One of the unofficial rites of passage in the coffee industry is attempting to grow a coffee plant from the seed. The realization that green coffee is actually a seed is traditionally followed by one or more failed attempts to germinate a seed. Not all attempts are unsuccessful, but those that are can likely be attributed to seed viability. While seed viability (or lack thereof) represents only a minor annoyance for the amateur coffee grower, there is a growing body of work in the research area suggesting that seed viability may play a more significant role in green coffee quality.

The Relationship of Seed Viability to Cup Quality in Green Coffee

By Chris Hallien

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Several research papers have been published over the years demonstrating a direct correlation between seed viability and cup quality scores in green coffee; the higher the seed viability, the higher the quality. (See page 53 for references.) The specific focus of research in the various efforts may differ, but common to all research is leveraging of test methods used by the broader seed industry to apply to green coffee in order to assess cup quality. The body of work provides a compelling case for applying quality measurements of the seed industry to further advance the understanding of green coffee quality.

Seed Basics and Classifications

From a scientific perspective, seeds are a function of the reproductive cycle of a plant. The flower of a plant, once pollinated, will develop one or more seeds. The seeds themselves are plants in an early “embryonic” stage of development, capable of developing into an adult plant. A typical seed consists of three parts: 1) an embryo, the portion of the seed containing the precursory tissue for the stem, roots and leaves 2) an endosperm, the portion of the seed containing nutrients for the embryo and 3) an endocarp, the seed covering. A typical coffee seed is approximately 5 percent embryo and 95 percent endosperm (a proportion that will be revisited later); the endocarp is the “parchment.”

Seeds can be classified from a variety of perspectives. For the purpose of this subject, the classification of interest pertains to the physiological behavior of a seed when undergoing a desiccation (drying) phase and subjected to freezing temperatures:

- **Orthodox seeds** can be dried to as low as 5 percent moisture content and tolerate freezing. The longevity of orthodox seeds ranges from one year to several hundred years, depending on the type of plant and the storage conditions. Examples of orthodox seeds include most grain and legumes, as well as crop plants such as corn and tomato.

- **Recalcitrant seeds** (unorthodox seeds) cannot be dried below 20 to 30 percent moisture content and cannot tolerate freezing. The longevity of recalcitrant seeds ranges from days to less than one year. Examples of recalcitrant seeds include cocoa, avocado, coconut and mango.

- **Intermediate seeds** do not fully conform to the definition of either orthodox or recalcitrant. In some cases, intermediate seeds may have drying capabilities lower than 20 percent moisture content but are not tolerant of freezing.
Coffee is classified as an intermediate seed due to its ability to be maintained for several months at 10 to 12 percent moisture content, despite not being tolerant of extreme drying and/or freezing temperatures.

Both the drying phase and exposure to extreme temperatures represent sources of stress to a seed. The above classifications relate to the seed’s ability to maintain viability when subjected to such stress. Viable seeds are those that are capable of germination when provided with suitable conditions, meaning that the embryo of the seed has maintained its capacity to grow after a period of dormancy. These traits are critical to the survival of plants in their natural settings, especially in seasonal environments; seeds deposited in one season may remain dormant for months or years, in unfavorable conditions, but can become metabolically active upon exposure to favorable conditions.

The commercial seed industry uses seed viability testing as a function of quality control, where testing is performed on individual seed lots. The tests serve as validation that the steps involved in the process of seed production (harvesting, sorting, drying and milling) were performed within parameters that yield a minimum number of viable seeds. From a commercial farming perspective, seed viability is critical to the overall effort, given the magnitude of investment in both time and money in field preparation, seed purchase and seed distribution. Quality control performed by the seed producer ensures a minimum percentage of viable seeds being sold, and redundant tests can be performed by the buyer to ensure viability prior to planting.

There are two important points of differentiation between the coffee industry and the broader farming industry:

1. Coffee seeds are sold to importers and roasters who have no intention of planting them; therefore, viability is not critical to the intended use.
Coffee farmers first germinate seeds in nurseries. Meaning that viability is verified when seedlings develop, prior to being transferred to locations on the farm.

These two facts make seed viability testing for green coffee mostly irrelevant. However, scientists have discovered that overall seed viability may play a significant role in influencing how coffee tastes. There are a variety of methods employed by scientists to determine seed viability, from time-honored traditional methods to increasingly advanced methods using greater technology.

Seed Viability Testing

Traditionally, seed viability was determined via germination testing, performed by attempting to germinate a sample of seeds and quantifying the percentage that were successful out of the number of total attempts. Germination time for many seeds can be several days to several weeks (the latter being the case for coffee). Thus, germination testing is not always practical for evaluating seed lots within a reasonable time frame. Several test methods have been developed as alternatives to germination tests, to expedite testing that has demonstrated a high correlation between key variables. The most common methods referenced in coffee research are:

- **Tetrazolium testing:** Uses the chemical triphenyltetrazolium chloride, or TTC, as an indicator for the presence of living tissue cells. TTC is a colorless solution that is converted into formazan, a red dye, when in contact with living cells. Living cells are stained while non-living cells remain unstained. The proportion of dyed seed material can be used to quantify the viability of the seed.
Conductivity testing: Uses electrical conductivity passing through a sample. The results are calculated via the measured resistance of the sample to an electrical current. Lower electrical values are correlated with higher seed viability. Higher electrical values are correlated with lower seed viability, which indicates that a compromise to cell membrane integrity has occurred.

Enzyme activity testing: Uses the observation of the increase in antioxidant enzyme activity (released during periods of stress) as an indication of the extent to which a seed has been exposed to stress.

Water activity: Uses the measure of total amount of water available for hydration of other substances within a sample. Water content within a substance is 1) strongly bound 2) less strongly bound or 3) weakly bound. Free water accelerates many of the chemical processes that contribute to seed deterioration.

All tests require some level of understanding of the seed under consideration in order to make assessments regarding seed viability when provided with results. Enzyme testing requires an understanding of the composition of a seed; similarly, water activity and conductivity are both influenced by the composition of the seed. Tetrazolium requires an understanding of the seed anatomy to make determinations on dying patterns. As a result, there is no universal number that can be applied as a threshold when determining seed viability. Water activity is a relatively new method recognized in the seed industry. This method is rapid and nondestructive but requires data collection and threshold determinations to apply in practice.

Coffee research has observed that despite a probability that the embryo has been compromised, viability testing of endosperm material still remains an accurate indicator of overall integrity of the seed in terms of cup quality. This suggests that cup quality, as it pertains to viability, is more closely correlated with the total amount of unstressed tissue than with an actual capacity of a coffee seed to germinate.
Coffee Processing and Potential Stress

Taken at its most simplified, the goal of coffee processing at origin is to separate the seed from the rest of the fruit and reduce the water content to between 10 percent and 12 percent (from approximately 40 percent at the time of harvesting). An overview of green coffee processing styles and descriptions of steps is beyond the scope of this discussion, but many articles in previous editions of Roast can be referenced on this topic (visit roastmagazine.com/articleindex for past issues).

Coffee Processing at Origin

In the same way that each unique coffee processing method yields different flavors, so too does it uniquely influence seed metabolism. Each processing method (and every step within each method) risks exposing the coffee seed to stress, at varying intensity and duration. As a result, the outcome of a specific processing method will likely yield a unique seed viability measurement—a consideration that must be taken into account when establishing baseline and threshold measurements for specific coffees.

A primary source of stress on coffee occurs when it is exposed to excessive temperatures. Coffees dried outdoors, such as those spread on open patios or placed in raised beds, risk being overexposed to direct sunlight for extended intervals between rotation. Coffees dried mechanically risk exposure to heat if furnace settings are too high for the load weight or if the mechanical agitation is not sufficient in distributing the load evenly in the drying process. All machinery and surfaces with which coffee comes in contact have the potential to cause stress.

The Impact of Stress on Green Coffee

When stressed, coffee will undergo chemical changes. The extent to which a coffee seed is stressed will cause changes both immediate and long-term. The basis of the enzyme activity testing is to determine the degree to which a seed has been stressed by evaluating chemical markers associated with this stress. Several significant reactions occur as a result of stress: changes in levels in antioxidants, amino acids, carbohydrate (glucose), and free fatty acids. These changes are concentrated in the endosperm, where nutrients for the embryo are stored. If the tissue is living, it will change TTC to red dye (formazan); if compromised, the tissue will may remain unchanged in the test.

Any changes in chemical composition have a potential impact on cup quality. The chemical changes that result from stress lead to observations in cup quality similar to those associated with past-crop coffees. A past-crop coffee is green coffee that was produced during the previous year’s harvest. Past-crop coffee often demonstrates a specific set of cup attributes, which are the result of aging and natural degradation. Current-crop coffees that demonstrate cup attributes similar in nature to that of past-crop coffee are often described as “woody,” although the sensory experience is very similar. Past-crop is a reference to a coffee’s age related to the harvest cycle rather than a quality descriptor.

An important note for roasters to remember is that these changes may affect roast development. Constituents necessary for chemical reactions to occur in the coffee roasting process may differ in proportion or may not be available, requiring changes to the roast profile.

Storage and Transportation Conditions

Green coffee’s susceptibility to stress extends well beyond the processing stages at origin. Transportation and storage conditions can be critical to quality. Shipment times for green coffee from origin to destination country can range between 30 to 60 days, or more. Throughout the process, disruptions and delays can be experienced due to transportation strikes, port strikes, customs holds and major weather events at port destinations, which can lead to coffee remaining exposed to temperature extremes for longer-than-anticipated (or desirable) periods of time. Overland shipments, via truck or rail, can further expose coffee to adverse conditions. Regardless of the initial quality of the coffee when it departed the farm or mill, quality will remain at risk and out of anyone’s control until it arrives at a destination warehouse or the roasting facility.

During storage, green coffee quality changes at a rate dependent largely on the storage conditions, temperature and humidity. Receipt of the green coffee is the first opportunity one has to assess the quality and make decisions regarding its use, its priority among other coffees in the inventory, and the storage conditions appropriate to maintain quality or determine its shelf-life potential.
The rate of change of green coffee quality can be modeled mathematically: the same model can then be applied to subsequent coffees matching a specific green coffee profile. The rate of quality decline for any given coffee can be established via measurements, both analytical and sensory. Measurements taken upon receipt are used to establish a baseline. Repeated measurements, taken at a given interval, are then leveraged in constructing the mathematical model used in projecting the shelf-life of a coffee. All existing models in the seed industry include temperature and humidity, along with other measurements, and target the half-life of a seed.

Summary

A growing body of research suggests that a direct and high correlation exists between seed viability and cup quality. Seed viability in coffee declines over time, naturally and with age. Compromise to seed viability of a fresh coffee can occur at any time during the coffee life cycle, due to stress, which accelerates the decline of the coffee quality and produces cup qualities similar in character to that of “past-crop.”

Traditional test methods required preparation time and an understanding of seed anatomy, but water activity meters are a progressing technology recognized in the seed industry as capable of accurate testing. Seed viability, along with other metrics, can be used to create models to predict quality declines for coffee over time. This information can be used to make decisions regarding the prioritization in usage of green coffee in current inventory and for future purchasing decisions related to quantity, packaging type, and shipping and storage conditions. Storage conditions are one of the only levers available to a roaster to preserve coffee quality, and modeling may assist in establishing optimal conditions for coffee while stored.

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