THE COFFEE ROASTER'S COMPANION

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Choosing Machinery

Selecting a roasting machine is a long-term commitment, and I hope readers do their homework before buying a machine. Most small roasters, especially first-time buyers, don't have the experience to evaluate machines properly, so if that's you, I recommend seeking expert advice before making what is probably your company's largest investment. You must choose carefully because the majority of machines on the market today will limit your coffee's quality or consistency, though their sales representatives may neglect to tell you that.

Features to Consider when Selecting a Roaster

Every roasting company has its unique list of needs and preferences when choosing a roaster, such as aesthetics, machine footprint, cost, and so on. While I can't comment on those company-specific requirements, I offer the following technical recommendations to help you choose a roaster.

Capacity

First, decide how much roasting capacity you need. Second, use a manufacturer's stated capacity as a starting point and look up a machine's BTU rating to estimate what its realistic capacity might be. Finally, given that every machine will have different heat-transfer efficiency, I recommend that you contact a few users of a given machine to ask about their typical batch sizes and roast times. Using those three pieces of information, you should have a good sense of the machine's realistic capacity.

Configuration

A roasting machine's configuration probably has the greatest effect on the quality of coffee that it can produce. As I'm sure you've gathered by now, I recommend single-pass roasters over recirculation roasters, despite the latter's energy efficiency. I also recommend an indirectly heated drum, or a double drum, over a standard flame-on-drum design. A single-pass roaster with a double drum or indirectly heated drum will maximize your chances of producing great coffee and minimize potential flavor taints due to bean-surface burning or a smoky roasting environment.

The Drum

If you buy a classic drum roaster with a flame-on-drum configuration, I recommend choosing a machine with a carbon-steel drum. Contrary to popular belief, most old, German "cast-iron roasters" have carbon-steel drums, not cast-iron drums. Those machines and many others often have cast-iron faceplates, drum spokes, and drum paddles, but steel drums. I have seen one machine with

Single-walled steel drum

a cast-iron drum (a small, newer roaster manufactured in Taiwan) and one machine with a sheet-iron drum, but every other machine I've ever seen has had a steel drum.

Most roasting drums are made of carbon steel, but some manufacturers have recently begun building machines with stainless-steel drums; this seems reasonable, but I don't have enough experience with them to have an opinion about their performance. Stainless steel drums may develop hot spots more easily than mild carbon steel ones, but that's probably not a serious concern, given the drum's rotation and an adequate thickness.

Airflow

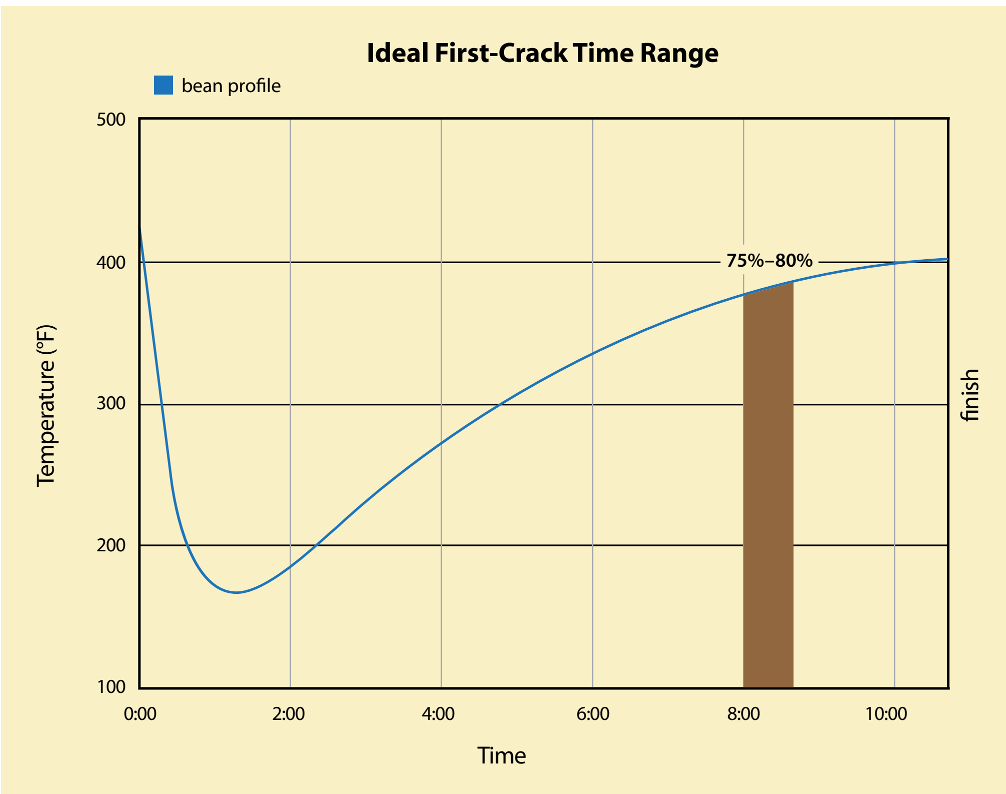
I've come across few roasters with inadequate airflow but several machines with poor airflow adjustment mechanisms. Ideally, your exhaust fan's RPM should be adjustable in minute, stepless increments. Subtler airflow adjustments will produce smoother roast profiles. Machines with two or three discreet airflow settings, usually controlled manually by a damper, are acceptable but limiting. Not only are the settings usually too far apart, forcing the machine operator to compromise and choose a suboptimal setting, but the large shifts

III. First Crack Shalt Begin at 75% to 80% of Total Roast Time

Experience has taught me that the roast time from the onset of first crack* to the end of a roast should make up 20%–25% of total roast time. Put another way, first crack should begin at between 75%–80% of total roast time. I'm confident that the optimal ratio is actually in a much narrower range, and the ratio should vary slightly depending on roast degree desired, but I don't have enough data yet to back up those beliefs.

If first crack begins at earlier than 75% of total roast time, the coffee will probably taste flat. If more than 80% of the total roast time elapses before first crack begins, development will likely be insufficient.

Most roasters seem to adjust a roast's "development time" separately from the rest of the roast curve, but such an approach will often lead to baked flavors or underdevelopment. Instead of focusing on development time, I recommend that roasters adjust the last phase of a roast curve to ensure it is proportional to the entire roast curve. I hope roasters will find this suggested ratio useful and that the conversation among roasters shifts from "development time" to "development time ratio" or a similar phrase.



First crack should ideally begin in the shaded zone.

* I consider the beginning of first crack to be the moment the operator hears more than one or two isolated pops.

11 Mastering Consistency

Much like the elusive "God shot" of espresso, most companies roast the occasional great batch but can't seem to reproduce it consistently. Variations in a roaster's thermal energy, green-coffee temperature and moisture, ambient conditions, and chimney cleanliness all collude to make roasting inconsistent. I've designed the tips in this chapter to help you control or lessen the impacts of these factors. Following these recommendations will help any roaster improve consistency.

How to Warm Up a Roaster

At a cupping of some lovely Cup of Excellence coffees a few years ago, I noticed that one of the samples was very underdeveloped and another was slightly underdeveloped. The other cups had varying degrees of good development. It dawned on me that those two cups had been brewed from, respectively, the first and second batches roasted that day. I suggested to my cupping host the order in which he had roasted the samples that morning. I had guessed the order correctly.

Every roaster I've ever asked has admitted to having difficulty with the quality of the first few batches of a roasting session. The problem is usually caused by inadequate warming up of the roasting machine. Most machine operators warm up a roaster to the charge temperature and then idle the machine at or near that temperature for some amount of time, usually 15–30 minutes, before charging the first batch. This protocol guarantees that the first batch will roast sluggishly compared with successive batches.

The problem is that temperature probes are poor indicators of a machine's thermal energy. (See "Charge Temperature" in Chapter 9.) As a cold roasting machine warms up, although the temperature probes quickly indicate that the air in the machine has reached roasting-level temperatures, the mass of the machine is still much cooler than the air in the drum. If one charges a batch at this point, the machine's mass will behave akin to a *heat sink* and absorb heat from the roasting process, decreasing the rate of heat transfer to the beans. After several roast batches, the machine's thermal energy will reach an equilibrium range within which it will fluctuate for the remainder of the roasting session.

The trick to normalizing the results of the first few batches of a roasting session is to seemingly overheat the machine during the warm-up, before stabilizing it at normal roasting temperatures. To my knowledge, there is no practical, precise way to measure a roaster's thermal energy. However, the operator can apply some informed experimentation to establish a protocol that brings a

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The Three Commandments of Roasting

Please don't take the word "commandment" too seriously. One may transgress some of these rules harmlessly on occasion. As with a certain other list of commandments, however, if you make a habit of ignoring the rules, you might end up in a bad place.

As a roaster and a consultant over the past nineteen years, I've had the opportunity to cup and view the roast data for each of more than 20,000 batches roasted on a variety of machines by various methods. About five years ago, I spent several days poring over reams of roast data in an attempt to find the common elements in the best batches I'd ever tasted.* To be clear, I'm not referring to "really good" batches. I focused only on the data from batches so special that I could "taste" them in my memory months or years after physically tasting them. That effort yielded what I think of as the "commandments of roasting."

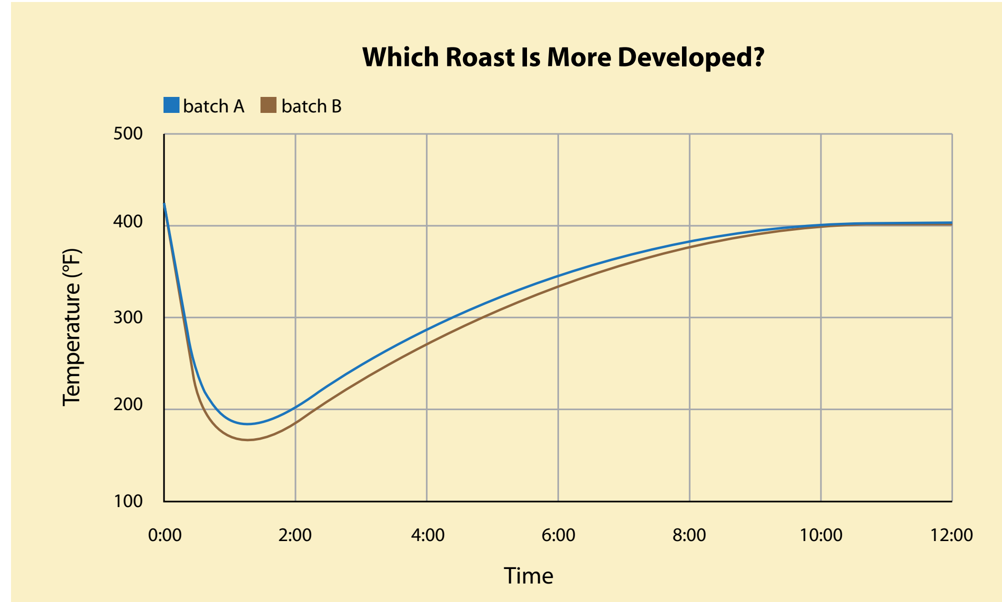
A method graduated to a commandment only if it seemed to apply to a great variety of coffees and roasting machines. I've been testing and refining the commandments for five years, and so far I've yet to find a situation in which coffee tastes better when a commandment is broken. I've also had opportunities to test the commandments in reverse; the times I've tasted stellar roasts from others and the roaster was kind enough to share the roast data with me, sure enough, the profiles conformed to the commandments.

I can't fully explain why these methods work. But I'm confident that if you remain open-minded and apply these techniques carefully and completely, you will be impressed by how much better your roasts taste.

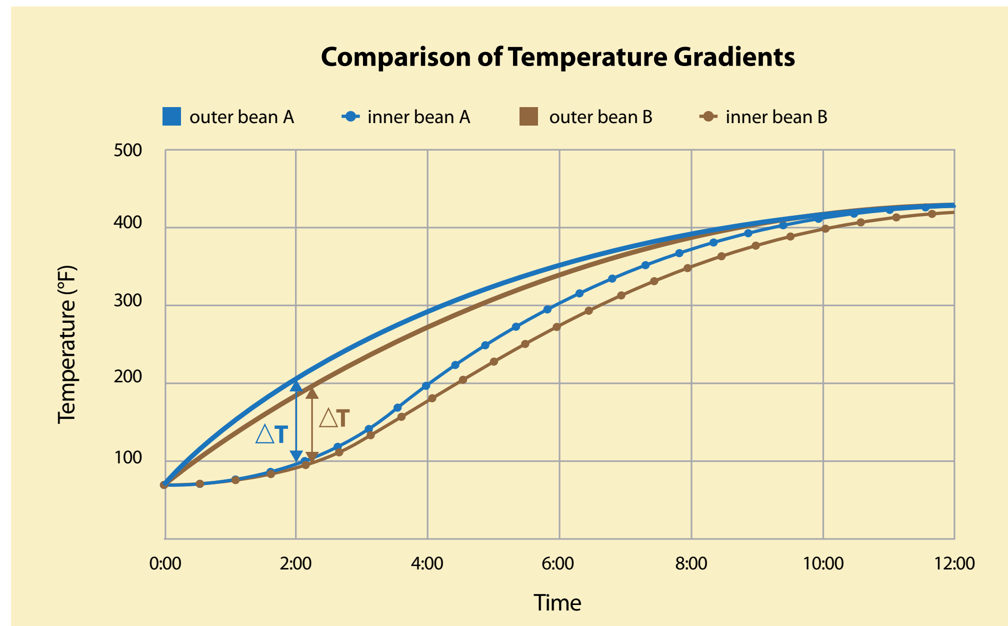
I. Thou Shalt Apply Adequate Energy at the Beginning of a Roast

Applying sufficient heat at the beginning of a roast is essential to achieving optimal flavor and proper bean development. While one may begin a roast with too little heat and still cook the bean centers adequately, the flavor of such coffee may suffer because the operator must lengthen the roast time excessively to compensate for the insufficient early heat transfer.

* I compiled and evaluated my roast data by using a pencil, calculator, and spreadsheet. These days one can analyze such data much more efficiently with the aid of computer software such as Cropster's "Roast Ranger" application.



Batch A and batch B had identical charge temperature, drop temperature, and roast time. Given that batch A's bean temperature initially rose more quickly than batch B's, batch A is more developed.



This graph illustrates the importance of establishing a large ΔT early in a roast. In batch A, the machine operator applied sufficient energy early in the roast, creating a large ΔT, which gave the inner bean the impetus to smoothly "catch up" to the outer bean by the end of the roast. Batch B began sluggishly, creating a smaller early ΔT. Relative to batch A, the operator applied more heat mid-roast to adequately cook the outer bean in a similar total roast time. However, the extra energy was too little, too late for the inner bean's temperature to match that of the outer bean, and batch B was underdeveloped.

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Roasting Machine Designs

A coffee-roasting machine is a specialized oven that transfers heat to coffee beans in a stream of hot gas while continually mixing the beans to ensure they roast evenly. Several types of roasters are in use today in the specialty coffee industry: classic drum roasters, indirectly heated drum roasters, fluid-bed roasters, recirculation roasters, and several others. Recirculation roasters return a portion of the exhaust air to the burner chamber to assist in heat generation for roasting. I will use the term "single-pass" to refer to machines that do not recirculate exhaust air. Each roaster design has distinct advantages and disadvantages, though no new design has eclipsed the popularity of the classic drum roaster, the design of which has not changed much in the past century.

Classic Drum

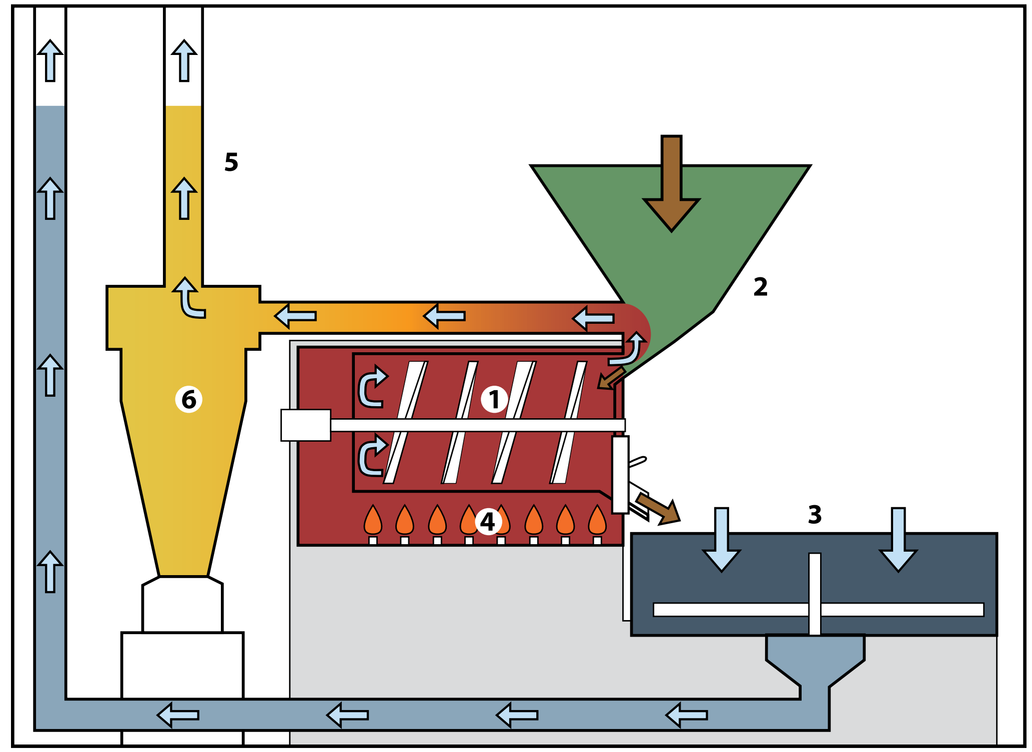
A classic drum roaster consists of a solid, rotating, cylindrical steel or iron drum laid horizontally on its axis, with an open flame below the drum. The flame heats both the drum and the air to be drawn through the drum. A fan draws hot gases from the burner chamber through the rotating beans and exhausts the smoke, steam, and various by-products of roasting and combustion out of the building through a vertical pipe, or "stack." The drum's rotation mixes the beans while they absorb heat by conduction from direct contact with the hot drum and convection from the air flowing through the drum.

At the completion of a roast, the machine operator opens the door to the drum, dumping the beans into the cooling bin, which stirs the beans while a powerful fan draws room-temperature air through the bean pile to cool it rapidly.

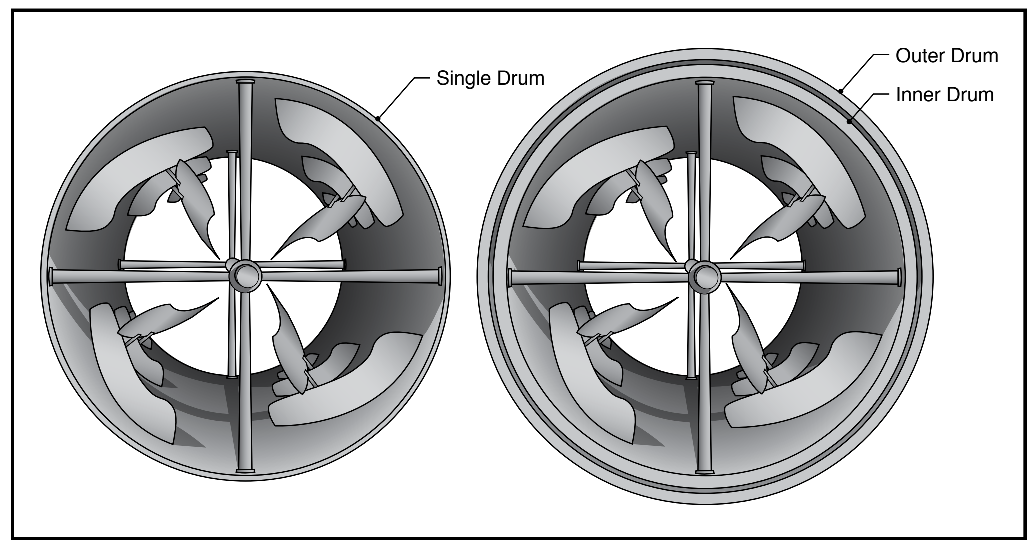
The best classic drum roasters have a *double drum* of two concentric layers of metal separated by a gap several millimeters wide. In a double drum, direct contact with the flame heats the outer drum, while the inner drum remains cooler. A double drum decreases conductive heat transfer and limits the risk of *tipping, scorching,* and *facing.* (Henceforth, these three are referred to in this text as "bean-surface burning.") If you buy a classic drum roaster, I strongly suggest finding one that has a double drum.

Advantages: The single pass of the roasting gas provides a clean roasting environment, and the drum serves as an effective heat-storage system, providing conductive heat transfer, especially during the first few minutes of a batch.

Disadvantage: Overheating the drum metal can easily lead to bean-surface burning.



Classic drum roaster. Beans (brown arrows) enter the roasting drum (1) through the loading funnel (2). After roasting, the beans cool in the cooling bin (3). Air (blue arrows) passes from the combustion chamber (4) through the roasting drum and exhausts through the chimney (5) by way of the cyclone (6), which traps chaff.



Single drum (left) and double drum (right)

To understand the Maillard reactions' contribution to flavor, consider the different effects of roasting and boiling on the flavor of meat: Roasting imparts aromatics, complexity, and depth of flavor absent in boiled meats. Maillard reactions contribute similar roast-flavor traits and complexity to coffee beans.

During roasting, once a bean's internal temperature is high enough to boil off most of its moisture, the temperature rises more rapidly, speeding Maillard reactions. This is one reason aroma development accelerates at mid-roast. Maillard reactions become self-sustaining at above 320°F (160°C).

Unlike Maillard reactions, caramelization is a form of *pyrolysis,* or thermal decomposition. Caramelization begins at approximately 340°F (171°C),[19] as the heat of roasting breaks apart molecules of sugar and produces hundreds of new compounds, including smaller, bitter, sour, and aromatic molecules and larger, brown, flavorless molecules.[19] Although most people associate the word "caramel" with a very sweet dessert food, caramelization, ironically, decreases the sweetness and increases the bitterness of a food or beverage. Lighter roasts are sweeter, and darker roasts more bitter and caramelly, primarily because of caramelization.

Caffeine Content and Roasting

Despite what almost everyone has heard, darker roasting does not decrease the caffeine content of coffee beans. Caffeine levels are virtually unchanged by roasting,[3] as caffeine is stable at typical roasting temperatures. Given that beans lose mass during roasting, their proportion of caffeine by weight increases during roasting. Therefore, assuming one brews coffee of all roast degrees with a particular ratio of water to ground-coffee mass, rather than volume, darker roasts will yield brewed coffee with higher caffeine content.

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Heat Transfer in Coffee Roasting

Coffee roasting machines transfer heat to beans by *convection, conduction,* and *radiation.* Each roasting machine transfers heat by a different mix of these mechanisms. The following is an overview of how machine design affects heat transfer. I discuss roasting machine designs extensively in Chapter 7.

Convection, Conduction, and Radiation

"Classic" (my term) drum roasters, which apply heat directly to the drum, cook beans primarily by convection and secondarily by conduction. Radiant heating from hot roasting-machine surfaces and between neighboring beans makes a small contribution to heat transfer as well. In a personal communication with me, a representative of a well-known German manufacturer estimated heat transfer in his company's drum roasters to be 70% by convection and 30% by conduction.

Indirectly heated drum roasters segregate the drum from the heat source to maintain a cooler drum during roasting. Convection contributes a higher proportion of the heat transfer in these machines.

Fluid-bed roasters have no drum, and they roast by keeping the beans aloft in a high-velocity stream of hot gases. Recirculation roasters, such as the Loring Smart Roaster™, capture and reuse a proportion of the exhaust air from the roasting process. Both of these roasting machine designs transfer heat almost exclusively by convection.

At the beginning of a roast batch, charging the beans introduces a large volume of room-temperature beans and air into the hot roaster, sending the *environmental temperature* in the roaster plummeting. During the first few minutes of a batch in a classic drum roaster, conduction from the hot drum plays a significant role in transferring heat to the beans. As the air temperature in the roaster rebounds after its initial plunge, convection comes to dominate heat transfer. In such a machine the drum acts as a "heat-storage" device that jump-starts development early in a batch. Convection-oriented machines call for the use of hotter charge temperatures to provide adequate heat transfer early in a roast and compensate for lack of a heat-storing drum.

> Establishing a high ΔT early in a roast and minimizing it by the end of a roast is essential to creating good inner-bean development and a uniform roast.

Heat Transfer and Temperature Gradient

The first two-thirds or so of roasting is an *endothermic* process, meaning the beans absorb energy, and heat is conducted from the outer bean to the inner bean. The *temperature gradient,* or "ΔT," within the beans largely determines the rate of heat transfer. Simply put, a

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