Roasting curriculum

Levels

- ***Foundation Level***
  The focus is on people attending the class and get some basic impressions and understanding (mainly physical) of the roasting process. They are instructed to do some basic calculations on some physical properties and doing them while instructed is sufficient to pass and get certified. The subject material and tests are designed to be relevant for people who will use this first certification process to consider if the vocation as a coffee roaster suits them. Pass mark is 60%

- ***Intermediate Level***
  Students are tested in their understanding of and skills in designing and executing different positive roast profiles as well their sensory recognition of different roast defects. Students are introduced to different chemical conditions and principles that cause the physical properties and reactions introduced at foundation level. It is expected that they are able to name these reactions and what they cause in terms of the physical and sensory properties of the final coffee. The pass mark of 70% means that the practical and theoretical tests need to be done satisfactory to pass and become certified.

- ***Professional Level***
  Advanced skills in profile development and the sensory evaluation of different profiles are tested at this level. Knowledge of the fundamental chemistry of coffee is tested as well as the chemical reactions occurring during coffee roasting. Roastery management principles including manufacturing efficiency, capital expenditure and decision making are introduced to ensure that successful students achieving the 80% pass mark have strong vocationally relevant skills.

Foundation

Sensory Foundation Level is a pre-requisite for the roasting Foundation course.

It is recommended that the Green Coffee Foundation Level is completed before taking the course.

Level 1: Knowledge – Remembering information				
Recognize	Memorize	List	Name	Relate
Define	Identify	Distinguish	Repeat	Recall
Level 2: Comprehension – Explaining concepts				
Restate	Describe	Explain		
Discuss	Identify	Express	Translate	Recognize
Locate	Report	Extrapolate	Convert	Review
Interpret	Abstract	Transform		

Curriculum

Topic	Knowledge Required	Skill Required	Blooms Taxonomy	Reference	Practical Test	Written Test
1.0 Heat transfer	The overall roasting process needs heat to progress and this is transferred from the heating element in the roaster to the beans during the roasting process. Heat always goes from a hot substance to a cold substance.	Explain that heat goes from hot to cold substances. Recognise that heat eventually leads to fires in roasters.	L2			
1.1 Fire	Since coffee is an organic substance inappropriate amounts of heat can lead to fire in the drum but also fire			Wiki: Fire_triangle Wiki: Fire_extinguisher		

	in the chaff collector and the chimney because of organic matter build-up. Although there is a principally big difference between the coffee roasting process and a fire, the beans are not far from catching fire in the end of a roast. In case of any irregularity in the end of a roast there is a great risk of fire. Because of this the roast master should always have a specific strategy to handle as part of their production routines.					
2.0 Basic roasting and the roasting cycle	Very different phases are present in the overall process of converting green coffee into well roasted coffee beans cooled to room temperature. Time and temperature evolution are main parameters for quality. In specialty coffee a 'flash roast' is defined as one under 5 minutes. A slow roast is defined as one between 10 and 20 minutes.	Has held green and roasted coffee in their hands and able to discuss the main differences Distinguish between the different basic stages of coffee in a roast cycle visually Can control the heat element in a roaster. Can repeat a roast profile by	L1	(Illy & Viani 2005; Huschke 2007) p. 18-22 (Toci et al. 2009; Illy & Viani 2005) p. 179ff Pdf on calculating percentage of change Pdf with SCAE roast log	Yes	

		repeating the heat element control plan for a roast. Can fill out a roast log correctly recording points in a roast specifically identified in an exam.				
2.1 Drying	Coffee is wet for conservational reasons: between 8 – 12.5% for specialty coffee. Because most of this will leave during the roasting process this is the main contributor to roast loss from green to roasted coffee. Applied heat is the driver of the drying process and this phase needs energy input all the time to progress. The drying process prepares the coffee for the later actual roasting process makes up approximately 60% of the overall process. So in a 15 minute roast the heating-drying phase will last around 10 minutes.	Can operate a total moisture meter to measure total moisture level of green coffee.	L2	(Clarke & Vitzthum 2001; Huschke 2007) p 20ff	Yes	

	1st crack indicates the end of this stage of the process.					
2.2 Roasting	When 1st crack is rolling the actual roasting process is starting. At this point in the roast most of the moisture has left and several different chemical processes have started. In general these processes leads to a brown colour of the beans but these chemical processes will start to *produce* heat so the roasting phase so now there is two sources of heat: (1) The heat source of the roaster and (2) inside each bean.	Ability to record 1st crack correctly (not first individual bean cracking but the overall batch) Plan and execute a flame reduction at or around 1st crack		(Illy & Viani 2005; Huschke 2007) p. 18-22		
2.3 Cooling	When roast colour is achieved cooling quickly is required to stop the roasting/colour development. 5 minutes for the beans to be below 30ºC in the cooling tray is the rule of thumb for the cooling process.	Measure temperature of beans in cooling tray with an infrared thermometer. Feel with their hands if the beans are close to 30ºC. Measure moisture level in roasted coffee		(Illy & Viani 2005; Huschke 2007) p. 21		
3.0 Light, Medium	All coffee has acidity and bitterness. For any given	Sensorially identify acidity	L1	(Clarke & Vitzthum 2001; Huschke 2007)	Yes x2	Yes

and Dark roasting	coffee the lighter the roast the more acidic and less bitter and vice versa (the darker the roast the more bitter and less acidic) As such the 'roast degree' is an integral part of a given 'product' sensory specification.	and bitterness in coffee.		p. 20, 26		

Keywords

- 1st and 2nd crack.
- 8-12% moisture in green beans
- Air (drum environment) temperature probe
- Airflow, chimney
- Bean temperature probe
- Chaff. Chaff collector
- Charge/Drop temperature
- Cooling phase / cooling time
- Cooling tray
- Dark roast high bitterness low in acidity. Opposite relationship for light roasts
- Dropping temperature
- Drum rotation
- Drying phase
- End temperature
- Fire extinguisher (water vs. CO2)
- Fire in the chimney
- Fire in the drum
- Light roast vs Dark roast
- Moist vs. dry period
- Total moisture meter
- Percentage change
- Quenching

- Reducing points
- Roast degree / roast colour
- Roast loss
- Roast loss, Volume increase, density drop
- Roast profile (time x temp)
- Roasting curve
- Roasting cycle
- Roasting drum
- Roasting process
- Sample spoon / tryer
- Silver skin.
- Slow roast vs. flash roast
- Stirring device
- Sweet spot.
- Turning point (minimum profile temperature)
- Ventilation

Literature

Necessary:

- Enclosed compedium provided på your trainer on Percentage chage calculations, Green coffee harvest schedule and profile analysis
- "Industrial Coffee Refinement" Reinhard Huschke, Verlag Moderne Industrie, 2007

Optional

- "Espresso Coffee" Andrea Illy & Rinantonio Viani, Academic Press, 2005

Equipment required

- Total moisture meter
- Infrared thermometer to measure temperature of the beans in the cooling tray
- One roaster pr. 2-3 students

Intermediate

Pre-requisites for participation in the Intermediate certification process:

- Roasting Foundation
- Sensory Foundation
- Green Coffee Foundation

Level 3: Application – Use information in a new way				
Translate	Illustrate	Sketch	Sequence	Prepare
Interpret	Operate	Employ	Carry	Generalize
Apply	Demonstrate	Schedule	Out	Repair
Practice	Dramatize	Use	Solve	Explain

Level 4: Analysis – Distinguish the different parts				
Distinguish	Contrast	Relate	Classify	Catalog
Differentiate	Calculate	Experiment	Discover	Investigate
Appraise	Criticize	Estimate	Discriminate	Breakdown
Analyze	Examine	Observe	Identify	Order
Compare	Test	Detect	Explore	Recognize
Determine				

Curriculum

Topic	Knowledge Required	Skill Required	Blooms Taxonomy	Reference	Practical Test	Written Test
1.0 Heat transfer	Heat is thermal energy inside a	Kontrol the heat surce in a coffee roaster		Wiki:Heat Wiki:Heat_transfer		

	material. Heat always goes from hot to cold materials. Heat can be transferred by different 'types' of heat transfer methods and different methods affects the beans differently			(Jansen 2006; Huschke 2007) p. 27ff (Huschke 2007; Illy & Viani 2005) p. 184ff (Belitz et al. 2009; Jansen 2006) p. 17f (Huschke 2007; Illy & Viani 2005) p. 183f (Clarke & Vitzthum 2001; Toci et al. 2009)		
1.1 Conduction/ Contact	Conduction is when materials touch each other and the heat diffuses from the hotter to the cooler body. Once the heat reaches the surface of the bean it is transferred inside bean by diffusing from the hotter surface to the colder centre which could lead to colour gradient inside bean	Identify burned spots on coffee as marks of aggressive contact heat transfer	L3	(Belitz et al. 2009; Clarke & Vitzthum 2001) p. 98-99 (Illy & Viani 2005) p. 183-184		Multiple choice
1.2 Convection	Convection is thermal energy transfer by means of hot air. It is a special kind of	Analyse a roast profile for the level of 'convection' in different stages of the roast (temperature difference between air and bean) and be	L4			Multiple choice

	contact heat transfer since heat is transferred when the hot air touch/is in contact with the colder bean. The magnitude of temperature difference between then air between the beans and the beans themselves is the magnitude of convection heat transfer at any given stage of the roast	able to adjust this to design a roast profile				
1.3 Radiation	Radiation is electromagnetic rays that naturally is emitted from a heat source and converted into thermal energy in the material it reaches. Radiation is not completely converted into thermal energy at the surface of the bean but there is an absorption gradient in the bean so some heat		L4			Multiple choice

	is added inside the bean without affecting the surface					
2.0 Basic roasting and the roasting cycle	Evaporation takes heat energy to proceed. Pyrolysis creates heat energy. Even if the same coffee is roasted to the same roast colour you can get very different sensorial results if the shape and timing in the roast profile is different. Roasting 'Defects' are worst case deviation from 'nice' profile. Cooling time should practically be as short as possible	Visually and sensorial identify roast defects (fast, scorched, baked, underdeveloped) and know their causes in different places in the roast cycle. Demonstrate the ability to design and execute different roast profiles.		(Baggenstoss et al. 2007; Illy & Viani 2005) p. 179ff + 192 (Illy & Viani 2005; Clarke & Vitzthum 2001) p. 90ff (Clarke & Vitzthum 2001; Jansen 2006) p. 14ff (Belitz et al. 2009; Huschke 2007) p. 20ff (Jansen 2006; Belitz et al. 2009) p. 940-943 Pdf with SCAE roast log	Yes	
2.1 Drying	Moisture leaves the beans during drying and goes from bean to the air between the beans that will become moist and get a higher specific heat capacity.	Visually identify beans at first crack. Combine inlet temperature and initial flame control during a roast profile to avoid: 1. Scorching of beans 2. Underdevelopment of beans		(Illy & Viani 2005; Huschke 2007) p 20ff (Clarke & Vitzthum 2001) p 90ff Wiki:Heat_capacity		Yes

	Temperatures are held low by evaporating water because evaporation is an endothermic process.					
2.2 Roasting	When the coffee is dry the temperature starts to rise quicker. The bean mass goes into pyrolysis where primarily the Maillard process is active. The Maillard reaction and Strecker degradation are the main contributors to CO_2 formation. This CO2 formation becomes an additional source of pressure build up	Demonstrate how to design and apply a flame control strategy around first crack that: 1. Prepares the last part of the roast from first crack 2. Continues until the target colour is achieved		(Jansen 2006; Belitz et al. 2009) p. 94		
2.3 Cooling	In specialty coffee air at room temp	Operate an infrared thermometer to monitor		(Clarke & Vitzthum 2001; Illy & Viani 2005) p. 181		

	is typically sucked through the beans to cool them down. In commodity coffee water quenching is often used which is an extremely rapid method that adds water to the roasting coffee to stop the roasting process quickly. If only a small amount of water is added hardly no water will stay in the coffee but if too much is used it will have a detrimental effect of coffee aroma quality and makes the coffee stale quicker	cooling time. Operate a total moisture meter to record and evaluate the moisture level in roasted bean. Determine if the residual moisture content of roasted beans meets quality parameters that will allow for preservation of aroma and shelf life.		(Jansen 2006; Baggenstoss et al. 2007)		
3.0 Basic properties and changes	Coffee is an organic substance. Green coffee has a high total moisture content: 8-12.5%. Drying green coffee makes	Control the overall roasting process from green to roasted coffee at room temperature		(Huschke 2007; Illy & Viani 2005) p. 179ff (Illy & Viani 2005; Clarke & Vitzthum 2001) p. 90ff (Clarke & Vitzthum 2001; Belitz et al. 2009) p. 938ff Pdf on calculating percentage of change		Distinguish between endo and exothermic reactions

	roasting possible. Pyrolysis is an exothermic anaerobe (does not need oxygen) process that drives a range of different chemical reactions that start around 1st crack.					
3.1 Volume change	Volume increases due to material gets soft when heated combined with water evaporating into steam and pyrolysis creates organic gasses + CO_2. A pressure is build-up by the evaporating water that will later be the primary driver of bean swelling. If this part is to slow (to low flame) the gas would leak before creating a pressure high enough to expand the bean and the coffee will be	Distinguishing different crack intensities and how it depends on energy transfer speed and make changes to the flame profile if the crack is not audible or just not loud enough. Measure and compare volume before and after roasting.		(Jansen 2006) p. 30f (Illy & Viani 2005) p. 180 (Huschke 2007; Clarke & Vitzthum 2001) p. 94		

	'underdeveloped'. If this part is too quick (to high flame) the surface of the bean will be scorched.					
3.2 Weight change	Water in form of vapour and organic material is lost when converted into gas that leaves the material	Measure weight of green and roasted coffee and calculate the difference. Calculate density and calculate density change from green to roasted coffee.		(Illy & Viani 2005; Jansen 2006) p. 34 (Jansen 2006; Clarke & Vitzthum 2001) p. 94 Pdf on calculating percentage of change	Weigh the coffee before and after roasting	Yes
3.3 Colour change	The product of Maillard reaction (melanoidins) is brown and happens quickly after drying is finished slightly above 100° Celsius. Know different industry standards for measuring colour. Some measure wavelength as well as reflection intensity	Use different types of colour measurement equipment and interpret the value in terms of product development, laboratory roasting and regional/cultural differences in roast degree preferences.		(Huschke 2007; Jansen 2006) p. 19 & 28f (Morgan & Brenig-Jones 2012; Huschke 2007) p. 24	Measure the colour on a colour measurement meter. Cupping of same coffee roasted to 4 different degree of darkness. Guess which of 5 samples are taken out when 1st crack stops	
3.4 Sugar change	Caramelization happens at high temperature (closer to 200° Celsius) so the Maillard reaction			(Tisbury 2012; Illy & Viani 2005) p. 193		Yes

	is much more pronounced due to it's lower activation temperature					
3.5 Acidity change	Acids are created very early in the process. The amount of different acids present in coffee changes as the roast degree continues. Most acids are reduced when darker, more typically commercial roast degrees are reached	Sensorial identify and rank acidity level. Use this sensory analysis as an indicator of roast level		(Illy & Viani 2005; Clarke & Vitzthum 2001) p. 18-30 (Clarke & Vitzthum 2001; Jansen 2006) p. 46-67, 57-61		Yes
4.0 Machine construction	Drum roaster. Fluid bed roaster. Batch vs. continuous roaster.	Understand the basic differences in design of commonly found roasters including: • Horizontal drum Roaster • Fluid Bed Roaster • Continuous Roaster Demonstrate an ability to safely experiment with any type of roasters to achieve a desired result based on cupping		(Huschke 2007; Illy & Viani 2005) p. 184ff (Jansen 2006; Huschke 2007) p. 27ff		
4.1 Ventilation	In the roast chamber: the airflow mixes	Explain how to install an exhaust chimney without causing problems such as	L4	Consult the manual for a given roaster for specifications and		Yes

	the hot air into the batch of beans and creates convention heat transfer In the chimney: Avoid resistance (length + bends). Organic build up adds resistance and increases fire risk	resistance that can lead to fire. Demonstrate knowledge of methods that can be used to maintain roaster exhausts such as chimney sweeps.		requirement for installation, maintenance of ventilation system		
4.2 Electricity	Electrical burners possible on small (batch size 12 and less) roasters.. Electrical heating elements are slow but are fine for roasting. Electricity always drives motors and general control circuits.	Plan roast profiles on gas and electrical roasters and understand how to compensate for differences in timing.				
5.0 Workspace management	Green coffee storage (60% relative humidity - 12% bean). Roaster, de-stoner, packing area, one-way valve bags, air filters, Lean management (5S). Production flow.	Plan a work space for: • roasting • packing • maintenance • cleaning • laboratory analysis	L4	(Morgan & Brenig-Jones 2012; Illy & Viani 2005) p. 111 (Clarke & Vitzthum 2001; Jansen 2006) p. 12		Yes

5.1 Tools for roasting	Food grade equipment to support product handling such as: • buckets/bins for green and roasted beans(buffers). • shovel/scoops for Other equipment to support the roasting process includes: • Logging sheets/software. • Timer • Temperature probes. • Hand held thermometer (infrared). • Moisture, density meters • roast colour meters • Scales It is important to organize the work place so that you can store green	Understand that coffee is a food product Explain the use of various supporting tools and equipment and their application to coffee roasting	L3	(Illy & Viani 2005; Huschke 2007) p. 6-7 + 65		

	and roasted coffee in safe containers with full batch traceability. Ergonomic tools are available for handling coffee. A quality control system either manual pen-and-paper or logging software is important for both food safety and quality. Basic lab equipment to monitor quality of green and roasted coffee supports roasted product safety, quality and consistency over time					
5.2 Cleaning, Maintenance & Troubleshooting	Cleaning and maintenance schedule.		L3	Should be described in the machine's instructions manual (Jansen 2006; Morgan & Brenig-Jones 2012) p. 151 (Belitz et al. 2009; Tisbury 2012)		
5.3 Ventilations	Highly flammable	Plan the ventilation aspect of				

	dry organic material builds up inside the ventilation system. Unfortunate consequences are: resistance to airflow if the tubes are clogged and fire risk! Depending of the brand of roaster and ventilation system cleaning of the inside of the pipes should be done every 2 to 6 months. Install clean out doors at appropriate areas of the chimney where build-up is forming so that it is easy to clean	a coffee roaster installation with respect to quality of the roasting process, variation and fire prevention and extinguishing.				
5.31 Chaff collector	The silver skin of the green beans fall of during roasting because the coffee beans expand and open up. This silver skin is called chaff in roasted coffee and is collected in	Plan fire prevention and extinguishing Be aware that chaff collectors are a very typical place for fires to start	L3			

	below a cyclone made for the purpose called 'Chaff collector'.					
5.32 Exhaust air cleaning	A number of methods are available in the marketplace for cleaning exhaust air. These include: • Afterburner • electro static • ceramic beds • ozone • UV light • water curtain • recycling exhaust air into burner	Plan appropriate exhaust cleaning to reduce needed frequency for chimney sweeping, reduced fire risk and reduced risk for neighbour complaint due to coffee roast odour in the neighbourhood.				
5.4 Cooling tray	Coffee should be hand warm max 5 minutes after roasting. Cooling tray screen should be cleaned regularly to keep cooling time down. Expect season variation on cooling time as the surrounding air is involved in the cooling process.	Obtain appropriate tool and maintenance plan for keeping the cooling tray holes clean to avoid reduced airflow in cooling tray due to clogged holes. Install inexpensive extra fans can speed up the cooling process by blowing onto the cooling coffee.				

Keywords

- 1st and 2nd crack.
- 8-12% moisture in green beans
- After burner
- Air (drum environment) temperature probe
- Airflow, chimney
- Bean temperature probe
- Buildup in chimney - Fire risk!
- Chaff. Chaff collector
- Charge/Drop temperature
- Conduction/contact/diffusion, radiation and convection heat transfer
- Cooling phase / cooling time
- Cooling tray
- Dark roast high bitterness low in acidity. Opposite relationship for light roasts
- Destoner
- Development time (from 1st crack to end of roast)
- Dropping temperature
- Drum rotation
- Drying phase
- Electrostatic filter
- End temperature
- Endotermic
- Evaporation is endothermic
- Exhaust filtration
- Exothermic
- Fire extinguisher (water vs. CO2)
- Fire in the chimney
- Fire in the drum
- Fluid bed roaster
- Grade. Screen. Bean size variation.
- Heat vs. temperature
- Lean production
- Maillard reaction
- Moist vs. dry period
- Moisture meter
- Myco toxins.
- Natural processiong
- Organic acids creation and degradation
- Percentage change
- Pre-blending vs. post-blending
- Processing
- Profile logging software
- Pupled Natural
- Pyrolysis
- Quenching
- Rate of Rise
- Reducing points
- 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 cycle
- Roasting drum
- Roasting process
- Silver skin.
- Slow roast vs. flash roast
- Storage conditions 12% bean moisture vs 60% RH in storage room
- Sweet spot.
- Turning point (minimum profile temperature)
- Ventilation
- Washed coffee

Literature

- Belitz, H.D., Grosch, W. & Schieberle, P., 2009. *Food Chemistry*, Springer
- Clarke, R. & Vitzthum, O.G., 2001. *Coffee*, Wiley-Blackwell
- George, M.L. et al., 2005. The Lean Six Sigma pocket toolbook, McGraw Hill
- Illy, A. & Viani, R., 2005. *Espresso Coffee*
- Huschke, R., 2007. *Industrial Coffee Refinement*
- Jansen, G.A., 2006. *Coffee Roasting*
- Morgan, J. & Brenig-Jones, M., 2012. *Lean Six Sigma For Dummies*, John Wiley & Sons
- Enclosed compedium provided på your trainer on Percentage chage calculations, Green coffee harvest schedule and profile analysis
- (Bertrand et al. 2012; Huschke 2007)

(Illy & Viani 2005; Jansen 2006)
(Illy & Viani 2005; Morgan & Brenig-Jones 2012)

Equipment required

- One coffee roaster (size 500g – 12kg) per 2-3 students. Specification to include:
    - Bean probe installed
    - Exhaust temperature gauge installed
    - Variable burner (gas/electric) integrated into design
    - Profiling software is optional but not necessary
- Natural daylight roasting light with CRI of 96 and K rating of 6500K
- Moisture meter for measuring moisture level in green beans and roasted coffee
- Density meter for green and roasted coffee
- Roast colour measure meter

Professional

Pre-requisites for participating in the certification process:

- Roasting Intermediate
- Sensory Intermediate
- Green Coffee Intermediate

Level 5 & 6: Synthesis – Create a new point of view					
Compose	Plan	Propose	Design	Assemble	Create
Organize	Manage	Construct	Set-Up	Prepare	Write
Identify	Integrate	Produce	Theorize	Build	Systematize
Formulate					

Level 6: Evaluation – Justify a position					
Judge	Select	Verify	Choose	Score	Appraise
Review	Measure	Assess	Compute	Decide	Revise
Evaluate	Value	Test	Categorize	Estimate	

Curriculum

Topic	Knowledge Required	Skill Required	Blooms Taxonomy	Reference	Practical Test	Written Test
1.0 Green coffee	Be able to identify parts of the anatomy of the coffee cherry. Skin, pulp, parchment, pergamino, silverskin, bean. Physical attributes of	Analyse green coffee with respect to bean size, density and total moisture level and design roast profiles according to the results		(Illy & Viani 2005; Clarke & Vitzthum 2001) p. 938 (Gonzalez-Rios & Suarez-Quiroz 2007b; Illy & Viani 2005) p. 87-102		

	green coffee including density, size, shape and moisture level vary from lot to lot					
1.1 Chemistry of green coffee				(Gonzalez-Rios & Suarez-Quiroz 2007a; Jansen 2006) page 8-11. (Illy & Viani 2005; Belitz et al. 2009) page 941, table 21.2		
1.2 Physical properties of green beans (moisture, density, size)	Moisture level depends on: • proper drying in the producing country • and in correct transportation and storage conditions. 8-12.5% moisture is normal for specialty coffee although around 10- 12% is the ideal. Higher than 12% and there is risk for mould formation. Lower than 8% and the tissue starts to get damaged and important substances can evaporate even at room temperature. Coffee is graded by	Be able to measure moisture, density and size of beans and use the information to design roast profiles		(Illy & Viani 2005; Jansen 2006) page 8-11. (Guenther et al. 2007; Belitz et al. 2009) page 941, table 21.2 (Suarez-Quiroz & Gonzalez-Rios 2004; Bertrand et al. 2012) (Illy & Viani 2005) p. 149-150 Bean size: (Clarke & Vitzthum 2001; Illy & Viani 2005) p. 103, 135-136		

	size and shape and this impacts on roasting strategies. Density in green coffee is strongly correlated with the altitude of a coffee growing area and also varies by species and variety					
1.3 Chemical properties of different processing methods	Small sugars are washed out with the washed process so it appears more acidic and with a lower body. More small sugars are available in natural coffee so it appears sweeter, with higher body, more bitter and darker as the Maillard process has more reducing sugars to progress at a given bean temperature	Understand and adapt when different processing methods behaves differently in the roasting process. Chose specific processing methods for different products depending on customer preferences for the product.		(Jansen 2006; Illy & Viani 2005) p. 99 (Huschke 2007; Gonzalez-Rios & Suarez-Quiroz 2007b) (Clarke & Vitzthum 2001; Gonzalez-Rios & Suarez-Quiroz 2007a)		
1.4 Health related issues of green coffee. Ochratoxins, Achrylamide	Ochratoxins are cancer risk factors developed by fungi during processing in the production countries. The concentration of	Demonstrate the ability to discuss health related topics relating to coffee roasting with customers		Ochratoxins: (Toci et al. 2009; Illy & Viani 2005) p. 209 Achrylamide: (Huschke 2007; Illy & Viani 2005) p. 368f Plenty info on the internet if these concepts are googled so the following scientific articles are not necessary to		

	Ochratoxins will be reduced yet not eliminated during the roasting process. The better grade of green coffee beans will contain less Ochratoxins. Achrylamide is another cancer risk factor developed during the roasting process yet also degraded by time so slow roasted coffee contains almost noting whereas flash roasted coffee contains a considerable amount	as well as authorities. Recognise that in many countries it is a normal requirement or part of due diligence to get coffee analysed for certain residues. Explain that this documentation may be needed either starting a roastery (the authorities) or when exporting coffee or selling to large institutions		read: (Huschke 2007; Guenther et al. 2007) (Clarke & Vitzthum 2001; Suarez-Quiroz & Gonzalez-Rios 2004)		
2. Physics of coffee roasting				(Illy & Viani 2005) p. 179ff + 192 (Clarke & Vitzthum 2001) p. 90ff (Illy & Viani 2005; Jansen 2006) p. 14ff (Jansen 2006; Huschke 2007) p. 20ff		
2.1 Heat transfer	Building on the knowledge from Intermediate on Contact, convection and radiation in this section there is a bigger focus on the dynamics of heat	Be able to analyse and explain any given roasting technology in terms of ascientific understanding		(Rivera et al. 2011; Clarke & Vitzthum 2001) page 90-100 (Meste et al. 2002; Toci et al. 2009) (Illy & Viani 2005; Huschke 2007) page 18-24		

	transfer	of heat transfer applied by that technology				
2.11 Heat transfer between materials (hot to cold)	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	Explain visualize and explain 'diffusion' of heat		Wiki:Heat_transfer		
2.111 Transfer of heat from roaster to bean	As consequence of 2.11 conductive heat will diffuse from the heating element of the roaster and onto the bean surface	Analyse 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. Apply this understanding to practical roasting techniques		(Jansen 2006; Huschke 2007) p. 27-39 (Clarke & Vitzthum 2001) p. 101-104 (Clarke & Vitzthum 2001; Illy & Viani 2005) p. 184-187 Wiki: Diffusion		
2.112 Transfer of	When the conductive heat reaches the	Understand how to avoid		(Jansen 2006; Clarke & Vitzthum 2001) p. 98-99		

heat from bean surface to bean centre	surface of the bean it is up to the conductivity coefficient to diffuse the heat towards the centre 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	extreme temperature differences because an unfortunate roast degree gradient will be formed in the beans Apply this understanding in a practical roasting examination		(Clarke & Vitzthum 2001; Illy & Viani 2005) p. 183-184		
2.12 Heat capacity of dry vs. moist air.	The heat capacity of moist air is higher than dry air so moist air is more efficient at conduction heat from air to beans. This is a technical focus of some roasting technologies.	Display an ability to control moisture level by controlling airflow speed or understand an important difference with roaster technology where exhaust air is recalculated into the roasting chamber		Wiki:Moisture Wiki:Heat_capacity		
2.2 Physical changes of beans						
2.21 Glass transition	Green beans at room temperature are			(Huschke 2007; Jansen 2006) p. 32-34 (Belitz et al. 2009; Rivera et al. 2011)		

temperature	'glass like' in their structural appearance but polymeric material like green beans will become 'leathery' or malleable 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			(Clarke & Vitzthum 2001; Meste et al. 2002) Wiki:Glass_transition		
2.22 Roast gasses.	First water (8-12.5% moisture of the green bean) will turn into vapour when heated. Later the Maillard reaction, Strecker degradation, Caramelization and decarboxylation of organic acids will create organic roast gasses like CO_2 and other small organic gasses			(Hertz-Schünemann, Dorfner, et al. 2013a) (Hertz-Schünemann, Streibel, et al. 2013b)		
2.23 Expansion (spongious).	The 'leathery' material with developing gasses (vapour, CO_2 and organic gasses) will	Demonstrate an ability to control a roast so that oils do not migrate to the		(Belitz et al. 2009; Illy & Viani 2005) p. 182 (McGee 2004; Jansen 2006) p. 23-26, 30-44 (Illy & Viani 2005; Clarke & Vitzthum		

	expand and the dense materiel will become a spongious structure with many small gas pockets and channels. Oils can travel through these channels Roast profiles which are not managed correctly can lead to a migration of oils to the surface. These oils will become rancid when O_2 from the air reaches the oils	surface of the roasted beans during exercises *(Note: In this exam no roasts progress beyond second crack)*		2001) p. 94		
2.24 Loss of water	Water will leave the material in an opposite direction of the heat going in. This is a prerequisite for the pyrolysis to take place. This is the major contributor to roast loss			(Clarke & Vitzthum 2001) p. 93-94 (Jansen 2006) p. 33-34		
2.25 Physical reason for increased	The darker the roast the more spongious the bean material with bigger internal channels that the	Apply knowledge of roast bean development to basic espresso	L4	(Clarke & Vitzthum 2001) p. 94-95 (Jansen 2006; Huschke 2007) p. 23		

solubility of dark roasted coffee	water can run through and harvest the soluble molecules. The less spongious and smaller cannels the less able the water is to harvest the soluble molecules in the more dense material	extraction parameters for different roast heights. Specifically know that when talking to clients that extraction methodology will be different because it is harder to extract from a lighter roasted coffee than dark roasted coffee where all other parameters remain equal				
3.0 Chemistry of coffee roasting				(Jansen 2006; Belitz et al. 2009) page 940-941 (Clarke & Vitzthum 2001) p. 13-14, 79, 82-85, 90-100 (Illy & Viani 2005) p. 194 Fig. 4.11		
3.1 Colour	The brown colour of coffee is primarily caused by the Maillard reaction and to a lesser extends by Caramelization. Since there is such an intimate relationship between the aroma chemistry	Demonstrate an ability to use roast colour measurement equipment and interpret the result for use in general profile-product development.		(Illy & Viani 2005; Belitz et al. 2009) p. 940, 284 (Jansen 2006; McGee 2004) p 779 (Clarke & Vitzthum 2001; Illy & Viani 2005) p. 193 (Clarke & Vitzthum 2001) p.13 (Belitz et al. 2009; Jansen 2006) p. 64 Wiki: Melanoidin		

	and colour, colour is an important macroscopic indicator followed closely by the roast master during roasting.	Explain that this equipment is a useful tool for analysis of variation tolerance for at given product during normal production processes				
3.2 Chemical reason for increased solubility of dark roasted coffee	Hydrolysis of carbohydrate makes the big pollysacharides 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	Specifically know that when talking to clients that extraction methodology will be different because it is harder to extract from a lighter roasted coffee than dark roasted coffee where all other parameters remain equal		Wiki:Hydrolysis		
3.4 Acidity		Use the sensory level of acidity to evaluate roast degree. Separate quality of acidity from intensity of acidity.		(Clarke & Vitzthum 2001) p. 18-30 + 59 (Bhumiratana et al. 2011; Jansen 2006) p. 46-67, 52-53, 57-61 (Illy & Viani 2005) p. 194 Fig 4.11		

		Analyse the quality of acidity to determine optimum roast profile.				
3.4.1 Acids from green coffee	Some acids are already present in green coffee such as Chlorogenic, citric and malic acids	Understand the signs of a fast roast and demonstrate how to adjust a roast when it is too fast ie. the chlorogenic acids are not degraded enough		(Illy & Viani 2005; Jansen 2006) p. 52-53 (Illy & Viani 2005; Clarke & Vitzthum 2001) p. 158 (Parat-Wilhelms et al. 2005; Illy & Viani 2005) p. 195-196		
3.4.2 Acids developed during roasting	Some acidic compounds are derivatives of carbohydrate (acetic, formic, lactic, clycolic...) and are developed very early in the roasting process and later degraded as the coffee becomes darker around and after 1st crack.			(Morgan & Brenig-Jones 2012; Jansen 2006)p. 58 fig 33 (George et al. 2005; Clarke & Vitzthum 2001) p. 22-25 (Illy & Viani 2005) p. 196-197		
3.5 Bitterness	Bitterness is primarily developed by the products of the Maillard reaction so a darker roast leads to higher	Demonstrate an ability to control the level of bitterness by controlling end colour whilst	L4	Bitterness (Morgan & Brenig-Jones 2012; Clarke & Vitzthum 2001) p. 53		

	bitterness	still retaining other positive sensorial attributes in a coffee				
3.6 Aroma of roasted coffee	On a crude level Flavour of coffee changes with roast degree but on a more subtle level even the same colour 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'	Demonstrate skills in expressing different characteristics of the same coffee at the same roast colour but with different roast profiles	L5	(George et al. 2005; Belitz et al. 2009) page 942-948 (Tisbury 2013; Clarke & Vitzthum 2001) p. 74-79 (Tisbury 2013; Bhumiratana et al. 2011)		Recognize: -Baked, scorched, fast, underdeveloped
3.7 Roast speed	The speed of the roasting process determines the kind of chemical reactions happening			(Toci et al. 2009) (Schenker et al. 2002) (Bicho et al. 2013)		
4.0 Sensory						
4.1 Taste and smell	Understand how tasting (gustation) and smelling (olfaction) is interconnected and	Understand and explain the importance and reasons behind the 'slurping'		(Tisbury 2012; Illy & Viani 2005) p. 316 - 351		

	the related anatomy	technique when cupping to colleagues and customers				
4.2 Evaluation methodology	In-out cupping. Triangulation.	Show how to apply this sensory methodology when making decisions. For example when developing new roast profile or new products		Intermediate sensory in the SCAE Certification Diploma System		
5 Business	Basic understanding of the elements of a business. The business model canvas is an intuitive and easy approach that is suitable for people without a mercantile background. The Lean KANO analysis (voice of the customer methodology)	Show an ability to visualize and understand a given roasting business and make better strategic decisions on which focus is the better when developing a given business (business model innovation). The model is a tool to better understand business development and a tool for communicating		Business model canvas. Book, canvas and videos available for free on website: www.businessmodelgeneration.com Wiki:Kano_model		

		any given business. Be aware that this is an advantage when investors or a bank is approached.				
5.1 Price calculations	The cost related to production of coffee including how to manage roast loss in price calculations	Explain how to manage cost and calculate profit for a given product or for a given quotation to a specific customer. The price calculation must still be profitable for the roasting business in the working example				
5.2 Product parameters	Central parameters for NPD (new product development) Linking roasting product development with sensory aspects of NPD	Have an ability to design a product with respect to specific demand from a specific customer segment Show how to select appropriate				

		tests to test a product and create a robust roasting specification that can align with a sensory specification				
5.21 Bean genetics, bean terroir	(1)Arabica/Robusta (2)Large Beaned Arabica vs std screens 15/16/17/18 (3) Pea Berry (4)High grown Vs low grown (5) Decaff	See 1.2				
5.24 Pre/post blend	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 compromise' but saves the extra production step. The right choice is the best cost-benefit depending on needs of i) the customer and ii) the roasting operation	Recognise that there are different strategies for creating blended products Relate these strategies to: • Equipment fit out • site layout • roast profile development • product costing				

5.25 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			(Morgan & Brenig-Jones 2012; Illy & Viani 2005) p. 202 (Illy & Viani 2005; Parat-Wilhelms et al. 2005)		
6 Roastery management	Basic knowledge of Lean production	Ability to design and operate a production that is designed around the preferences and demans 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)		
6.1 Batch size requirements related to yearly turnover calculations		Calculate the size of the roaster needed for a specific business scenario Be able to apply knowledge of	L4/L5			

		maintenance scheduling to this capacity planning				
6.2 Environment. Pollution. Neighbour complaints. Regulation (EU, local authorities). Filter options.	Afterburner, electro static 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 (March/April 2004; pg. 33) Stack Overflow—A no-loss stack can make your roastery more efficient (and keep your neighbours happy) (Sept/Oct 2009; pg. 46) The Brave World of Energy-Efficient Roasting—A generation of technologies saves energy and money (July/Aug. 2008; pg. 20)		
6.3 Work space design	Draw a production flow. PEMME, SIPOC, KANBAN	Design a workplace using basic lean production approaches		(Clarke & Vitzthum 2001; Morgan & Brenig-Jones 2012) (Belitz et al. 2009; George et al. 2005)		
6.4 Work space	Lean 5s methodology to	Ability to tidy up the workplace		(Clarke & Vitzthum 2001; Tisbury 2013) Wiki:Fire_triangle Wiki:Fire_extinguisher		

management	tide up the workplace. Fire prevention and extinguishing	systematically. Prevent and fight fires		(George et al. 2005; Tisbury 2013)		
6.5 Purchase planning	Knowledge of seasonality of coffee availability and lead times in the supply chain Know that this applies for all coffees and planning in advance is necessary when specific named farms and traceability are built into product specifications	Demonstrate knowledge of how to plan ahead to secure amounts of green coffee needed from harvest to harvest to ensure continuity of supply		Wintgens (2009)		
6.6 Online and offline measurement equipment. Profile logging software. Handling measurement variation.		Be able to discuss the merits of profiling software available in the marketplace Be able to discuss the differences between manual data logging and automated systems		www.coffee-mind.com/variation-analysis/ Profiling software manufacturers specifications		
6.7		Understand		(Jansen 2006; Tisbury 2012)		

Scheduled maintenance		maintenance necessary on different roasting systems. Explain how to build maintenance into workflow planning in a roastery		(Clarke & Vitzthum 2001; Morgan & Brenig-Jones 2012) p. 150 Manufacturers specifications		

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
- Endotermic
- 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
- Myco toxins.
- Natural processiong
- Organic acids creation and degradation
- PEMME
- Physical properties
- Pre-blending vs. post-blending
- Processing
- Profile logging software
- Pupled Natural
- Purchase planning
- Pyrolysis
- Quenching
- Rate of Rise
- 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
- Sweet spot.
- 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

Enclosed compedium provided på your trainer on Percentage chage calculations, Green coffee harvest schedule and profile analysis

Baggenstoss, J. et al., 2007. Influence of Water Quench Cooling on Degassing and Aroma Stability of Roasted Coffee. *Journal of Agricultural and Food Chemistry*, 55(16), pp.6685–6691.

Belitz, H.D., Grosch, W. & Schieberle, P., 2009. *Food Chemistry*, Springer.

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*.

Bhumiratana, N., Adhikari, K. & Chambers, E., IV, 2011. Evolution of sensory aroma attributes from coffee beans to brewed coffee. *LWT - Food Science and Technology*, 44(10), pp.2185–2192.

Bicho, N.C. et al., 2013. Impact of Roasting Time on the Sensory Profile of Arabica and Robusta Coffee. *Ecology of Food and Nutrition*, 52(2), pp.163–177.

Clarke, R. & Vitzthum, O.G., 2001. *Coffee*, Wiley-Blackwell.

George, M.L. et al., 2005. The Lean Six Sigma pocket toolbook: A quick reference guide to nearly 100 tools for improving process quality, speed, and complexity. McGraw Hill

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 ...*.

Guenther, H. et al., 2007. Acrylamide in coffee: Review of progress in analysis, formation and level reduction. *Food Additives and Contaminants*, 24, pp.60–70.

Hertz-Schünemann, R., Dorfner, R., et al., 2013a. On-line process monitoring of coffee roasting by resonant laser ionisation time-of-flight mass spectrometry: bridging the gap from industrial batch roasting to flavour formation inside an individual coffee bean. *Journal of Mass Spectrometry*, 48(12), pp.1253–1265.

Hertz-Schünemann, R., Streibel, T., et al., 2013b. Looking into individual coffee beans during the roasting process: direct micro-probe sampling on-line photo-ionisation mass spectrometric analysis of coffee roasting gases. *Analytical and Bioanalytical Chemistry*, 405(22), pp.7083–7096.

Huschke, R., 2007. *Industrial Coffee Refinement*,

Illy, A. & Viani, R., 2005. *Espresso Coffee*,

Jansen, G.A., 2006. *Coffee Roasting*,

McGee, H., 2004. On food and coking. The science and lore of the kitchen. null, p.null.

Meste, M.L. et al., 2002. Glass Transition and Food Technology: A Critical Appraisal. *Journal of Food Science*, 67(7), pp.2444–2458.

Morgan, J. & Brenig-Jones, M., 2012. *Lean Six Sigma For Dummies*, John Wiley & Sons.

Parat-Wilhelms, M. et al., 2005. Influence of defined milk products on the flavour of white coffee beverages using static headspace gas chromatography–mass spectrometry/olfactometry and sensory analysis. *European Food Research and Technology*, 221(3-4), pp.265–273–273.

Rivera, W. et al., 2011. Effect of the roasting process on glass transition and phase transition of Colombian Arabic coffee beans. *Procedia Food Science*, 1(0), pp.385–390.

Schenker, S. et al., 2002. Impact of Roasting Conditions on the Formation of Aroma Compounds in Coffee Beans. *Journal of Food Science*, 67(1), pp.60–66.

Suarez-Quiroz, M. & Gonzalez-Rios, O., 2004. Study of ochratoxin A-producing strains in coffee processing. *... Journal of Food ...*.

Tisbury, J., 2013. *Your 60 Minute Lean Business - 5S Implementation Guide*, lulu.com.

Tisbury, J., 2012. *Your 60 Minute Lean Business - TPM*, lulu.com.

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 ...*.

Equipment required

- One coffee roaster (size 500g – 12kg) per 2-3 students. Specification to include:
  - Bean probe installed
  - Exhaust temperature gauge installed
  - Variable burner (gas/electric) integrated into design
  - Profiling software is recommended but not necessary
- Natural daylight roasting light with CRI of 96 and K rating of 6500K
- Moisture meter for measuring moisture level in green beans and roasted coffee
- Density meter for green and roasted coffee
- Roast colour measure meter