

A Question of Freshness

By Paul Songer from the Specialty Coffee Association of America

Specialty coffee products are capable of a variety of flavor profiles. Regardless of the product, it is generally agreed that the best coffee is the freshest coffee, and thus more special. A widely accepted definition of freshness is difficult, however, because, from a flavor perspective, coffee is constantly on the move.

After roasting, two processes immediately commence:

- (1) desirable flavors are lost and
- (2) undesirable flavors are increased.

Most freshness standards (and studies) are concerned with the latter process and seek a point at which coffee is still acceptable, though admittedly not at its best. This leads to a rather simple definition of coffee freshness: Coffee is no longer fresh when it is stale.

This definition is seldom relevant in the specialty arena. Few consumers are going to pay a premium for a product based on a lack of negative qualities. Specialty coffee as a market segment exists because it is realized that average coffee can be a lot better. Freshness of product makes this flavor experience available to the consumer.

Developing measurable standards of freshness can be tricky. The flavor experience referred to as coffee is the result of perception of a multitude of individual chemicals and their interactions. Each of these chemicals has its own characteristic flavor and individual rates and means of deterioration. The purpose of this article is to describe some of these changes and how they affect coffee flavor over time.

Trouble in the Bean

The flavor constituents of roasted coffee are the result of high roasting temperatures. After roasting, they continue to be affected by environmental factors, their own natural instability, and interaction with other compounds. The most important of these processes are:

Dissipation into other media. Aromatics evaporate from the surface of the coffee into the atmosphere or are dissolved into solvents, where they often interact with other chemicals.

Non-enzymatic browning reactions. These involve carbohydrates, usually sugars, in caramelization and Maillard reactions. Caramelization occurs when a sugar gives up water and carbon dioxide, changing the structure of the sugar and its taste. The Maillard reaction is the result of an interaction between amino acids and carbohydrates in which an aromatically perceived substance is formed. When the Maillard reaction takes place at a high temperature (as in coffee roasting), the result is usually desirable roasted flavors and aromas, but when it takes place at a lower temperature, the result is flat, gluey, and cardboard-like flavors.

Oxidation. Oxidation is any reaction in which one or more electrons are moved from one chemical to another, producing two different compounds. In coffee, the most common process is that an oxygen molecule donates two electrons to a compound, forming a new (differently perceived) compound and bonding with hydrogen to form water.

The engine that drives all of these processes forward is thermal energy (heat). This energy can be in the immediate environment, a result of other chemical reactions, or already present in the product.

To begin a more detailed examination of the staling process, components of coffee flavor can be separated into classes of highly volatile (responsible for flavor loss) and less volatile compounds (responsible for poor flavor).

Coffee Aroma: A Complex Balance of Diverse Compounds

The coffee flavor aspects most subject to change are those that comprise aroma. They originate from the entire catalog of flavor producing aspects of specialty coffee: roast style, origin, type of processing, etc. In a 1989 study, it was stated that over 20% of all aromatics then known had been found in roasted coffee, some 1600 compounds. Interactions of the aromas add greater complexity. How they cancel out, reinforce, or contrast to each other affects aromatic perception of the coffee.



Established 1992

The basis of coffee aroma is sulfurous compounds. These include strong smelling mercaptans (skunk smell is an example) or onion, garlic, and even sweet, honey-like aromas. All sulfur compounds are highly susceptible to oxidation in the presence of oxygen. Some of these compounds, those that have toast, bread, or roasted-meat aromas, are relatively stable, but others change quite rapidly. One of the most important sulfur compounds in terms of coffee freshness is methanethiol (also known as methyl mercaptan), shown in numerous studies to have a large impact on consumer perception of coffee freshness. It also conceals less desirable aromatics, such as the "green pea" aroma. Highly susceptible to dissipation as well as oxidation, when ground coffee is set in open air, reduction of methanethiol can be perceived within one day and 70% is gone within three weeks. Concurrently, other mercaptans increase through oxidation of other sulfur compounds as the coffee ages. When the concentration of furfurylmercaptan is between 0.01 and 0.5 ppb (parts per billion-very small amounts), it is perceived as freshly roasted coffee, but in higher concentrations is perceived as staleness.

Certain aromatic compounds are present to a greater degree in darker roasted coffees. These include phenols (spicy/clove-like, astringent), pyradines (smoky/ash), pyrazines (earthy/musty), and pyrroles (smoky/dark roast). The spicy phenols tend to evaporate quickly. Pyradines are more stable, but are negatively perceived in too great a concentration. Pyrazines, some of which are key odorants of Arabica coffee, are highly volatile and subject to dissipation upon exposure to air and non-enzymatic browning. Pyrroles are dissolved in the naturally occurring coffee oils and subject to oxidation. These compounds are not present in large amounts compared to other aromatics, but they are strong in aroma and slight deterioration can have a dramatic effect on flavor.

The most delicate aromas are also the most volatile. Aldehydes can be stinging and pungent (formaldehyde, for instance) or sweet, fruit-like, and floral. Some aldehydes combine with acids under high heat conditions to form esters, which can be identified as having distinct aromatic qualities, like pineapple, pear, or peach. They are easily oxidized (changing into acid and water) or dissipated, especially when subject to increased temperatures and/or wet conditions. Certain malty/sweet/caramel-smelling aldehydes were found to decrease by 50% within fifteen minutes of grinding and exposure to open air. The best Arabica coffees typically have a higher concentration of these aldehydes. Arabica coffees also contain more of a "butter" aroma, which is similarly delicate and readily lost due to dissipation.

Luckily, there are structures present that help to preserve these aromatic substances. One is the coffee bean itself. In addition, carbohydrates and proteins encapsulate some aromatic substances (referred to as "glasses") and will only be released as the result of disruption (through grinding or increased temperature) or dissolving into a liquid. Some coffee aromatics are contained within the lipids (oils and waxes) of the coffee, which do not deteriorate as quickly due to the presence of pyrrole and other antioxidant substances. Under ideal conditions, coffee aromatics will only be released upon application of thermal energy and solvent (hot water) in the form of brewing, after which they can be enjoyed.

The decline of coffee aroma is one of inevitable attrition. The first compounds to be released are the sweet-smelling aldehydes, closely followed by the buttery aromas. Next, the earthy pyrazines take their leave. More of the aldehydes are affected by oxidation, alcohol-based aromas evolve into pungent aldehydes, and the sulfur compounds change their character as the methanethiol oxidizes and evaporates. Green pea aroma and smoky/ash aromas become predominant. As greater amounts of furfurylmercaptan develop, the dreaded and distinct stale aroma is created. Noticeable changes in aroma occur within a day, more obvious changes occur within 8-10 days and 50% of the total aromatics can be gone within three weeks (even in whole bean coffee).

Less Volatile Coffee Flavor Components

The most prolonged aspect of coffee staling is lipid oxidation. This occurs in stages. The first stage is the uptake of the oxygen by the oil and production of peroxides. Any oxygen taken on by coffee can cause this to occur. Like all oxidation processes, two chemicals are formed. Peroxides create breakdown products (highly aromatic undesirable substances), then attack an unoxidized lipid molecule to re-form peroxide. The peroxide acts as a catalyst; the more peroxides present the faster the oxidation. Stale flavor is significant after 2 weeks of storage in the presence of oxygen. The process is one of acceleration: once it begins, products of oxidation increase until all possible paths are exhausted and the coffee is dead stale.

Modes of Deterioration

The most obvious solution to enjoying fresh roasted coffee flavor is to brew it and consume it soon after roasting (microroasters have an advantage here). The next best solution is to remove the freshly roasted coffee from those environmental influences that will cause flavor deterioration. Separation from oxygen has been the primary strategy, with good reason. Oxidation obviously contributes significantly to flavor degradation and loss. Ambient air contains 19-21% oxygen and only 14 cubic centimeters of oxygen (or 70 cc of ambient air) are enough to render a pound of coffee dead stale.

A typical 12-oz. foil package has 800-1000 cc of volume, of which about 600 cc is the actual (whole bean) coffee. Estimating a total of 900 cc, 300 cc of gas is present. If there is 4% or more oxygen present in the package, it is enough to render the coffee completely stale, given enough time and thermal energy.

Inevitably, coffee is in contact with oxygen for a certain period before packaging. A common myth is that coffee is not able to take on oxygen immediately after roasting due to carbon dioxide degassing. However, Michael Sivetz estimates that instead of 21%, about 10% oxygen surrounds degassing coffee -certainly enough to initiate oxidation.

Separating the coffee from oxygen is not the only freshness issue. The common thread in all deterioration processes is thermal energy. The rate of staling will be a function of the thermal energy applied to the coffee and how it is distributed. An important mechanism of thermal energy distribution is moisture. Roasted coffee will also absorb water at any time it is exposed to humid conditions, especially in the presence of high temperatures. Water quenching can add additional water and some of the deterioration processes themselves create water as a by-product. Within whole bean or ground coffee, water will take one of two forms: free or bound.

"Free" water is mobile and can increase staling processes by retaining and delivering thermal energy and oxygen to the aromatics, acids, and oils, or bringing together sugars and protein to initiate non-enzymatic browning. "Bound" water (bound to surfaces) is not as mobile or available to solvate reactants. The ratio between free and bound water is called "water activity." It is increased any time the coffee comes into contact with humidity or high temperatures ("bound" water often becomes "free" water upon heating). A relatively low ambient humidity of 25% can cause roasted coffee to increase its moisture content to 5%, with water activity also increasing. Lipid oxidation is accelerated at heightened water activities, but is not usually measured in coffee, despite its effect on freshness. Studies show that a water activity ratio of above 0.5 contributes significantly to increased rates of non-enzymatic browning and lipid oxidation. More studies on water activity and its relation to coffee freshness are currently being conducted.

The temperature at which coffee is stored and fluctuations in temperature has a direct effect on the rate at which coffee stales. Besides providing the thermal energy necessary for staling, even a temporary rise in temperature causes greater solubility of any oxygen present and heightened water activity.

Prevention of Flavor Deterioration

A few strategies of prevention of flavor deterioration of coffee over time are as follows:

Dissipation and non-enzymatic degradation of aromatics. This happens spontaneously, is accelerated by high temperatures and humidity, and is not prevented by removal of oxygen. The primary solution to this aspect of freshness is maintenance of cool, dry conditions and preservation of aroma preserving structures including the bean itself.

Non-enzymatic browning. Temperature and moisture contribute mostly to this process. Strategies for prevention include moisture-resistant packaging (so additional free moisture cannot be absorbed), managing the ambient conditions (temperature and humidity) around cooling, quenching, and packaging, and avoiding extremes of temperature during storage.

Oxidation of aromatics and lipids. Oxidation rates are a function of the available oxygen, surface/volume ratio of particles, temperature of storage, and water activity. All strategies previously mentioned will apply. In addition, as much oxygen must be removed from packaging as possible.

It would seem logical that preservation of coffee flavor could occur through refrigeration or freezing. Refrigeration is regarded as a failure as it causes the moisture and lipids to emulsify, probably accelerating oxidation and observably rendering the coffee somewhat gummy. Some have found freezing to be adequate (reportedly most successful with dark roasts, with low moisture content). The Technical Standards Committee of the SCAA does not recommend freezing because limited testing indicates that freezing diminishes flavor.

Toward Developing a Freshness Standard

The purveyor of specialty coffee must apply standards that are easy to measure and track. The most available measure is that of time. Any standard based on time measurement, however, must accurately reflect the amount and type of flavor deterioration that can be allowed and the rate at which that deterioration will occur. The most important question of freshness is: What will coffee taste like when finally brewed?

The following should be considered in determining a standard of freshness for a specialty coffee product:

- 1) The character and purpose of the particular product must be judged. Coffees known for their delicate and sweet aromas (such as certain East African coffees) depend on aldehydes for their unique flavor and are not good candidates for open bins or ground sales. Dark roasts have their own inherent tendencies. This may require considerable tasting over time and different freshness standards for different products.
- 2) Packaging options should be examined in terms of their abilities and their weaknesses. Water resistance, permeability, sealing ability, puncture resistance, and insulation qualities of packaging material should be taken into account. Equipment must be well maintained and checked regularly.
- 3) The critical points at which the coffee is exposed to conditions that can cause premature staling must be closely examined and controlled. The most important of these are cooling/quenching, just after cooling before packaging, during storage, upon grinding, and just before brewing. The ambient conditions (temperature, humidity) under which these take place will partially determine the rate of deterioration and the maximum amount of time before the next stage. Higher temperature and humidity may indicate that the coffee should be cooled and packaged at a quickened pace.
- 4) The conditions under which the coffee will be stored and transported including potential changes in moisture activity and temperature during transport must be considered.
- 5) Random production samples should be measured regularly for package oxygen and product water activity for purposes of quality control. Oxygen content should be less than 2% if the packaging system is functioning properly; if the water activity level is above 0.5, the circumstances of quenching, grinding, and packaging should be examined.
- 6) A standard of freshness should be based on the degree and type of staling reactions that can be allowed to take place before that particular product is no longer of specialty quality. Once this is determined, the estimated rate of staling can be computed in the form of a time measurement.

Freshness of the coffee that a roaster or retailer sells and serves is a direct reflection of the standards and abilities of that operation. It will determine one's competitiveness in the marketplace and the ability of the consumer to experience a product that is unique and worth seeking out. The bottom line is flavor. For specialty coffee, flavor means freshness.

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