Variations in Coffee Processing and Their Impact on Quality and Consistency

By

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This report, "Variations in Coffee Processing and Their Impact on Quality and Consistency", is hereby approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE IN FORESTRY

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Abstract

Arabica coffee is the primary cash crop for many farmers in the mountains of Panama. Virtually all of the production from the provinces of Veraguas and Coclé is consumed within Panama. Since the export market pays significantly higher prices, many coffee farmers are interested in producing coffee of sufficient quality for this market. Inconsistencies and poor practices during processing and drying of coffee were noted during the 2006 harvest in a coffee producing area in the highlands of the province of Veraguas. Since coffee quality depends on environmental conditions, cultivar, careful processing, and sufficient drying, these inconsistencies may disqualify a product with potential for export.

During the 2007 harvest, experiments varying the fermentation time and final moisture content of dried coffee were conducted. Forty-five samples representing five samples each of three categories of fermentation times and three categories of degree of drying in nine possible combinations were prepared and cupped. Cupping, the blind, objective evaluation of coffee quality based on aroma and taste, was done by two technicians at the Café Ruiz coffee cupping laboratory. The scores were analyzed to look for statistically significant differences.

Well-processed samples scored higher in most cupping categories and overall quality. Fermentation had a larger effect than drying, and the interaction between the two also proved important. The overall cupping scores of well-processed samples were higher on average, but also had significantly smaller standard deviations. This is particularly important, since consistency is critical in the production of export-quality coffee. With the right environmental conditions and careful processing, production of export-quality coffee in the highlands of the provinces of Veraguas and Coclé may be possible.

Introduction

In rural Panama, it is impossible to stop at someone's house without two things happening. First, you are ordered to sit down. Second, you are given coffee. It is often weak, tepid, and loaded with incredible amounts of sugar. Coffee is the only thing that can be considered a luxury in many rural families' diets and is the primary cash crop for many areas of Panama, and nothing represents the friendliness and hospitality of Panamanians more. Some is exported, but most is sold cheaply for domestic consumption. Farmers told me about a few times in the past when their coffee sold to exporters for high prices, and many wondered why that had not continued. In fact, most coffee farmers had heard that not only had a Panamanian coffee ranked the highest in the world in a competition, it had also fetched the highest price ever paid for green coffee beans, $130 a pound. Contrast this with the $0.85 or $1.00 a pound that local farmers were receiving and it is easy to understand their confusion and feelings that someone must be making quite a bit of money from their coffee. So I began to wonder, could this area produce high-quality coffee for export? If so, what adjustments would be needed to meet the quality and consistency demanded by the market? Finally, if possible, would it take much extra time, effort, or equipment? If so, would it be worth it?

During my time in the *campo* (countryside), I grew coffee, planted coffee, pruned coffee, picked coffee, processed coffee, roasted coffee, talked coffee, and drank sometimes incredible amounts of coffee. I also changed many of my preconceived ideas about the situation; this often occurred after frustrations made me realize I was not seeing things the way local coffee producers were. These realizations made me back up several steps and often change my approach; this may have been the biggest thing I got out of the "Peace Corps Experience".

Summary

The purpose of this study was to determine the impact of variations of fermentation and drying processes on coffee quality, especially in the highland regions of central Panama that currently produce only low-quality coffee. Chapter 1 covers background on the country of Panama, including information on geography, climate, economics, and history. Chapter 2 details the origin of coffee, an introduction to processing and quality, a brief overview of the international coffee market, and discusses the importance of coffee in Panama. Chapter 3 focuses on a description of the study area's characteristics, with a particular emphasis on coffee production. Specific coffee processing techniques and their variations are discussed, as well as the challenges faced by coffee producers. Chapter 4 describes the specific farm used for the study, and the methods in the field, the cupping lab, and methods used for analyzing the data. Chapter 5 presents the results of the field work, cupping scores, and statistical analyses of those scores. Chapter 6 discusses the conclusions that can be drawn from the results, particularly those significant to coffee farmers in the study area, and offers recommendations for improving coffee quality.

Chapter 1- Background on Panama

Geography

The Republic of Panama is an isthmus connecting North and South America. Panama has an area of 78,200 sq. km., and is slightly smaller than South Carolina (U.S. Dept. of State, 2007). The isthmus was formed by tectonic uplift associated with nearby plate boundaries and related volcanism. The isthmus is a relatively slender strip of land, narrowing to approximately 50km across, and punctuated by the Azuero Peninsula jutting to the south. Panama is generally S-shaped (Figure 1.1), curving from the Costa Rican border in the west to the border with Colombia in the southeast.

Figure 1.1: Map of Panama (CIA, 2007; map is in the public domain, see Appendix 1).

One of the most notable geographic features of Panama is the spine of mountains forming the Continental Divide. This ridge was formed by plate tectonics and volcanism, and is called the Cordillera Central. Many of the higher peaks of this range are extinct or dormant volcanoes, including the highest peak in the country, Volcan Baru.

Panama is characterized by a high diversity in topography, ecosystems, and climate for such a small country (St. Louis & Doggett, 2004). Ecosystems vary widely from rich, primary rainforest on the Atlantic slope of the Cordillera to denuded, desert-like areas on the Azuero Peninsula.

Climate and Natural Resources

The climate of Panama is influenced by its location between two oceans and its tropical latitude. The country has three characteristic climate zones: tropical humid, subtropical humid, and tropical dry. Tropical humid areas fall below 700m in elevation, have an average temperature of 28 to 34 degrees Celsius, and an average annual rainfall of 260 to 550 cm. Subtropical humid areas are above 700m in elevation, with an average temperature of 18 to 20 degrees Celsius, and an average annual rainfall of 400 to 700 cm. Tropical dry areas are found primarily on the Azuero Peninsula, and have an average temperature of 28 to 34 degrees Celsius, and an average rainfall of 100 to 150 cm. Two seasons are normal in most parts of the country: a short dry season (generally January to April) and a long wet season (May to December) (Black and Flores, 1989). The Caribbean side of the country generally receives more rainfall than the Pacific side.

Biodiversity is high in Panama, but is threatened, primarily by deforestation. While on paper there is protection for large portions of natural vegetation, lack of enforcement is chronic. Like many tropical areas, the soils in most of Panama are not well-suited for agriculture since they have thin, nutrient-poor topsoil (CIA, 2007). Deeper soil horizons are often decomposed bedrock, which is a clayey oxisol and does not retain soil moisture well. Along with poor soils, many areas have rugged terrain; when combined with heavy rainfalls and less-than-ideal farming practices, soil erosion is a common problem.

People

As of 2004, the population was 3.2 million, with 57% living in urban areas (St. Louis & Dogget, 2004). The bulk of this was mestizo (70%), with people of West Indian descent making up 14% (mostly along the Caribbean Coast), whites making up 10% (most living in or near Panama City), and indigenous groups accounting for the remaining 6% (CIA, 2007). There are seven main indigenous groups in Panama: Ngöbe, Kuna, Emberá, Buglé, Wounaan, Naso, Bri Bri (CELADE, 2003). Along with Spanish and English, several native languages are regularly spoken; the number reported varies from seven (Black and Flores, 1989) to fourteen (Cohen, 1976) depending on how they are distinguished, since some are similar.

Economics

The per capita GDP (as of 2005) was $4,513 (U. S. Dept. of State, 2007). However, the income inequality index is 0.56 (FAO, 2006), which is among the highest in Latin America. Poverty affects 37% of the population, and extreme poverty is at 19% (FAO, 1999). Undernourishment afflicts 25% of the population. These problems are most common in indigenous areas, where 95% of the population lives in poverty.

Eighty percent of the country's GDP is accounted for by the service sector, which includes income from the Canal, financial services, flagship registry, insurance, and tourism. The focus of the economy, politics, and population on the Canal area has led to feelings of disenfranchisement in the rural population (U.S. Department of State, 2007).

Panama uses the American dollar for its currency, a move that has helped stabilize the economy and curtail inflation. The country is currently undergoing a massive boom of development and investment. There is an established minimum wage of seven dollars a day; however, this really only applies to formal businesses and industry. The rate for semi-skilled labor in the countryside of Veraguas and Coclé provinces is around $3 to $4/day, including a lunch, as of 2007. Some labor, particularly coffee harvesting, is paid according to a rate based on volume or weight.

Arable land makes up 9% of Panama, with another 20% considered suitable for pasture (FAO, 2006). Fishery product exports account for $448 million of income annually, and agricultural exports bring in $320 million annually (FAO, 2006). Forestry exports earn approximately $84 million annually.

History

Before the arrival of European explorers, Panama was inhabited by societies that farmed, fished, and traded. Unlike some other Latin American cultures of the Pre-Colombian era, they did not construct extensive stone monuments, and relatively little is known about them. Archeological evidence indicates that even then Panama was an important trade pipeline (McCullough, 1977).

Spanish explorer Rodrigo de Bastidas arrived in what is now Panama in 1501, marking the beginning of over 300 years of Spanish colonial rule. The Spanish used Panama primarily as a trade zone, bringing gold and wealth from Peru and elsewhere across the isthmus on the *Sendero Las Cruces* (The Crosses Trail) and the *Camino Real* (Royal Road) and returning with imported goods from Europe. Slave trading was also a large business, since the Spanish authorities did not tax these transactions. Cross-isthmus trade declined in 1739 with the destruction of the port city of Portobello by the British; the Spaniards began sailing around South America instead (McCullough, 1977).

The call for independence from Spain first came from the town of Los Santos in central Panama, and Panama received its independence on November 28, 1821. It remained part of Gran Colombia, along with many other current South American nations.

Interest in constructing a canal began in the 1500s (Black & Flores, 1989), but proved infeasible. The technology of the time relied heavily on manual labor, and diseases such as yellow fever, malaria, and smallpox would have ravaged any workforce assembled for such a task. The idea was revived sporadically over the next few centuries, but never seriously until gold was discovered in California, and Panama once again became a main transportation route. Numerous companies and countries expressed interest in constructing a canal. However, a cross-isthmus railroad proved far easier, and an American company completed one in 1855. This succeeded immediately because of increased traffic from the Gold Rush in California; sailing and crossing the isthmus on foot or by train was faster and safer than crossing the continental U. S. at that time.

In 1878 the French received a contract from Colombia to build a sea-level canal along the same route as the railroad. Work was begun shortly thereafter by Ferdinand de Lesseps, the famed builder of the Suez Canal. The project was plagued by construction and financial problems, but these paled in comparison to problems with yellow fever and malaria, which killed 22,000 workers (McCullough, 1977). By 1889, the project was bankrupt with approximately 2/5ths of the excavation completed. The American government and businesses had followed the construction with great interest, and wanted to see it completed. Representatives of the French canal company, the United States government, and the Colombian government negotiated for the sale of the canal to the United States, but progress was frustratingly slow.

A festering political frustration with Colombia came to a head when the Colombian government refused to allow the sale of the French canal to the Americans. Independence was declared by rebelling Panamanians on November 3, 1903; and backed by the U. S. military, which prevented Colombian soldiers from reaching the country. A controversial treaty securing a "Canal Zone" as an essentially sovereign American territory was quickly signed, allowing the construction to resume on a massive scale.

During the 20th Century, the Panama Canal was the focal point of the country, both politically and economically. Construction of the canal by the Americans began in 1904, and proved more difficult than they had expected. Nothing as large and challenging had ever been built, and logistical problems with simply housing and feeding so many workers required strong, efficient management. The fatalities caused by malaria and yellow fever were largely overcome when their vector was discovered to be the mosquito and massive efforts to eradicate these insects began (McCullough, 1977). Still, problems with unstable bedrock and flooding slowed the efforts, and forced a change from a sea-level canal to one using a lock system.

The American ownership of the canal and the surrounding Canal Zone (an approximately ten-mile wide and fifty-mile long strip) was contentious from the start. Dissatisfaction with the American presence grew over the decades, and reached a critical point in 1964, with a controversy over flying the Panamanian flag in the Canal Zone. This culminated in a clash between student protesters and the U.S. military which lasted for several days and left 27 dead and hundreds injured. Debate over what to do about the ownership of the canal dominated the 1968 elections; shortly after Arnulfo Arias was elected, the military, led by Omar Torrijos, overthrew him in a coup. This marked the end of a period dominated by a “commercially oriented oligarchy” (Dept. of State, 2007).

Torrijos ruled the country as a military dictatorship, albeit one that was popular with much of the population. He improved infrastructure in rural and urban areas, built schools, and prioritized rural development projects. But he is perhaps best remembered and loved by the Panamanians for negotiations with President Carter that led to a new treaty agreeing to turn over the management of the Canal and Canal Zone to Panama in 1999. Despite this success, Panamanian politics grew increasingly fractured and factional in the late 1970s. Torrijos’ death in a plane crash in 1981 led to a chaotic power vacuum marked by conflict between the military, political parties, and government officials. This ended with the deft consolidation of power by Manuel Antonio Noriega, who had been an important deputy to Torrijos.

Noriega, who Torrijos had called “my gangster”, cracked down on political opposition in the press and on the streets. He had ties to the CIA and Colombian drug lords, and was involved in the Iran-Contra affair (Buckley, 1991). Political stability decayed during his years in power, culminating when he declared war on the U. S.; President George H. W. Bush responded by invading the country in 1989. Noriega was captured and extradited to the U. S. to face charges related to drug smuggling. He was found guilty and as of January 2009 was still in prison.

Post-invasion, much of the Panamanian government was in shambles, and some parts of the capital had been destroyed, but peace soon prevailed and the government was restored. Since this low-point, Panama has had several democratically-elected Presidents; Martin Torrijos, son of the famous general, is serving until May of 2009. Corruption is still considered a significant problem (Dept. of State, 2007). Many government jobs, including poorly-paid agricultural extensionists, are tied to political affiliations, and when a new party takes power, there is a large turnover that slows down many government services for several months.

The period from 1991 to 2008 marked a time of economic growth and peace, and with the successful turn-over of the canal in 1999, the ensuing decade is the first that Panama has been an independent and whole country. The capital has undergone a dramatic boom in real estate and development, most visibly marked by the dozens of high-rises being constructed along the waterfront. Resorts have sprung up on previously empty stretches of beach. Little of the money fueling this development has reached the rural parts of the country, where life continues much as it has for decades.

Three news stories have thrust Panama into the international limelight during the period from 2006 to 2008. The first group pertains to the expansion of the Canal to allow larger boats to pass; an expensive undertaking with poorly understood environmental impacts. The second relates to the boom in real estate. The third, while less publicized, has to do with the record-setting prices a Panamanian coffee has sold for at auction, along with a higher profile in the specialty coffee world for many Panamanian coffees.

Chapter 2- Background on Coffee

The history of coffee production and consumption is full of intrigue, entertaining anecdotes, and tall tales. It is the second most important international commodity after oil, and the market can be quite volatile (Willson, 1999). Getting coffee from a red fruit on a tree to a hot beverage in a cup is a complicated process with many steps. Most of these steps can have a measurable effect on how that final beverage tastes.

Coffee History

While the true history of the first cup of coffee is lost in obscurity, two stories about the origin of coffee as a beverage are worth sharing here. In the first, Mohammed, ill and praying to Allah, was brought coffee and the Koran by the angel Gabriel. The coffee gave him "enough strength to unseat 40 men from their saddles and make love to the same number of women." (Smith, 1985) The second recounts a goatherd who, upon noticing his goats dancing and prancing, found that they had eaten from a coffee tree. Monks who saw this odd behavior gathered coffee beans and made a beverage that they started using to stay more alert during long prayers.

While the true origin of coffee as a beverage is lost in the past, it did originate in Ethiopia, and was "discovered" around 850 AD (Smith, 1985). Historical evidence indicates that at first the dried fruit was steeped like tea to make a beverage; when the first beans where roasted, ground, and brewed into what we know as coffee is lost in the annals of history. For a time, Arabs controlled coffee production by not allowing access to coffee farms by outsiders, and by heating beans before export to prevent them from germinating. An Indian pilgrim apparently smuggled viable beans to Mysore, India, around 1600 AD. Still, the Arabians controlled the flow of coffee beans to Europe until 1616, when a Dutch trader stole a coffee plant and propagated plants for the Amsterdam Botanical Gardens. Seeds from those plants were brought to numerous Dutch colonies, and soon spread throughout the tropical world (Clifford and Willson, 1985).

Although it soon became the second largest commodity traded internationally (after oil), for centuries, the quality of coffee was not important. The explosion of

American gourmet coffee consumption, led by Starbucks, has had a notable impact on the international coffee market since the 1990s. While this has not been as noticeable of a benefit to coffee farmers as one may think (Gresser & Tickell, 2002), it has still opened up alternatives for farmers, especially those capable of producing specialty coffees.

Coffee Markets

While there are at least 90 species in the *Coffea* genus, only *Coffea arabica* and *Coffea canephora* are cultivated for commercial production (Willson, 1999). These are commonly known as arabica and robusta, respectively. Arabica originated in the highlands of Ethiopia (Ferwerda, 1976) and is grown at altitudes above 500m. Research (Silva et al., 2005) and anecdotal evidence suggests that the best quality coffee grows above 1000m asl. Arabica has a milder and more flavorful taste and lower caffeine content than robusta, which is more resistant to insect damage and disease (Willson, 1999). Arabica requires soil that is slightly acidic (5.2-6.3pH); it can be grown on more acidic or alkaline soils, but nutrient availability may become a problem (Willson, 1999).

One major challenge for coffee production is the wide fluctuation in market price. For example, during the period from 1994 to 2004, the International Coffee Organization's indicator price for a pound of green arabica beans ranged from $0.54 to $2.22 (ICO, 2006). The annual average prices for arabica beans (Figure 2.1) reached a 30-year low in 2001 (Gresser & Tickell, 2002); when adjusted for inflation, this was the lowest price farmers have seen during the 20th century. These low prices are forcing many smallholder farmers to look for ways to increase their profits, including focusing on a higher quality product that can be exported.

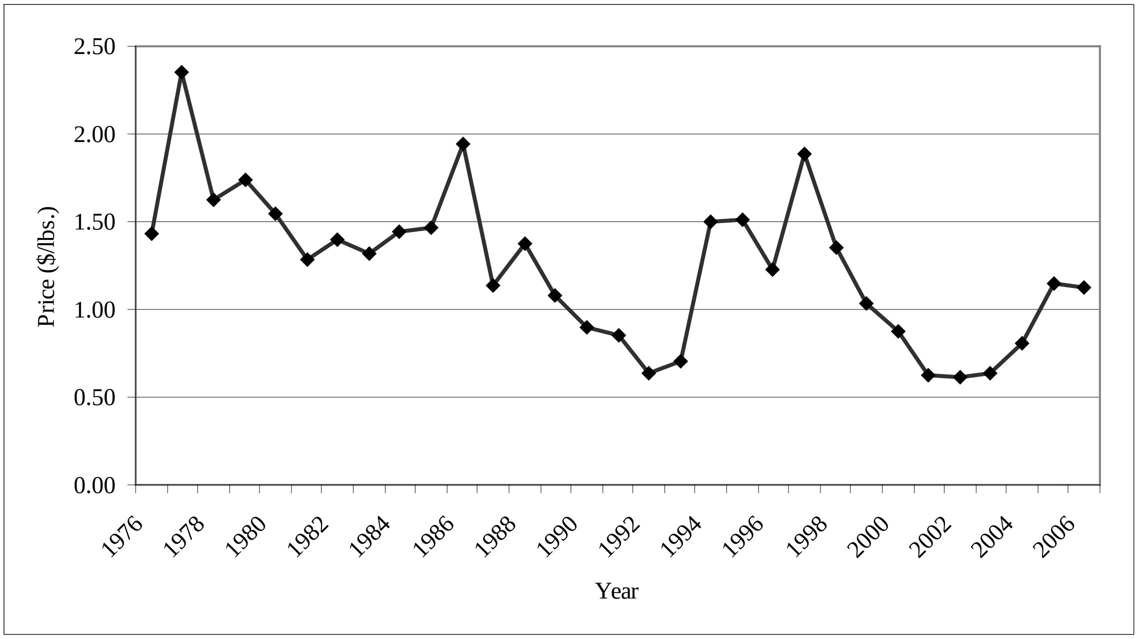

Figure 2.1- Average annual coffee prices for arabica beans on the New York Coffee Exchange (ICO, 2006).

Processing

Most arabica coffee is processed in one of two ways: dry processing and wet processing. Dry processing is simpler; more often used in East Africa, and involves simply allowing the harvested fruits to dry in the sun intact. When they are dry, the beans are removed by a machine. Wet processing is more common in Latin America, and involves more steps. The beans are removed from the fruit, allowed to ferment to remove a slippery mucilage layer, washed, and dried. Wet processing is discussed more thoroughly in Chapter 4, since this method was used for this study. A side-by-side comparison drying coffee from wet-processing and dry-processing (Figure 2.2) illustrates the obvious difference in appearance between the two.

Figure 2.2: Wet-processed (depulped & washed; left) and dry-processed (dried in fruit; right; photo by Noah Daniels).

Quality

Coffee quality may seem subjective, since it is related to how it tastes and smells, and personal preferences and sensitivities can vary widely. However, there is an increasing body of research that treats coffee quality as a quantifiable characteristic. Researchers are currently looking into which of the approximately 800 chemical compounds present in roasted coffee are linked most strongly to aroma and perceived quality (Farah, *et al.*., 2006), and they are finding that processing methods are important (Bytof *et al.*, 2000; Knopp, et al., 2006).

Research on coffee quality has traditionally focused on varietal and environment (for example, Vaast *et al.*, 2006 and Silva et al., 2005), along with roasting processes (for example, Arya & Rao, 2007), as the largest impacts on coffee quality (Bytof *et al.*, 2000). Recently, researchers have begun to look into processing as an important determinant of quality. In blind cupping tests, wet-processed coffee generally scores higher than dry-processed coffee. It had been assumed that this was because wet-processed coffee had a higher percentage of ripe fruit harvested, while dry-processed had a wider range of ripeness, including unripe and overripe fruits (Selmar *et al*., 2006). Processing experiments with samples of similar ripeness show that the processing method itself creates significant differences in the beans. The two main processing methods have a measurably different effect on the sugars and flavor precursors present, which in turn play a role in complex metabolic processes that the bean undergoes during processing and drying. These studies have also shown that the metabolic processes are related to germination, which starts to occur even when the period between harvest and final drying is short. Finally, investigations have shown that drying causes stress metabolism that can also play a role in the chemical compounds present (Bytof *et al.*, 2005).

Drying is also considered an important step in quality coffee production, since moisture levels higher than 12% can promote microbial growth and mycotoxin formation (Reh *et al.*, 2005). Sufficient drying for smallholder coffee farmers in Panama is difficult for reasons discussed later.

Coffee in Panama

Coffee production in Panama is economically important, but has not developed to the extent of neighboring Costa Rica and Colombia. As of 1996 (FAO, 1996) 32000 ha were being cultivated in Panama, much less than the 101000 ha in Costa Rica and 965000 ha in Colombia. In addition, Panama was producing only 388 kg/ha of coffee, while Costa Rica and Colombia were producing 1412 kg/ha and 995 kg/ha, respectively. Panamanian coffee production is commonly conducted by smallholders with minimal inputs and management efforts, while farms in the neighboring countries focus on the export market and use more inputs such as fertilizer and pesticide (Boot, 2001). Worldwide, coffee production is dominated by smallholders: 70% comes from farms of 25 acres or less (Gresser & Tickell, 2002). Anecdotal and documented evidence (Boot, 2001) suggest that the amount of coffee planted and harvested in Panama is decreasing; it is being replaced by cattle pasture in some areas, or simply abandoned in others.

Several varietals of *C. arabica* are commercially important in Panama. *Typica*, also known as criollo, is the oldest and most common (Arauz, 2005). It produces moderately and is sufficiently resistant to diseases, insect damage, and poor management to make it a popular choice for both smallholder and commercial production. In addition, it has a good flavor, especially when grown at higher elevations (700 to 1800m ASL). Geisha (also spelled Gesha) is an Ethiopian varietal that was introduced by the Ministerio de Desarrollo Agropecuario (MIDA) in 1975 (Araúz, 2005) specifically because it is somewhat resistant to some fungal diseases. Its acceptance was limited, since it produces fewer beans than other popular varietals. However, it has recently gained notoriety when auction lots from Finca Esmeralda in western Panama started winning every cupping competition they were entered in and fetched record-setting prices for green beans over the last three years, peaking at $130/lbs. in 2007 (Owen, 2009). This is especially noteworthy when many other specialty coffees sell for $1/100^{th}$ of that. Consequently, many coffee producers throughout the country have renewed interest in this varietal.

Catuai and Caturra are dwarf varietals that have proven moderately popular, especially with farmers using a more input-intensive approach. They produce well, and are more compact and therefore easier to harvest than Criollo. Catimor is a arabica/robusta hybrid that is resistant to the fungus Roya Anaranjada (Araúz, 2005) and produces more than Criollo. However, it is shorter lived, requires fertilization, and has a taste that is considered inferior.

Robusta coffee (*Coffea canephora*) is also an important crop in lower areas (below 700m) throughout the country. Robusta is generally considered to be of lesser quality, and grown almost exclusively for domestic consumption; however, one renowned American importer of green beans now offers robusta beans produced by indigenous Ngöbe tribes (Owen, 2009).

Volcanic settings provide good conditions for growing coffee around the world, and this is especially the case in Panama. Volcanic soils tend to be younger with more nutrient availability and are often well-drained, important characteristics for coffee health. The slopes of Volcan Baru are home to Finca Esmerlda and the majority of export quality coffee production in Panama.

Panama produced approximately 9.4 million kg of coffee during the 1999/2000 harvest, of which 4.7 million kg were exported (Boot, 2001). This number may underestimate production and domestic consumption, since a significant volume is likely consumed in the areas of production and not easily accounted for by numbers from commercial coffee enterprises. Production dropped consistently throughout the 1990s. Panamanians drink significantly less coffee than their Costa Rican neighbors, just 1.3kg/year per capita as opposed to 3.9kg/year (World Resource Institute, 2004). Both are dwarfed by the world-champion coffee drinkers of Finland, who brew 11.4kg/year per capita.

Panama is somewhat insulated from intense market fluctuations, since a significant proportion of its low to mid-grade production is for consumption within Panama rather than export (Boot, 2001), and the prices can then reflect local market factors rather than a surplus of robusta from Vietnam, or a frost in Brazil. Panamanian specialty coffee producers have also followed two other strategies for dealing with price fluctuations. The first is negotiating exclusive, five-year contracts with Starbucks with stable and higher pricing than the market value. The second is establishing name recognition and a market for their coffee based on quality, which allows them to charge a higher and more stable price for their beans. This approach has become much easier as Panamanian coffee's prominence has risen in the past five years.

Government agencies and non-government organizations (NGOs) are involved with assisting and promoting coffee production in Panama. This assistance can range from providing seedlings and technical support to sponsoring trips for coffee farmers to successful farms. Peace Corps volunteers work with many coffee farmers, and helping them to improve quality and quantity of production has become one of the focuses of the Sustainable Agricultural Systems (SAS) sector of the Peace Corps program. I was one of these volunteers from 2006 to 2008, and my experience with coffee production inspired this study.

Chapter 3- Study Area Overview

Study Location Description

The initial planning and experiments for this study were performed in 2006 in Chitra, a county in the province of Veraguas, in central Panama. The samples for this study were collected during the 2007 harvest from a farm in the nearby town of Zancona, in the province of Coclé (Figure 3.1).

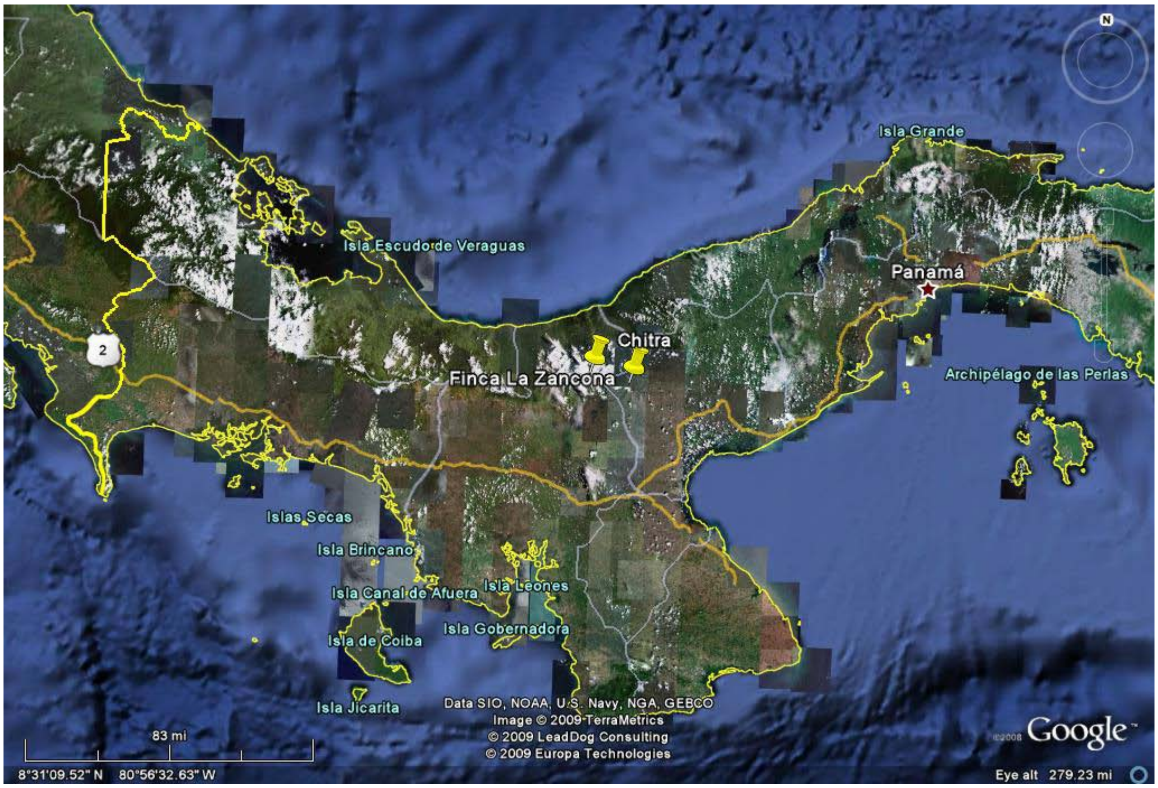

Figure 3.1: Satellite image of Panama with the study site of *Finca La Zancona* (Farm of Zancona) and town of Chitra marked (2008, source: Google Earth; permission for use in Appendix 2).

The southern foothills of the Cordillera Central mountain range are dominated by agriculture. The hills and valleys are a patchwork of plots for corn, dryland rice, *yuca* (more commonly known as casava), beans (*porotos*, *guandu*, etc.), coffee, bananas, citrus, and pasture for cows. Coffee and citrus are important cash crops.

Soils and Topography

Soils fall into three general categories: alluvial, volcanic, and decayed bedrock. Decayed bedrock soils dominate the area, with volcanic soils in the valley of Media Luna, and some alluvial soils near the rivers and streams. The decayed bedrock soils are typical humid tropical soils: prone to erosion, fertile only when regularly replenished with organic material from plant cover. Most parts of this region have seen slash and burn agriculture, which rapidly strips the ground of the thin cover of fertile soil. Most slash and burn agriculture takes place on steep slopes (Figures 3.2 and 3.3). These are not only extremely prone to erosion, they are also susceptible to landslides. The areas with the richest soils are often coffee farms, since they retain the most forest-like structure, slowing erosion and replenishing the organic matter in the soil.

According to ANAM (*Autoridad Nacional del Ambiente*, the equivalent to the National Park Service combined with the Environmental Protection Agency of the United States) sources, the average rainfall is 2265 mm/year, with 90% of that falling during the eight-month long rainy season (Rueben Urriola, personal communication). Potential evapotranspiration is 900-1200 mm/year. Approximately 64% of the watershed that includes the Chitra area is deforested and converted to agricultural land.

Figures 3.2 and 3.3 illustrate the patchwork of forest and agriculture, including some farm plots and pasture on steep slopes. Some buildings and houses are visible in Figure 3.3, but most are obscured by trees that locals keep around their houses for shade or food production. No houses are visible in Figure 3.2, since there are none; most people live in the central area, and only travel up to these higher farm plots to work, sometimes a four-hour roundtrip on foot.

Figure 3.2: View north towards the Continental Divide in Chitra, Veraguas (photo by Noah Daniels).

(a) (b)

Figure 3.3: Panoramic views of the Zancona (a) and Chitra (b) areas (Photos by Noah Daniels).

Agriculture

Government and NGO sponsored efforts to improve agriculture in the highlands of Veraguas and Coclé have had mixed results. These include a cooperative focused on coffee, a collective farm, and a variety of smaller projects. Many times a concept is introduced, but not fully understood before rushing to the implementation phase. We saw many farmers who had been introduced to the concept of planting on contours on slopes, but most had not grasped the technical details for effective implementation of this technique. When they tried to use it, they did so poorly, and often grew frustrated, viewing the whole idea negatively. Long-term support for these projects is uncommon.

Another problem is petty theft of equipment and agricultural products. Coffee fruit is sometimes stolen, though not often due to the time involved and risks of getting caught. Theft of drying coffee or stored coffee is more of a concern. Anecdotal evidence, acquired from conversations with farmers and other Peace Corps Volunteers, suggests that theft of agricultural products is common throughout the country, and occurs in indigenous communities as well (Slatton, 2004).

Coffee's Importance

Coffee is the most popular cash crop in the highlands of Veragaus and Coclé; as such, it represents the largest cash influx. Most families have a *cafetal* or *finca*, which are small coffee farms. Most of these are old and poorly maintained; many of the plants were planted by the previous generation of farmers and need to be pruned or replaced. An objective evaluation of coffee production methods in use has shown that most practices are mediocre or poor when production quantity and quality are considered. Minimizing the labor required is the overriding concern of most coffee producers. As a result, the only time most producers even think about their coffee is during the harvest season of late October through December, though other practices, such as pruning and weeding, should take place during other parts of the year.

There are two main measurements for coffee, the *lata* and the *quintal*. A *lata* (literally "can") is a five gallon bucket, one of the most readily available and useful containers around. This measure is used for fruit and washed beans; the payment of workers is also based on this volumetric measurement (the normal rate in the study area is $1/*lata*). The workers' payment is standardized in this area, and does not change as the market rate for coffee changes, so the risk of price fluctuations falls on the landowner. The shift from a volume to a weight measurement occurs when dried beans are sold to the local store or coffee buyer. *Quintales* is the colloquial expression for 100-pound sacks of coffee, almost always dried, with or without the parchment surrounding and protecting the bean. This measure is used for commercial transactions and larger volumes.

Harvesting

During the coffee harvest, most practices are focused on quantity and speed, not quality. Many areas are harvested only once, and all ripe and unripe beans are picked. This practice is called picking *en parejo* (paired), and is much faster than picking only ripe fruit. Harvesting is often done from early in the morning until early afternoon (between 1PM and 3PM), totaling around five to seven hours. By that time, the heavy rains have usually started, and most workers have harvested all the coffee they can carry, often up to 80 lbs. It is hard work during the least pleasant weather of the year, so there is a sense of relief when the harvest and rainy season are finally over.

Sorting

When time allows, often later the same day or the next day, the fruit are sorted into two groups. The first group is over-ripe (*sobre-madura*), ripe (*madura*), and semi-ripe (*café pintón*); these are soft enough to be depulped by a machine. The unripe (*verde*) beans can damage the machine, and are set aside to be processed differently. This job may be done by women and children while the men in the household are out harvesting more coffee, or it may be done by the whole family in the afternoons or evenings. Sorting the coffee can take a significant amount of time. Families who hire several pickers during the day may stay up sorting late into the night, and this job is considered quite tedious, especially weeks or months into the harvest.

There are two ways to avoid the considerable time investment for sorting. First, harvest only fruit that can be depulped by machine, and leave the unripe fruit behind for a later harvest. Harvesting this way is significantly slower; informal tests and anecdotal evidence indicates it can take up to twice as much time to pick a similar volume. Still, it may be more efficient since sorting time is almost eliminated. One major disadvantage of this approach is that more time is spent in the *cafetal,* and during the harvest many afternoons bring heavy rain.

The second way to avoid sorting is to simply store all the picked fruit, allow the pulp to rot, and let the coffee dry over the course of several months. This gives the coffee a "strong" taste that is not considered favorable by locals. Still, it apparently fetches a similar price when sold in bulk for domestic consumption, so it may be a more efficient approach if quality is not a concern. Only a few coffee producers in Chitra do this, although it is the norm in Zancona and other coffee producing towns nearby.

Processing

After depulping with a machine, the beans are allowed to ferment to break down the sticky mucilage layer, taking between six and twenty-four hours. Ideally, the beans should be washed thoroughly of the decayed mucilage immediately after the fermentation is completed. However, many producers in the study area ferment the beans for longer periods of time, up to several days. This gives the coffee an identifiable "overfermented" taste that is considered undesirable from a quality viewpoint.

The harvested green, unripe fruit is too firm to pass through the depulper without damaging it, so it is sorted out and stored. When the skin turns yellow, the pulp has decayed enough that the fruit can be passed through a depulper.

After washing, the beans are ready to be dried. Since the coffee harvest coincides with the rainy season, drying the coffee sufficiently is difficult. Most producers have an area near their house that is either dirt or concrete for drying the beans in the sun. The beans are often placed on *sacos* (plastic bags) so that they may be gathered up quickly when the rains start. Many producers avoid this work by selling washed coffee beans, which sell for approximately $9/lata. A few local innovators have solar coffee driers, which is a wire mesh tray with a plastic roof over it (Figure 3.4). The main buyer of coffee in Chitra uses the floor of a former bar to slowly dry the coffee.

Figure 3.4-Small solar coffee drier (Photo by Karinne Knutsen, permission in Appendix 3).

Solar driers dry coffee more rapidly than simply putting it in the sun for two reasons. First, the roof traps warm air, raising the temperature inside the drier higher than the ambient air temperature. Second, coffee laid out without a roof over it invariably gets at least a little wet between the start of a rain storm and when it is gathered up and stored, prolonging the time needed for drying. It may also pick up moisture from the ground. Much, if not all, of the coffee in the study area is not dried to the levels recommended for commercial purposes, increasing the likelihood of fungus or infestations of coffee berry borers, which create undesirable tastes in the coffee.

Most coffee producers in the study area sell their coffee immediately to one of the local stores. While coffee buyers also come to the area several months later, few producers are willing to wait until their arrival to sell their coffee, even though they may offer a slightly better price. This seems largely related to aversion to the risk of storing the coffee (since it may become infested with coffee berry borer and lose weight), and the risk that the price may go down. While coffee prices are somewhat stable for locally produced and consumed coffee, the global coffee market has a definite influence; years of high or low international prices are noted in the collective memory of the farmers.

Variations in Processing

In some communities near the study area of Zancona, the coffee farmers use a variation on dry-processing instead of the wet-processing described above. Coffee producers in the Zancona area use structures called *galeras*, which have corrugated steel roofs and an elevated drying floor. Coffee is not depulped, but put on the drying floor and simply left. The drying floor is often made of *caña blanca*, a native cane species with stems around 1cm in diameter and usually several meters long. This floor allows for some air circulation. When the top of the *galera* is full, many farmers will simply store additional coffee on the ground below the drying floor (Figure 3.5). Some farmers stir the coffee, but most do not. Eventually, the coffee fruit rots, gets covered with a white mold, and as time passes, dries out. The coffee is then sent through a coffee peeler, and sells for a similar price to the wet-processed coffee from Chitra. A major advantage of this method is the ease of processing, since you simply return from the farm and dump the coffee in the *galera*. Sorting, fermenting, and washing are eliminated.

Figure 3.5: Overflow coffee being dried on the ground floor of a *galera* (Photo by Noah Daniels).

A potential disadvantage is the need for a *galera*, but local farmers do not view it as a disadvantage, since the lower portion of the structure is used as an open-air living and storage area that is protected from the rain and hot sun, a real advantage when the rainy season lasts at least seven months. Another potential disadvantage of this method is the bad flavors that the rotting fruit and mold can impart; no locals mentioned this, and it is likely that the dark roast preferred by Panamanians hides these flavor defects. A final potential disadvantage is the additional time required for this method before the coffee can be sold, although no mention of this was made by coffee farmers using this method. While this method seems to result in less work for the farmer, only a few farmers in Chitra have started using it.

An interesting side note is that recently, specialty coffee producers in the Boquete area (western Panama) have begun experimenting with dry-processing and "*miel*" processing, in which the coffee is depulped, but washed & dried before the fermentation is complete, leaving some mucilage on the beans. The flavor profile of Latin American beans and the rainy season coinciding with the harvest traditionally led producers to exclusively wet-process their coffee, so these variations are new. Experimentation is critical, since the market is competitive, and everyone wants to find the Next Big Thing that sells for more than a few dollars a pound.

Workers

The relationship between landowners and their workers can be a difficult one in any coffee producing area (Gresser & Tickell, 2002). The entire production of coffee depends upon sufficient cheap manual labor during several months of the year. The labor situation in Chitra is often cited by landowners as a major roadblock for quality coffee production. They say that there is not enough labor available, so the workers have more power to decide how and what to harvest. Labor costs are high, and landowners may need to take out a loan to pay workers. Since workers are normally paid by volume picked, they will naturally pick everything available as quickly as possible, often stripping leaves, breaking branches, and harvesting all fruit regardless of ripeness. This damages the plants considerably, increases their susceptibility to disease, and reduces the following year's harvest (Willson, 1999).

A complicating factor is that the workers are often members of the landowners' extended family, and therefore may be difficult to fire or reprimand. The relative isolation of the study area and modest coffee production also reduces the potential for migrant workers to come to the area. Some landowners chose to pay by the day instead of by volume, but others say this is also problematic, since the workers may pick less in order to stretch out the harvest. Similar problems have been overcome in the Boquete area in western Panama by paying around 50% more and educating the workers regarding expected quality standards.

The farm used for this study, Finca Zancona, does things differently. While they have some local help, they rely heavily on harvesters from neighboring communities, generally two to five hours away on foot. They provide housing and cooking facilities at the farm, and sell staples such as rice and sardines from a small store at a competitive price. The convenience of this arrangement and a slightly higher pay per volume help them attract sufficient labor.

Another harvest approach that is common in Chitra puts off the harvest until the dry months of January and February. By this time, the coffee has dried on the branches, and fallen to the ground. Harvesters gather the dried fruit from the ground. This approach is slower than harvesting from the tree, but has several advantages. First, it delays the harvest until the weather is better, the ground is drier, and the children are out of school and available to help. Second, it may be easier in poorly-managed plots with high, intertwined branches, since in these areas much work goes towards simply pulling the branches down to pick the ripe fruit. Finally, since the fruit is dried, it will weigh less than an equal amount of ripe fruit, and therefore be easier to carry long distances. It is favored for more remote areas, since relative ease of transport with lighter loads and drier trails is increased. However, this method is slow and requires stooping for hours on end.

Domestic and International Markets

Much of the coffee sold in central Panama is bought by Café Duran. Duran is the biggest coffee company in Panama, and dominates the domestic market. They produce a full range of coffee, from low-quality blends dominated by robusta and roasted corn to high-quality high-altitude Arabica for export, but their focus is towards the mid to low-quality range for domestic consumption. Since all of their coffee is bought domestically and the vast majority is sold domestically, the prices are somewhat insulated from the price changes of the international coffee market. Therefore, Café Duran often sets a buying price for coffee that stays unchanged throughout the harvest, and sometimes for several years. This relative isolation from the world market is not as apparent in the more export-focused coffee regions of western Panama, where prices paid can vary by the week. Anecdotal evidence indicates that instant coffee, such as Nescafe, has not garnered much of the coffee market in Panama, unlike some other Latin-American countries.

The international coffee market has had several notable impacts on Chitra in the past. In 1986, prices climbed to near-record levels (Figure 3.1). Farmers still remember the foreign coffee buyers who came to Chitra and offered the cooperative higher prices for quality coffee. The following year the harvest was marked by a strong focus on quantity rather than quality, as well as speculative buying by locals. The combination of an international price drop to more normal levels and noticeably lower quality coffee led the previous buyers to offer much less for the 1987 harvest, and many locals lost significant amounts of money. Many producers remember this series of events bitterly, and are still suspicious and generally ignorant about what drives the sometimes wild fluctuations in the international coffee market.

Consumption

Local coffee producers save some of their coffee harvest for their own consumption; indeed, coffee is the most popular local beverage. It is drunk from early in the morning until late at night, and is offered to any visiting guest. The coffee is roasted and brewed simply, with a focus on getting the most taste for volume of coffee. Roasting is done in a large cast aluminum pot on top of a *fogon*, which consists of three stable rocks with sticks of wood burning in the center. While the time and methods vary, it is generally roasted darkly and can take over an hour. For comparison, the darkest coffee roasts generally commercially available in the United States are Italian roast; the coffee preferred by Panamanians would be darker than a Spanish roast, which is in turn darker than Italian. After roasting, some prefer to grind it immediately, since it is slightly softer and easier to grind while still warm. The grind is invariably fine. To make a cup of coffee, a small amount of the grounds are added to a boiling pot of water. After a few minutes, the grounds settle and the beverage is poured or scooped out. The resulting beverage is sweetened with a large amount of sugar and generally without milk. Due to the weak brew and dark roast, it has little caffeine but a taste that is considered "strong"-it more closely resembles charcoal than coffee. Many coffee farmers take pride in drinking "*café puro*", meaning coffee that has not been supplemented with roast grains or legumes to stretch it out. Many producers do not save enough coffee to last until the next harvest, and therefore end up buying coffee from the store.

Challenges

I arrived in Chitra with great hopes and ideas about improving coffee quality so that it could be exported and sell for a higher price. A week of pre-service training had been devoted to coffee production, often emphasizing the goal of attaining export-quality. However, as I spent time and worked with the coffee producers, several real hurdles became apparent.

First, most coffee farmers in Panama like bad coffee. I say this objectively, since brewed coffee quality is something that can be consistently and objectively evaluated. The way it is processed, roasted, brewed, and sweetened by locals leaves little evidence of the complex taste that is sought after in the specialty coffee market and masks the bad tastes and flavors associated with poor processing techniques. Therefore, producers do not know that there is a huge range of flavors and aromas in coffee, and that they may be beneficial or detrimental to how much buyers are willing to pay for coffee. While there have been solid efforts by former and current Peace Corps Volunteers in many coffee producing communities to educate producers about quality, the concept is still not well understood.

Upon realizing this, I backed up and changed my approach to this whole situation, trying to educate the farmers on coffee quality, but it seemed to be too little, too late, from a dubious source. I could all but hear them say, "who does this *gringo* think he is, showing up and telling us (in awful Spanish) we are making bad coffee, when I've been a coffee farmer all my life, and I make good coffee?"

Second, there is shortage of labor. The age gap caused by emigration of young people to Panama City or provincial capitals for work has robbed much of rural Panama of those that could be most productive in agriculture. Hired labor is unreliable and relatively expensive, since laborers are generally paid one-third of the value of the picked fruit. Most owners of coffee plots repeatedly mention hired labor unreliability being a serious problem for even production of low-quality coffee. Many of the producers are middle-aged, and their children are unlikely to return and take up a low-paying, difficult agricultural lifestyle if they have become accustomed to the city's relative luxuries. Therefore, they have little interest in investing effort for the future generation.

Third, the price that is paid for coffee locally does not vary based on quality, so there is no incentive to spend more time or money to improve coffee quality. In fact, it makes more sense to sell poorly-dried coffee, since it weighs slightly more per volume. Directly related to this is the relative isolation of the study area, which results in a lower flow of information and buyers who may be willing to pay more for quality. Buyers that do come in from other areas tend to arrive during the summer, several months after the harvest, and most producers do not want to wait that long to sell their coffee, especially if they have been paying workers to harvest. While the coffee company that eventually ends up with most of the area's harvest (Café Duran) does market and even export some higher quality arabica coffee, it handles that aspect of the business from their offices and facilities in the province of Chiriqui, several hours to the west. Their facility in Coclé is not set up to deal with higher grades, which creates another hurdle.

Fourth, producers are not organized. Previous cooperatives and producers' associations have failed for several reasons: poor leadership, unrealistic expectations, and a "hand-out" focused mentality. Without some degree of organization, opportunities for a better price such as Fair Trade certification or organic certification are not available. A look at the literature on coffee quality improvement projects reveals an almost exclusive focus on cooperatives, acutely revealing the increased difficulties in situations without the benefit of organization.

Finally, bad roads are a major problem for any economic activity in the study area. Even though coffee has the highest value per weight of the few cash crops in the area, it still needs to be transported, and the cost reduces any profit. Without many coffee buyers, the lack of competition keeps the price low. Road improvements in neighboring areas also seem to be contributing to a shift towards citrus production, which can only be profitable with relatively good transportation.

The history of coffee in Chitra had an episode that will greatly influence changes in coffee production here. There was a cooperative, called "*La cooperativa la esperanza de los campesinos*" (The Hope of the Country People Cooperative) from 1990 to 1993 that focused on quality coffee, and was founded with significant assistance from a Canadian NGO. It included a processing facility (*beneficio*), storage area, store, and truck that could take the coffee out of Chitra. It failed, according to local farmers, because of poor management and outright theft of its resources, though poor international coffee prices during the early 1990s may have played a role as well. It paid well for freshly picked, ripe coffee cherries, since by buying these it could control processing and quality. Therefore, while the cooperative was functional, the producers became familiar with the basics of quality harvesting and processing. This works in favor of any project to improve coffee quality, since many producers remember not only the methods but the better price they brought.

A disadvantage is that many producers think that quality coffee can only be produced with a *beneficio* buying and processing the coffee consistently. Realistically, they may be right; leaving the processing to each producer opens the door to inconsistent and poor methods, which may be hard to identify and fix before the coffee is collected and consolidated. In fact, a *beneficio* may be a reasonable end-goal of a coffee quality improvement project. A good example for this is in a community to the west, Santa Fe, which has a well-established cooperative that processes and markets its own brand of coffee, Café El Tute, throughout Panama. They also export a container of their best coffee to Germany every year; this operation may prove to be a good model for coffee producers in the study area.

This history of producing both export-grade and poor-quality coffee sets the stage for this study. The farmers are now producing coffee that is indifferently processed, and receiving a low price for it. They know that they have produced coffee that has earned a higher price, and would like to regain that market. They do not know the best way to reach that goal, or even what a good first step would be.

Chapter 4- Methods

Initial Experiments

While only a small part of western Panama has gained fame for producing excellent coffees, a far larger part of the country produces coffee, including the mountains of central Panama. During the harvest of 2006, coffee farmers in Chitra revealed an interest in earning more from their coffee, but did not have a good sense of how to accomplish this goal. Several farms were selected for an initial investigation to determine if the environmental conditions and varietals had potential to produce quality coffee, and also to compare carefully processed coffee with samples processed by local methods from the same farms.

The samples were cupped by coffee professionals with extensive backgrounds in cupping. Both cuppers said that the coffee had strong potential, and were surprised to hear where it had come from, since they had not thought that Veraguas had much potential for quality coffee production. However, even with careful attention to the processing, the coffee had not been dried sufficiently, which was apparent from both the appearance and taste of the samples. Still, they said that the coffee, if well-processed and dried, would score in the 80s, which would be sufficient for export; this was enough encouragement to continue with plans for more extensive and complete processing experiments and comparisons during the next harvest.

Study Site

The coffee for this study was harvested from Finca Zancona, just above the community of Zancona, owned by Meri and Mingo Riquelme of Bajo Grande, Coclé, Panama. It covers roughly twenty hectares, a portion of which is provisionally certified organic by Biolatina, the primary organization doing organic certifications in Panama. All of the coffee for this study was harvested from an area of approximately 0.3 ha to ensure that variations in soil and microclimate were minimized. The farm is well-managed, with practices like pruning, organic fertilization, and soil conservation followed to a greater degree than most small coffee farms in rural Panama. It ranges from approximately 800 to 950m ASL, with the study plot at approximately 900m ASL, and is located near the border of General Omar Torrijos National Park. The aerial photo (Figure 4.1) shows the relatively continuous forest cover of the national park (on the left) compared to the patches of forest, farm, and pasture on the right. Also of note is the slash and burn agriculture being implemented inside the boundary of the national park; agricultural use is not uncommon in nominally protected areas throughout Panama.

Figure 4.1: Satellite photo of the Finca Zancona area (2008, source: Google Earth, permission in Appendix 2).

The farm is dominated by *Coffea arabica*, with several varietals present: caturra, criolla, and bourbon. Part of the farm has *Coffea canephora*, but was not included in this study. Samples for this study included several varietals; the percentage of each likely varied slightly from one harvest day to the next. According to Dr. Maria Ruiz, this is not considered an important factor for the cupping done in this study, since it was focused on processing defects which easily eclipse the subtle flavor and aroma variations among varietals.

The amount of shade is considered an important factor in production and quality of coffee (Vaast et al., 2006). Shade helps minimize biennial bearing and die-back of branches resulting from the plant having difficulties allocating carbohydrates. It can also produce cooler average temperatures in the farm, helping lower-elevation farms mimic the environmental conditions of higher-elevation areas. The farm used in this study has less shade than many other local farms (Figure 4.2); it can be considered a multi-species, low-density system, while many other nearby farms use a multi-species, high-density system. Tree species are carefully selected for a variety of benefits. Some, such as banana trees (Figure 4.3), provide food for the farmers. Others, such as the Corotú (*Enterolobium cyclocarpum*), are nitrogen-fixing and have small, compound leaves that filter the sunlight, rather than block it. Still others, such as the Caribbean Pine (*Pinus caribaea),* can be harvested for wood. Lower levels of shade can cause biennial bearing; this means a large harvest followed by a small one, and is often accompanied by some branch die-off. The owners of this farm prevent this by applying both chemical fertilizer and composted coffee fruit as an organic fertilizer on the non-organic portion of the farm.

Figure 4.2: Finca Zancona coffee farm. Peace Corps Volunteer for scale (Photo by Noah Daniels).

Figure 4.3: Another view of Finca Zancona, looking to the north. Banana trees used for shade and banana production are prominent (Photo by Noah Daniels).

Soils in Finca Zancona are derived from decomposing volcanic bedrock. They tend to be somewhat acidic with a thin cover of decaying organic material. A low, flowering vine called *Siempre Vive* (Verbena sp.) has been planted in this plot; it is a common and popular as a cover in coffee farms since it does not interfere with the coffee plants, out-competes grass species, and makes it easier to spot snakes, a real concern among Panamanian farmers. It also reduces the amount of "cleaning" or weeding significantly. However, it is falling out of favor with some high-end coffee growers, since it traps moisture that supports fungi that attack coffee plants (Ruiz, personal communication).

Harvest

Since *Arabica* varietals of coffee ripen over a range of several months, harvesting must be selective and focused on only red, ripe fruit. Therefore, harvesting is done by hand, and any incidentally harvested unripe or over-ripe fruit is removed at the end of the harvesting period each day. The first batch was harvested on October 16, 2007 and the last on November 29, 2007. Between four and nine samples were harvested per day (Table 4.1; Appendix 4).

Date	Number of Samples Harvested
10/16/2007	4
10/25/2007	9
10/31/2007	7
11/2/2007	5
11/9/2007	7
11/17/2007	7
11/29/2007	6

Table 4.1: Number of samples harvested per harvest day at Finca Zancona.

Only ripe fruit was harvested. Figure 4.4(a) shows an example of the fruit harvested, along with an example of fruit harvested for specialty coffee for export near Boquete (Figure 4.4b); Figure 3.5 (page 26) is an example of fruit harvested for domestic sale and consumption. The harvesting was done by myself with help from Karinne Knutsen and Darlene Yule, both Peace Corps Volunteers; careful attention was paid to harvest only ripe, undamaged fruit.

(a)

(b)

Figure 4.4: (a) coffee harvested for this research, (b) coffee harvested for specialty coffee for export (Photos by Noah Daniels).

Nine categories of samples representing three stages of fermentation (well, medium, and poorly fermented) and three stages of drying (well, medium, and poorly dried) were created. Five samples of each category resulted in 45 samples in total. Since the harvest occurred over seven days spread out over a seven week period, these samples were queued up in a random order using a random number generator to avoid potential biases from harvesting all of one category in one day. Between four and seven samples were harvested per day.

Processing

Processing is done immediately after the end of harvesting, since the quality of the bean begins to degrade within hours of being picked. Fortunately, the coffee for this experiment was harvested less than a kilometer from the *beneficio* (coffee processing area), so immediate processing was possible.

The fruit was first sorted with a float test, in which it is immersed in water, and any floating fruit (generally damaged, diseased, or poorly developed) is removed. Any other detritus that may have been collected with the ripe fruit (leaves, twigs, etc.) is also removed at this stage.

Depulping is the act of removing the fruit surrounding the coffee seeds. This is accomplished using a depulping machine with a rotating cylinder of copper sheeting perforated to create lines of small, raised teeth. The fruit is grabbed by the teeth and squeezed against a stop, expelling the coffee beans, while the skin continues around and is washed away. Fruit size can vary significantly, which leads to beans which are not depulped and other beans which are damaged by the machine. Scraps of the fruit skin, unpulped fruits, and damaged beans were removed by hand from the samples, as these can give the coffee undesirable flavors.

Depulping removes the fruit, but leaves a slimy coating of mucilage surrounding the bean. Fermentation allows microbial decomposition of this layer, after which it can be washed away. The time required for fermentation depends on ambient temperature, which is often determined by altitude in coffee growing areas (Katzeff, 2001). According to coffee experts familiar with processing in Panama, the time required may range from as little as six hours in the hot lowlands to sixty hours in the cool highlands (Maria Ruiz, personal communication). Published processing guides and other resources recommend determining a fermentation time for a locale experimentally. Many small-scale farmers in Panama simply allow it to ferment around 20 to 30 hours (Bryan Richardson, personal communication); this is determined not by time required for complete fermentation but rather the practical considerations of labor allocation during the coffee harvest.

During the 2006 harvest, it was determined experimentally that fermentation times of twelve to sixteen hours would be sufficient. Since there could be some variation based on temperatures, it was decided to determine fermentation time for each batch harvested using observations rather than arbitrary times. Determining a fermentation time for each batch harvested takes into consideration ambient temperature differences during each day, which can be significant during the harvest, since it coincides with the rainy season. Many days during this season can be cool and wet, but sometimes there is a break that brings sunny, steamy weather for a day or two. Additionally, the number of samples per harvest day varied and may play a small role in fermentation times, since a larger sample may retain heat better, speeding the process during cool nights (Ruiz, personal communication).

Completion of fermentation can be determined by simple manual tests. The simplest is to push a stick or hand into a pile of fermenting coffee (Katzeff, 2001). If it is done fermenting, a hole will remain when the stick or hand is removed. Otherwise, it will collapse back into itself. This test was done every two hours starting ten hours after depulping.

Once the well-fermented sample completed fermentation, the moderately and poorly fermented samples were washed at 133% and 166%, respectively, of the well-fermented time. The selection of these additional times was based on informal surveys of coffee producers regarding their fermentation times. No one gets up in the middle of the night to wash coffee (represented by the well-fermented time), but many do it first thing the next morning before heading out to harvest (represented by the 133% fermentation time), and some wait until they return from harvesting (represented by the 166% fermentation time). An additional overfermented sample of 200% of the good fermentation time was considered and rejected, since that amount of time is unlikely to occur if the producer is attempting to produce quality coffee.

Consider the following example of the timing of these stages of processing. A batch of coffee may be picked and depulped by 3:00 PM. At moderate altitude and moderate temperature (500 to 800m, and 21 to 23 degrees C), fermentation may be completed at 4:00 AM the next morning. However, a washing time of 7:20 AM (133%) is much more common. Sometimes the batch may be left fermenting until other work is done, pushing the washing back to 11:40 AM (166%).

After fermentation is complete, the next step is washing the coffee to remove the mucilage residue. Leaving even traces of mucilage on the beans increases the chances of mold and gives the beans an off flavor that is readily detectable.

Washing was done with clean water in five gallon buckets. The beans were immersed, stirred, and rinsed. Stirring involved rubbing handfuls of beans together to help break up and remove any remaining mucilage. When the beans feel "like a handful of rocks" (Bryan Richardson, personal communication), they are free of mucilage; when the water comes away clear and clean, the cleaning stage is completed. Generally, this would require a minimum of five rinses and approximately fifteen minutes of stirring for the samples that were fermented an appropriate amount of time. For the over-fermented samples, washing was much easier, since the mucilage had decayed further and needed little abrasion to remove it from the beans. Regardless, all samples were washed at least five times for the sake of consistency. The beans are now free of any pulpy residue from the fruit, and ready to be dried.

Drying brings the moisture content of the beans from above 50% down to 10-12% for well-dried beans (Selmar et al., 2006). This is most often accomplished with solar energy, although mechanical dryers fueled by natural gas, electricity, or wood are also frequently used for larger-scale coffee farms. Since the coffee harvest coincides with the rainy season in mid-elevation coffee producing regions of Panama, solar drying is a difficult proposition, and much of the coffee harvested by smallholders is not sufficiently dried. However, solar dryers that use a roof of clear plastic and trays of wire or plastic mesh are considered reasonably effective; one was used for this study. It was designed to exclude chickens, leaves, and other things that may reduce the coffee quality, while allowing exposure to the sun and maximum air flow.

Samples are put in the solar dryer immediately after washing. The size of the individual compartments in the dryer allowed for a thickness of one bean for the initial drying, maximizing exposure to the sun. A metal mesh base allowed for airflow to help speed the drying process. Samples were stirred frequently, ranging from several times an hour when first put in the dryer, to several times a day as they dried. At this stage of processing, the beans are still covered with a thin, brittle skin called parchment. This layer is left intact to protect the beans during storage and transport, often it is removed immediately before export or roasting.

The dryness of coffee is important not only to prevent fungal growth, but also to maximize value, since green coffee is sold on a weight basis. There are several methods for testing the moisture content of coffee, including conductivity, color and near-infrared spectroscopy (Reh et al., 2006). Degree of dryness was tested with two methods: dental and digital. The dental method involves peeling the parchment off of an individual bean and biting it with your incisors. If it is easily dented or even cut by the bite, it is not dry. If a hard bite barely dents the bean, it is dry. The dental method is subjective and a little dangerous, since another Volunteer broke his tooth doing this test. The digital method relied on a digital grain moisture meter (Figure 4.5). This meter has a range of 10 to 24% moisture content, reads to 0.1% moisture, with an accuracy of +/- 1%. It has settings for rice, paddy, wheat, and corn. Experiments with the different settings compared to the results of the dental method and compared to other settings implied that either the rice or corn settings may be most appropriate for coffee; for the sake of consistency the corn setting was always used.

Figure 4.5: Measuring moisture content in the solar coffee dryer (Photo by Karinne Knutsen, permission in Appendix 3).

Three categories of moisture content were used for this experiment. Well-dried samples had a moisture content of 10.0-12.0% water. Moderately-dried samples had a moisture content of 12.1-14.0% water. Poorly-dried samples had a moisture content of 14.1-16.0% moisture (Table 4.2).

Fermentation category	Category code	Definition
Well-fermented	FG	Fermented until mucilage can be removed by washing
Moderately-fermented	FM	133% time of well-fermented samples
Poorly-fermented	FP	166% time of well-fermented samples

Drying category	Category code	Definition
Well-dried	DG	10-12.0% moisture content
Moderately-dried	DM	12.1-14.0% moisture content
Poorly-dried	DP	14.1-16.0% moisture content

Table 4.2: The definitions and codes used for each category of fermentation and drying of the samples.

For the well-fermented and well-dried samples, the codes FG and DG were used instead of FW and DW to minimize the possibility of mistaking a written “w” with an “m” in field notes.

Storage is an important step, since the dried coffee can easily absorb flavors or moisture that degrades the quality. Once the samples reached their target moisture they were put into gallon ziploc bags, sealed, and stored in a cool, dry area away from potential contaminants, such as chickens and smoke sources. The moisture levels were checked frequently to ensure that the levels had equilibrated and stabilized at the target moisture levels. If the samples proved too moist, they were returned to the dryer.

Cupping

The samples, stored with their parchment covering, were peeled shortly before the cupping. Generally peeling is done with machines for larger quantities of coffee, but for home consumption and for cupping, a *pilón* was used (Figure 4.6). This *pilón* is essentially a large mortar and pestle made from a tree trunk. The coffee is put in the *pilón*, and a piece of wood similar to a baseball bat is used to hammer on the coffee. Slowly the parchment is broken and falls away from the bean; since it is much lighter than the beans it is easily removed by shaking and blowing on the coffee.

Figure 4.6: *Pilón* being used to remove parchment from coffee (gringo for scale; photo by Karinne Knutsen, permission in Appendix 3).

Once the samples are peeled, they are ready for the final moisture content test. This was done with a Shore Model 920 moisture meter, which is a much more specialized (and costly, around $1000) instrument than the meter used for testing the moisture content during the drying process.

Next, the samples are evaluated for their appearance. The color, size, and shape of the beans can all indicate the quality of the coffee. For example, a blue-green bean is desirable, while a white-green bean is not. Smaller beans usually indicate higher altitude, and are generally denser. Even how the bean was processed can be easily determined by its appearance. The number of visually defective beans plays a large role in how the coffee is graded. Defects may include black beans, mottled beans, broken beans, and crystallized beans; each of these indicates a specific problem with the processing that will also be apparent in the next step, the cupping of the samples.

The samples are now roasted; this is done on uniform 100g samples. The roast time is determined by the first crack, which is exactly what it sounds like- a sharp crack that indicates that the bean has reached approximately 355 degrees F internally. The goal is a light to medium roast that is consistent among the samples; this occurs shortly after "first crack".

After roasting, the coffee is allowed to rest overnight in containers that allow some outgassing of the beans, but help prevent any staling. Next, it is ground to a fine grind, which allows for an optimal 18 to 22% extraction rate from the coffee (Katzeff, 2001).

After roasting and grinding, the cupping begins. The samples were randomly assigned new numbers to eliminate potential bias of the cuppers and ensure a blind cupping. The 45 samples were cupped in groups of six. Dry, ground samples are evaluated for fragrance. Eight ounces of water just below boiling temperature (195-205 degrees F) is added to eleven grams of ground coffee. Special cups with a shape optimized for cupping are used (Figure 4.7).

Figure 4.7: Special cup used for cupping coffee (Photo by Noah Daniels).

After sitting for three to five minutes, the cap of saturated coffee grounds is "broken" with the bottom of a special cupping spoon and the aroma is evaluated. The cup is then stirred, and any grounds that still float are removed. Only now is the sample ready to be tasted.

The cuppers use a special spoon to remove a small amount of the sample, then slurp it into their mouths rapidly and with a lot of air. This helps aerate and cool the coffee, bringing the flavors out and volatilizing some compounds, allowing them to be detected with the nose as well as the tongue. Cuppers taste each sample several times as the coffee cools, looking for previously masked flavors. Each sample is rated by aroma, flavor, body, acidity, balance, aftertaste, and general evaluation. Each category is given a score of one to ten, and the numerical scores are accompanied by a description (Table 4.3).

Score	Description
10	Exceptional
9	Excellent
8	Outstanding
7	Very Good
6	Good
5	Regular
4	Mediocre
3	Poor
2	Very Poor
1	Unacceptable

Table 4.3: Description of cupping scores used by the Cafe Ruiz cupping lab.

This varies slightly from the Specialty Coffee Association of America (SCAA) quality rating, which only goes from six to ten; however, the descriptions are similar. This difference is likely because the SCAA only deals with high-quality coffees, which will presumably never score below six in any category, while Cafe Ruiz may deal with a sometimes lower range of quality. The Cafe Ruiz cupping form is slightly more detailed and has more space for comments than the standard SCAA form, allowing for better feedback to the farmers that provide the bulk of the cupping laboratory's business. It also includes a section allowing for deduction of points later in the cupping, as the cup cools and flavors change, without having to change the initial scores for individual categories. This section, shown on the form as "-2x *taza*" and "-4x *taza*", is not always used; when it is, it results in a simple deduction of points from the final score. Another system worth noting is the Brazilian scoring system, which uses categories such as strictly soft (very smooth flavor, slightly sweet, low acidity), hard (astringent flavor, rough taste, lacks sweetness), and *rio zona* (intolerable taste and smell) rather than a numerical system (Farah et al., 2006). The cupping categories, along with the points deductions, are summed to reach the overall score.

Along with the numerical score, a description of the smells and flavors detected in each sample is done. This may include aromas such as fruity, woody, or floral; and flavors such as chocolate, citrus, wine, or grass. The points per category are tallied, with a possible high score of 100. Any coffee scoring over 90 is exceptional, and a minimum of 80 is needed for export (Ruiz, personal communication). A review of such websites as Coffeereview.com and Sweetmarias.com shows that the highest quality coffees range from around 85 to 93.

The score is based on fragrance, aroma, acidity, body, flavor, and aftertaste. Points may also be added or subtracted based on uniformity of the sample, cleanness on the palate, sweetness, balance, and overall evaluation. Samples that show interesting or unusual flavors may be cupped again to see if the flavor is consistent among cups or merely a fluke.

Two professional coffee cuppers, Octavio Castillo and Jose Acosta, cupped the 45 samples on January 24 and 25, 2008. They are employees of Cafe Ruiz, a coffee company that has the only certified cupping laboratory in Panama. The lab is run by Dr. Maria Ruiz, and regularly cups samples from many other coffee farms and exporters throughout Panama. Dr. Ruiz is also a great friend to the many Peace Corps Volunteers who are working with coffee producers, regularly donating her time and expertise to help improve coffee production for small farmers.

Evaluating the fragrances and tastes in a cup of coffee may seem subjective, and on some levels, it is. However, the entire process of cupping coffee focuses on eliminating conditions that may mask these tastes and using trained personnel with a talent for detecting and distinguishing subtle differences, and a strong memory for flavors. It has been used as an accepted method for quality evaluation in numerous studies, although some studies have had ambiguous results (Silva et al., 2005).

Statistical Analyses

With two cuppers evaluating 45 samples on seven characteristics, there is ample data for several statistical analyses. There are two main ways of grouping the scores: by the combination of the processing categories (FG/DM and FP/DG, for example) or by cupping categories (flavor and aftertaste, for example). These can also be tested by category and level; for example, degree of fermentation or drying. Analyzing the scores with different groupings allows for a better picture of relationships and impacts of the fermentation and drying on scores.

The overall scores from each cupper for the five samples in each of the nine categories were averaged, and a standard deviation calculated. A standard deviation was also calculated for each of the categories of cupping scores, and a Levene's test for homogeneity of variance was then applied to determine if the score variances of the processing categories were statistically similar.

The next step was an Analysis of Variance (ANOVA) on sample scores grouped in several ways. A critical value of 0.10 was used for all analyses, resulting in a 90% confidence interval. All ten scores (five per cupper) for each cupping category were used for the ANOVA.

ANOVA was performed on the scores for each coffee grouped by harvest date to determine if the samples' scores were influenced by the date. Coffee from early harvest dates often scores worse in cupping evaluations than coffee from the same farm during the middle to later parts of the harvest (Ruiz, personal communication). The first harvest date, in mid-October, may be impacted by this. The final sample harvests occurred at the end of November, well before the final harvests in Finca Zancona. The farm's owner planned on picking all the remaining fruit, ripe or not, when enough labor became available in early December; no further sampling would have been possible after this event.

A Tukey's honestly significant difference test (α=0.10) was also done on all of the sample groupings. This determines which of the comparisons between groups accounts for the difference found with ANOVA. ANOVA and a Tukey's test were performed on the cuppers' scores to see if Jose's scores differed from Octavio's.

Further ANOVA and Tukey's tests were done on the following groups: aroma, flavor, acidity, body, general evaluation, aftertaste, and balance. As previously mentioned, all ten scores for each characteristic were used in the analyses. ANOVA and Tukey's tests were also done to compare the scores of the samples that had been infested by coffee berry borer to those that were not.

A Pearson Correlation Coefficient was calculated to compare how scores for the cupping category scores for each processing category sample were related. A 90% confidence interval was used.

All tests were performed using SAS software version 9.1: PROC GLM for the ANOVA, Levene's, and Tukey's tests and PROC CORR for the Pearson's Correlation Coefficient.

Chapter 5- Results

The results of this study fall into three categories: processing, cupping, and statistical analysis. The processing results include fermentation times and final moisture contents of the samples. The cupping results are the numerical scores given to the samples by the cuppers, including graphic presentation of the scores. The statistical analysis section details the ANOVA and Tukey test results.

Processing

Fermentation times proved to be similar for each harvest day (Appendix 4). While there is the potential for unusually warm or chilly days during the rainy season, none occurred while harvesting and fermenting samples, so temperatures and times were consistent. Ideal fermentation times were around sixteen hours, with only minor variations.

Even before the cupping was conducted, a significant advantage of drying coffee to below twelve percent moisture content became apparent. The coffee berry borer (*Hypothenemus hampei*) is present in Panama, and infests and consumes stored, processed coffee. Infestations were found in six poorly-dried samples and four moderately-dried samples, and none in well-dried samples. This may be coincidence, but it has been noted that this pest prefers poorly-dried and stored beans (Clifford & Willson, 1985). To minimize the impact of this infestation and prevent its spread, all samples were put under strong sun for approximately eight hours to kill the insects and their larvae. After this treatment, no further infestation was apparent. Infested samples were submitted for cupping without any sorting or removal of affected beans.

The final bean moisture content averages (Figure 5.1, Appendix 5) were measured with a handheld moisture probe before transport to the cupping lab, and again in the lab with a different instrument. Each bar is the average for the fifteen samples in that category, along with error bars showing one standard deviation (1σ).

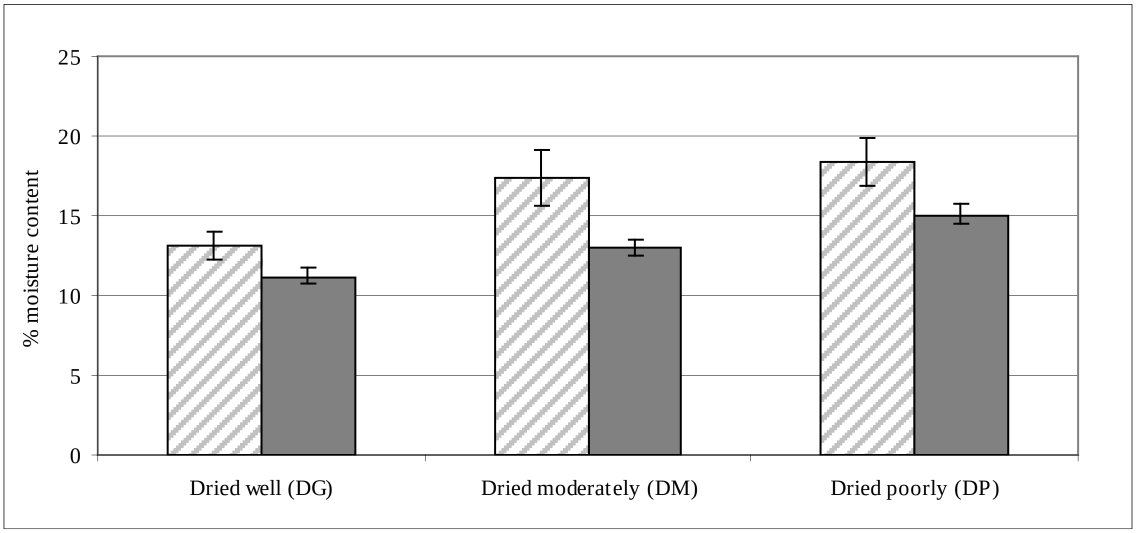

Figure 5.1: Average final moisture contents by percentage as measured at the cupping lab (bar on the left) and at the processing site (bars on the right), with error bars showing one standard deviation.

The disparity between the two averages in each category is possibly caused by two factors. First, the measurements were done with two different instruments, a probe based moisture meter at the processing site and a bulk sample based meter at the cupping lab. The cupping lab's meter is possibly more accurate, since it has been designed and calibrated specifically for coffee and used in a controlled environment; so the samples may not have been accurately measured at the processing site before being stored in sealed plastic bags. Second, travel from the processing site to the cupping lab took several days. The samples passed through the more humid lowlands, and despite being sealed in plastic bags, may have picked up some moisture, since coffee is notoriously hygroscopic.

The final moisture contents were consistently higher than they should have been for each category. High moisture contents give the coffee a "baggy" flavor, and this was present in the samples. The cuppers were able to look past this and focus on other flavors and defects while cupping.

Cupping

The cupping was blind, so the cuppers did not know how any particular sample had been processed. A brief look at the scores of the cupping categories after the cupping showed no strong trends of high scores for well-processed samples and lower scores for poorly-processed samples (Figures 5.2 to 5.8).

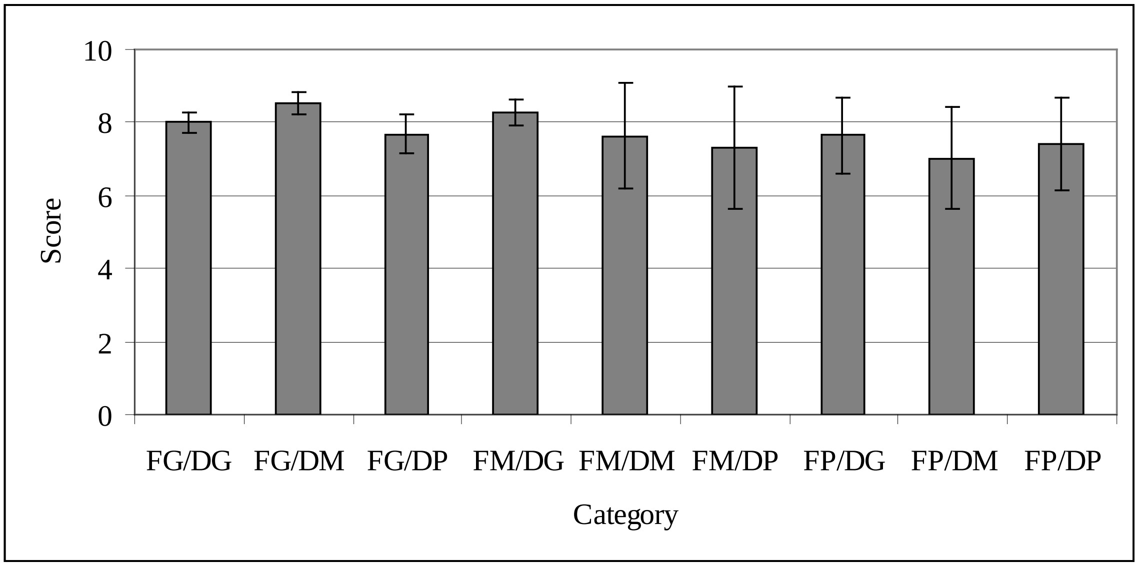

Figure 5.2: Average scores with standard deviations for aroma.

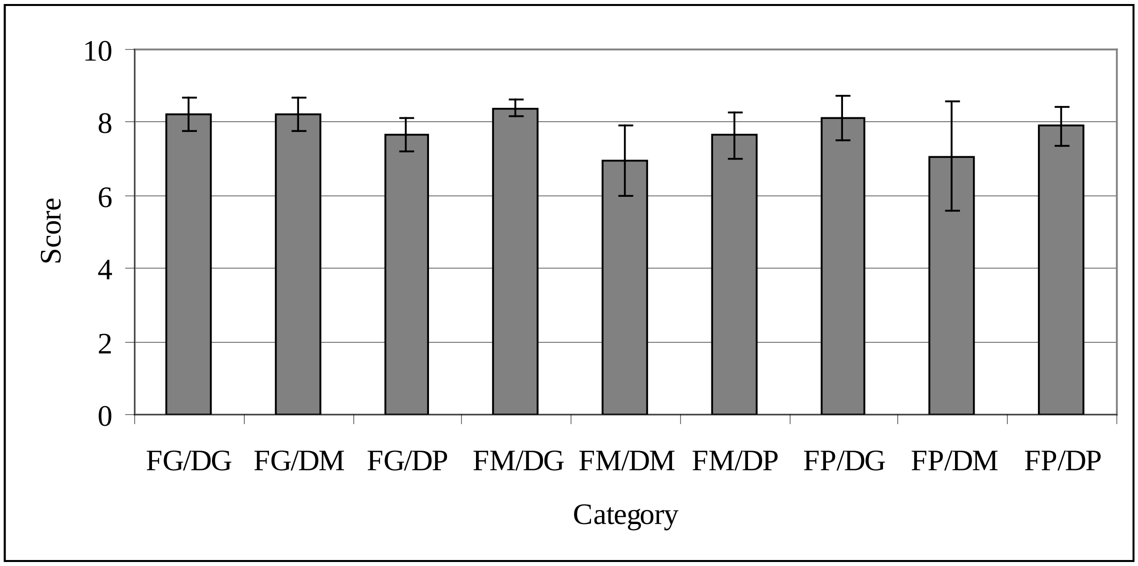

Figure 5.3: Average scores with standard deviations for acidity.

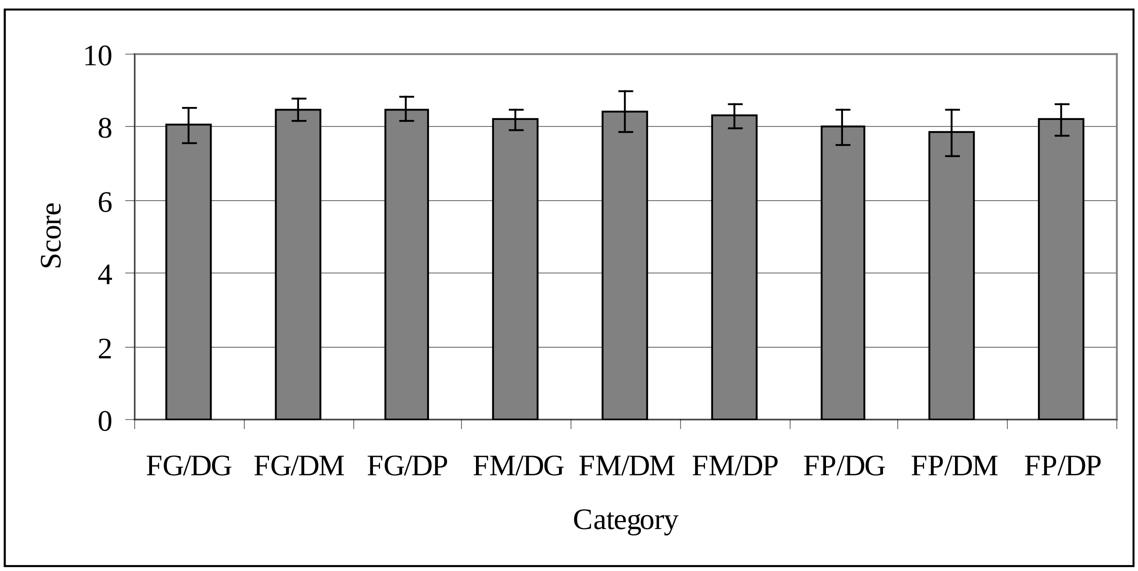

Figure 5.4: Average scores with standard deviations for body.

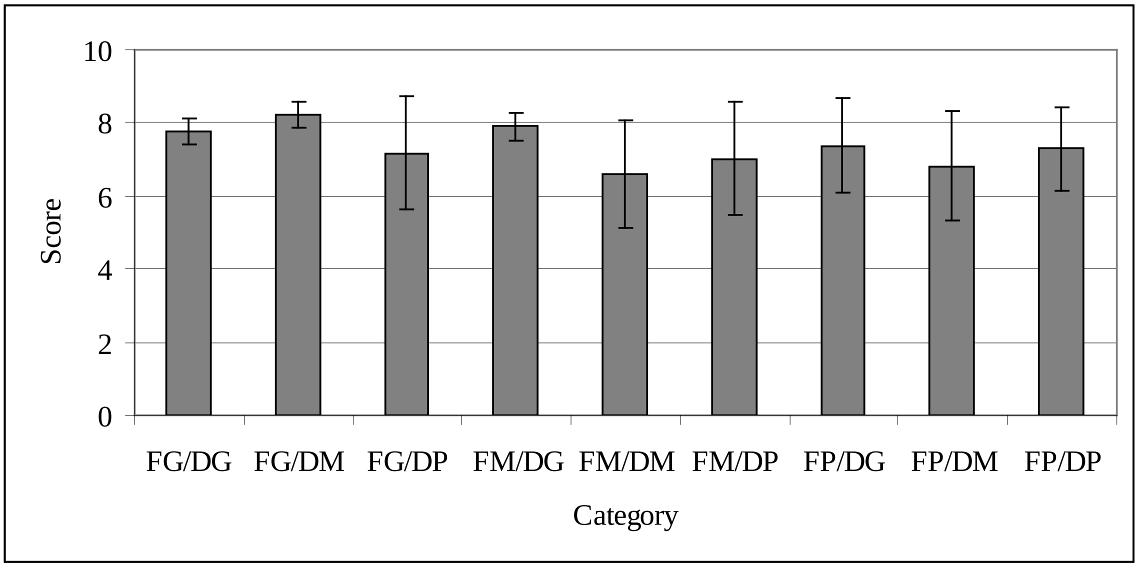

Figure 5.5: Average scores with standard deviations for flavor.

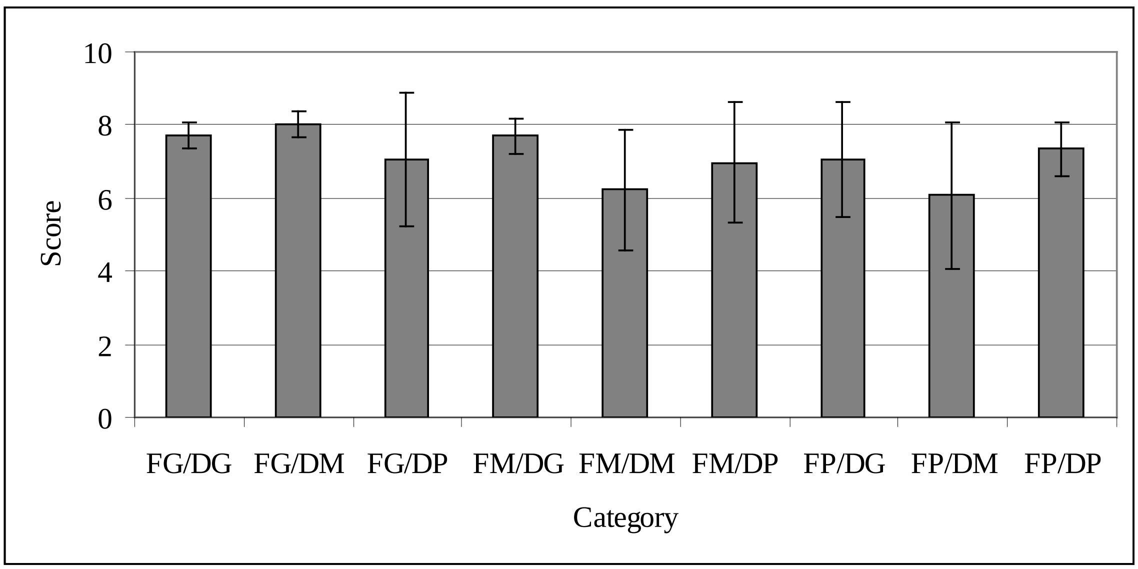

Figure 5.6: Average scores with standard deviations for aftertaste.

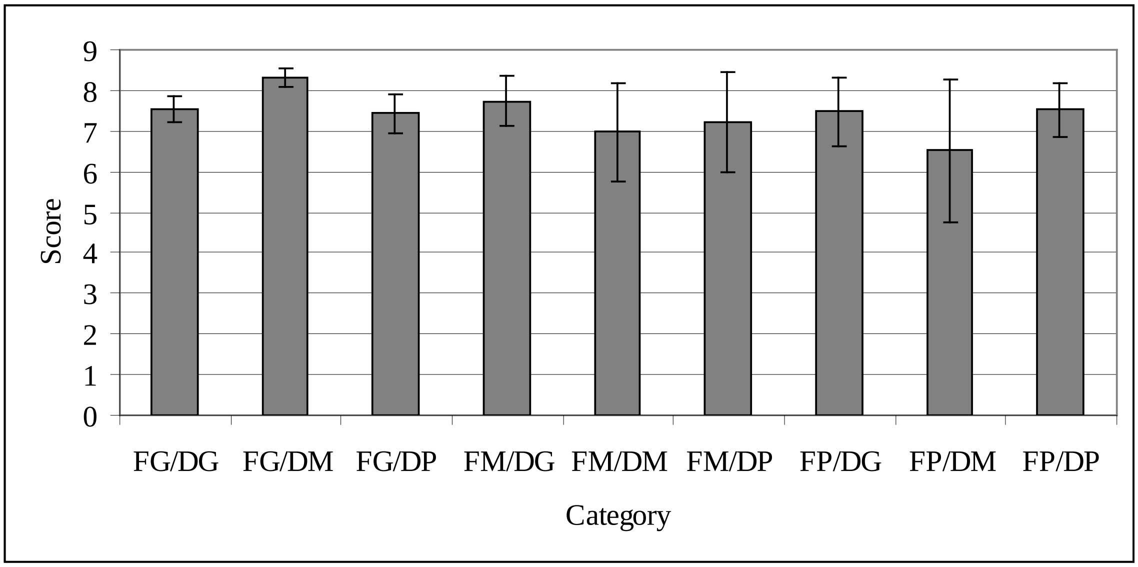

Figure 5.7: Average scores with standard deviations for balance.

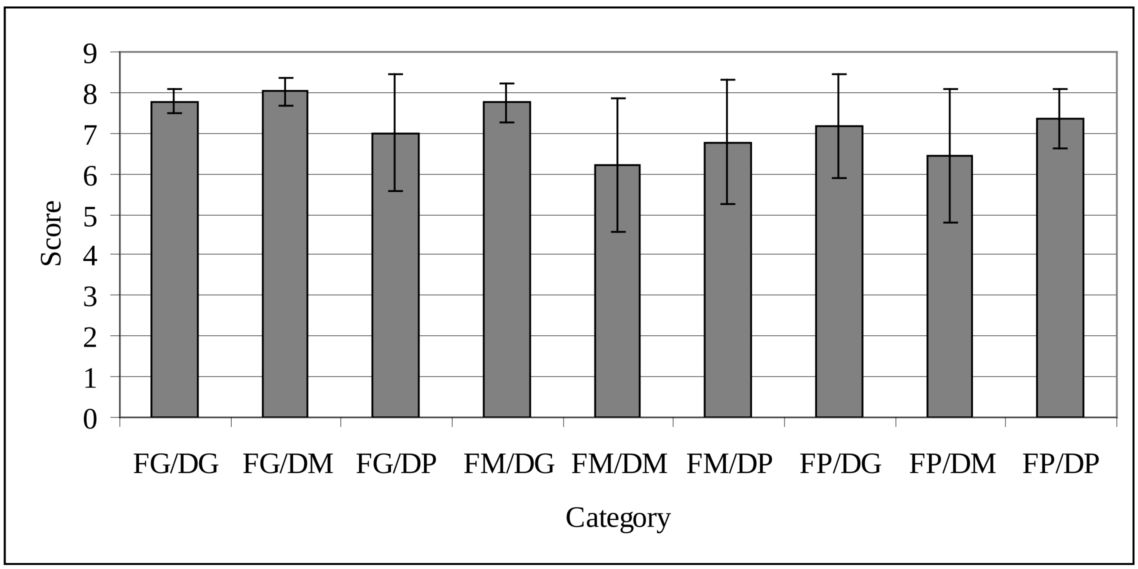

Figure 5.8: Average scores with standard deviations for general evaluation.

While the average scores for the well-processed samples (FG/DG, FG/DM, and FM/DG in particular) tend to be higher, with smaller standard deviations for their scores in each of these categories, the differences among the scores of the processing categories are not dramatic. This is particularly true for the body category, where all samples scored similarly (Figure 5.4).

The score categories used for point deductions as the cup cools (-2x *taza* and -4x *taza*) did not show any obvious trends (Appendix 6 and 7). Since the deductions, which ranged from zero to twelve points of the final score, could not be attributed to any of the specific cupping categories, their impact was only considered as part of the total score for each sample. While some of the poorly-processed samples did score well, many also scored poorly.

Most of the well-processed samples scored decently enough, but what seemed more significant was their consistency in the overall score (Figure 5.9, Appendix 6, Appendix 7).

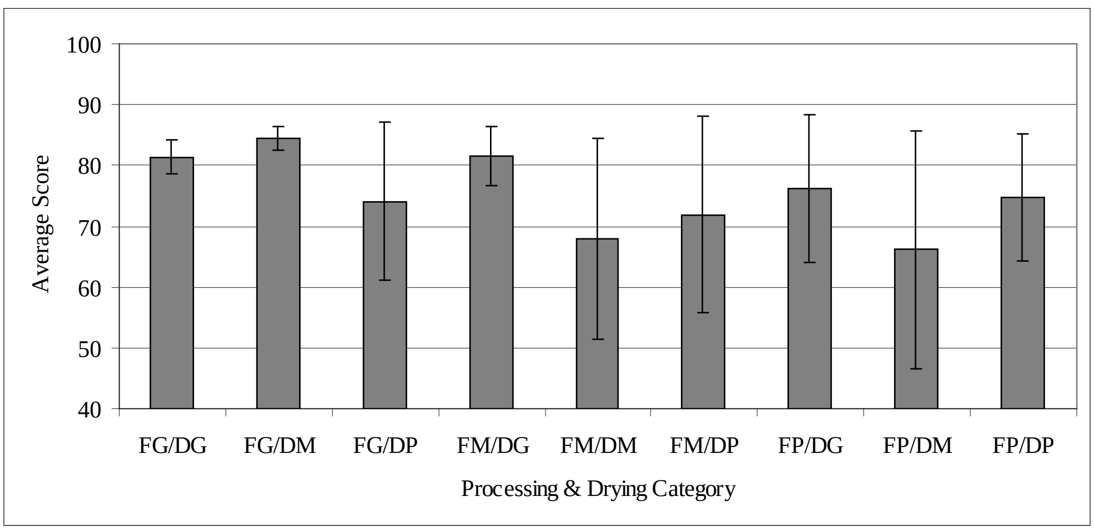

Figure 5.9: Average of the overall scores, with one standard deviation shown with error bars.

Three samples (FG/DG, FG/DM, and FM/DG) that had the most careful processing had the highest average scores, and the smallest variation of scores. The standard deviations of the other samples are often large, and even the worst average scores could overlap with the best within one standard deviation. While the variation of the well-processed samples were smaller, whether that difference was statistically significant or not was determined with the Levene's test.

The Levene's test of homogeneity of variance determined that at a 90%

confidence interval, overall score (P=0.0277), aroma (P=0.0618), acidity (P=0.0062), body (P=0.0465), and balance (P=0.0005) had statistically different variances. Only flavor (P=0.3334), aftertaste (P=0.1470), and general evaluation (P=0.1672) did not. Consistency is important in coffee quality, especially to buyers of export quality coffee, and the smaller range of variations for most of the categories, especially the overall score, indicate that the well-processed samples have more consistent scores.

Statistical Analyses

The ANOVA score (P=0.9049) comparing only the two cuppers' overall score results indicates that there is not a statistical difference, but there was some variation in their scores. When the score is divided into the individual cupping categories and an ANOVA performed (Table 5.1), the general evaluation category has the only statistically significant difference between the cuppers.

Category	P score
Overall	0.9049
Balance	0.1417
General Evaluation	0.0077
Body	0.4169
Flavor	0.4268
Aftertaste	0.1615
Aroma	0.5054
Acidity	0.3792

Table 5.1: The P-scores from ANOVA analyses on cupping categories comparing cuppers (α=0.10).

General evaluation is the vaguest category in the cupping, and it seems likely that the two cuppers were using it differently. This difference did not effect the overall score (P=0.9049) enough to make them statistically different.

The ANOVA on harvest dates (P=0.0002) showed a significant difference between some of the overall scores of samples. This difference was caused by comparisons of the first harvest day's scores (10/16/07) and every other day's scores

(Appendix 8). This may be because the quality of fruit harvested at the beginning of the season is considered inferior (Ruiz, personal communication), or because the four samples from the first day were all processed poorly (Appendix 4), which was a result of the randomization of sample order.

The infested sample overall scores had a strong negative correlation with overall scores of non-infested samples (r=-0.6068, P=<0.0001) and a correlation with dryness (r=0.2848, P=0.0065). An ANOVA on the overall score of the infested samples compared to other samples (P=<0.0001) reinforced that the infested values had significantly lower scores.

ANOVA for fermentation, drying, and the interaction between them (Table 5.2) was performed on the cupping categories.

Category	Fermentation	Drying	Ferm./Drying Interaction
Overall	0.0486	0.0728	0.0952
Balance	0.0475	0.4263	0.0118
Body	0.0118	0.0992	0.2283
Flavor	0.1200	0.1844	0.1035
Aftertaste	0.0673	0.1189	0.0607
Aroma	0.0438	0.1971	0.2192
Acidity	0.1040	0.0002	0.0090
General Evaluation	0.0404	0.0600	0.0266

Table 5.2: The P scores from ANOVA analyses on cupping categories comparing fermentation, drying, and their interaction (α=0.10).

The cupping category scores show that fermentation has a significant impact on all of them except for flavor and acidity. Drying had less impact, proving significant for overall score, body, and acidity. The interaction between fermentation and drying was significant for overall score, acidity, aftertaste, balance, and the general evaluation.

The overall score was affected by fermentation, drying, and the interaction between fermentation and drying. The interaction is especially notable, since it means that fermenting and drying the coffee well had a larger effect on the score than simply adding up the effects of good fermentation and drying.

These results warranted a Tukey's test to find out which cupping categories were different when the processing categories were compared. (Table 5.3, Appendix 9).

	FG and FM	FM and FP	FG and FP	DG and DM	DM and DP	DG and DP
Balance	same	same	**different**	same	same	same
General Evaluation	**different**	same	**different**	**different**	same	same
Body	same	**different**	**different**	same	same	**different**
Flavor	same	same	same	same	same	same
Aftertaste	same	same	**different**	**different**	same	same
Aroma	same	same	**different**	same	same	same
Acidity	same	same	same	**different**	same	**different**
Overall score	same	same	**different**	**different**	same	same

Table 5.3: Comparisons of processing methods for statistically significant differences with a Tukey's test (α=0.10).

The most differences were between the well-fermented and poorly-fermented samples, and the least between the moderately dried and poorly-dried samples. When the nine sample categories were compared with a Tukey's test, only FG/DM vs. FP/DM and FG/DM vs. FM/DM proved significantly different (α=0.10, Appedix 10).

Pearson Correlation Coefficients

The results of the Pearson Correlation (Table 5.4) show strong relationships among the cupping scores.

	Overall	Aroma	Acidity	Body	Flavor	Aftertaste	Balance	General Evaluation
Overall	1.0000	0.8265	0.6569	0.3202	0.9362	0.9115	0.8912	0.9059
		(<.0001)	(<.0001)	(0.0021)	(<.0001)	(<.0001)	(<.0001)	(<.0001)
Aroma		1.0000	0.4733	0.3569	0.7117	0.6720	0.8066	0.6796
			(<.0001)	(0.0006)	(<.0001)	(<.0001)	(<.0001)	(<.0001)
Acidity			1.0000	0.0901	0.5967	0.5994	0.6453	0.6407
				(0.3985)	(<.0001)	(<.0001)	(<.0001)	(<.0001)
Body				1.0000	0.2544	0.2940	0.3426	0.2272
					(0.0155)	(0.0049)	(0.0009)	(0.0313)
Flavor					1.0000	0.9362	0.8074	0.9331
						(<.0001)	(<.0001)	(<.0001)
Aftertaste						1.0000	0.7891	0.9488
							(<.0001)	(<.0001)
Balance							1.0000	0.7610
								(<.0001)

Table 5.4: Pearson's Correlation Coefficient for cupping categories (P value in parentheses).

Many of the cupping categories' scores are highly correlated with each other. The exception to this is the body scores. Despite the disparity between the cuppers' general evaluation scores, they still have a high correlation with the overall score. Processing coffee well has a positive and correlated impact on many of the categories which are used to evaluate the quality of coffee.

Chapter 6- Conclusions

There are at least ten steps between harvesting and roasting a coffee bean (Katzeff, 2001). Even when I focused on doing all of the steps correctly for the well processed samples, there was still some variability and difficulties. The most significant was drying the coffee sufficiently with a solar dryer during the rainy season.

According to Dr. Maria Ruiz, of Café Ruiz, none of the coffee producers who export their coffee from Chiriquí, the western-most province in Panama, dry their coffee with only sunlight. They all employ mechanical drying either to supplement sun drying or replace it entirely. It is worth noting that in the highlands of Chiriquí the harvest coincides with much dryer weather during December to March, rather than the peak wet season rainfall during October and November, coinciding with the harvest in the highlands of Veraguas and Coclé to the east. Dr. Ruiz says sun drying to recommended moisture contents is not economically practical when the volume of coffee harvested and sheer space required are considered.

This study corroborated the difficulty of drying coffee sufficiently. There were many days that I wanted to go harvesting, but simply could not since my dryer was full and my samples were not drying due to extensive cloud cover and rain. Even for a farmer harvesting a relatively small volume of coffee, the amount of space (and infrastructure) needed to completely solar dry coffee would be substantial. Drying the coffee to ten to twelve percent moisture content may simply be impossible without some form of mechanical drying, which complicates the situation considerably.

Varying the processing steps of fermentation and drying has a measurable impact on coffee quality. It was hypothesized that the well-processed samples, such as FG/DG and FG/DM would earn significantly higher scores than FP/DP or FP/DM. The former did indeed earn higher average scores and had smaller standard deviations. There was high variability among many of the poorly processed samples' scores in both the cupping categories and overall scores.

The statistical similarity between the two cuppers' scores was encouraging. If cupping is to have any credibility as an objective, replicable method, different cuppers' scores for a group of samples should be statistically similar. The only cupping category that proved to be significantly different for the cuppers was general evaluation, which is the most vague of the cupping categories. It is likely that one of the cuppers was using the "-2x *taza*" and "-4x *taza*" deductions and the other the general evaluation category to adjust the final scores.

The strong correlations between most of the cupping categories, such as flavor and general evaluation ($r=0.933$, $P<0.0001$) (Table 5.4), indicate that good coffee scores well in all categories. Body scores showed little variation by processing category, and were not as correlated as other cupping categories. Body and acidity may be characteristics that are more heavily impacted by environmental conditions at the farm than the processing differences (Silva et al., 2005).

Fermentation had an impact on more cupping category scores than drying. The interaction between fermentation and drying was also significant in the overall score and several individual cupping categories. Fermentation may be more important to the final score than drying, but when the interaction is considered, they both need to be done carefully to assure a quality product.

The most noteworthy result for a coffee farmer is the standard deviations of the overall scores (figure 5.9, page 59). They are smallest for the samples that are fermented well and dried well (FG/DG), fermented well and dried moderately (FG/DM), and fermented moderately and dried well (FM/DG). These samples also had the highest average scores. The lower variances in well processed samples were apparent in all of the individual cupping categories except for body.

Cupping focuses on favorable flavors and aromas, but also looks for defects, and defective beans can have a disproportionate impact on scores. A large batch of good coffee representing weeks or even months of careful harvesting and processing can be damaged with one day's worth of poorly done coffee (Katzeff, 2001). While some of the samples that were fermented or dried poorly had good scores, many also had poor scores, and even a small portion of the poorly scoring coffee can dramatically reduce the score of a larger batch. Each lot is cupped when purchased for export, so consistency during a harvest and from year to year is also important for establishing a reputation for quality.

Recommendations for Farmers

The highest scores from all 45 samples were in the mid-80s, and three processing categories averaged above 80. This is a significant score, since it means that the coffee from Finca Zancona could be exported, and therefore demand a higher price than it currently receives. It is worth reiterating that this farm was selected because it seemed to have the highest potential in the area for quality coffee production based on management practices and environmental conditions. Many other local farms were not as well maintained or are at lower elevation, and the initial tests from the 2006 harvest indicate that they would have lower scores, likely in the 70s.

The next step for farmers will be to determine whether it is worth it to them to pursue the export market. Producing coffee that scores above 80 points is simply the first step; finding a buyer is never guaranteed. There is a great deal of ignorance regarding coffee prices, quality, and export; as a result, many farmers have a vague feeling that they are not getting enough money for their coffee, and often mention that someone else in the chain, often the local buyer, must be making a lot of money off of them. A little education and information on the coffee market can help create a more realistic view of the situation.

There are enough hurdles that there may be more practical ways for the farmers to make more money, such as taking better care of their farms to increase production, rather than quality. Simplifying the processing methods by eliminating the sorting and depulping steps and allowing the fruit to rot off the beans would save time and effort. Some farmers are already doing this, and are still selling their coffee for the same price as those who are putting a considerable amount of effort into wet-processing their beans. The farmers could use the time saved to better maintain the coffee farms, especially by pruning, increasing the yield of their farms. Since the coffee harvest is one of the busiest times of the year, simply having a little more free time may be considered a real benefit of simplification of processing.

If a farmer does want to pursue the export market, starting with a small batch of their most promising coffee is recommended. This coffee would be carefully harvested from the portion of the farm with the best environmental conditions, such as highest elevation, and healthiest plants, then processed well and sufficiently dried. A small pilot batch would allow the farmer to get a sense of the increased workload and have enough to look for a buyer for ensuing batches if they find it worthwhile.

Drying the coffee to ten to twelve percent moisture content may not benefit the farmers who are not producing export-grade coffee. One advantage is a smaller chance of infestation by the lesser coffee berry borer, which can reduce the coffee's weight. Since the coffee is sold by weight, that loss may be more than offset by the additional mass of the higher moisture content.

Recommendations for Peace Corps Volunteers

My recommendation for Peace Corps volunteers working with coffee farmers is twofold. First, process and dry a sample well, especially if you can get the farmer to do these steps with you, then have it cupped to determine the coffee's potential. Many areas simply may not have the conditions to produce export-quality coffee if they are not already doing so. For example, the coffee produced in the area west of the study area that has a soil pH of 4.0 (Ed O'Brian, personal communication) may never score above 80, despite having good varietals and climatic conditions. This will help the farmers better understand the true potential of their farms, and then set reasonable and attainable goals. Second, contacts with coffee professionals should be cultivated, since they can not only provide information on the coffee, but also recommendations for improving it, and possibly even a shortcut to the export market that is mutually rewarding.

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Appendix 4: Harvest dates and fermentation data.

Sample	Type	Harvest Date	Harvest time start	Harvest Time End	Depulped	Fermentation Optimum
1	FG/DG	11/9/07	8:30:00 AM	12:30:00 PM	1:30:00 PM	5:30:00 AM
2	FG/DG	10/25/07	9:00:00 AM	1:30:00 PM	2:00:00 PM	3:00:00 AM
3	FG/DG	11/2/07	7:30:00 AM	1:30:00 PM	3:00:00 PM	6:00:00 AM
4	FG/DG	11/29/07	9:00:00 AM	12:30:00 PM	1:30:00 PM	6:00:00 AM
5	FG/DG	11/29/07	9:00:00 AM	12:30:00 PM	1:30:00 PM	6:00:00 AM
6	FG/DM	11/2/07	7:30:00 AM	1:30:00 PM	3:00:00 PM	6:00:00 AM
7	FG/DM	11/29/07	9:00:00 AM	12:30:00 PM	1:30:00 PM	6:00:00 AM
8	FG/DM	10/31/07	7:30:00 AM	11:30:00 AM	12:00:00 PM	1:00:00 AM
9	FG/DM	11/17/07	8:30:00 AM	1:30:00 PM	2:00:00 PM	9:00:00 AM
10	FG/DM	11/9/07	8:30:00 AM	12:30:00 PM	1:30:00 PM	5:30:00 AM
11	FG/DP	11/29/07	9:00:00 AM	12:30:00 PM	1:30:00 PM	6:00:00 AM
12	FG/DP	11/2/07	7:30:00 AM	1:30:00 PM	3:00:00 PM	6:00:00 AM
13	FG/DP	11/17/07	8:30:00 AM	1:30:00 PM	2:00:00 PM	9:00:00 AM
14	FG/DP	10/25/07	9:00:00 AM	1:30:00 PM	2:00:00 PM	3:00:00 AM
15	FG/DP	10/31/07	7:30:00 AM	11:30:00 AM	12:00:00 PM	1:00:00 AM
16	FM/DG	10/25/07	9:00:00 AM	1:30:00 PM	2:00:00 PM	3:00:00 AM
17	FM/DG	11/17/07	8:30:00 AM	1:30:00 PM	2:00:00 PM	9:00:00 AM
18	FM/DG	10/31/07	7:30:00 AM	11:30:00 AM	12:00:00 PM	1:00:00 AM
19	FM/DG	10/31/07	7:30:00 AM	11:30:00 AM	12:00:00 PM	1:00:00 AM
20	FM/DG	10/25/07	9:00:00 AM	1:30:00 PM	2:00:00 PM	3:00:00 AM
21	FM/DM	10/31/07	7:30:00 AM	11:30:00 AM	12:00:00 PM	1:00:00 AM
22	FM/DM	10/25/07	9:00:00 AM	1:30:00 PM	2:00:00 PM	3:00:00 AM
23	FM/DM	10/25/07	9:00:00 AM	1:30:00 PM	2:00:00 PM	3:00:00 AM
24	FM/DM	11/17/07	8:30:00 AM	1:30:00 PM	2:00:00 PM	9:00:00 AM
25	FM/DM	11/9/07	8:30:00 AM	12:30:00 PM	1:30:00 PM	5:30:00 AM
26	FM/DP	11/17/07	8:30:00 AM	1:30:00 PM	2:00:00 PM	9:00:00 AM
27	FM/DP	10/25/07	9:00:00 AM	1:30:00 PM	2:00:00 PM	3:00:00 AM
28	FM/DP	10/16/07	8:00:00 AM	2:30:00 PM	3:30:00 PM	6:30:00 AM
29	FM/DP	11/17/07	8:30:00 AM	1:30:00 PM	2:00:00 PM	9:00:00 AM
30	FM/DP	10/25/07	9:00:00 AM	1:30:00 PM	2:00:00 PM	3:00:00 AM
31	FP/DG	11/9/07	8:30:00 AM	12:30:00 PM	1:30:00 PM	5:30:00 AM
32	FP/DG	10/31/07	7:30:00 AM	11:30:00 AM	12:00:00 PM	1:00:00 AM
33	FP/DG	10/16/07	8:00:00 AM	2:30:00 PM	3:30:00 PM	6:30:00 AM
34	FP/DG	11/2/07	7:30:00 AM	1:30:00 PM	3:00:00 PM	6:00:00 AM
35	FP/DG	10/31/07	7:30:00 AM	11:30:00 AM	12:00:00 PM	1:00:00 AM
36	FP/DM	11/17/07	8:30:00 AM	1:30:00 PM	2:00:00 PM	9:00:00 AM
37	FP/DM	11/29/07	9:00:00 AM	12:30:00 PM	1:30:00 PM	6:00:00 AM
38	FP/DM	10/16/07	8:00:00 AM	2:30:00 PM	3:30:00 PM	6:30:00 AM
39	FP/DM	11/9/07	8:30:00 AM	12:30:00 PM	1:30:00 PM	5:30:00 AM
40	FP/DM	10/16/07	8:00:00 AM	2:30:00 PM	3:30:00 PM	6:30:00 AM
41	FP/DP	11/29/07	9:00:00 AM	12:30:00 PM	1:30:00 PM	6:00:00 AM
42	FP/DP	10/25/07	9:00:00 AM	1:30:00 PM	2:00:00 PM	3:00:00 AM
43	FP/DP	11/9/07	8:30:00 AM	12:30:00 PM	1:30:00 PM	5:30:00 AM
44	FP/DP	11/9/07	8:30:00 AM	12:30:00 PM	1:30:00 PM	5:30:00 AM
45	FP/DP	11/2/07	7:30:00 AM	1:30:00 PM	3:00:00 PM	6:00:00 AM

Appendix 5: Field and laboratory measured moisture contents for samples.

Original Sample #	Fermentation	Drying	Lab moisture content (%)	Field Moisture Content (%)
1	FG	DG	12.4	11.5
2	FG	DG	12.0	12.0
3	FG	DG	13.7	11.1
4	FG	DG	13.4	11.8
5	FG	DG	12.2	11.3
6	FG	DM	18.6	13.0
7	FG	DM	18.2	13.3
8	FG	DM	19.0	12.7
9	FG	DM	19.1	12.6
10	FG	DM	16.9	12.4
11	FG	DP	19.9	15.0
12	FG	DP	18.7	16.1
13	FG	DP	18.0	14.7
14	FG	DP	18.5	15.1
15	FG	DP	19.9	14.0
16	FM	DG	12.2	12.0
17	FM	DG	12.3	11.7
18	FM	DG	13.7	11.0
19	FM	DG	13.0	10.3
20	FM	DG	12.5	10.1
21	FM	DM	16.8	14.0
22	FM	DM	13.9	13.4
23	FM	DM	17.1	12.3
24	FM	DM	19.1	13.4
25	FM	DM	18.3	13.2
26	FM	DP	19.2	14.9
27	FM	DP	15.2	14.0
28	FM	DP	15.2	15.3
29	FM	DP	18.6	14.3
30	FM	DP	18.6	16.2
31	FP	DG	15.2	11.5
32	FP	DG	13.7	11.0
33	FP	DG	14.4	11.0
34	FP	DG	13.3	11.1
35	FP	DG	12.8	10.0
36	FM	DM	17.8	12.6
37	FP	DM	16.6	12.9
38	FP	DM	15.2	13.0
39	FP	DM	19.8	13.2
40	FP	DM	14.2	13.0
41	FP	DP	17.0	14.4
42	FP	DP	19.8	14.4
43	FP	DP	19.9	14.7
44	FP	DP	19.2	16.0
45	FP	DP	17.9	15.5

Appendix 6: Cupping scores from Jose Costa.

Original Sample #	Total Score	Aroma Score	Acidity Score	Body Score	Flavor Score	Aftertaste Score	Balance Score	General Evaluation Score	"-2xTaza"	"-4xTaza"
1	79.75	8.25	8.5	8.25	8	7.75	7.5	8	-6	
2	76.75	8	7.5	7.75	7.5	7.25	7.25	7.5	-6	
3	84.25	8.25	8.25	8.25	8	8.25	8	8.25	-3	
4	83	8	8.25	8.5	7.75	7.75	7.75	8	-3	
5	79.5	7.75	8.5	8	8	7.75	7.25	7.75	-6	
6	82.25	8.25	8.25	8.25	7.75	7.5	7.75	7.5	-3	
7	85	8.75	8.5	8	8.25	8	8.25	8.25	-3	
8	87.25	9	8.5	8.5	8.75	8.5	8.5	8	-3	
9	86	8.5	8.25	8.5	8.5	8.25	8.5	8.5	-3	
10	84.5	8.5	8.25	8.5	8.5	8	8.5	8.25	-3	
11	78	8.5	7.75	8.75	7	7	7	7.5	-6	
12	75.5	7.5	7.5	8.5	7.5	7.5	7.5	7.25	-6	
13	69.25	7.25	7.5	8.25	7.25	7	7	7.75	-6	
14	69.75	6.75	8	8	7.5	7.5	7.5	7.5	-3	
15	81.75	8	8.5	8.25	7.5	7.5	7.5	7.5	-3	
16	83.5	8	8.25	8	7.75	7.75	7.75	8	-3	
17	82.75	8.5	8.5	8.25	8.25	7.5	7	7.75	-3	
18	84.25	8.25	8	8.5	8	8.25	8	8.25	-3	
19	85.25	8.5	8.25	8.25	8.25	8.25	6.25	8.25	-3	
20	84	8.25	8.25	8.25	8	8	8	8.25	-3	
21	32.5	4	6	8.75	4	5	4	4	-12	
22	75.75	8.25	7.75	7.75	7	7	7	7	-6	
23	84.75	8.75	8	8.5	8.25	7.75	8.25	8.25	-3	
24	85.25	8.5	8	8.25	8.25	8.25	8.25	8.25	-3	
25	79.75	8.25	8.25	8.25	7.75	7.75	7.75	7.75	-6	
26	50	5	7	8	5	6	5	6	-12	
27	78.75	8	8	8.5	7.5	7.5	7.5	7.25	-6	
28	77	7	8	8.5	7.25	7.5	7.25	7.5	-6	
29	86.25	8.25	8.25	8.5	8.5	8.75	8.5	8.5	-3	
30	78.25	7.75	7	8.5	7.5	7.5	7.5	7.5	-6	
31	76.75	8	8.25	7.75	7.5	7	7.25	7	-6	
32	78.25	8.25	8.25	8	7.5	7.25	7.5	7.5	-6	
33	60.75	6	7.5	7.5	6.75	6.5	6	6.5	-6	
34	84.25	7.75	8.25	8.5	8.25	8.25	8.25	8.5	-3	
35	77.25	8	8.25	8.25	7.5	7	7	7	-6	
36	63	7	7.25	7	6	5	6	6.75	-3	
37	79	8	8	8	8	7.75	7.75	7.5	-6	
38	35	6	6	7	5	4	4	5	-12	
39	85.75	8.5	8.5	8.5	8.25	8.25	8.5	8.25	-3	
40	45.25	4	6	7.75	6.5	4	4	6	-12	
41	82.25	8	7.75	8.5	7.75	7.75	7.75	7.75	-3	
42	54	7	7	8	4.5	6.25	6.25	6.5	-12	
43	86.25	8.75	8.5	8.25	8.5	8.25	8.5	8.5	-3	
44	62.25	5	7.25	7.75	7	7.25	7	7	-6	
45	78.25	7.5	8	8.5	7.5	7.25	7.5	7.5	-6	

Appendix 7: Cupping scores for Octavio Castillo.

Original Sample #	Total Score	Aroma Score	Acidity Score	Body Score	Flavor Score	Aftertaste Score	Balance Score	General Evaluation Score	"-2xTaza"	"-4xTaza"
1	85.75	8.5	9	8.5	8.25	7.75	7.5	8	-3	
2	78	8	7.5	7	7	7.25	7	7.25	-3	
3	82.75	7.75	8.5	7.5	8	8.25	8	7.75	-3	
4	82.25	7.75	8	8.5	7.75	7.75	7.75	7.75	-3	
5	81.25	7.75	8.25	8.25	7.5	7.5	7.5	7.5	-3	
6	82.75	8	7	8.25	8.25	8.25	8.25	7.75	-3	
7	83.75	8.25	8.5	8.25	8	7.75	8.25	8.25	-3	
8	81	8.5	8.5	9	7.75	7.5	8.25	7.5	-6	
9	86.5	8.75	8.25	8.75	8.5	8.5	8.5	8.25	-3	
10	85	8.75	8.25	8.75	8	8	8.25	8	-3	
11	83.25	8.25	6.75	9	7.75	8.25	7.75	7.5	-3	
12	82.5	7.5	7.75	8.5	8.25	8.25	7.75	7.3	-3	
13	77.25	8	7.5	8.75	7.5	7.25	7.5	6.75	-6	
14	40.25	7.75	7.75	8.25	3	2	6.5	3	-12	
15	83.75	7.25	7.75	8.75	8.5	8.25	8.25	8	-3	
16	82.5	7.5	8.75	7.5	8.25	8	8	7.5	-3	
17	80.25	8.25	8.5	8.25	8	7.75	8	7.5	-6	
18	79.25	8.5	8.25	8.25	7.5	7.25	8	7.5	-6	
19	84.25	8.75	8.5	8.5	8	7.5	8.25	7.75	-3	
20	68.75	8.25	8.75	8.25	7	6.75	8	6.75		-12
21	54.5	6.75	7	8	5.5	4	6.75	4.5		-12
22	54	6.75	6	9	5	4	6.5	4.5		-12
23	73.5	8.25	6.75	9.25	6.5	5.75	7	6	-6	
24	66.5	8.25	5.75	9	5.75	5	6.75	5	-6	
25	73.25	8.5	6	7.5	8	7.75	7.5	7	-6	
26	85.25	9	8	8	8.5	8.5	8.25	8	-3	
27	38	4	8	8	4	3.5	5	3.5		-12
28	64.5	6.75	8.5	7.75	6	5	7.5	5		-12
29	83.75	9	6.75	8.5	8.5	8.25	8.25	7.5	-3	
30	77.5	8.5	7	8.75	7.5	7.25	7.5	7	-6	
31	81	8	8.25	7.75	7.5	7.25	7.75	7.5	-3	
32	84.75	8.25	8.75	8.25	8	8	8.25	7.75	-3	
33	48.5	5.5	6.75	7	4	3	6.25	4	-12	
34	84	8.5	8	8.5	8.25	8	8	7.75	-3	
35	86.5	8.25	9	8.5	8.5	8.5	8.5	8.25	-3	
36	73.25	6.75	8.5	8.25	6.75	6.25	6.75	6	-6	
37	80.25	7.75	7.75	8.75	8.25	8	8	7.75	-3	
38	40	6	3.75	8.25	4	3	4.75	3		-12
39	88.5	8.5	8.25	8	8.5	8.5	8.5	8.25		
40	71.5	7.75	6.75	7	7	6	7	6	-6	
41	76	7	8.25	8	7.25	7.25	7.25	7	-6	
42	67	5.75	7.5	7.25	6.5	6	7	6	-6	
43	84.1	8.5	8	8.75	8	8	8.25	8	-3	
44	78.25	8.75	8	8.5	8.25	8	8	7.75	-6	
45	79.25	8	8.75	8.5	7.75	7.5	7.75	7.5	-6	

Appendix 8: Tukey's test for samples grouped by harvest date (α=0.10).

Contrast	Difference	Standardized difference	Critical value	Pr > Diff	Significant
11/2/2007 vs 10/16/2007	26.263	4.914	3.022	< 0.0001	Yes
11/2/2007 vs 10/25/2007	11.297	2.542	3.022	0.158	No
11/2/2007 vs 11/17/2007	4.771	1.023	3.022	0.947	No
11/2/2007 vs 10/31/2007	4.396	0.942	3.022	0.964	No
11/2/2007 vs 11/9/2007	0.800	0.171	3.022	1.000	No
11/2/2007 vs 11/29/2007	0.450	0.093	3.022	1.000	No
11/29/2007 vs 10/16/2007	25.813	5.019	3.022	< 0.0001	Yes
11/29/2007 vs 10/25/2007	10.847	2.583	3.022	0.145	No
11/29/2007 vs 11/17/2007	4.321	0.975	3.022	0.958	No
11/29/2007 vs 10/31/2007	3.946	0.890	3.022	0.973	No
11/29/2007 vs 11/9/2007	0.350	0.079	3.022	1.000	No
11/9/2007 vs 10/16/2007	25.463	5.099	3.022	< 0.0001	Yes
11/9/2007 vs 10/25/2007	10.497	2.615	3.022	0.135	No
11/9/2007 vs 11/17/2007	3.971	0.933	3.022	0.966	No
11/9/2007 vs 10/31/2007	3.596	0.845	3.022	0.979	No
10/31/2007 vs 10/16/2007	21.866	4.379	3.022	0.001	Yes
10/31/2007 vs 10/25/2007	6.901	1.719	3.022	0.606	No
10/31/2007 vs 11/17/2007	0.375	0.088	3.022	1.000	No
11/17/2007 vs 10/16/2007	21.491	4.304	3.022	0.001	Yes
11/17/2007 vs 10/25/2007	6.526	1.625	3.022	0.666	No
10/25/2007 vs 10/16/2007	14.965	3.126	3.022	0.038	Yes

Appendix 9: Means from Tukey's test for samples grouped by fermentation and drying categories.

	FG	FM	FP	DG	DM	DP
Balance	7.7583	7.3083	7.175	7.5833	7.3917	7.2667
General Evaluation	7.6017	6.9167	6.9917	7.5667	7.0433	6.9
Body	8.3417	8.3083	8.0167	8.0833	8.25	8.3333
Flavor	7.725	7.175	7.1667	7.6833	7.2167	7.1667
Aftertaste	7.6	6.9667	6.8333	7.5	6.775	7.125
Overall Score	79.95	73.792	72.37	79.667	72.842	73.603
Aroma	8.0667	7.7417	7.3667	7.975	7.725	7.475
Acidity	8.0417	7.6667	7.7	8.25	7.7417	7.4167

Appendix 10: Tukey's test for samples grouped by processing categories.

Contrast	Difference	Standardized difference	Critical value	Pr > Diff
FG/DM vs FP/DM	18.250	3.298	3.187	0.037
FG/DM vs FM/DM	16.425	2.968	3.187	0.088
FG/DM vs FM/DP	12.475	2.254	3.187	0.382
FG/DM vs DG/DP	10.275	1.857	3.187	0.645
FG/DM vs FP/DP	9.640	1.742	3.187	0.719
FG/DM vs FP/DG	8.200	1.482	3.187	0.861
FG/DM vs FG/DG	3.075	0.556	3.187	1.000
FG/DM vs FM/DG	2.925	0.529	3.187	1.000
FM/DG vs FP/DM	15.325	2.769	3.187	0.141
FM/DG vs FM/DM	13.500	2.439	3.187	0.278
FM/DG vs FM/DP	9.550	1.726	3.187	0.729
FM/DG vs DG/DP	7.350	1.328	3.187	0.920
FM/DG vs FP/DP	6.715	1.213	3.187	0.951
FM/DG vs FP/DG	5.275	0.953	3.187	0.989
FM/DG vs FG/DG	0.150	0.027	3.187	1.000
FG/DG vs FP/DM	15.175	2.742	3.187	0.150
FG/DG vs FM/DM	13.350	2.412	3.187	0.292
FG/DG vs FM/DP	9.400	1.699	3.187	0.746
FG/DG vs DG/DP	7.200	1.301	3.187	0.928
FG/DG vs FP/DP	6.565	1.186	3.187	0.957
FG/DG vs FP/DG	5.125	0.926	3.187	0.991
FP/DG vs FP/DM	10.050	1.816	3.187	0.672
FP/DG vs FM/DM	8.225	1.486	3.187	0.859
FP/DG vs FM/DP	4.275	0.773	3.187	0.997
FP/DG vs DG/DP	2.075	0.375	3.187	1.000
FP/DG vs FP/DP	1.440	0.260	3.187	1.000
FP/DP vs FP/DM	8.610	1.556	3.187	0.825
FP/DP vs FM/DM	6.785	1.226	3.187	0.948
FP/DP vs FM/DP	2.835	0.512	3.187	1.000
FP/DP vs DG/DP	0.635	0.115	3.187	1.000
DG/DP vs FP/DM	7.975	1.441	3.187	0.878
DG/DP vs FM/DM	6.150	1.111	3.187	0.971
DG/DP vs FM/DP	2.200	0.398	3.187	1.000
FM/DP vs FP/DM	5.775	1.044	3.187	0.980
FM/DP vs FM/DM	3.950	0.714	3.187	0.998
FM/DM vs FP/DM	1.825	0.330	3.187	1.000