The Flavor of Roasted Coffee

By Dolf DeRovira

The flavor notes that define coffee encompasses a rich and distinctive taste that distinguishes a quality cup of coffee. Dolf DeRovira reports on the nature of flavor as it is affected by the intricate science of roasting.

One of the greatest gifts that coffee gives to us is flavor. Few beverages can boast such an inherently complex flavor profile, much less a profile so varied in its myriad regional forms. Further, the complex character of coffee's flavor is affected by roasting techniques that further elaborate on the potential for this remarkable beverage to amaze, intrigue, and satisfy its consumers.

The Green Coffee Bean

The flavor notes that define different varieties of coffee can be attributed to many factors; including the environment, handling conditions, and subtle genetic tweaks that have occurred within a coffee crop over time in any given area. What effect do subtle differences in wind, light, altitude, irrigation, and nearby vegetation have on coffee plants? How does the mineral content of the soil affect the bean and its resultant flavor upon roasting? The nutrients that the tree ingests should have a great deal of effect upon the chemical makeup of the bean and its resultant flavor. Is it possible that the chocolate character typical of Guatemalan Antigua is due to high protein content in the soil?

Throughout the world there are characteristics that define the unique signature flavor profiles of individual sources. Kenyan coffees have a unique floral profile, while Colombian coffees exhibit distinctive wine-like nuances and Sulawese coffees impart remarkable berry-like overtones. The different flavor profiles are created by the character of the soil and cultivation methods used within each region that alter the green coffee bean's internal chemistry.

Over time, the coffee industry has come to use standardized terms to help distinguish between flavor characteristics. The principle terms used to define a coffee's distinctive flavor within the green bean itself are floral, grassy, herby, peanutty, sour, and sweet. The Flavor Dynamics coffee cupper kit (sold and marketed by the Specialty Coffee Association and developed by myself and a panel of experts within the SCAA) is an excellent tool to learn to identify these attributes, as well as those developed upon roasting.

Coffee beans are born with a complex mix of chemical components - such as carbohydrates, proteins, fats, minerals, sugars, and acids - that are waiting to be changed into the flavorful substances we enjoy. In the bean, carbohydrates are broken down during ripening to create the sugars that provide a seed embryo's nutrition and allow it to grow into another plant if it is sown and raised properly. It is these sugars that provide the basic building blocks for the wondrous Caramelization and Maillard reactions that produce amazingly flavorful aromas during roasting.

Sugars and carbohydrates are not coffee's only flavor-producing component; fats also play a role in defining a coffee's characteristic taste. Oils within the bean oxidize to form grassy, herby, or peanutty characteristics. Sour chemicals - acidulants - are also found within most coffee beans at differing levels. Floral characteristics, described by many as being a combination of jasmine and apricots or peach, have a more complicated biogenesis but form at least in part from fats that form hydroxy acids and then undergo a cyclization.

There are also flavor characteristics that are developed through the ripening process. Larger molecules called macronutrients are chopped up into smaller components to provide sustenance for the growing embryo. In this process, however, aroma compounds are also formed. These compounds are similar to those found in fermentation, as the ripening process goes through a phase where microorganisms and enzymes aid in the simplification of these larger molecules. The by-products of ripening, which include esters and volatile acids, are often described as tasting winey, earthy, and fruity. Combinations of fruity and woody characteristics can together give the impression of berry-like notes. If a secondary fermentation occurs due to microorganism contamination, the bean then develops the unpalatable taint called ferment.

But the most interesting development of flavors occurs when the bean is heated and two major reactions contribute to the wealth of aromas we have come to enjoy in the cup.

The Roasting Process

When coffee beans are added to a roaster, the temperature of the bean is raised. At lower temperatures (a bit above the boiling point of water), the changes to a bean's flavor are relatively minimal. As the bean heats up, it expands and trapped gases evaporate, along with some trapped moisture. This expansion causes an audible crackling sound known as the first crack. Although minimal, the evaporation of trapped gases and moisture can distill off some of the bean's inherent aroma characteristics at this stage.

As the temperature rises the bean's sugars undergo what is known as caramelization. This is the same process that food experiences when being cooked under low moisture conditions, such as pan sautéing. The flavors formed at this point in the roasting process fall into the category of "brown characters" and are typically described as caramel-like notes. The chemicals that are produced at this point are flavor volatiles that include chemical compounds, such as alcohols, furans and enols that contribute more and more to the overall caramel-like profile. The darkening color of the bean also increases a bit at this point.

Simultaneous to caramelization, other components characteristic to the green coffee bean begin to be volatilized. It is at this stage that the bean's regionally-defined inherent flavor characteristics begin to diminish and the caramelized notes within the flavor profile increase. It is the combination of these roasted brown notes with the regional nuances of a coffee crop that combine to make the most interesting and complex flavor profiles.

As the temperature rises further, the coffee's flavor really starts to get interesting. The color darkens considerably and flavors form with great intensity as another reaction comes into play - the Maillard Reaction, first described by chemist Louis Maillard in 1912. There are more works written on the Maillard Reaction than any other chemical reaction on the planet, and it is by far the most complicated reaction in the food sciences. Further, its resultant aroma chemicals are the most commonly enjoyed flavor notes of any involved in food or beverages.

Technically, the Maillard Reaction is known as a non-enzymatic browning reaction because it takes place without the presence of enzymes. The reaction is resultant of two elements within the bean - tiny sugars, known as "reducing sugars," and amino acids, the basic building blocks of proteins. Although the Maillard Reaction can occur at room temperature at a slow rate, it is accelerated by the application of heat, taking off considerably after 250°F. Common examples of the Maillard reaction include the browning of roast beef, the roasting of nuts, and of course the roasting of coffee beans. This reaction creates a host of aromatic chemicals that excite the imagination and are described in the flavor lexicon with words like toasted, roasted, nutty, and chocolate. The Maillard Reaction is responsible for many of the best flavors that we appreciate in our foods, and is a big reason why coffee tastes so great.

Up to this point in the roasting process, we have had to pump heat into the beans to make them roast. Soon, however, the temperature reaches a point where things change a bit. As in the fireplace when wood burns with a crackling sound, the woody cellulose materials within the bean start burning and emit popping and crackling noises, known in industry the second crack. At this point the reaction shifts from being endothermic (absorbing heat) to being exothermic (giving off heat). This roasting condition must be monitored closely as it can be dangerous and can result in a fire.

The flavor characteristics that are produced at the second crack and beyond tend to be quite different from those at lower temperatures, as phenols become the primary class of aroma chemicals that are produced at this point. These oxidative products exhibit characteristics that are commonly described as smoky, woody, or even asphalt-like. The woody characteristic at this point is more reminiscent of wood smoke than are the tannin-like compounds that are present in the green bean. Most coffee consumers with a sophisticated palate agree that a bit of these nuances in a full city roast is enjoyable; however it is still controversial whether or not higher amounts of these burnt characters contribute positively to the coffee cup.

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