by Neil H. Mermelstein

A lot goes on behind the scenes *to produce the full-bodied aroma and flavor of coffee from your favorite coffee beans.*
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Coffee Quality Testing

Coffee is one of the most popular beverages in the world. According to the National Coffee Association (NCA), 58% of American consumers surveyed for its 2011 "National Coffee Drinking Trends" report said they had drunk coffee the previous day. It is available in numerous traditional and gourmet varieties and blends and in many forms, including whole beans, ground, instant, and ready-to-drink beverages. It is also available for in-home brewing in a variety of packages, including single-serving packages such as instant coffee packets and Keurig *K-Cup*® brewing cups, and it is used as an ingredient in other products.

Coffee Production & Processing

Of about 60 species of coffee trees, two dominate world trade: *Coffee arabica* (referred to as Arabica), which constitutes 75% of production, and *Coffee canephora* (called Robusta). Coffees from the three main growing regions—Latin America, Southeast Asia, and Africa—have distinctively different flavor characteristics.

The fruit of the coffee tree is called the coffee cherry and is harvested when it turns bright red. Within the cherry are two beans, each surrounded by a thin, silvery membrane called silver skin. A parchment-like covering surrounds the two beans and is covered by a thin layer of mucilage, a layer of pulp, and skin.

After harvesting, the beans are sorted and cleaned by flotation to separate unripe, overripe, and damaged cherries and remove dirt, twigs, and leaves. Then they are processed and dried to a moisture level of about 11% by either of two methods. In the dry method, the beans are spread out to dry in the sun. In the wet method, the pulp is mechanically removed and the bean is dried with the parchment left on. The beans are sorted by weight and size, fermented by natural enzymes for up to 48 hr to remove the mucilage, rinsed, and sun dried or machine dried. The dried beans are called parchment coffee.

The beans processed by either method are then sent to a mill for hulling, where the outer layers of the beans, including the parchment, are mechanically removed; the beans may be polished to remove any silver skin that remains on the beans. The beans are then sorted by size and weight, examined to remove any unacceptable beans, and graded on the basis of size, growing location and altitude, harvesting and processing methods, and taste. The resulting beans, called green coffee, are bagged, stored, and shipped to importing countries for roasting and grinding. According to the NCA, approximately 7 million tons of green coffee is produced worldwide each year.

Roasting at high temperatures (about 400°F) develops the aroma and flavor in the beans and causes the beans to turn brown and release the oil they contain. The roasts are generally classified into four categories. Light roasts are light brown with a mild flavor and no oil on the surface. Medium roasts (also called American roasts) are medium brown with a stronger flavor and no oil on the surface. Medium-dark roasts are dark brown with a slightly bittersweet aftertaste and some oil on the surface. And dark roasts have a pronounced bitterness and a shiny, oily surface. Coffee beans are often blended before or after roasting to provide desired flavor characteristics and then ground for

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brewing. The degree of grind varies with the brewing method that will be used. Coffee for preparation in an espresso machine is much finer than that for drip brewing.

Coffee is marketed in several general categories, ranging from traditional/mainstream to specialty/gourmet. Traditional/mainstream coffee, the everyday coffee sold for mass distribution by brands such as *Maxwell House* and *Folger's,* consists mostly of Arabica beans, is readily available, can be obtained in large quantities, and looks and tastes the same every time. Specialty/gourmet coffee, marketed by such companies as Starbucks and Peet's, includes high-quality beans with specific flavor attributes and identity, is purchased directly from farmers or cooperatives, and is batch roasted in relatively small volumes. Coffee may also be concentrated and sold as liquid concentrate for use principally in foodservice or as an ingredient.

Coffee is brewed in a drip coffee maker, an espresso machine, percolator, a French press/plunger, a Moka stove-top octagonal Italian-style brewer, or a machine such as the Keurig *K-Cup* system, which uses a pre-measured sealed disk or capsule. Instant coffee is made by roasting and grinding coffee beans to a large size and extracting the aroma and flavor with very hot water in a countercurrent extractor. The coffee is concentrated in a thermal evaporator or freeze concentrator, which may include an aroma recovery step, and is then freeze dried or spray dried. The result is a fine powder that might be further processed by steam agglomerating it to increase the particle size.

Decaffeinated coffee is made by extracting the caffeine from the green beans with either water and activated carbon, a solvent such as methylene chloride or ethyl acetate, or supercritical carbon dioxide. The coffee is later dried, roasted, blended, and so on.

Evaluating Quality

The quality of the coffee consumers drink depends on numerous factors, such as the cultivar, growing altitude, climate, soil chemistry, harvesting and processing conditions, drying method, storage conditions (temperature, humidity), transportation method (container type and size), roasting conditions, grind size, packaging, age, and brewing method. Spencer Turer, Director of Coffee Operations at the independent coffee-testing company Coffee Analysts (www.coffeeanalysts.com), said that testing is conducted throughout the supply chain, but the amount of testing changes. Exporters and importers usually use basic sensory and physical evaluations to determine whether the product meets their quality standards for grade and are free of sensory defects. At the roaster, the testing becomes a lot more rigorous, and the regional, national, and multinational coffee companies become much more involved in dynamic quality control, using a variety of instrumental analyses as well as sensory evaluation. Turer said that although many strides have been made in instrumentation for flavor and aroma detection and identification, the simplest, least expensive, and most replicable results in coffee testing are obtained by sensory analysis, specifically the cupping method for flavor and aroma.

In this method, which is used at all stages of production, the taster or "cupper" first evaluates the overall visual quality of the beans (grading the beans for defects, size, moisture, aroma, and color), then roasts a sample in a laboratory roaster, grinds the roasted beans, and evaluates the roasted coffee fragrance. The cupper then adds boiling water to a standard amount of the ground coffee and allows the coffee to steep in the cup for about four minutes, smells the aroma, breaks the crust of grounds to complete the aroma evaluation, and then skims the floating grounds and oils from the top of the cup. After allowing the coffee to cool, the cupper tastes the beverage by forcefully slurping a spoonful to

Using the cupping method, *Spencer Turer of Coffee Analysts evaluates the aroma and flavor of coffee samples.*

Trade & Scientific Organizations Related to Coffee

Association for Science and Information on Coffee (www.asic-cafe.org). ASIC brings together global specialists working in the different fields of coffee science and technology, giving them the opportunity to present and compare their investigations. It encourages and coordinates research to contribute to better use of coffee and improvement of coffee quality. The 24th ASIC International Conference of Coffee Science will take place November 11–16, 2012, in San José, Costa Rica.

Coffee Quality Institute (www.coffeeinstitute.org). CQI provides training and technical assistance to coffee producers and other individuals in the supply chain to increase the value, volume, and sustainability of high-quality coffee production. It also works toward creating systems and infrastructure that encourage a focus on quality and lead to higher farmer incomes.

Green Coffee Association (www.greencoffeeassociation.org). This trade association provides resources and other benefits for individuals and companies dealing with the export, transport, storage, insuring, financing, importing, trading, and roasting of green coffee.

Institute for Scientific information on Coffee (www.coffeeandhealth.org). Founded in 1990 by major coffee companies in Europe, ISIC collects and evaluates studies and scientific information about coffee and health, supports independent scientific research on coffee and health, and disseminates balanced scientific information.

National Coffee Association of U.S.A. Inc. (www.ncausa.org). Founded in 1911, NCA is the leading trade organization for the coffee industry in the United States. It serves all segments of the U.S. coffee industry and focuses on market and scientific research, domestic and international government relations, issues management, public relations, and education. Its next national convention will be held March 22–24, 2012, in Charleston, S.C.

Specialty Coffee Association of America (www.scaa.org). The world's largest coffee trade association, SCAA establishes quality standards; conducts research on coffee, equipment, and craft; and provides education, training, resources, and other services. Its next annual symposium and exposition will be held April 18–22, 2012, in Portland, Ore., and will include a discussion about the next generation of sensory analysis and implications for quality control, product development, and marketing.

Papers on Coffee Presented at IFT Annual Meetings

2001
"Coffee Adulteration and Analytical Approaches to Authentication" by C.W. Harrell of the Procter & Gamble Co.

2006
"Effect of Ground Coffee Bean Storage Time on Coffee Quality" by Carolyn F. Ross of Washington State University.

2007
"Coffee Bitterness Assessment with the Electronic Tongue" by Michel Manach of Alpha MOS Inc.

2009
"Total Phenolics and Antioxidant Capacity of Coffee During the Roasting Process" by Alberto M. de Azeredo of the University of Florida.
"Coffee Roasting Color Analysis" by Alberto M. de Azeredo of the University of Florida

2010
"Coffee Roasting Color Kinetics" by Alberto M. Azeredo of the University of Florida.
"An Investigation of the Applicability of SIFT-MS in Process-Line Monitoring of Coffee Aroma" by David Paterson of Syft Technologies.
"Coffee (*Coffea arabica*) Quality Mapping in Honduras: Effect of Altitude on Green Bean Chemical Composition and Roasted Coffee Quality" by Francisco J. Bueso of Zamorano University.

2011
"Comparison of Minolta, HunterLab, and Machine Vision in Assessing the Color of Roasted Coffee and the Agtron/SCAA Coffee Roast Classification Standards" by Alberto M. Azeredo of the University of Florida.
"Effects of Different Time-Temperature Conditions on Coffee's Chemical and Physical Properties" by Niya Wang of the University of Guelph.

see if it meets expected standards, and then spits it out.

Using this procedure, the cupper can evaluate the coffee sample quality and blend different beans for product development or to determine the proper roast for specific flavor characteristics. According to the NCA, an expert cupper can taste hundreds of samples of coffee a day and still taste the subtle differences between them. Turer pointed out that the cupping process follows scientific protocols to ensure that the only variable in the test is the coffee being sampled. All aspects of the process are strictly controlled, including coffee roast parameter, time between roasting and cupping, grind size, coffee portion weight, water quality, water temperature, cupping vessels, and so on. The cupper records the intensity and quality of the dry bean fragrance and the aroma, acidity, body, flavor, and finish of the beverage.

Turer said that the physical laboratory tests that may be conducted on green coffee are density, moisture content and water activity, bean size, grade (defect counts), and color. Tests for roasted coffee are residual oxygen and carbon dioxide within packages, moisture content and water activity, roast color, grind particle size or broken bean counts, brewed coffee dissolved solids, pH, and Brix/refractive index. Chemical testing for coffee includes ochratoxin A, caffeine, nutrient analysis, microbiological analysis, and pesticides. Other tests that may be performed on roasted coffee are caffeine, chlorogenic acids, lipids, carbohydrates, total polyphenols, total proteins, and mycotoxins. Standard analytical methods for coffee have been published by AOAC International (see table), the International Organization

for Standardization (ISO), and other organizations.

Norm Ouellette, Vice President, Global Quality Assurance at Starbucks Coffee Co. (www.starbucks.com), said that taste testing is done at various stages of production: green beans selection and receipt, roasting, grinding, and final beverage. In the plant, the coffee is roasted to the desired color, a determinant of flavor, and then pulverized, and the color is measured using light reflectance instrumentation. The moisture content is determined after roasting since it affects quality and shelf life. The flavor is spot-checked by the cupping method during roasting and blending. In the grinding process, the particle size is measured using sieves. The grind is very important as it affects the product brewed by the consumer. At the warehouse level, taste—and maybe color and moisture—is tested again. There is some use of gas chromatography and high-performance liquid chromatography to conduct other analyses, he said, but not much use of near-infrared spectrometry.

Ouellette said that high-performance liquid chromatography is used a lot to analyze for caffeine content. Typical measurements on soluble coffee include pH, solids estimation by Brix, and final product moisture content, which is very important for flavor and shelf life. Typical analyses for liquid concentrate include measurement of solids concentration by Brix, pH, and titratable acidity.

He added that packaging is very important for coffee quality. Coffee must be kept away from oxygen because the coffee oils oxidize very readily, causing the coffee to stale. Coffee packages contain some residual oxygen, and roasted coffee will release carbon dioxide, so packages must be degassed and/or include a vent to release the internal pressure and also prevent oxygen from entering the sealed container. Cans, metal or plastic, must have a good seal and low moisture and oxygen transmission rates.

AOAC Official Methods of Analysis for Coffee

Method No.	Title	Method
920.88	Green Coffee	Macroscopic examination procedure, physical examination
920.89	Coloring Matter in Green Coffee	Identification procedure, sampling
920.90	Roasted Coffee	Macroscopic examination, physical examination
920.91	Roasted Coffee	Sample preparation
920.92	Acidity (Total) of Roasted Coffee	Titration
920.93	Ash of Roasted Coffee	Alkalimetric ammonium molybdophosphate method, gravimetric method, spectrophotometric method
920.94	Caffeine in Roasted Coffee	Power-Chesnut method, gravimetric method
920.95	Chicory in Roasted Coffee	Infusion method, microscopy
920.96	Coating and Glazing Substances in Roasted Coffee	Munson-Walker general method, polarimetric method, saponification No. (Koettstorfer No.) titrimetric method
920.97	Petroleum Ether Extract of Roasted Coffee	Gravimetric method
920.98	Fiber (Crude) in Roasted Coffee	Ceramic fiber filter method, digestion, gravimetric method
920.101	Starch in Roasted Coffee	Munson-Walker general method, gravimetric method
925.14	Chlorides in Roasted Coffee	Gravimetric method
925.15	Sugars in Roasted Coffee	Volumetric, electrolytic method
950.40	Caffeine in Roasted Coffee	Bailey-Andrew method, titration
957.04	Chlorogenic Acid in Green Coffee	Spectrophotometric method
957.05	Chlorogenic Acid in Roasted and Instant Coffee	Spectrophotometric method
960.25	Caffeine in Roasted Coffee	Micro Bailey-Andrew method, extraction, titration, digestion
965.25	Caffeine in Green Coffee	Bailey-Andrew method, Kjeldahl method, titration, digestion
968.11	Moisture (Loss on Drying) in Roasted Coffee	Vacuum oven method I, gravimetric method
979.11	Caffeine in Roasted Coffee	Chromatographic-spectrophotometric method
979.12	Moisture (Loss on Drying) in Roasted Coffee	Vacuum oven method II, gravimetric method
973.21	Solids (Soluble) in Roasted Coffee	Gravimetric method
995.13	Carbohydrates in Soluble (Instant) Coffee	Anion-exchange chromatography with pulsed amperometric detection
970.46	Aflatoxins in Green Coffee	Thin-layer chromatography
975.38	Ochratoxin A in Green Coffee	Thin-layer chromatography
988.16	Filth in Ground Coffee and Coffee Substitutes (Cacao Bean and Its Products/Chocolate,Coffee/ Ground Coffee, Press Cake)	Sedimentation, flotation, visual examination, microscop
2000.09	Ochratoxin A in Roasted Coffee	Immunoaffinity column high-performance liquid chromatography
2004.10	Ochratoxin A in Green Coffee	High-performance liquid chromatography

Advances & Challenges

When asked about advances in coffee testing, Turer said that one is the establishment of AOAC and ISO standard protocols for assessing quality. Another is that in the last two generations, the coffee industry has made great strides in utilizing

Coffee Quality Testing continued...

food science, including the use of instruments to evaluate roast color instead of the naked eye. Using the most contemporary technology provides greater efficiency, accuracy, repeatability, and cost effectiveness, he said. Another advance is the general understanding of sensory evaluation and use of expert panels and contemporary sensory methods that are valid and credible from a scientific perspective.

Ouellette said that sensory evaluation methods continue to improve, color-measuring instruments now provide more information than before, and automation and precision of instrumental analyses are increasing. He added that sophisticated instruments such as the electronic nose may aid in product development but may not be cost-effective for day-to-day evaluation of coffee.

Turer said that the major challenge ahead is providing consistent quality in spite of changes in weather patterns and economics that affect farmers' productivity. Consumers don't want to know that weather conditions, increased insect or mold activity, or drought affected the amount of coffee produced or that the strength or weakness of the dollar is affecting farmers' ability to buy equipment or fertilizer. Consumers simply want to open a package of coffee and see that it looks, smells, and tastes the same, he said.

He added that since there is no universal practice for farming and harvesting coffee, the technologies used vary by country and culture, and the quality control testing differs in different countries. Cupping is the industry standard for sensory evaluation, but different countries do it differently. Testing protocols at the exporters, importers, and roasters may be different, but they should be internally consistent. The professionals doing the sensory evaluation must do it the same way each time so that the only variable is the quality/characteristics of the coffee.

Ouellette said that as the demand for high-grade, high-grown, really good Arabica coffee increases, maintaining the quality of green coffee will require improved and sustainable agricultural practices and methods for evaluating green coffee. Producers need to strive for good, consistent crop-to-crop quality, which is not easy in agricultural production. **FT**

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