A Comparison of Four Solar Drying Methods on Natural Process Coffee in El Paraíso, Honduras

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From left to right: Jose Manuel Rodriguez Rodriguez, Brenda Issamar Cruz Lopez, Gyventzley Eugene, Kyle Freedman, Delide Joseph, Enrique (Kike) Ferrufino Gonzalez. Source: Kyle Freedman

From left to right: Gyventzley Eugene, John Zeller, Kyle Freedman, Delide Joseph. Source: Kyle Freedman

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1. Executive Summary

This study evaluated the performance of four solar drying methods in El Paraíso, Honduras at Misión El Paraíso, a 139 ha farm with 23 ha under coffee production. Two solar dryers (UC Davis chimney solar dryer and UC Davis pallet solar dryer) were compared to two conventional drying methods: an open-air concrete patio dryer and an African raised bed for drying natural process coffee. Results showed no significant difference in dryer air temperature and moisture loss between dryers. Quality amongst the drying methods varied between evaluations. IHCAFE scored 81.3, 81.5 and 62 for the patio, raised bed, and chimney dryers respectively compared to 19, 19, and 32 for Cafetano. Scores for all natural process coffees were considerably lower than the grower standard of patio-dried washed coffee which scored an average of 83 for IHCAFE and 84 for Cafetano. The natural process patio and raised bed coffees along with the grower standard fall within the range of 80-100 required to be considered specialty coffee. Although dryer rates did not differ, solar collector dryers can provide alternative methods of drying that can provide better protection to coffee during drying from rain and insects. Drying can increase quality, prolong storage, and ultimately allow producers to sell their coffee at higher prices in specialty coffee markets.

2. Introduction

2.1 Global & Honduran coffee markets

The total global market value of coffee is estimated at $100 billion and is expected to reach over $150 billion by 2026 (Business Wire 2020). Globally, 25 million smallholder producers grow 70-80% of the world's total coffee (Fairtrade International 2021, International Coffee Organization 2019). The market is generally divided into commodity and specialty coffee based on quality (Rafael 2020, Donnet 2006). Commodity coffee is regulated by organizations such as the Intercontinental Exchange (ICE) and sold on the New York Stock Exchange (NYSE) in the United States. Commodity coffee is often purchased from individual farms by processors or intermediary companies who combine coffees into larger lots prior to sale on the NYSE or other commodity trading platforms. The quality of coffee in mixed lots can vary greatly as they may combine coffees from different countries, regions, processing methods, cultivars, and harvest maturities. Specialty coffee on the other hand is purchased directly from individual producers by green coffee buyers or roasters where detailed information about the producer, location, cultivar, and methods of production are known. In addition, these coffees have been evaluated for physical, chemical and sensory quality and have met the green coffee buyer's preferences for specialty coffee. Specialty coffees are sold at higher prices due to their desirable flavor and aroma, while the sale price of commodity green coffee is often lower than its production costs. A recent report that analyzed production costs of six Latin American countries reported costs from US$1.05 to $1.40 /lb of green coffee (Cardena 2019). These costs are above the recent 52-week price low of commodity coffee which was US$1.02 /lb of green coffee (Business Insider 2021). This results in producers operating at a loss and poses high risk for ensuring sustainable livelihoods for coffee producers.

Honduras, situated in Central America with a population estimated at 10.1 million, is the third largest coffee producer in Latin America and fourth globally (USDA 2020, UNFPA 2021). The economy of Honduras is largely agricultural and Honduras is the largest producer of coffee in Central America with 1 million people employed in the sector (Bunn et al. 2018). In addition, 110,000 families rely on coffee production as their primary income with 95% farming less than 7 ha (Bunn et al. 2018). Honduras produces about 7 million 60 kg bags of *Coffea arabica* annually and the crop is grown in 15 of the 18 national departments (USDA 2020). Total national production of green coffee has increased annually by 5% with a 9% increase in the 2020-21 season (Bunn et al. 2018, USDA 2020).

Given the historically low prices of commodity coffee, specialty coffee provides an opportunity for producers to receive a higher return. Exports of specialty coffee in Honduras increased to 2.4 million 60 kg bags in 2016-17, a 145% increase from the previous year (USDA 2020). This represents a valuable opportunity to support coffee producers with the tools needed for transitioning from the commodity market where producers operate at a loss. Natural process coffee, where whole cherries are dried, is the oldest method of coffee processing. These coffees are increasing in specialty product offerings requiring less postharvest infrastructure and are more environmentally sustainable. Natural process coffee is not common in Honduras and may present an opportunity for product diversification and entry into specialty coffee markets. However, several challenges are associated with producing high quality natural process coffee including pests and disease, changes in climate, improper drying conditions and a lack of knowledge of postharvest processing (Café Imports 2021). Drying of coffee in Honduras is mainly conducted in lower altitude valleys where high temperatures and lower relative humidity along with less annual rainfall provide ideal conditions for sun drying.

Overall, Honduras lacks the infrastructure to support specialty coffee and proper postharvest processing due to unsuitable climate and limited access to knowledge and technology (Café Imports 2021). This makes natural process an ideal method to address these challenges. In order to support producers in transitioning to specialty coffee production, and specifically natural process, access to new technologies and training on the appropriate drying methods is needed. This project focused on 1) evaluating the use of two solar drying technologies compared to two conventional drying methods to determine which would be best suited for this climate, with the intent of a) introducing natural process coffees as an alternative to the conventional washed coffee which should reduce water use and diversify processing methods appealing to specialty coffee markets, and b) to introduce new technologies to improve postharvest processing and quality.

3. Background

3.1 Project rationale

Honduras has a special place in my heart as my partner grew up outside of the capital, Tegucigalpa, and her parents have lived there for over 30 years. Several trips to visit her family developed a deeper connection to the people and land including visits to local coffee farms and processing facilities. After moving to Davis, CA in 2019 and joining Discovery Church, I met John Zeller, and we immediately became close friends bonding over Honduras and coffee. John's sister had been travelling to El Paraíso, Honduras since 1999 to provide medical support after hurricane Mitch devastated the region. John made his first trip in 2006 and has been supporting the development of the rural village that is now Misión El Paraíso ever since. Coffee production is a major source of livelihoods in this area and for the Misión El Paraíso community. As John and I met, he began to tell me the story of this wonderful community and brainstorming ways to support its development, ranging from advancements in coffee production to establishing home gardens to supplement household nutrition. The goal of Misión El Paraíso is to build a strong community where families can have a safe place to live, steady employment, and foster a sense of community leading to a better life. Because coffee is the main livelihood for the families at Misión El Paraíso, project ideas were focused on how to raise incomes for the producers by improving quality and educating them on industry postharvest processing standards. Having previously travelled to Honduran coffee regions, I was aware of some of the challenges producers were facing with postharvest processing. Building off of my experience working at the Horticulture Innovation Lab at the commencement of this project in 2019, I provided John with some of the resources related to small-scale postharvest technologies. John corresponded with his farm manager, Brenda, who is the liason with the rest of the community, and there was interest in testing some of the drying technolgoies for coffee, specifically the UC Davis chimney solar dryer. This dryer along with the pallet dryer have not been tested with coffee. African raised beds, another drying technology, are becoming more common throughout Honduras as local extension services are promoting their use. In addition, sun drying using concrete patios is the prevalent method of drying and the development of a research project comparing these four drying methods unfolded.

3.2 Participatory research

A common theme throughout the history of international development has been for researchers and those in positions of power to design and implement research projects based on their knowledge and understanding of a local place's problems and needs. While this is often good-intentioned, it often neglects to empower and enable those whom these projects affect to design research that they feel is valuable and needed. Participatory research focuses on the fact that those who live in a place where research and development interventions may be considered, are not only capable of analyzing their own realities but are much more knowledgeable and equipped to do so than outsiders (Chambers 1994). In applying these principles to this project in Honduras, the intention was to provide options for small-scale postharvest drying technologies that could be used at Misión El Paraíso and allow the producers to make their own design adjustments to fit their individual needs. These designs would serve as a springboard for future technologies and methods of processing their coffee. In some ways, we succeeded in this approach as adaptations were made without involvement from John and I and the producers were very engaged in learning new concepts they had not been exposed to. In other respects, we did not adhere to these participatory research principles as perhaps the producers would have chosen to build different dryers or focus on a project completely unrelated to coffee altogether.

3.3 Dry chain

Coffee, like many fresh fruits, has a high water content combined with sugars, amino acids, and proteins which allows microorganisms to grow and can lead to spoilage (Pereira and Moreira 2021). While postharvest losses as a result of spoilage and microbial growth is not a common issue in the coffee sector due to the roasting process which kills off any microorganisms, reductions in quality as a result of microbial and chemical reactions is a major problem. For this reason, it is essential to dry coffee from its initial 60-65% moisture content wet basis (MCwb) to 10-12% MCwb for safe storage and prolonged shelf life (Wintgens 2012, Gosh 2014). The dry chain, similar to the cold chain, focuses on drying food products quickly after harvest and keeping them dry to prevent microbial growth and chemical reactions from causing degradation (Bradford et al. 2018). Two key components of the dry chain are drying and storage and this project focused primarily on drying by introducing new methods and evaluating their performance in the tropical climate of Misión El Paraíso.

3.4 Postharvest processing of green coffee

Coffee trees come to fruit-bearing maturity after 3 years, and the cherries are harvested by hand or mechanically (Wintgens 2012). Manual harvesting enables better selection of mature red cherries, since cherry maturity is very different on each branch due to uneven flower development. Mechanical harvesting is most common in countries such as Brazil that have flatter topography for operating harvesting machines and where production is oriented in crop rows (Wintgens 2012). Coffee cherries undergo a series of processing stages including wet milling, drying, dry milling, sorting, storage, and transportation (Figure 1).

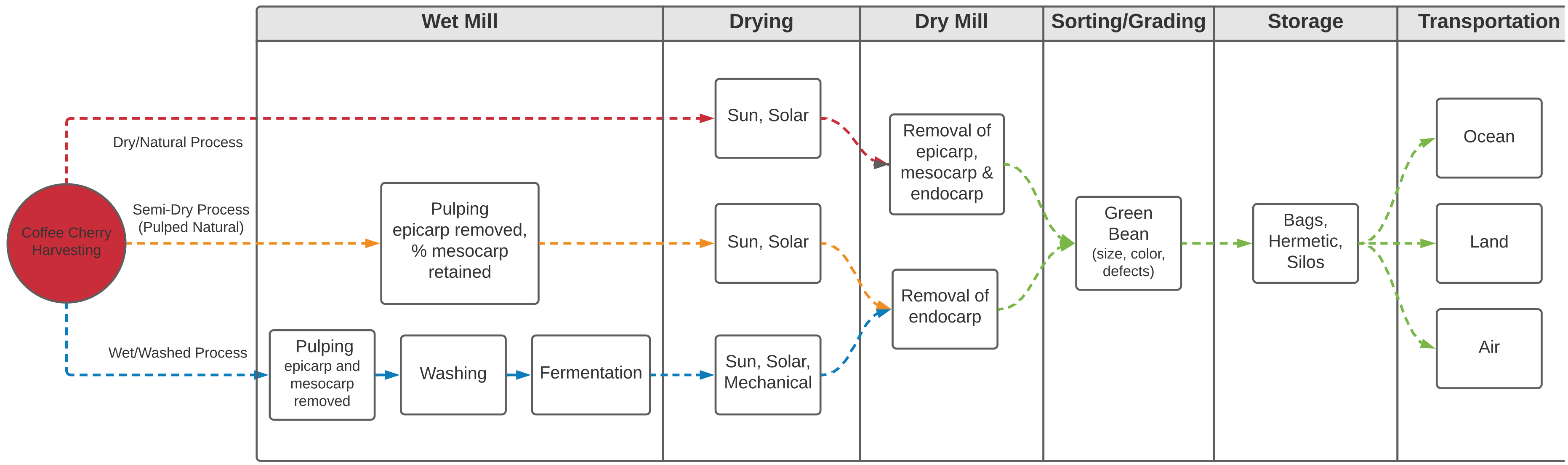

Figure 1. Primary postharvest processing stages of green coffee

After harvesting, producers select between the two most common processing methods, wet or natural (Figure 2A and 2B). While other methods exist, these are the two most common in the coffee industry. Wet process includes the removal of the outer skin layers or exocarp as well as some pulp or mesocarp, known as wet milling. This is accomplished through the use of a rotating metal drum that presses the coffee cherries and separates the exocarp from the bean (Figure 3). The beans are then submerged in water to under go fermentation and washed to remove the remaining mesocarp. Once fermentation and washing are completed, parchment coffee results and is ready for drying. These coffees are characterized as more acidic with a clean flavor profile (Poltronieri and Rossi 2016). Wet process coffees are also commonly called washed coffees.

A)

B)

Figure 2. (A) Side-by-side comparison of natural process coffee and (B) wet process parchment coffee in El Paraíso, Honduras dried on a concrete patio. Source: Kyle Freedman

Figure 3. Small-scale metal depupling machine that presses whole cherries through a rotating metal drum, separating the exocarp from the parchment in El Paraíso, Honduras. This machine is connected to a motor attached by a rubber belt to automatically rotate the drum. Source: Kyle Freedman

If wet milling is not selected, whole cherries can be directly subjected to drying, known as the natural process. Cherries are unaltered maintaining the exocarp and are not washed with any water. Spontaneous fermentation is accomplished during drying as the cherries naturally break down. These coffees are sweeter, have less acidity, a silky mouthfeel and more complex flavor compounds (Poltronieri and Rossi 2016, Taveira et al. 2015).

Both wet and natural process coffees are then dried to reduce water content through applied heat and airflow and enable producers to reduce the deterioration of the coffee beans. Once coffee beans are dried, dry milling is accomplished to remove the parchment layer for washed coffee and the exocarp, mesocarp and parchment for natural process. Mechanical hulling machines are used for both coffees resulting in green coffee beans. Green coffee beans are then sorted to remove debris and foreign objects, graded according to green coffee standards, and shipped to their final destination. When green coffee is exported to consuming countries, it is roasted and brewed for final consumption.

3.5 Coffee drying methods

Drying of coffee can be organized into three main types; sun drying, solar collector drying, and mechanical drying. Sun drying is the oldest method of drying and consists of using both energy from the sun and natural airflow from wind to evaporate water from the coffee. Sun drying includes open-air methods such as patio and raised bed, as well as covered sun drying in greenhouse dryers. Patio dryers use a flat, outdoor surface, which can be made using bare ground, mats, tarps, concrete, tile, stone, or asphalt. Sun drying systems rely on frequent mixing of the coffee to expose beans at lower levels (Wintgens 2012). Raised or African beds are another form of sun drying that use mesh or wire to suspend the coffee above the ground. These can be constructed using various materials with the objective of allowing airflow above and below the coffee. Because these dryers are suspended off the ground, they are subject to less contamination and debris, which can maintain quality. Greenhouse dryers are a modified form of sun drying that combines the utilization of solar energy with a structure protecting coffees from precipitation. Greenhouse dryers differ from sun drying methods such as patio and raised bed in that they induce a greenhouse effect by trapping air warmed by solar radiation. Reduced air ventilation through the use of plastic or other materials increases air temperatures by 10-15°C above ambient air temeprature (Brenndorfer et al. 1985, Wintgens 2012).

Managing environmental conditions during sun drying, such as air temperature and relative humidity, is difficult. Changes in weather and lack of sun exposure during evening hours can significantly increase drying time due to moisture absorption from high night time relative humidities and dew. High temperatures and inadequate ventilation for greenhouse dryers can also create a baking effect, heating the coffee to excessive temperatures. It is recommended that coffee cherry temperatures during drying do not exceed 40-45°C as higher temperatures can cause beans to crack, bend, degrade cellular membranes impacting color and reduce sugar content affecting sensory evaluation (Correa et al. 1994, Souza, 2000, Sfredo et al. 2005, Wintgens 2012). Cracking of parchment and other membranes as a result of high temperatures can expose the beans to insects causing further damage (Wintgens 2012). Patios and raised beds allow coffee to be exposed to insects, pests, debris and rainfall, which can reduce quality. Sun drying in the humid tropics poses more challenges as rehydration can make it difficult to sufficiently dry products without the growth of microorganisms (Bradford et al. 2018).

Solar collector dryers consist of a compartment that holds the product to be dried with a transparent or opaque exterior enabling energy from the sun to enter (Tiwari 2016). The dryer captures this energy using components such as black plastic or fabric which heats air that enters from an opening or inlet. Hot air passively moves over the coffee beans or cherries reducing the moisture content and increases the humidity of air exiting the dryer. Solar collector dryers should be sufficiently insulated to minimize heat loss (Tiwari 2016). Examples of solar-collector dryers include cabinet and chimney solar dryers (VijayaVenkataRamana et al. 2012, Tiwari 2016).

Mechanical dryers differ from sun and solar drying methods in their use of a fuel or energy source, which generates high temperatures and forced airflow. Fuel sources include wood, charcoal, gas and coffee byproducts such as coffee hulls. Each source provides a consistent amount of energy in the form of heat, which is forced through the coffee using fans. Hot air evaporates water as it moves through the product and is vented out. Mechanical dryers take less than 81 hours to dry coffee down to 10-12% MCwb for both natural and wet process (De Souza e Silva 2011, Siquiera et al. 2016, Sotelo-Valer et al. 2020). The faster drying times associated with mechanical dryers enable producers and processors to dry coffee in larger volumes as well as reduce labor needed to dry equivalent amounts using open-air or solar methods. Although mechanical drying was not the focus of this study, advantages of mechanical dryers include the control of consistent temperature and airflow, which reduces the drying time.

3.6 Storage

Bags or sacks are the most common form of storage for coffee. These come in many different materials and sizes, but the use of jute, sisal and polypropylene are widespread throughout coffee producing regions (Wintgens 2012). These materials are permeable and allow the moisture content and water activity of the coffee to increase to unstable levels that vary depending on the surrounding ambient conditions in which the coffee is stored. Numerous studies have shown that these permeable storage materials allow for coffee degradation due to increases in microbial and chemical activity as a result of changes in moisture content and water activity (Bucheli et al. 2000, Ribeiro et al. 2011, FAO 2021).

3.7 Coffee quality

Coffee quality is influenced by pre and postharvest factors such as cultivar, soil, climate, altitude, harvest maturity, temperature, processing, drying, dry milling, sorting, storage, transportation, roasting, and beverage preparation. Quality can be categorized by physical, chemical, microbial and sensory parameters. Physical quality includes size, color, and defects or damage. Chemical quality includes green coffee composition such as total soluble solids, acids, volatile compounds, proteins, and fats. In addition to physical and chemical attributes, microbial quality addresses the types of microorganisms present on coffee and their metabolites, which can be harmful to human health. Changes in chemical and microbial composition can affect sensory quality, or the organoleptic properties of the final beverage such as taste and aroma.

3.8 Natural process coffee

The use of natural process coffee was prioritized in this study for two reasons; 1) to introduce a method for product diversification that requires less processing infrastructure and is sought after in specialty coffee markets, and 2) to improve sustainable resource management by significantly reducing the amount of water needed for processing. Natural process coffees, which dry the entire coffee cherry, are known to have high body, lower acidity, and more fruit notes compared to wet process (Poltronieri and Rossi 2016). While these attributes are desirable, it is difficult to find high quality natural process coffees amongst specialty markets due to the high presence of damage and defects from sun drying (Poltronieri and Rossi 2016). Coffee defects can be broken down into primary and secondary. Primary defects include full black beans, full sour, dried cherry/pods, fungal damage, foreign matter, and severe insect damage (Coffee Research 2006, Kosalos et al. 2013, International Coffee Organization 2021). Secondary defects include partial black beans, partial sour, parchment not removed during hulling, floaters, unripe beans, shells, hull/husk pieces, and slight insect damage (Coffee Research 2006, Kosalos et al. 2013, International Coffee Organization 2021). Alternative drying methods such as solar collector dryers that provide protection to the coffee cherries during drying may reduce damage and improve quality sufficiently to be considered specialty coffee. In terms of natural resource use and sustainability, natural process coffees require no water unlike wet process. Wet process coffees use between 1,000-2,000 liters per 45 kg of green coffee or 22-44 liters/kg (Arce et al. 2009). The wastewater and fruit flesh resulting from the processing of 1 ton of cleaned coffee is equivalent to 273 m^3 of domestic sewage, or the equivalent of daily sewage waste from 2,000 people (Chanakya and De Alwis 2004). A lack of infrastructure and procedures for the disposal of coffee cherry flesh from wet process results in dumping along roads and streams (Figure 4). Not only would proper drying of natural process coffees offer product diversification to Honduran producers, it would also significantly reduce waste contributing to environmental pollution.

Figure 4. Dumping of wet process cherry flesh and waste along a stream in El Paraíso, Honduras in December 2019. Source: Kyle Freedman

4. Materials and Methods

4.1 Project site and context

Misión El Paraíso is a 139 ha farm located about 38 km from the city of El Paraíso, Honduras (Figures 5 and 6). Honduran coffee production is concentrated in 15 of the 18 national departments with El Paraíso ranking as the 4th largest producing region in the country (IHCAFE 2021). This 23 ha coffee farm is managed by 10 core families with the remaining land area utilized for forest to provide shade for cultivation, timber, and a small amount of fruit production including plantains and bananas. While the land area under coffee cultivation for this farm is not considered small-scale, production is of low quality and sold to local processors or *beneficios* representative of other small-scale coffee farms in Honduras (FAO 2017).

The climate of Honduras is characterized by a dry and wet season. The dry season runs from December to May and the wet season from June to November. Climate change in Honduras is causing more extreme conditions in coffee growing regions including higher temperatures and lower precipitation during the dry season and intense rains during the wet season (Bunn et al. 2018). Peak harvest at Misión El Paraíso is between December and January which coincides with the transition between the wet and dry season (Bunn et al. 2018). Precipitation during harvest can impact how well coffee can be dried and safely stored and open-air sun drying methods may be less effective due to coffee exposure to rain.

Figure 5. The project site at Misíon El Paraíso (yellow pin) is located 38 km from the nearest city of El Paraíso where the coffee is sold. Due to poor roads, this short distance takes over 2 hours by car and without drying and storage practices in place, forces the farm to make frequent trips. The yellow line represents the border between Honduras (north of the line) and Nicaragua (south of the line). Source: Kyle Freedman

Figure 6. View of the research site and surrounding coffee farm at Misión El Paraíso in El Paraíso, Honduras. Source: Kyle Freedman

4.2 Dryer Construction

The chimney and raised bed dryers were constructed 15 m from an existing patio dryer (Figure 7A). The UC Davis chimney solar dryer was constructed in accordance with the manual produced by the Horticulture Innovation Lab. The manual was translated into Spanish and provided to the farm manager via email. The chimney dryer was constructed by the producers prior to the arrival of the research team. One major change to the dryer's design was the overall dimensions. The field team during construction did not believe the standard dimensions would accommodate a sufficient volume of coffee that is typical during harvest. Constructed dimensions for the drying table were 1 m wide, 1.2 m tall, and 6.1 m long. The chimney dimensions were 1 m wide, 3.1 m tall, and 0.34 m deep (Figure 7B). Although the dimensions were significantly larger than the original design, the 2:1 ratio of drying table to chimney size was maintained. Wood was cut and milled from resources on the farm. All other materials including the clear greenhouse grade polyethylene plastic, black pastic, staples and nails were sourced outside of the farm. A total of 6 drying trays were constructed with the first tray left empty with the remaining 5 filled with coffee (Figure 7C and 7D). HOBO data loggers were placed in trays 1, 3, and 5.

A) B)

C) D)

Figure 7. A & B) UC Davis chimney solar dryer constructed in El Paraíso, Honduras in December 2019. C & D) View of drying trays inside the the chimney dryer. Source: Kyle Freedman

The UC Davis pallet solar dryer was built according to the manual provided by the Horticulture Innovation lab (Figure 8A). The wooden box was constructed using local pallets as well as wood milled from the farm. A 12v 25w fan connected to a 12v 30w solar panel was mounted to the top of the bin lid forcing warm air within the plastic to move through the coffee.

Because the wood was milled directly from the farm and there was no access to solid plywood sheets, wood was joined together to construct the box. This created gaps between the wood on the sides and top of the drying bin which allowed water to enter. Plastic was added under the drying bin lid to prevent water from entering (Figure 8B).

A) B)

Figure 8. A) Construction of the UC Davis pallet solar dryer in El Paraíso, Honduras. B) Plastic was added to the underside of the bin lid to protect the coffee from rain entering through gaps between the wood. Source: Kyle Freedman

The African raised bed was constructed using a design by Demarli Estate in Panama (Figure 9A)(Perfect Daily Grind 2016). This resource included a Spanish translation which was brought to Honduras and provided to the producers to aid in construction. Materials included wood cut and milled from the farm, metal wire, black weed fabric, staples, and nails. Concrete cinder blocks were used to raise the bed off the ground three blocks high in the rear and four in the front due to uneven ground. Three pieces of pliable metal stakes were stapled evenly across the bed and bent to the opposite side to form hoops for polyethylene plastic to rest ontop to protect the coffee during precipitation (Figure 9A and 9B). Plastic was open on either ends to allow airflow and was removed when there was no rain.

A) B)

Figure 9. A) African raised bed constructed from wood and mesh frabric raised off the ground by cinder blocks in El Paraíso, Honduras. Metal stakes were bent across the bed to allow plastic to be attached during rain. B) African raised bed (left) with plastic cover on top and sides open to allow ventilation.

The existing concrete patio dryer had previously been constructed by the farm. This dryer was a concrete slab situated about 15 m to the west of the chimney and raised bed dryers (Figure 10A). A metal fence surrounded the patio dryer to prevent animals from entering the drying area. The grade or slope of the patio dryer is unknown though moisture tended to pool on the surface indicating that the slope was insufficient for proper drainage (Figure 10B).

A) B)

Figure 10. A) Concrete patio dryer that was previously constructed by the farm in El Paraíso, Honduras. B) Natural process coffee drying with moisture pooling on the patio from rain. Source: Kyle Freedman

4.3 Storage Materials

Samples of coffee from each dryer were stored in hermetic storage bags (GrainPro) at the conclusion of the drying process (Figure 11). GrainPro bags are made from high-strength polyethylene and are impermeable, preventing water and insects from entering (De Bruin et al. 2014). These bags were purchased from GrainPro USA and cost $16.50 for 10, 15 kg bags. In addition, these bags had built in plastic zippers to ensure all samples were sealed air tight. The size of bags used were 15 kg to ensure a sufficient amount of coffee remained after hulling for quality analysis. Misión El Paraíso uses woven polypropylene (Figure 11) and this was the first time hermetic storage bags such as GrainPro were used. These bags were sourced locally and their price ranges from $0.05 to $1.00 per bag depending on the quantity purchased.

Figure 11. 60 kg woven polypropylene bags on the left (white and red) and 15 kg hermetic GrainPro bags (green) on the right in transit to be sold in El Paraíso, Honduras. Source: Kyle Freedman

4.4 Moisture content and water activity measurement

We did not collect direct data in this study on moisture content and water activity values in the coffees but the UC Davis DryCard™ was used in each bag at the final stages of the study during storage. The DryCard™ utilizes cobalt chloride humidity paper to determine equilibrium relative humidity around stored products reflecting dryness through color changes (Zambrano et al. 2019). This tool can estimate water activity in as little as 30 minutes and is about the size of a business card (Thompson et al. 2017). Production costs of the DryCard™ can be as little as $0.05 and retail between $1.50 and $2.68 per card. The use of a DryCard™ in each sample GrainPro bag enabled the producers to monitor changes in water activity through the color indicator strips on each card while bags were kept in storage prior to hulling. This was important as the coffee remained in storage from the end of the drying process which concluded on December 26, 2019 until hulling on July 6, 2020.

4.5 Quality

This study analyzed sensory quality, as this is the most common method of quality evaluation in Honduras. Sensory analysis was conducted using the Specialty Coffee Association (SCA) cupping protocols (SCA 2021). Cupping consists of using trained, industry experts to sample brewed coffees assessing them for general characteristics of aroma, taste, and flavor (Seninde and Chambers 2020). A final score out of 100 points is assigned and covers a range of sensory attributes evaluating fragrance/aroma, flavor, aftertaste, acidity, body, balance, uniformity, clean cup, sweetness, defects, and an overall score (SCA 2021). Coffees that receive a cupping score between 80-100 are classified as specialty (SCA 2021). Those that receive scores under 80 cannot be classified as specialty and are considered commodity.

4.6 Methodology

Coffea arabica cherries were harvested from the same trees at a 23 ha coffee farm in El Paraíso, Honduras and randomly assigned to one of four solar dryers; a concrete patio, a raised bed, the chimney solar dryer, and the pallet solar dryer. Handling of the coffee was the same for all dryers. The patio dryer received 100 kg, the raised bed 84 kg, the chimney solar dryer 84 kg, and the pallet dryer 117 kg. The loading for each dryer was 14 kg/m^2 for the chimney, 21 kg/m^2 for the raised bed, 11 kg/m^2 for the patio, and 81 kg/m^2 for the pallet dryer. Differences in the amount of coffee used were due to the size and capacity of each dryer. Coffee was dried using the natural process in which whole coffee cherries are dried without depulping and washing. Drying was initiated on December 14, 2019 and continued through December 26, 2019. Temperature/Relative Humidity data loggers (HOBO Onset, Massachusetts) were placed in each dryer to record temperature, relative humidity, and dew point every 10 minutes during drying to determine the mass transfer of water in the coffee and how the coffee may equilibrate to the surrounding headspace relative humidity. Data loggers were placed in trays 1, 3 and 5 for the chimney dryer. The raised bed had two data loggers on either side on top of the coffee. The patio dryer had one data logger on top of the coffee which also served to collect ambient temperature, relative humidity and dew point information. The pallet dryer had three data loggers, one at the inlet under the pallet, one under the coffee, and one on top of the coffee. Data loggers were covered with folded carboard or plastic pieces to protect the sensors from solar radiation and rain (with the exception of the data loggers in the pallet dryer as they were not directly exposed to solar radiation). Coffees were mixed twice a day in each dryer. Each dryer contained four mesh bags (TecUnite, China) with 200g samples used to take mass measurements twice a day to measure water loss. Final MCwb was measured at Zamorano University prior to dry hulling using a capacitance moisture meter.

Upon completion of drying, 15 kg from each dryer were stored in plastic hermetic storage bags (GrainPro, Massachusetts) and hulled to green bean form at Zamorano University. A DryCard^{TM} was placed in each bag to monitor the water activity of the green coffee during storage. Samples from each dryer were given to *Instituto Hondureño del Cafe* (IHCAFE) in El Paraíso and Cafetano, an independent specialty coffee roaster in Tegucigalpa, to conduct roasting and cupping to determine the sensory quality of each coffee. Samples were provided with a letter code corresponding to each dryer to eliminate any bias resulting from the cupper's knowledge of the processing and drying methods used. Both IHCAFE and Cafetano had 2 cuppers evaluate each sample separately.

5. Results

5.1 Effect of dryer on air temperature

The thermal performance of the patio, chimney, and raised bed dryers were evaluated using temperature data. Average air temperatures for the chimney, pallet, raised bed, and patio dryers were 25.1°C, 26.0°C, 22.7°C, and 25.9°C respectively (Table 1). Average ambient air temperature was 25.9°C represented by the patio dryer. The pallet dryer had the highest average air temperature, though this dryer was removed from the study after 2 days as several fan blades broke when opening the bin lid. The raised bed had the lowest average air temperature of all dryers. Maximum air temperatures for the chimney and patio dryers exceeded the recommended threshold of 40-45°C for coffee drying which can contribute to quality loss. All dryers showed a common temperature fluctuation between day and night time conditions where the peaks in Figure 12 represent day time air temperature and the valleys represent the night time air temperatures.

Table 1. Minimum, maximum and average air temperatures for all four dryers

	Min Temp °C	Max Temp °C	Average Temp °C
Chimney	16.8	49.0	25.1
Pallet	21.3	40.7	26.0
Raised Bed	15.2	39.3	22.7
Patio*	17.5	43.3	25.9

**Patio dryer data also represents ambient air temperature*

A common relationship across all dryers was high daytime temperatures corresponding to low relative humidty fluctuating with low night time temperatures and high relative humidity in the absence of the sun (Figures 13-16). The higher the air temperature, the greater capacity the air has to hold moisture, which reduces relative humidity. As temperatures drop, the air can hold less moisture and saturated air that meets the dew point temperature causes condensation to form.

Due to several rain events that caused the patio dryer sensor to get wet, relative humidity data was missing and these values were removed (Figure 15). A consistent pattern was high daytime temperatures decreasing at night which raised the relative humidity allowing the coffee to equilibrate with the surrounding humid air and thus increasing in moisture content (Figures 13 and 14). Overall, it is clear the temperature and relative humidities across all four dryers fluctuated greatly during drying, contributing to the long and inconsistent drying time. The relative humidity of the chimney dryer also took longer to reach its peak values compared to the raised bed. This may be due to the protective plastic barrier around the drying chamber of the chimney holding warm air for longer periods. As the temperature cooled, the relative humidty gradually increased.

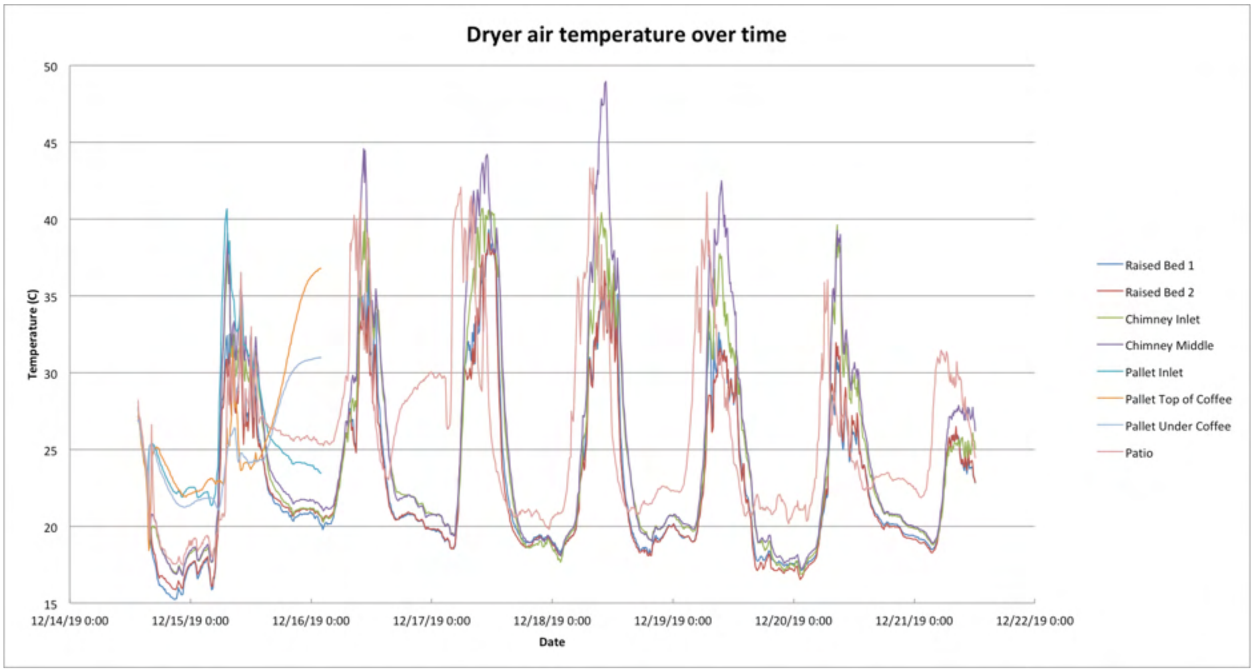

Figure 12. Air temperature (°C) of the chimney, raised bed, patio and pallet dryers over the first 9 days of drying in El Paraíso, Honduras in December 2019. Raised bed 1 and 2 indicate the two data loggers that were used in the dryer.

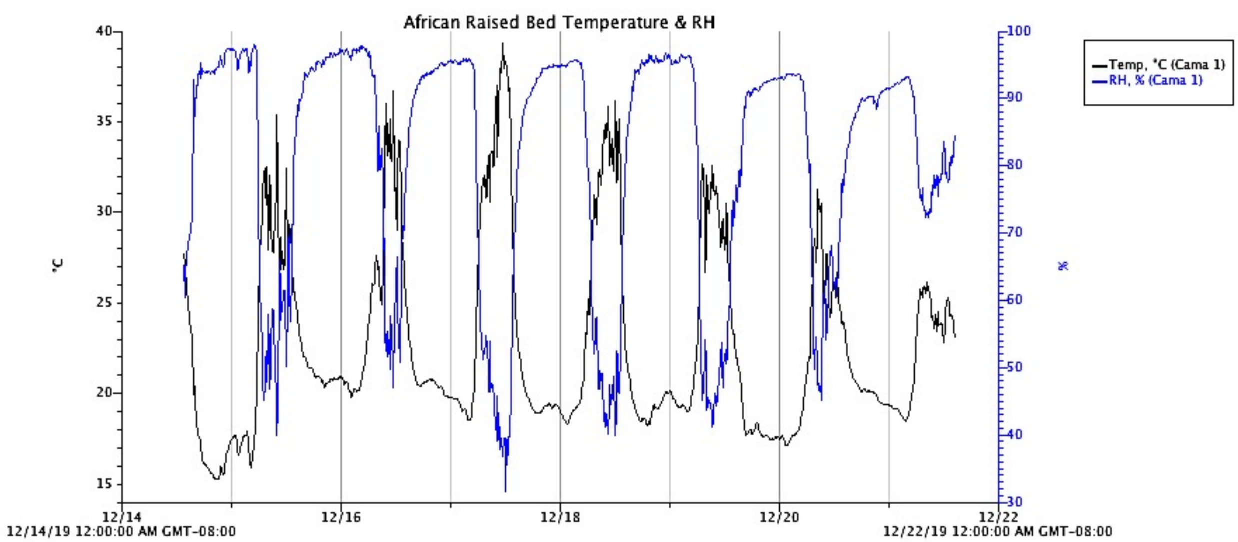

Figure 13. Raised bed relationship between air temperature (°C) and relative humidity during the first 9 days of drying in El Paraíso, Honduras in December 2019.

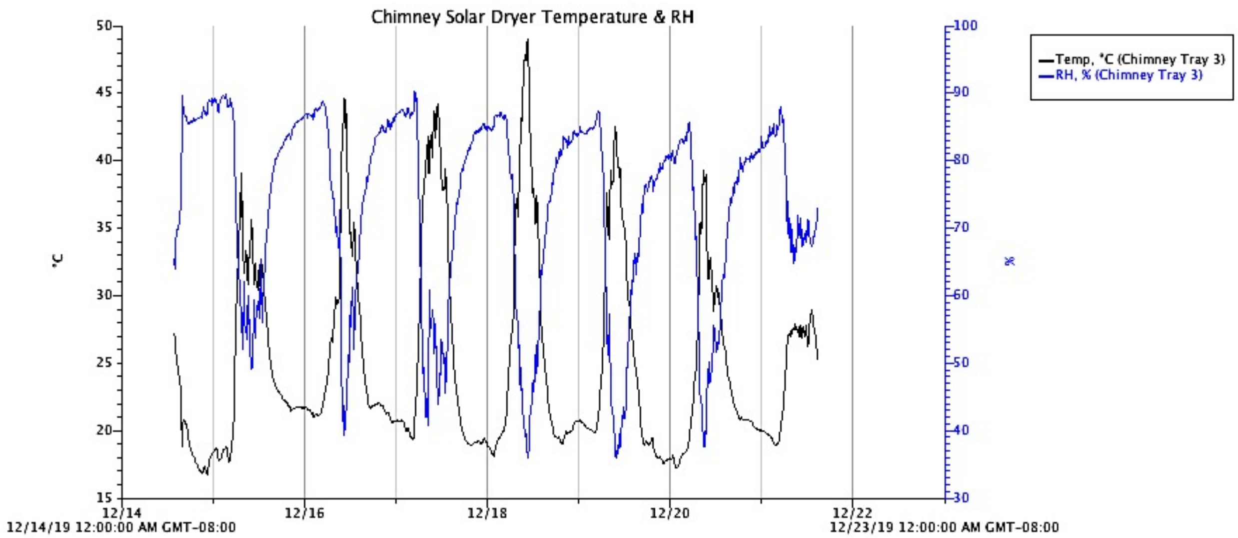

Figure 14. Chimney solar dryer relationship between air temperature (°C) and relative humidity of tray 3 during the first 9 days of drying in El Paraíso, Honduras in December 2019.

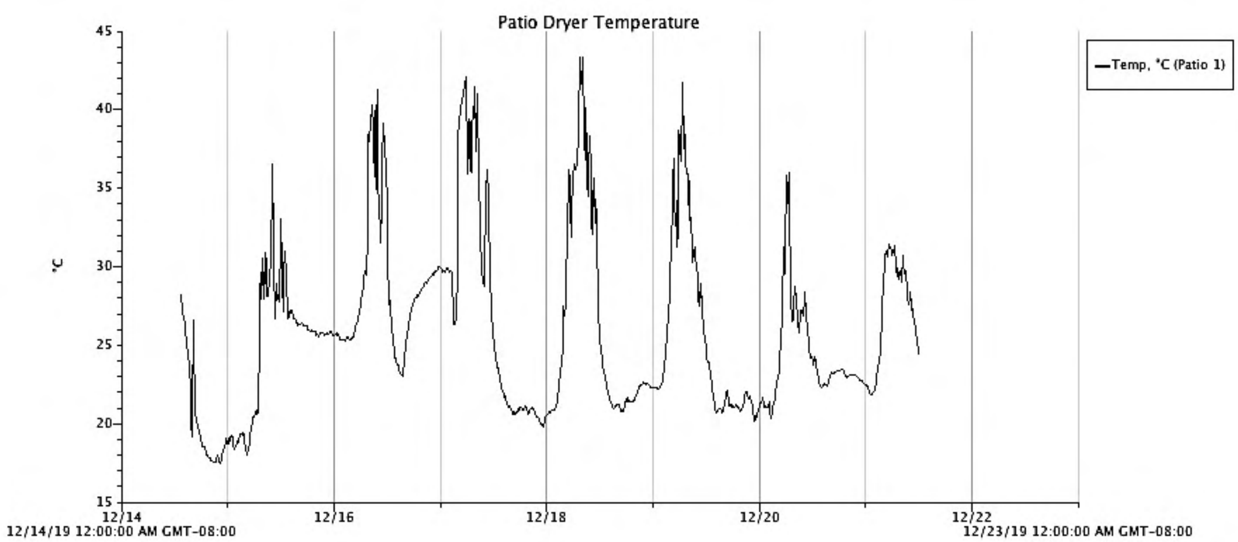

Figure 15. Patio dryer air temperature (°C) during the first 9 days of drying in El Paraíso, Honduras in December 2019. Relative humidiy data were removed as the logger did not properly collect them.

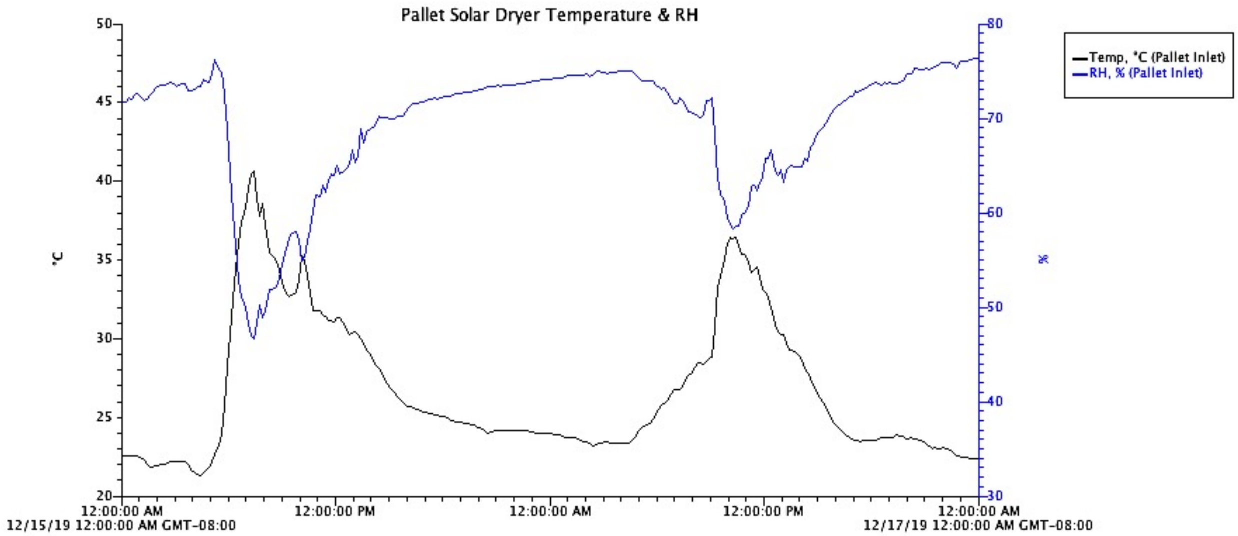

Figure 16. Pallet solar dryer relationship between air temperature (°C) and relative humidity of the inlet during the first two days of drying in El Paraíso, Honduras in December 2019. This dryer malfunctioned after two days and provided limited data.

5.2 Effect of dryer on water loss

Rate of water loss during drying was 11.5 g/day for the chimney, 11.2 g/day for the raised bed, and 11.5 g/day for the patio (Figure 10). Differences in water loss were not significant between dryers. Insufficient data were collected for the pallet dryer as it was only operational for 2 days and the second day water loss was only 5 g. Initial and final moisture contents were similar across all samples (Table 2). Initial moisture contents reflect reports of 60-65% MCwb for coffee cherries. The final MCwb of the raised bed was slightly higher than the target range of 10-12%. Due to a lack of moisture content measurement tools, the head processor assessed the physical characteristics of the dried coffee cherries for all dryers using his teeth and crushing the beans to determine their dryness. This is common practice for small-scale coffee farmers that lack quantitative measurement tools for moisture content.

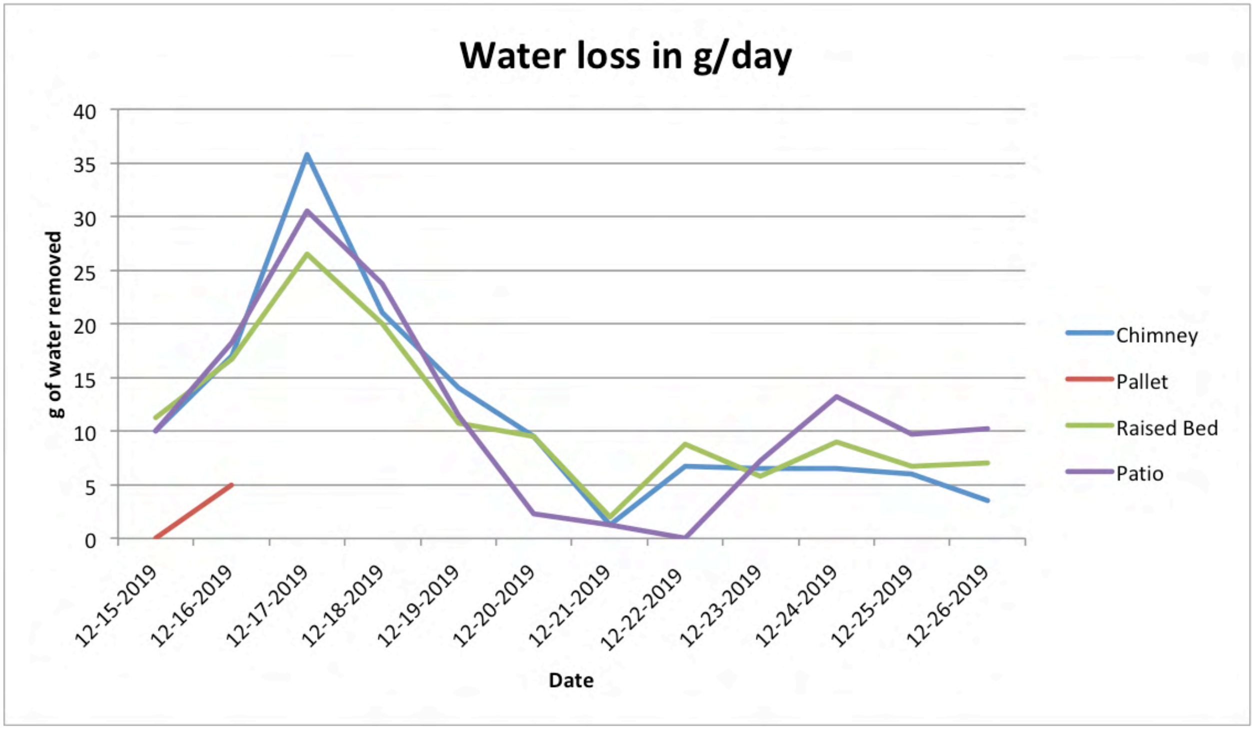

Figure 10. Water loss in g/day of 200g sample bags in the chimney, pallet, raised bed, and patio dryers tested in El Paraíso, Honduras in December 2019.

Table 2. Initial and final MCwb for the chimney, raised bed, and patio dryers

	Chimney	Raised Bed	Patio
Initial MCwb	69%	67%	66%
Final MCwb	10.2%	12.9%	11.7%

5.3 Effect of dryer on sensory quality

Cupping scores varied widely between evaluators with IHCAFE scoring much higher than Cafetano (Table 3). Patio and raised bed natural process coffees were 81.3 and 81.5 respectively for IHCAFE, falling into the lower range of specialty coffee classification. The grower standard used wet processing and the patio dryer and scored higher than all experimental coffees. Both IHCAFE and Cafetano had two cuppers conducting the quality analysis, 4 in total, though IHCAFE averaged these together into one final score when providing the quality analysis (see Appendices A-H for quality analysis score sheets). Cafetano cuppers scored exactly the same for each coffee. While cupping analysis was supposed to be done separately according to SCA standards, it is possible these procedures were not followed and all coffees were cupped together.

Table 3. Cupping quality analysis scores of experimental coffees (Natural) compared to grower standard (Washed) for the patio, chimney, and raised bed dryers in El Paraíso, Honduras.

	Washed-Patio	Natural-Patio	Natural-Raised Bed	Natural-Chimney
IHCAFE-1	83	81.3	81.5	62
Cafetano-1	83	19	19	32
Cafetano-2	85	19	19	32

6. Discussion and Recommendations

6.1 Dryer performance and coffee quality

The climate of Misión El Paraíso proved challenging to effectively dry natural process coffees. The high initial moisture content at the onset of drying for natural process coffees of 60-65% MCwb compared to washed coffees, which begin drying at about 45% MCwb, require higher and more consistent temperatures or increased airflow. The difference in moisture content is due to more moisture being bound in the skin and flesh of the coffee cherries compared to washed coffees that have little residual water on the surface from the washing process. No significant difference in the rates of moisture loss between the chimney, raised bed, and patio dryers were exhibited. Based on the final moisture contents, the chimney and patio dryers dried the fastest. Drying times of coffee vary based on ambient environmental conditions as well as the depth of coffee and frequency with which it is mixed. Studies conducted on sun drying of natural process coffee have shown it can take from 12 days to 4 weeks which is representative of the 13 days it took for our coffees to dry (Wintgens 2012, Villalba et al. 2017). One study in Brazil evaluated the shifts in temperature and relative humidity of sun-dried coffee between day and night conditions which ranged between 10°C to 28°C and 34.5% relative humidity and 61.2% relative humidity (Taveira et al. 2015). While these temperatures were not much higher than our study, the relative humidity was significantly lower. A lack of consistent drying temperature combined with high relative humidity can prolong the drying time of coffee.

Drying depth also plays an important role in drying time and the rate of moisture loss. Organizing coffee in thin layers of 20 kg/m^2 has been shown to increase the drying rate and prevent fungal growth of sun-dried coffee compared to thick layers (Kouadio et al. 2012). Thin layer drying was maintained for all dryers except for the pallet dryer that has a higher loading capacity. While the drying trays of the chimney dryer were constructed larger than the original UC Davis chimney solar dryer design, the amount of coffee added to each tray may have exceeded the recommended capacity. The increased size of the trays caused the middle to sag and may have prevented sufficient airflow under the coffee.

Due to precipitation during the experiment, the patio dryer experienced instances of rehydration as the plastic cover was kept off during drying until it rained. Unexpected rain created a delay in getting to the dryer and covering it with plastic. In addition, sun-dried coffees exhibit greater defects due to their exposure to insects, pests, and debris which can reduce quality (Nakendo et al. 2018, Sunarharum et al. 2018). The chimney dryer was fully protected due to the enclosed drying chamber and it is recommended that any dryer used in this climate have sufficient protection from rain and other environmental elements. Even though the plastic provided protection for the chimney dryer, mixing was more difficult given the thick layers and having to open and close the plastic cover. Furthermore, the coffee was not removed from the chimney dryer at night which was recommended. Drying times may have been reduced by following this procedure. While sun drying requires low investments from producers, managing environmental conditions during drying, such as temperature and relative humidity are difficult. Changes in weather and sun exposure during evening hours can significantly increase drying time and can cause moisture reabsorption.

The quality of the experimental coffees in this study were very low but this is not surprising given the prolonged drying time and drying conditions. Due to the initial 60-65% MCwb of natural coffees, it is important that moisture is quickly reduced over the first few days to prevent fungal growth and excessive fermentation causing phenolic and other undesirable flavor attributes that were noted in the quality analysis. White mycellium were seen on all coffees during the first few days of drying along with fruit flies above the patio and raised bed dryers. The long drying times required for open-air sun drying of natural process coffees result in maintaining higher moisture content for extended periods during drying, contributing to greater fermentation and moldy flavors (Sunarharum et al. 2018). Although these challenges can contribute to reduced sensory scores, studies drying natural process coffees in patio dryers have shown higher sensory scores compared to washed coffees (Taveira et al. 2015). Other studies have indicated the physcial loss of quality of sun-dried natural process with 62% of defects for every 100 beans compared to 31% for washed coffees (Nakendo et al. 2018). Scores also varied greatly between analyses conducted by IHCAFE and Cafetano. Cupping as a means of evaluating sensory quality is subjective, and therefore preference or familiarity with natural process coffees may have contributed to these differences. Natural process coffees are not the prevalent processing method in Central America and often have a fruity and winey flavor as opposed to the acidic and clean attributes characteristic of wet process coffees that are more common. Lack of exposure or experience with these flavors could have played a role in the differences between the two evaluations. This may be further supported by the high scores received for the grower standard which was wet processed but similarly dried using the patio dryer. Both coffees were harvested from the same trees and handled similarly, yet the removal of the skin and pulp altered the taste in the final cup. Due to the subjectivity of sensory quality, further studies might incorporate physical and chemical quality measurement.

6.2 Introduction of new technologies

Prior to carrying out this project, Misión El Paraíso was not engaging in any postharvest processing beyond wet processing. Without proper drying and storage technologies and knowledge of best practices, their coffees were often kept in wet piles prior to bagging and transporting to the nearest city of El Paraíso (Figure 11).

Figure 11. Piles of wet processed coffee prior to bagging and transport at Misión El Paraíso. Source: Kyle Freedman

Not only would this coffee quickly degrade in transit, but the high moisture content contributes to more frequent trips to the nearest city as the higher weight per bag would reduce the total amount of coffee the farm truck could hold each trip. Consequently, more frequent trips requires increased fuel use which can add to production costs. The introduction of the chimney and raised bed dryers allowed the producers to experience simple methods of drying that can improve quality, prolong storage, and reduce the number of trips needed.

One gap in the coffee industry, especially for small farms, is the availability of low cost, portable tools to measure moisture content and water activity. Moisture and water activity meters cost over $250 for moisture meters and $2,000 for water activity (Thompson et al. 2017, Zambrano et al. 2019, AgraTronix 2021). One such solution that was used in this project and could be applied more broadly to coffee production is the DryCard™. The production costs of these cards are as little as $0.05/card with retail costs between $1.50 and $2.68 pe card making them an affordable option for use by smallholder producers and green coffee buyers (Thompson et al. 2017, Zambrano et al. 2019). Additional low cost options for measuring moisture content aside from water activity would be useful for monitoring drying progress, but the DryCard™ is effective in assessing the equilibrium relative humidity of the coffee beans, and thus whether they are being properly stored.

6.3 Local extension linkages

While not a direct objective of this project, connecting Misión El Paraíso with IHCAFE has proved to be a valuable resource for quality improvement and sustainability. By connecting with IHCAFE to conduct quality analysis of coffee samples from each drying method, the producers at Misión El Paraíso were able to assess their coffee for the first time ever. They had previously never assessed their product's quality, and because they were connected with the local services provided by IHCAFE, they can continue to link changes in production and postharvest practices to quality outcomes to determine which have a positive impact. This is an important step towards establishing direct relationships with green coffee buyers, which can offer higher prices, as buyers will often require proof of quality analysis or will conduct their own cupping assessments. Even though scores varied between IHCAFE and Cafetano, IHCAFE scores for the patio and raised bed were in the specialty coffee range along with the grower's standard, a positive result for their first quality assessment. Although the highest scored coffees were the grower's standard wet processing method, they did incorporate drying as well as the use of the hermetic storage bags, practices that were not being carried out previously and may have contributed to the high scores. The farm has continued to analyze their coffees throughout different harvest periods to assess what practices may improve their quality over time. As a result of the relationship established during this project, IHCAFE has conducted sensory analysis for the 2021 harvest and their score increased from 83.7 to 84 (Appendix I). This is a small increase, yet signifies continued coordination and quality evaluation with IHCAFE.

Since the conclusion of this project, Misión El Paraíso has worked with IHCAFE to establish a larger greenhouse solar dryer on top of the concrete patio dryer (John Zeller, personal communication, April 24, 2021). This dryer consists of three levels of raised beds or the equivalent of 54 of the raised beds tested in this study and is fully enclosed by clear polyethylene plastic with air vents along the roof (Figure 12). The capacity of this dryer is significantly greater than the dryers we evaluated and provides more protection from rain and insects. This style of coffee dryer is growing in use amongst coffee producers lacking the infrastructure for mechanical drying. While this dryer can increase capacity and protect coffee from rain and pests, it still remains difficult to control the temperature and relative humidity as it relies on ambient conditions and lacks mechanical components to manage temperature and air speed. In addition, it lacks ventilation in the right locations as air vents along the top will not allow air to enter as warm air from the drying coffee will exit through these vents. The owner of Misión El Paraíso has indicated that slow moisture loss is still an issue and that coffees at lower levels of the raised beds do not dry as quickly as those in the upper levels (John Zeller, personal communication, July 22, 2021). One opportunity to improve its functionality could be to incorporate elements from the pallet dryer such as a solar panel and fan that could force humid air out of the dryer allowing the air around the coffee to hold more moisture and dry the coffee quicker. Alternative options would be to keep the roof of the greenhouse dryer to provide protection but open up the sides to increase airflow. Potential studies could also characterize the drying conditions of this type of dryer to better determine areas for improvement and how it compares to other dryers such as the chimney, raised bed, and patio. Nonetheless, this dryer has helped the farm to dry large quantities of their coffee and reduce trips to El Paraíso saving costs.

A) B)

Figure 12. A new solar dryer built in partnership with IHCAFE where the patio dryer was previously located. This dryer incorporates elements of the other dryers evaluated in this project including polyethylene plastic (A) to provide protection from rain and pests as well as to increase temperature through the greenhouse effect along with stacking raised beds (B) to increase loading capacity. Source: John Zeller

6.4 Accessing specialty coffee markets

A motivating factor for this project was to support Misión El Paraíso in adopting postharvest processing practices that improve quality and would enable them to enter specialty coffee markets where they can receive higher prices. A major step in this direction has been to adopt drying and storage procedures and conduct routine quality assessments to better understand their quality and compare to requirements of green coffee buyers. One major challenge with transitioning to specialty coffee markets is that there are no systems in place that can easily enable producers to connect interested buyers. The processors in El Paraíso which the farm currently sells to, operate as intermediaries which pay low prices to producers in the region and add their own value by sorting, drying, hulling, and distributing. IHCAFE has indicated that national competitions such as the Cup of Excellence (COE) which allow producers to enter samples and compete for best coffee can serve as a good method for accessing green coffee buyers. COE is a non-profit international organization that organizes national coffee competitions to highlight the best coffees. Participants are provided with training, access to auctions and support to establish producer-buyer relationships (COE 2021). This is a critical avenue which Misión El Paraíso should participate in to identify new markets for their product to increase prices and producer livelihoods.

Many factors exist that contribute to productive value chains enabling producers to access the right resources and actors to achieve their goals and improving quality is only one of them. Access to the necessary information such as market prices, available technologies, and best practices can be difficult to come by especially for producers like those at Misión El Paraíso that are isolated from local towns and cities and lack the communications infrastructure to access timely information. *Beneficios* or intermediaries that procure coffee from small producers such as Misión El Paraíso often have a wealth of information that is rarely shared with the producers and inhibits their ability to add value. Sources of social capital such as cooperatives and producer organizations may enable the producers to form alliances which can facilitate access to information including training, better financial resources, a stronger ability to bargain, and reduced transaction costs (Palma et al. 2020).

Technology adoption is also an important facet of value chains, yet there are risks associated with implementing new innovations for rural farmers. Farmers require information about the options available to them and the risks and costs associated with adopting new technologies (Hartwich et al. 2010). Before introducing a new technology, it is important to understand how innovations are shared and sources of information on which technologies are best suited for their use. Studies in Honduras have shown that while private organizations remain strong influencers with new innovations to improve coffee production, development organizations like IHCAFE are equally important and producers trust them when considering new technologies (Hartwich et al. 2010). Trust may have played a role in the new greenhouse dryer that was built ontop of the patio dryer. This technology was introduced by IHCAFE and the producers trusted that this was a good option to upgrade their postharvest drying technology as IHCAFE has a local presence and has provided increased support to the farmers over recent years. While I built a strong rapport with the families and they took interest in testing the dryers , they ultimately adopted a technology from a locally trusted source. It is important to better understand both the sources of new technology that small-scale producers trust as well as the design features that are most important to their needs and environment. In addition to features of the new greenhouse such as greater capacity, being fully enclosed, and providing easier access to adding, mixing and removing the coffee, selection of this dryer may have been influenced by factors such as adherence to local authorities, perception from neighboring farms, as well as access to local support services if challenges operating or repairing the dryer arise.

6.5 Recommendations for future research

Due to the malfunctioning of the pallet dryer, further evaluation should be conducted to test this dryer for both wet and natural process. Initial observations showed that this dryer can hold a high capacity of coffee, but that this increased the depth of coffee and thus may prove more challenging to dry quickly. The greater volume of coffee also makes it more difficult to mix may cause damage to the beans when trying to stir lower levels of beans to the top.

In addition, research on the use of small-scale moisture content and water activity measurement tools is needed to effectively support proper drying and storage. Currenty producers rely on physical appearance such as visual attributes or texture of coffee to know if it is dry, which can often result in the coffee being too dry or too moist. Having quantitative measurements in realtime can enable more accurate postharvest handling. Technologies such as the DryCard™ should also be evaluated for broader use in coffee along the supply chain. Currently green coffee buyers may only record water activity measurements when coffee departs to its final destination and when it arrives. The DryCard™ provides an easy measurement for small-scale producers to track water activity from drying through storage.

7. Conclusion

Overall, the performance of the chimney, raised bed and patio dryers did not differ significantly. Due to the costs associated with building the chimney and raised bed dryers, it may not be cost effective to use these dryers compared to the existing patio dryer. Drying parameters including temperature, relative humidity, and dew point fluctuated greatly across all dryers contributing to the longer drying times characteristic of many sun dried systems. Quality varied between IHCAFE and Cafetano with IHCAFE scoring the natural patio and raised bed coffees as specialty and both evaluators scoring the grower standard as specialty. Natural process coffees may still provide an avenue for producer diversification, yet the high initial moisture content of natural process coffee requires higher air temperatures, increased airflow or both. Furthermore, because a different dryer other than the ones evaluated in this study was adopted, a better understanding of the producer's needs and sources of information and influence can support access to appropriate drying technologies that would lead to successful adoption and sustainable use. Overall, the introduction of postharvest processing practices including drying, storage, and quality evaluation have contributed to improvements in coffee production at Misión El Paraíso and have fostered collaboration with local organizations such as IHCAFE that can sustain knowledge gained from this project.

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Appendix

Appendix A. IHCAFE Quality Analysis - Chimney

INSTITUTO HONDUREÑO DEL CAFÉ
IHCAFE.
REGIONAL EL PARAISO.

LABORATORIO DE CONTROL DE CALIDAD DEL CAFE.
Centro de Investigación y Capacitación Profesor Fredy Espinoza Mondragon

CODIGO DE LA MUESTRA: RM1617-0080 | 80

INFORME DE ANALISIS ORGANOLEPTICO DEL CAFÉ.
Cosecha 2019/2020.

DATOS GENERALES	
NOMBRE PRODUCTO	Enrique Ferrufino Gonzales
LUGAR/COMUNIDAD	La Esperanza
MUNICIPIO	Danli
DEPARTAMENTO	EL PARAISO
NOMBRE FINCA	Inversiones y Proyectos Mision
VARIEDAD	LEMPIRA
ALTURA m.s.n.m	900
CORTE	Muestra C

ANALISIS FISICO	RESULTADO
HUMEDAD	9.8
RENDIMIENTO DE TRILLA	2.133
FACTOR DE CONVERSIÓN	0.469
% DE DAÑO	35.944
RENDIMIENTO EXPORTABL	3.330
DENSIDAD	
>ZARANDA 16%	
GRANOS QUAKER	

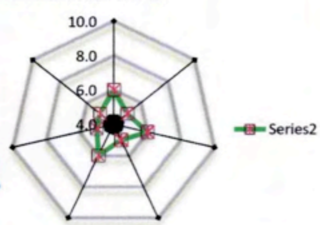
ANALISIS	NOTA
AROMA	6.00
SABOR	5.00
SABOR RESIDUAL	6.00
ACIDEZ	5.00
CUERPO	6.00
BALANCE	5.00
PUNTAJE CATADOR	5.00
UNIFORMIDAD	8.00
LIMPIEZA	8.00
DULZURA	8.00

Fragancias / Aromas: fenol

Sabores: fenol

PERFIL DE TAZA	
62	FG
NOTA	

Balance en Taza



EQUIVALENCIA DE NOTAS			
10	Perfecto	Unico	>+ 95
9	Excelente	Especial	90-94
8	Muy Bueno	Muy Bueno	85-89
7	Bueno	Bueno	80-84
6	Normal	Normal	75-79
5	Mediocre	Pobre	70-74
4	No Bueno	Defectuoso	<-70
3	Malo		
2	Muy Malo		
1	Horrible		

OBSERVACIONES/RECOMENDACIONES:

Hector F. Vallejo | 01-oct-20
Fecha de analisis

IHCAFE. *Al Servicio de la Caficultura Hondureña*

Appendix B. IHCAFE Quality Analysis – Raised African Bed

IHCAFE
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INSTITUTO HONDUREÑO DEL CAFÉ
IHCAFE.

Café de HONDURAS

REGIONAL EL PARAISO.

LABORATORIO DE CONTROL DE CALIDAD DEL CAFE.

Centro de Investigación y Capacitación Profesor Fredy Espinoza Mondragon

CODIGO DE LA MUESTRA:	RM1617-0082	82

INFORME DE ANALISIS ORGANOLEPTICO DEL CAFÉ.

Cosecha 2019/2020.

DATOS GENERALES	
NOMBRE PRODUCTO	Enrique Ferrufino Gonzales
LUGAR/COMUNIDAD	La Esperanza
MUNICIPIO	Danli
DEPARTAMENTO	EL PARAISO
NOMBRE FINCA	Inversiones y Proyectos Mision
VARIEDAD	LEMPIRA
ALTURA m.s.n.m	900
CORTE	Muestra E

ANALISIS FISICO	RESULTADO
HUMEDAD	12.1
RENDIMIENTO DE TRILLA	2.000
FACTOR DE CONVERSIÓN	0.500
% DE DAÑO	29.578
RENDIMIENTO EXPORTABL	2.840
DENSIDAD	
>ZARANDA 16%	
GRANOS QUAKER	

ANALISIS	NOTA
AROMA	7.50
SABOR	7.50
SABOR RESIDUAL	7.00
ACIDEZ	7.50
CUERPO	7.50
BALANCE	7.50
PUNTAJE CATADOR	7.00
UNIFORMIDAD	10.00
LIMPIEZA	10.00
DULZURA	10.00

Fragancias / Aromas:

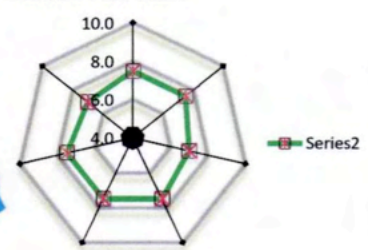
Chocolate dulce   Caramelo

Sabores:

Chocolate   seco

PERFIL DE TAZA	
81.5	HG
NOTA	

Balance en Taza



EQUIVALENCIA DE NOTAS			
10	Perfecto	Unico	>+ 95
9	Excelente	Especial	90-94
8	Muy Bueno	Muy Bueno	85-89
7	Bueno	Bueno	80-84
6	Normal	Normal	75-79
5	Mediocre	Pobre	70-74
4	No Bueno	Defectuoso	<-70
3	Malo		
2	Muy Malo		
1	Horrible		

OBSERVACIONES/RECOMENDACIONES:

INSTITUTO HONDUREÑO DEL CAFE CATACION REGIONAL Nº 4 EL PARAISO

Hector E. Vallejo

01-oct-20

Fecha de analisis

IHCAFE. Al Servicio de la Caficultura Hondureña

Appendix C. IHCAFE Quality Analysis – Patio

INSTITUTO HONDUREÑO DEL CAFÉ
IHCAFE.

REGIONAL EL PARAISO.

LABORATORIO DE CONTROL DE CALIDAD DEL CAFÉ.
Centro de Investigación y Capacitación Profesor Fredy Espinoza Mondragon

CODIGO DE LA MUESTRA:	RM1617-0081	81

INFORME DE ANALISIS ORGANOLEPTICO DEL CAFÉ.

Cosecha 2019/2020.

DATOS GENERALES	
NOMBRE PRODUCTO	Enrique Ferrufino Gonzales
LUGAR/COMUNIDAD	La Esperanza
MUNICIPIO	Danli
DEPARTAMENTO	EL PARAISO
NOMBRE FINCA	Inversiones y Proyectos Mision
VARIEDAD	LEMPIRA
ALTURA m.s.n.m	900
CORTE	Muestra D

ANALISIS FISICO	RESULTADO
HUMEDAD	10.9
RENDIMIENTO DE TRILLA	2.375
FACTOR DE CONVERSIÓN	0.421
% DE DAÑO	29.078
RENDIMIENTO EXPORTABL	3.349
DENSIDAD	
>ZARANDA 16%	
GRANOS QUAKER	

ANALISIS	NOTA
AROMA	7.50
SABOR	7.50
SABOR RESIDUAL	7.00
ACIDEZ	7.25
CUERPO	7.50
BALANCE	7.50
PUNTAJE CATADOR	7.00
UNIFORMIDAD	10.00
LIMPIEZA	10.00
DULZURA	10.00

Fragancias / Aromas:

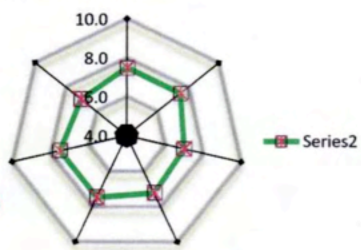
Chocolate dulce   Caramelo

Sabores:

Chocolate   Aspero Seco

PERFIL DE TAZA	
81.25	HG
NOTA	

Balance en Taza



EQUIVALENCIA DE NOTAS			
10	Perfecto	Unico	>+ 95
9	Excelente	Especial	90-94
8	Muy Bueno	Muy Bueno	85-89
7	Bueno	Bueno	80-84
6	Normal	Normal	75-79
5	Mediocre	Pobre	70-74
4	No Bueno	Defectuoso	<-70
3	Malo		
2	Muy Malo		
1	Horrible		

OBSERVACIONES/RECOMENDACIONES:

Hector E. Vallejo

01-oct-20
Fecha de analisis

IHCAFE. Al Servicio de la Caficultura Hondureña

Appendix D. IHCAFE Quality Analysis – Grower Standard (Washed Patio)

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IHCAFE.

Café de HONDURAS

REGIONAL EL PARAISO.

LABORATORIO DE CONTROL DE CALIDAD DEL CAFÉ.

Centro de Investigación y Capacitación Profesor Fredy Espinoza Mondragon

CODIGO DE LA MUESTRA:	RM1617-0078	78

INFORME DE ANALISIS ORGANOLEPTICO DEL CAFÉ.

Cosecha 2019/2020.

DATOS GENERALES	
NOMBRE PRODUCTO	Enrique Ferrufino Gonzales
LUGAR/COMUNIDAD	La Esperanza,Apali
MUNICIPIO	Danlí
DEPARTAMENTO	EL PARAISO
NOMBRE FINCA	Inversiones y Proyectos Mision
VARIEDAD	LEMPIRA
ALTURA m.s.n.m	900
CORTE	Muestra A

ANALISIS FISICO	RESULTADO
HUMEDAD	12.1
RENDIMIENTO DE TRILLA	1.308
FACTOR DE CONVERSIÓN	0.765
% DE DAÑO	18.706
RENDIMIENTO EXPORTABL	1.609
DENSIDAD	
>ZARANDA 16%	
GRANOS QUAKER	

ANALISIS	NOTA
AROMA	8.00
SABOR	7.50
SABOR RESIDUAL	7.50
ACIDEZ	7.50
CUERPO	7.50
BALANCE	7.50
PUNTAJE CATADOR	7.50
UNIFORMIDAD	10.00
LIMPIEZA	10.00
DULZURA	10.00

Fragancias / Aromas:

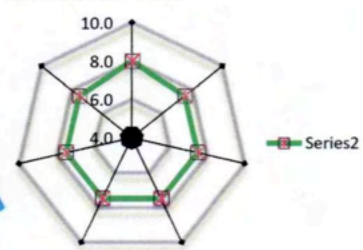
Chocolate Dulce

Sabores:

Chocolate Caramelo

PERFIL DE TAZA	
83	HG
NOTA	

Balance en Taza



EQUIVALENCIA DE NOTAS			
10	Perfecto	Unico	>+ 95
9	Excelente	Especial	90-94
8	Muy Bueno	Muy Bueno	85-89
7	Bueno	Bueno	80-84
6	Normal	Normal	75-79
5	Mediocre	Pobre	70-74
4	No Bueno	Defectuoso	<-70
3	Malo		
2	Muy Malo		
1	Horrible		

OBSERVACIONES/RECOMENDACIONES:

INSTITUTO HONDUREÑO DEL CAFE CATACION REGIONAL N° 4 EL PARAISO

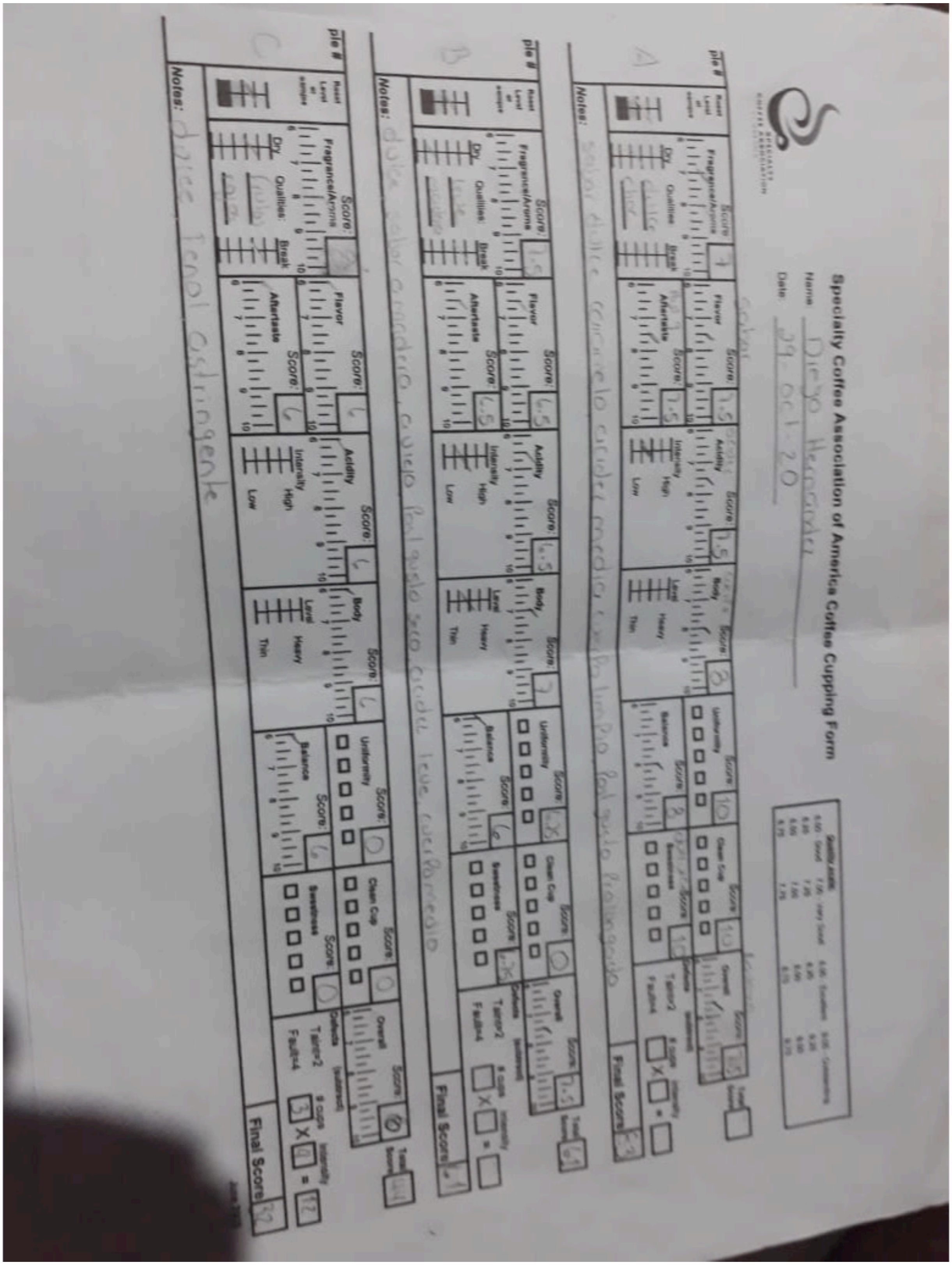
Hector E. Vallejo

01-oct-20

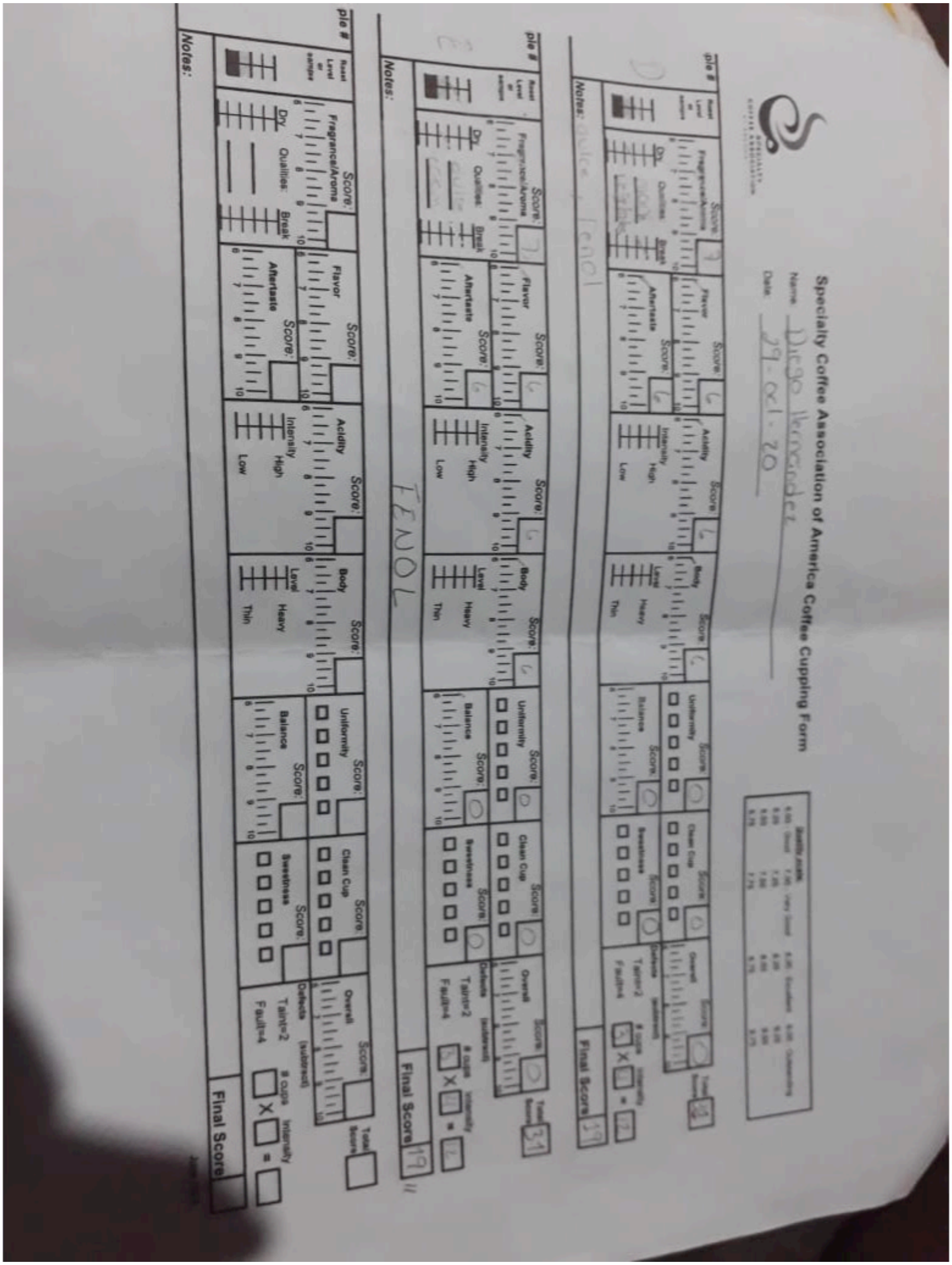
Fecha de analisis

IHCAFE. Al Servicio de la Caficultura Hondureña

Appendix E. Cafetano Quality Analysis – Cupper 1



Appendix F. Cafetano Quality Analysis – Cupper 1


Specialty Coffee Association of America Coffee Cupping Form

Name: Diego Hernandez

Date: 29-oct-20

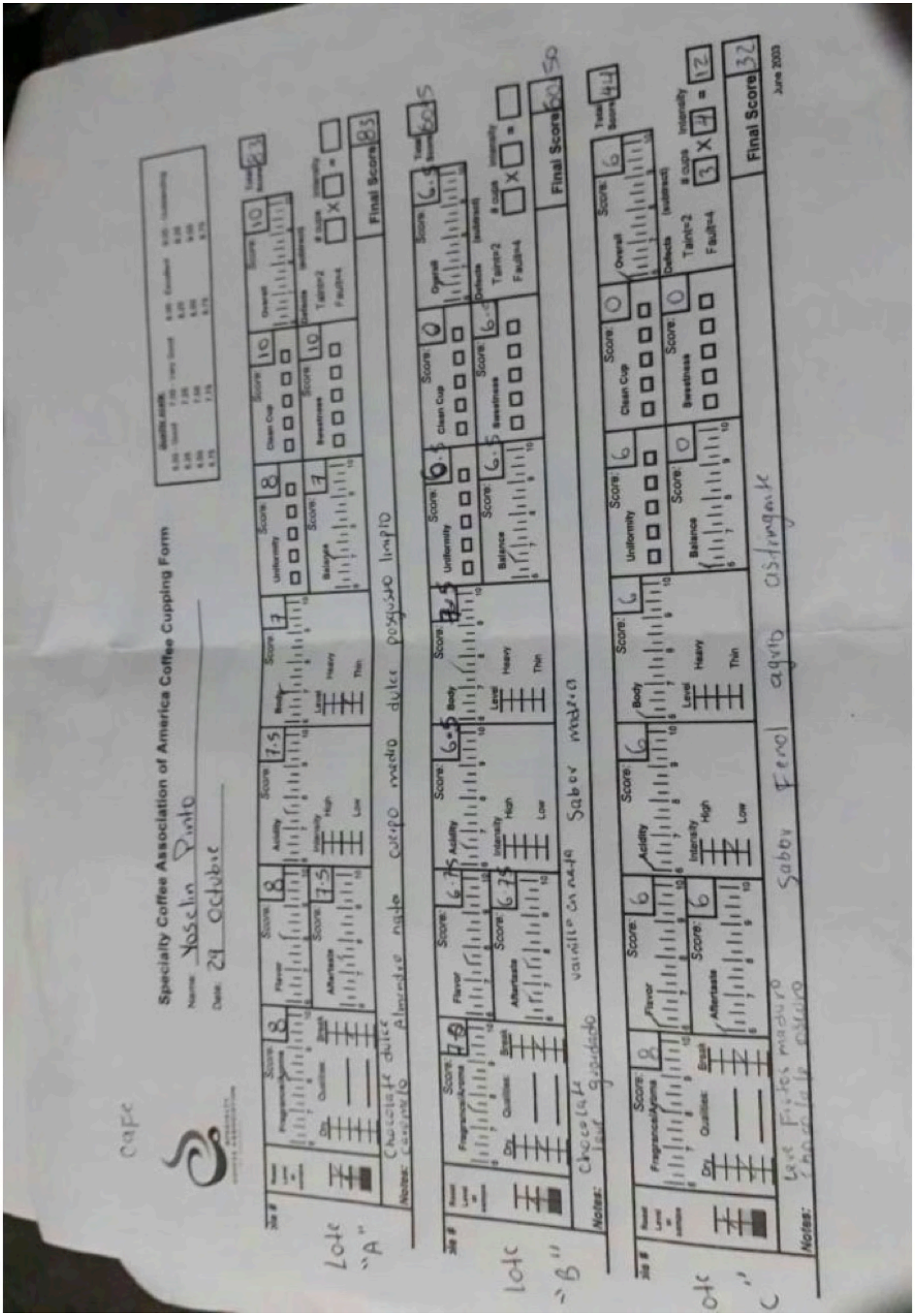
Sample # | Roast Level of Sample | Fragrance/Aroma Score: | Dry Qualities: Break | Flavor Score: | Aftertaste Score: | Acidity Score: Intensity High Low | Body Score: Level Heavy Thin | Uniformity Score: | Balance Score: | Clean Cup Score: | Sweetness Score: | Overall Score: | Defects (subtract) Taint=2 Fault=4 # cups Intensity | Total Score

Notes: dulce, fenol | Final Score

Notes: FENOL | Final Score

Notes: | Final Score

Appendix G. Cafetano Quality Analysis – Cupper 2


Specialty Coffee Association of America Coffee Cupping Form

Name: Yoselin Pinto

Date: 29 octubre

Cafe

Lote "A" — Final Score 83

Notes: Chocolate dulce caramelo almendra nata cuerpo medio dulce posgusto limpio

Lote "B" — Final Score 60 / 50

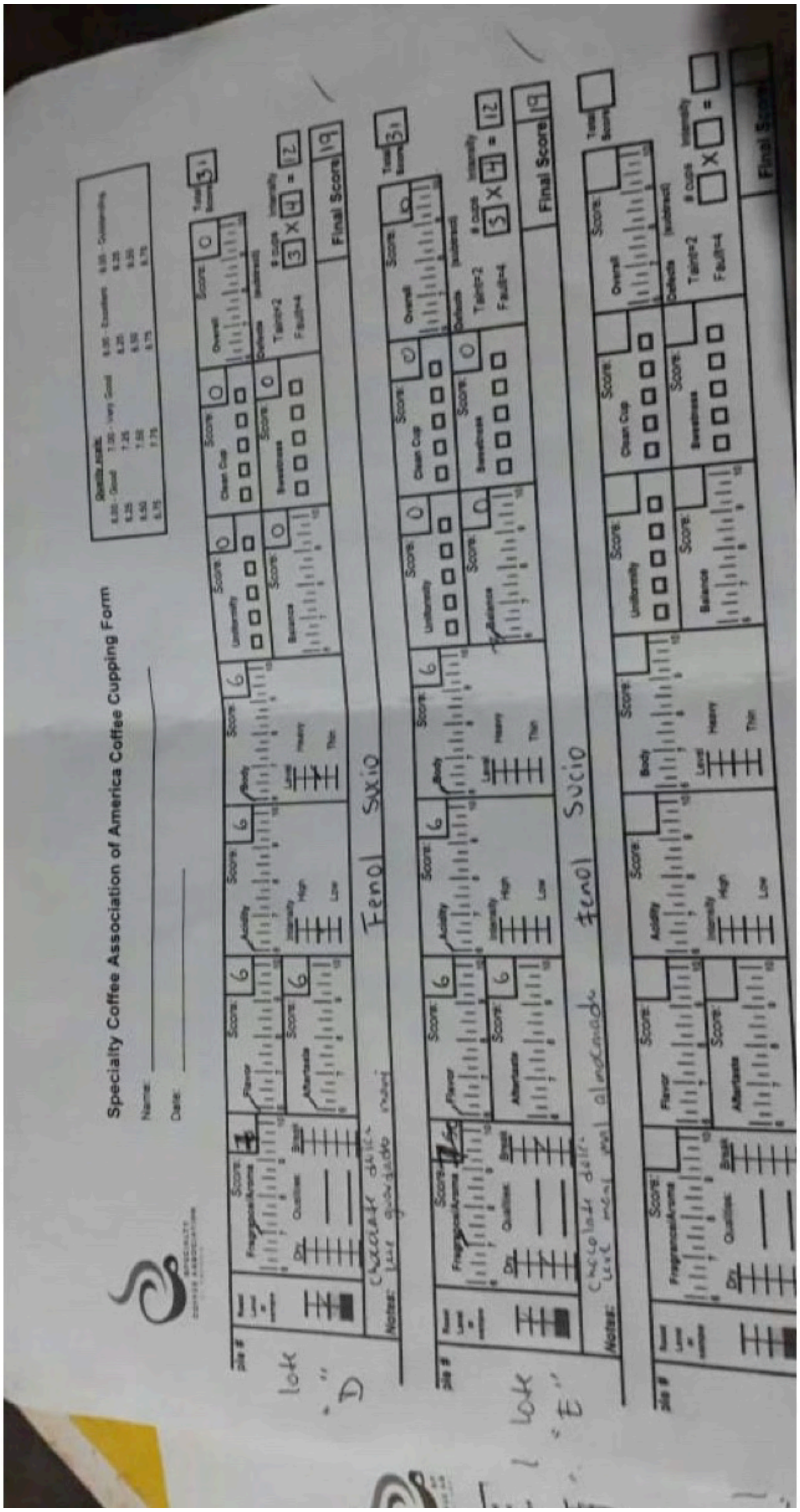
Notes: Chocolate leve quemado vainilla canela Sabor madera

Lote "C" — Final Score 32

Notes: Leve frutos maduro chocolate oscuro Sabor fenol agrio astringente

June 2003

Appendix H. Cafetano Quality Analysis – Cupper 2



Appendix I. IHCAFE 2021 Quality Analysis – Post Project Assessment

INSTITUTO HONDUREÑO DEL CAFÉ
IHCAFE.

REGIONAL EL PARAISO.

LABORATORIO DE CONTROL DE CALIDAD DEL CAFÉ.
Centro de Investigación y Capacitación Profesor Fredy Espinoza Mondragon

CODIGO DE LA MUESTRA:		

INFORME DE ANALISIS ORGANOLEPTICO DEL CAFÉ.

Cosecha 2020/2021.

DATOS GENERALES	
NOMBRE PRODUCTOR	INVERSIONES Y PROYECTO MISION
LUGAR/COMUNIDAD	BUENA ESPERANZA, AZABACHE
MUNICIPIO	DANLI
DEPARTAMENTO	EL PARAISO
FINCA/LOTE	LOS PINOS
VARIEDAD	LEMPIRA
ALTURA m.s.n.m	1,450
PROCESO	LAVADO

ANALISIS FISICO	RESULTADO
HUMEDAD	10.6
RENDIMIENTO DE TRILLA	1.20
FACTOR DE CONVERSIÓN	0.80
% DE DAÑO	
RENDIMIENTO EXPORTABLE	
DENSIDAD	
>ZARANDA 16%	
GRANOS QUAKER	

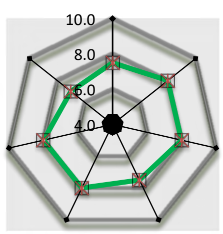
ANALISIS SENSORIAL	NOTA
AROMA	7.50
SABOR	8.00
SABOR RESIDUAL	8.00
ACIDEZ	7.50
CUERPO	8.00
BALANCE	8.00
PUNTAJE CATADOR	7.00
UNIFORMIDAD	10.00
LIMPIEZA	10.00
DULZURA	10.00

Fragancias / Aromas:
CHOCOLATE DULCE FRUTOS SECOS

Sabores:
CHOCOLATE DULCE CARAMELO

PERFIL DE TAZA	
84	HG
NOTA	

Balance en Taza



EQUIVALENCIA DE NOTAS			
10	Perfecto	Unico	>+ 95
9	Excelente	Especial	90-94
8	Muy Bueno	Muy Bueno	85-89
7	Bueno	Bueno	80-84
6	Normal	Normal	75-79
5	Mediocre	Pobre	70-74
4	No Bueno	Defectuoso	<-70
3	Malo		
2	Muy Malo		
1	Horrible		

OBSERVACIONES/RECOMENDACIONES:

INSTITUTO HONDUREÑO DEL CAFE CATACIÓN REGIONAL Nº 4 EL PARAISO, EL PARAISO

Hector Vallejo/Catador

18 de Febrero 2021
Fecha de analisis

IHCAFE. Al Servicio de la Caficultura Hondureña