Post-harvest Processing and Quality Assurance for Speciality/Organic Coffee Products

Alastair Hicks
FAO Regional Office for Asia and the Pacific
Bangkok, Thailand

Abstract

This paper covers the post-harvest aspects, processing and quality assurance for speciality/organic coffee products. It starts with the origins of coffee, what aspects provide inherent quality, and diseases that deter quality. It then touches on coffee harvesting, the timing for harvesting and development of fruit color. It discusses picking systems, both manual and mechanical and their effects on quality.

It discusses coffee processing, both the dry and wet methods. The dry method involves sorting, cleaning and winnowing, flotation sun-drying and mechanical drying. The wet method, yielding 'washed' or 'mild' coffee, involves pulp removal, into flesh, skin and beans. Then separation into mature and immature beans, followed by fermentation, washing and drying. The effects of over and under-drying on quality are discussed.

Hulling to remove dry flesh and parchment, then optional polishing is mentioned. The importance of grading, sorting and storage, as well as bagging and export, are covered. Further processing includes blending, roasting and cooling. The pyrolysis and color development effects of roasting by drum or hot air roasting; then cooling by water or air methods are discussed. Critical storage issues are described, followed by grinding and brewing and further quality aspects of coffee.

Keywords: *Speciality coffee, organic coffee, harvesting, picking systems, post-harvest, processing, cleaning, winnowing, flotation, fermentation, hulling, polishing, blending, roasting, cooling, pyrolysis, grinding, brewing.*

Introduction

Coffee growing and drinking spread around the world starting in the Horn of Africa, in Ethiopia, where the coffee tree probably originated in the province of Kaffa. The succulent outer berry flesh was eaten by slaves taken from present day Sudan into Yemen and Arabia, through the great port of its day, Mocha, now synonymous with coffee. Coffee was certainly being cultivated in Yemen by the 15th century. The Dutch obtained some live coffee trees in 1616, and brought these back to Holland where they were grown in greenhouses. In Asia, the Dutch were also growing coffee in Malabar in India, and in 1699 took some to present day Indonesia, now the fourth largest exporter of coffee in the world.

In Europe, Venetian traders first brought coffee to Europe in 1615, opening the first coffeehouse in 1683, with the most famous, Caffe Florian in Piazza San Marco, opening in 1720. It is still open for business today. The largest insurance market in the world, Lloyd's of London, began life as a coffee house started in 1688 by Edward Lloyd.

In America, the first reference to coffee being consumed in North America is from 1668 and, soon after, coffeehouses were established in New York, Philadelphia, Boston and other cities. The Boston Tea Party of 1773 was actually planned in a coffeehouse, the Green Dragon.

It was the Dutch again who first started the spread of the coffee plant in Central and South America, where today it reigns supreme as the main continental cash crop. By 1825,

South and Central America were on track towards their coffee destiny.

The importance of coffee in the world economy is clear because it is one of the most valuable primary products in world trade. Its cultivation, processing, trading, transportation and marketing provide employment for millions of people worldwide. This new found 'coffee culture' has spread to the rest of the world.

The Coffee Plant

Coffee belongs to the botanical family Rubiaceae, which has some 500 genera and over 6,000 species. There are probably at least 25 major species, all indigenous to tropical Africa and certain islands in the Indian Ocean, notably Madagascar. All species of *Coffea* are woody, but they range from small shrubs to large trees over 10 m tall; the leaves can be yellowish, dark green, bronze or tinged with purple.

The two most important species of coffee economically are *C. arabica* (arabica coffee) - which accounts for over 70% of world production - and *C. canephora* (robusta coffee). Two other species grown on a smaller scale are *C. liberica* (liberica coffee) and *C. dewevrei* (excelsa coffee).

Coffee is a tropical plant that grows between the latitudes of 25°N and 25°S but requires very specific environmental conditions for commercial cultivation. Temperature, rainfall, sunlight, wind, and soils are all important, but requirements vary according to the varieties grown.

Ideal average temperatures range between 15 - 24°C for arabica and 24 - 30°C for robusta at altitudes around 2,000 m. In general, coffee needs an annual rainfall of 1,500 to 3,000 mm, arabica coffee needing less than other species. The pattern of rainy and dry periods is important for growth, budding, and flowering.

Whereas robusta can be grown between sea level and about 800 m, arabica does best at higher altitudes but less than 2,000 m, because of frost damage. Arabica can be grown at lower levels further from the equator, until limited by frost. All coffee needs good drainage, but it can grow on soils of different depths, pH, and mineral content, given suitable applications of fertilizer.

Coffee Inherent Properties

The various physical characteristics of coffee such as weight, volume, size, shape, color, solubility, moisture content, texture, etc. in its different forms, play an important part in the way it is treated and in the design of equipment to process it. Coffee is harvested when its red color indicates that the appropriate maturity has been reached. Later on, color is a guide to the degree of roast of the beans.

Flotation or winnowing is used to physically separate defective berries on the basis of density and to remove twigs and stones.

Size, shape, and color are used to grade beans after they have been dried to an even moisture content for storage. Because coffee beans have a porous, spongy texture, they can easily be contaminated by microscopic fungi, giving rise to off-flavors, or can pick up strong odors, and deteriorate rapidly if allowed to become too moist. Some typical physical properties of coffee are listed below:

Bulk density	**(lb/cu ft)**
Red berry	50
Wet green beans	50
Dry beans or pergamino	25
Light roast beans	23
Dark roast beans	18
Coarse ground coffee	19
Fine ground coffee	25

Weight Yields

Wet process: 550 lb fresh berry yields 225lb wet pergamino, and 120 lb dry pergamino, in turn, yields 100 lb dry polished coffee.

Dry process: 550 lb fresh berry yields 200 lb dry berry and, in turn, yields l00 lb dry polished coffee.

Roasting causes on average a 16% loss in weight and an increase in bean volume of 50-80%.

Moisture

Fresh berry: 50%
Green bean: 8-13%
Roast coffee: < 7% (depending on humidity)
Soluble powder: < 4%.

Coffee Maturity

Coffee plants reach maturity after three to four years, then they bear fruit in lines or clusters along their branches. The fruit turns red or 'berry-like' when it is ready to be harvested.. Depending on the type of coffee plant, the 'berry' takes from 6 to 11 months to ripen.

Many pests and diseases can affect the plant or its fruits, including leaf or seed fungal diseases; nematode invasion of roots; insect attack of the leaf or 'berry'. Integrated pest management is vital to yield and product quality.

Coffee Harvesting

When ready to be harvested, the fruit on the coffee tree turns a dark berry color -- this is about 8 to 9 months after flowering has taken place. The time of harvest varies but usually there is only one harvest per year. North of the equator, the harvest takes place between September and March. South of the equator, the harvest takes place in April and May, even until August. In some countries where the division between the wet and dry seasons is not clear (e.g. Kenya and Colombia) there may be two flowerings a year, giving a main and secondary crop. Countries on the equator are able to harvest fruit all year round.

Ripe fruits can be plucked by hand, or picked with small rakes, or else with poles: the first two systems are used where low-cost labor is available, and they are more selective; the pole system is quicker, but less careful; and needs further berry-cleaning.

Where the terrain allows it, harvesting can today be effected with special automatic machines - a single machine can do the work of 100 men, gathering 95% of the fruits in one go. The machine uses a series of multiple vibrating rods which, when introduced into the canopy by a special moving machines, causes the ripe berries to fall. Using a machine is cheaper but not only the ripe berries are picked - if there are green berries mixed in then the coffee will taste bitter; if there are over-ripe berries then the final product has an acrid taste.

Most coffee, however, is picked by hand by either selective or strip picking. Selective picking involves the pickers making several passes among the coffee trees at intervals of about 10 days to ensure that only the fully ripe beans are taken. Strip picking means the entire crop is picked in just one pass. Selective picking is more expensive, but it produces the best results, and is used for arabica beans. On an average coffee farm, the pickers may gather between 50 and 100 kg of coffee berries per day. Of this total weight only 20% is coffee bean.

Coffee Processing

Coffee processing must begin immediately after the fruit is harvested, to prevent the pulp from fermenting and deteriorating. The coffee beans can be prepared for roasting in one of two ways:

The Dry Method

This is the oldest, simplest, and cheapest method. It produces 'natural' coffees and is adopted mostly in Brazil and Western Africa. First, the harvested berries are sorted and cleaned to separate the unripe, overripe, and damaged berries, and to remove dirt, soil, twigs, and leaves. This is done by hand winnowing, using a large sieve. Unwanted berries or other materials not winnowed away are picked out from the top of the sieve. The ripe berries can also be separated by flotation in washing channels close to the drying areas.

The harvested berries are then spread out, in the sun on large concrete or brick patios or on matting. They are raked regularly to avoid fermentation and to expose them evenly to the sun's rays. If it rains or the temperature falls, the berries are covered for protection. After two or three days, coffee berries are put in drying rooms, where they are dried by the heat of a burner at 45-60^{o}C. It can take up to four weeks for moisture content of each berry to reach an optimum 12% at their centers when the outer shell will become dark brown and brittle. The berries can then be stored in large silos where they stabilize their moisture content.

The drying operation is the most important stage of the process, since it affects the final quality of the green coffee. Coffee that has been overdried will become brittle and produce too many broken beans during hulling (broken

beans are considered to be defective beans). Coffee that has not been dried sufficiently will be too moist and prone to rapid deterioration caused by the attack of fungi and bacteria.

The Wet Method

It is another method of preparation. It produces so-called 'washed' or 'mild' coffees and is adopted in Central America, Mexico, Colombia, Kenya, and Tanzania. This involves more capital outlay, more water, and more care than the dry method. It does help to preserve the intrinsic qualities of the bean better, producing a green coffee which is homogeneous and has few defective beans. The coffee produced by this method is regarded as being of better quality and commands higher prices. The main difference between the wet and dry methods is that the wet method removes the pulp from the bean within 12-24 hrs of harvesting instead of allowing the berries to air dry.

Pulping: The beans are separated from the skin and pulp by using a pulping machine that squeezes the berries between fixed and moving surfaces. The flesh and the skin of the fruit are left on one side and the beans, enclosed in their parchment covering, on the other. The clearance between the surfaces is adjusted to avoid damage to the beans. The lighter, immature beans are then separated from the heavier, mature beans through specially designed washing channels or by shaking the beans through a strainer into a tank of water.

Fermentation: The beans are then stored in fermentation tanks for up to two days during which time the slimy layer of the berry is separated from its parchment-like covering, by natural enzymes. The length of the fermentation process is based on the condition of the beans and the climate's condition. When the altitude is low, the fermentation time is short. At higher altitudes, the fermentation can take up to 48 hrs.

Washing: The coffee is then washed in quantities of water (about 100 L for 10 kg of coffee). It must then be dried to about 10% moisture. This can be done by solar or by mechanical. After 7 to 15 days the beans are known as parchment coffee and ideally remain in this form until immediately before export.

Coffee Hulling

The outer coverings of the bean (dried coverings of the original berries in dry process, hull and dried parchment layer in wet process) are then removed. This process is known as 'hulling' and is usually done just before the coffee beans are sold for exporting.

Coffee Polishing

Polishing of beans is an optional process. The polishing process is used to remove the outer filament and any of the parchment like husk that remains on the bean after hulling. While polished beans are considered superior to unpolished ones, in reality there is little difference between the two.

Coffee Grading

Although coffee beans are of fairly uniform size and proportion, they are graded first by size and then by density. (The elephant bean is the only exception.) Beans are sized into different grades by running the beans through sieves and screens with specifically-sized holes.

Coffee Sorting

They are then sorted by using an air-jet to separate heavy and light beans. Over-fermented or unhulled beans are now removed. This is usually done by hand as the beans move along a conveyor-belt. It can also be done by electronic sorting which can remove beans known as 'stinkers' that are defective but cannot be distinguished by eye. Flawed or discolored beans are removed before bagging into sacks marked with grade, plantation, and country of origin, ready to be exported.

Coffee Exporting

The principal coffee markets are the New York and London Commodity Exchanges, which trade arabica and robusta, respectively.

Naturally, the price of coffee varies in relation to supply and demand. It is influenced not only by the quality and quantity of the coffee produced, but also by atmospheric factors (freezing temperatures, for example) and changes in the political order.

Storage

Before coffee beans are shipped, however, they have to be stored, and to prevent them spoiling or losing quality, a number of precautions have to be taken. These include paying particular attention to humidity, storage facility location, and storage duration.

The preferred place to store coffee is in the vicinity of its production site, i.e., a relatively high altitude with low air moisture. If it is too humid, beans are not separated from their husk (sun-dried pulp) or hull (parchment membrane) until before sending them for shipping.

Coffee beans should be stored in low moisture conditions so as not to be attacked by mold. The maximum water level safe in the bean is 12% by weight. After reaching this by thorough drying, any re-wetting and airborne moisture absorption must be prevented (e.g. rain, fog, condensation).

Raw coffee beans are often stored for years before roasting. Their sturdy structure usually prevents them from being spoiled by external agents, however, nothing can be done against the inherent biochemical activity in the seed. In this case, some minor components transform into other components which taste woody and harsh after roasting.

Shipping

When ready to be shipped, they are moved by conventional transportation to the docks. There, stevedores experienced in the careful handling of coffee see that the bags are properly stowed aboard the ship ready for their journey. More than 1/3 of the world's coffee is shipped to the USA, followed next by Germany.

The top export grade of bean is SHB (strictly hard bean) or strictly high grown, which means that the coffee beans are produced at a minimum altitude of 1,330 m above sea level.

Between five and six million tons of unroasted or 'green' coffee are produced each year. Beans are often kept and transported in coarse hessian bags. Beans are also shipped in bulk using bulk containers with plastic liners. On arrival in the destination country, the shipments are sent to warehouses or direct to the roaster.

Coffee Tasting

The tasting of coffee is a rigorous and disciplined process, done by an expert to evaluate the brew and determine its characteristics. The taster first assesses the green beans for their appearance. A small quantity is then roasted in a laboratory roaster and tested for its flavor and aroma. After the coffee has been infused in water, the brew is 'nosed'; after three minutes the brew is lightly stirred and smelled again. The resulting foam is removed and the tasting begins. A small spoonful of coffee is taken into the taster's mouth and it is 'chewed' around before being spat out. The procedure is repeated with all of the samples and notes are made as each one is sampled. The taster is looking at criteria such as acidity, body, aroma, and flavor.

Acidity

This is a desirable characteristic in coffee. It is the sensation of dryness that the coffee produces under the edges of your tongue and on the back of your palate. The role that acidity plays in coffee is not unlike its role as related to the flavor of wine. It provides a sharp, bright, vibrant quality. Without sufficient acidity, the coffee will tend to taste flat. Acidity should not be confused with sour, which is an unpleasant, negative flavor characteristic.

Body

'Body' is the feeling that the coffee has in your mouth. It is the viscosity, heaviness, thickness, or richness that is perceived on the tongue. Typically, Indonesian coffees possess greater body than South and Central American coffees. Coffees with a heavier body will maintain more of their flavor when diluted with milk.

Aroma

This is a sensation that is hard to separate from flavor. The aroma contributes to the flavors we discern on our palates. Subtle nuances, such as 'floral' or 'winy' characteristics, are derived from the aroma of brewed coffee.

Flavor

Flavor is the overall perception of the coffee in your mouth. Acidity, aroma and body are all components of flavor. Describing the tastes and flavors of different roasts is as subjective as putting a wine into words. In both cases there's no substitute for your own personal tastes.

Coffee Blending

Coffees of various origins are usually blended by the trade in different proportions so as to make a cup with varying acidity and taste characteristics. As different batches of coffee taste differently from each other as it is a natural product, blending is one way in which constant quality is achieved. With more than 100 coffee growing regions in the world, each producing beans with distinctive characteristics, proper blending is obviously essential to balance the flavors needed to create a superior espresso. A single coffee bean will generally not possess the complexity necessary and many espresso blends will contain three to seven different types of beans.

Coffee Roasting

Among roasters there is no agreement as to which should occur first, the roasting or the blending. Some people believe that roasting each varietal separately, to maximize it's flavor characteristics, and then blending, will produce the best result while others believe that if roasted together, the aromas of the different beans are homogenized during roasting. Blending before roasting certainly has its difficulties in that the homogeneous roasting of beans of different size, weight and country of origin has to be achieved.

When green, coffee keeps for a long time, provided it is protected from moisture. Storage, in fact, can improve it. It is entirely devoid of smell. To release the aroma, coffee has to be roasted, an operation which many coffee lovers insist on performing themselves. A good roaster must be part artist, and part scientist, to maintain quality and consistency.

In the development of flavors, roasting is probably the most important of the steps considered so far. Well roasted coffee should be brown, of varying degrees of darkness, but never black. If not sufficiently roasted, it produces a colorless infusion, and is rough and astringent. If over-roasted it produces a black, bitter and unpleasant drink.

In the roasting process coffee beans undergo many pyrolytic reactions which lead to the formation of the substances responsible for their sensory qualities, accompanied by important physical changes. It is during the roasting that sugars and other carbohydrates within the bean become caramelized, creating a substance that is known as 'coffee oil'. Technically, this delicate chemical is not actually an oil, but it is what gives the coffee its flavor and aroma.

The modern machines used for roasting evolved from crude vessels around 1200 AD, through the first cylindrical design about 1650, to computerized roasters now used by major coffee companies. Yet in the 900 years or so that coffee has been roasted, the basic concept remains the same: create a flavorful, evenly roasted bean from the green coffee of the fields.

During the industrial roasting process a small quantity of sugar molasses, or various other products is sometimes added, to 'coat' the berries. This coating, which is permissible by law, gives the berries a better color and more shiny appearance, prevents the loss of aroma and has the further advantage for the merchant of increasing the weight. Unfortunately this enables him to use inferior quality or damaged grains.

Speciality coffees, on the other hand, are generally roasted in small batches. The two

most common roasting methods are drum and hot-air roasting.

Drum Roasting

Drum-type roasting machines roast the coffee beans as they tumble in a rotating drum that is typically heated by gas or wood. When the desired roast is achieved, the beans are poured into a cooling hopper to keep them from overcooking. There are three main parts in a traditional drum roasting machine: a heat generator, a vessel, where coffee is continuously agitated by rotation of the vessel or by forced heated air, and a cooler where the coffee temperature is reduced.

Hot Air Roasting

The hot-air roaster, also known as a fluid bed roaster, roasts the coffee beans as they lift and tumble on a current of hot air. Most green coffee is roasted at approximately 400^{o}C. The roasting process causes the coffee beans to swell and increase in size by over 50%, while at the same time greatly reducing their weight.

Once the beans have left the roasting machines they must be cooled immediately to prevent autocombustion from modifying the proper grade of toasting that has been achieved. There are three ways of cooling roasted beans:

1. Water cooling: a shower of water chills the hot roasted beans. Coffee absorbs water so this process increases the specific weight.
2. Cooling in normal air.
3. Cooling in forced air.

A lightly roasted bean may range in color from cinnamon to a light chocolate tan. Lighter roasts are generally not used for espresso since they produce a sharper, more acidic taste than do darker roasts.

Darker roasts, in contrast, have a fuller flavor approaching a bittersweet tang. As the roast darkens, caffeine and acidity decrease proportionately. Dark roasts can range in color from a medium-chocolate brown with a satin-like luste, to an almost black bean with an oily appearance. As a result of this, extremely dark roasts will tend to have a smoky flavor and are better suited for brewed coffee rather than espresso. The amount of oil drawn to the surface of the bean increase proportionately to the length of roasting time.

After roasting, coffee does not keep its aroma for long; it is, therefore, better not to roast or not to buy coffee exceeding current needs. It is advisable to keep it in airtight pack-aging to prevent light, heat and moisture ingress.

Coffee Grinding

Grinding is the last operation through which coffee has to go before being actually made. Ideally, coffee should be ground immediately before being made, as ground coffee quickly loses its aroma.

In times past, coffee was ground in wooden or marble mortars with a pestle. Later on the scene were different kinds of crank and drawer coffee grinders, and finally the modern-day electric ones. The old coffee grinders are different from the modern-day electric ones, because coffee is ‘ground’ by the wheel and not ‘minced’, as happens with the various electric-blade coffee grinders which heat the coffee, further roasting it and losing some of its flavor.

Coffee Brewing

There are four basic methods of brewing coffee: *boiling*, *steeping*, *percolating* and *filtering*. Coffee experts consider filtering the best method of extracting the soluble essences of ground coffee. The coffee is contained in a paper or cloth filter. Very hot, but not boiling, water is poured over the grounds and allowed to flow into a container where it will not come into contact again with the grounds. For perfect coffee, earthenware or glass receptacles should be used, since contact with metal lowers the quality of the drink.

Coffee Making

Every culture seems to have their own way of preparing their favourite cup of coffee. Gathered together here are the most popular

methods of making coffee here to choose and decide on: The Perfect Cup, Espresso Coffee, Cappuccino, Turkish Coffee, Cafetiere/French Press, The Vacuum Pot, The Drip Filter, The Cold Water Brewer, The Percolator.

Coffee Substitutes

The number of products which aim at replacing coffee is considerable, done in order to bring the cost of the coffee down. Various grains and roots have been used, or for adulterating purposes. Apart from *chicory*, the most important adulterants are the following: *fig*, *date*, *acorn* (mildly astringent), *malt*, *barley*, and other roasted cereals, often flavored with steam passed through coffee, *chick-pea* and *lupins*, are used a great deal in Brittany. This is by no means a complete list. These products, which have a remote resemblance to that of real coffee, are harmless, though undesirable.

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