</td>
<td>(George et al. 2005; Belitz et al. 2009) page 942-948 (Tisbury 2013; Clarke &amp; Vitzthum 2001) p. 74-79 (Tisbury 2013; Bhumiratana et al. 2011)</td>
<td></td>
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<tr>
<td>Roast speed:</td>
<td>4.01.06 The speed of the roasting process determines the kind of chemical reactions happening.</td>
<td>(Toci et al. 2009) (Schenker et al. 2002) (Bicho et al. 2013)</td>
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### 5.0 SENSORY

<p>| Taste and smell | 5.01.01 Understand how tasting (gustation) and smelling (olfaction) is interconnected and the related anatomy. Understand and explain the importance and reasons behind the 'slurping' technique when cupping to colleagues and customers. | (Tisbury 2012; Illy &amp; Viani 2005) p. 316 - 351 |</p>
<table>
<thead>
<tr>
<th>Evaluation methodology</th>
<th>5.01.02</th>
<th>Evaluation methodology: In-out cupping. Triangulation.</th>
<th>Make decisions in when developing new roast profile and new products</th>
<th>Intermediate sensory in the Coffee Skills Program</th>
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<tr>
<td><strong>6.0 BUSINESS</strong></td>
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<tr>
<td>6.0.1.01</td>
<td></td>
<td>Ability to understand customer preference for different product features. The Lean KANO analysis (voice of the customer methodology)</td>
<td>Wiki:Kano_model</td>
<td></td>
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<tr>
<td>Price calculations</td>
<td>6.0.1.02</td>
<td>The cost related to production of coffee including how to manage roast loss in price calculations</td>
<td>Ability to manage cost and calculate profit for a given product or for a given quotation to a specific customer who needs a special price (yet still be a good business!)</td>
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<tr>
<td>Product parameters</td>
<td>6.0.1.03</td>
<td>Central parameters for product development</td>
<td>Ability to design a product with respect to specific demand from a specific customer segment</td>
<td></td>
</tr>
<tr>
<td>Bean genetics, bean terroir</td>
<td>6.0.1.04</td>
<td>(1) Arabica/Robusta (2) Large Beaned Arabica vs std screens 15/16/17/18 (3) Pea Berry (4) High grown Vs low grown (5) Decaf</td>
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<tr>
<td>Number of components</td>
<td>6.0.1.05</td>
<td>More components gives a broader sweet spot (parameter range where the coffee is balanced) Fewer components gives a narrower sweet spot but more character</td>
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<tr>
<td>Roast degree</td>
<td>6.0.1.06</td>
<td>Darker roast gives a broader sweet spot but less character and vice versa</td>
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<tr>
<td>Pre/post blend</td>
<td>6.0.1.07</td>
<td>Post blending provides the opportunity to roast each component optimally but has the cost of extra production steps. When pre blending you have to roast the ‘best</td>
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compromise’ but saves the extra production step.

The right choice is the best cost-benefit depending on if the customer will put extra value that exceeds the extra cost of post blending.

| 6.01.08 | Addition of milk to coffee | Milk changes the appearance of coffee and dampens some taste and flavours but adds a creamy aspect. If the customer adds milk it is important to design the product so the coffee still has the right appearance for the customer after the milk is added. |

(Illy & Viani 2005; Parat-Wilhelms et al. 2005)

| 7.0 Roastery Management |

| 7.01.01 | Basic knowledge of Lean production | Ability to design and operate a production that is designed around the preferences and demands of customers with maximum uptime and most satisfied customers (fewest defects) |

(Jansen 2006; Morgan & Brenig-Jones 2012) (Belitz et al. 2009; George et al. 2005)

| 7.01.02 | Batch size requirements related to yearly turnover calculations | Calculate the size of the roaster needed for a specific business scenario |

| 7.01.03 | Environment. Pollution. Neighbor complaints. Regulation (EU, local authorities). Filter options: | Afterburner, electrostatic filter, ceramic beds, ozone, UV light, water curtain, recycling exhaust air into burner |

(Huschke 2007) 55-58  
Articles on environment issues from Roast Magazine Blowing Smoke—Ways to clean up, reduce and recirculate roaster emissions (Sept/Oct 2006; pg. 24)  
Clear the Air—Removing the myths of emission control
<table>
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<th>Topic</th>
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<th>Source(s)</th>
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</table>
| Work space design                       | 7.01.04 | **Draw a production flow.** PEMME, SIPOC, KANBAN  
| Work space management                   | 7.01.05 | **Lean 5s methodology to tide up the workplace.** Fire prevention and extinguishing  
| Purchase planning                       | 7.01.06 | **Purchase planning:** Knowledge of seasonality of coffee availability when traceability down to the farm (even microlot) is part of the product description  
**Ability to plan ahead to secure amounts of green coffee needed from harvest to harvest so you don't run out of important coffee between harvest**  
| Online and offline measurement equipment. Profile logging software. Handling measurement variation. | 7.01.07 |                                                                                                                                                                                                             | ([Jansen 2006; Tisbury 2012](https://www.coffee-mind.com/variation-analysis/)) ([Clarke & Vitzthum 2001; Morgan & Brenig-Jones 2012](https://www.coffee-mind.com/variation-analysis/)) |
| Scheduled maintenance                   | 7.01.08 |                                                                                                                                                                                                             | ([Jansen 2006; Tisbury 2012](https://www.coffee-mind.com/variation-analysis/)) ([Clarke & Vitzthum 2001; Morgan & Brenig-Jones 2012](https://www.coffee-mind.com/variation-analysis/)) |
Keywords

- 1st and 2nd crack.
- 5S
- 8-12% moisture in green beans
- Acrylamide
- After burner
- Air (drum environment) temperature probe
- Airflow, chimney
- Batch traceability in production system
- Bean temperature probe
- Buildup in chimney - Fire risk!
- Business model canvas
- Caramelization
- Charge/Drop temperature
- Chemical browning reactions are driven by temperature
- Chemical properties
- Conduction/contact/diffusion, radiation and convection heat transfer
- Cycklic vs Aliphatic acids
- Development time (from 1st crack to end of roast)
- Diffusion: Gas and temperature
- Electrostatic filter
- Endothermic
- Evaporation is endothermic
- Exhaust filtration
- Exothermic
- Glass transition temperature
- Grade. Screen. Bean size variation.
- Heat vs. temperature
- In-out cupping
- KANBAN
- Key odorants
- Lean production
- Maillard reaction
- Moisture meter
- Mycotoxins.
- Natural processing
- Organic acids creation and degradation
- PEMME
- Physical properties
- Pre-blending vs. post-blending
- Processing
- Profile logging software
- Pulped Natural
- Purchase planning
- Pyrolysis
- Quenching
- rate of change
- Roast air temperature vs. product temperature.
- Roast colour meter
- Roast defects (scorched, baked, underdeveloped)
- Roast degree / roast colour
- Roast gases
- Roast logging system
- Roast loss
- Roast loss, Volume increase, density drop
- Roast profile (time x temp)
- Roasting curve
- Roasting drum
- Roasting process
- SIPOC
- Soluble solids
- Storage conditions 12% bean moisture vs 60% RH in storage room
- Strecker degradation
- Thermal energy - molecular vibration. Absolute zero/Kelvin scale
- Triangulation
- Turning point (minimum profile temperature)
- Washed coffee
- Water activity (steam pressure, Chemical reactions during roast, degassing speed)

**Literature**


Bertrand, B. et al., 2012. Climatic factors directly impact the volatile organic compound fingerprint in green Arabica coffee bean as well as coffee beverage quality. *FOOD CHEMISTRY*.


Gonzalez-Rios, O. & Suarez-Quiroz, M.L., 2007a. Impact of “ecological” post-harvest processing on coffee aroma: II. Roasted coffee. ... *Journal of Food* ....

Gonzalez-Rios, O. & Suarez-Quiroz, M.L., 2007b. Impact of “ecological” post-harvest processing on the
volatile fraction of coffee beans: I. Green coffee. ... Journal of Food ....


Toci, A.T. et al., 2009. Effect of the fluid flow speed changes on the chemical composition of coffee samples roasted in an industrial semi-fluidized bed roaster. ... Conference on Coffee ....

1999 Structural Properies of Coffee Beans as Influenced By Roasting Conditions

2000 Schenker Pore Structure of Coffee Beans Affected by Roasting Conditions

Equipment required
- Minimum one roaster per student
- Moisture meter to measure moisture level of green beans and roasted beans
- Colour measuring meter to measure colour of roasted coffee
- Roast logger software
- Rulers for test