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KOPERNIK PROJECT REPORT – EXPERIMENTATION PROJECTS

IMPROVING DRYING PROCESSES: THE SOLAR BUBBLE DRYER

CONTEXT

This project was conducted in Angkah Village in the western part of Tabanan Regency, Bali. Angkah Village covers an area of 1,802km^2 and mostly consists of rice fields and small plantations. The village has a population of 2,179 people, consisting mainly of farmers, who own small plantations, as well as plantation workers.

Local economic activity relies heavily on agriculture, specifically commodities such as rice, cacao, cloves and coconut. Tabanan Regency produces 28% of Bali's annual cacao harvest, making Tabanan Regency Bali's second largest producer after Jembrana Regency.[1] Most of the cacao plantations in Tabanan are owned by individuals or farmers. It is common practice for farmers in Angkah village to form a working group, known as a *UPH* which stands for *Unit Pengolahan Hasil,* or Crop Processing Unit, where members coordinate their farming activities.

The average yield of cacao production in Tabanan was 605 kg/ha in 2015[2], similar to the average yield of cacao production across Bali which is 626 kg/ha[3]. The peak cacao season in Tabanan lasts from May to September, and low season is typically from October until December.

In general, activities for cacao production in Tabanan are divided into pre-harvest and post-harvest activities. Pre-harvest activities include planting, maintenance and harvesting. Post-harvest activities include fermentation, drying, storage and selling. This project focused on the post-harvest activities for cacao during which most farmers are dependant on the weather, having no means to protect their drying crops from rain, dust and animals.



[1] *Badan Pusat Statistik Provinsi Bali (2015). Bali in Figures 2015. BPS-Statistics of Bali retrieved from http://bali.bps.go.id/webbeta/website/pdf_publikasi/Bali%20Dalam%20Angka%202015.pdf*

[2] *Directorate General of Estate Crops Indonesia (2017). Three Crop Estate Statistics of Indonesia, Cacao 2015-2017. Directorate General of Estate Crops, retrieved from http://ditjenbun.pertanian.go.id/tinymcpuk/gambar/file/statistik/2017/Buku-Kakao-2015-2017.pdf*

[3] *Ibid*

HYPOTHESIS

We hypothesized that using the solar bubble dryer will help farmers dry their cacao beans faster and increase the quality of the beans.

METHODOLOGY

For this project, Kopernik bought fresh cacao beans from *UPH Subak Abian Buana Mekar*, a cacao processing unit in Angkah Village. We asked Pak Adi, Head of *UPH Subak Abian Buana Mekar*, to help us conduct the fermentation and drying process. The raw cacao beans purchased were first fermented in Kopernik's three-tier fermentation box, previously built for Kopernik's "Improving Processing Technologies: Cacao Beans Phase 1" project.

After the beans had been fermented, we compared two methods of drying to test our hypothesis:

1. The Floor Solar Drying (FSD) method – the current traditional practice in Angkah Village.
2. The Solar Bubble Dryer (SBD) - a portable solar dryer designed to minimize the effects of the weather on the drying process.

Fifty kilograms of fermented cacao beans were used for each drying method. Monitoring was performed daily to measure the cacao bean's moisture level as well as the indoor and outdoor temperatures.

The following table summarizes the methodology of the experiment for comparing the drying processes (Figure 1):

DRYING PROCESS	SBD	FSD	Quality Testing
DURATION	7 days	7 days	1 day
TOOLS	- Thermometer and - Hygrometer	- Thermometer - Hygrometer	- Cutter - Weight Scale
MEASUREMENT	- Sample temperature and moisture - Outdoor and indoor temperature/humidity	- Sample temperature and moisture - Outdoor temperature/humidity	- Temperature (Celcius) - Moisture content - Drying quality - Flavour characteristic - Number of drying days

Figure 1. Summary of experiment methodology

FINDINGS

Drying Performance

We measured the drying performance by comparing the time taken to reach the optimum moisture level for dried cacao beans (<7.5%[4]) for each drying method. On average, the temperature inside the SBD was higher than on the ground for the FSD method. The SBD's surface is designed to absorb the heat from the sun and magnify the temperature inside. The highest temperature for the SBD during the drying period was 56.9 °C while for the FSD method, it was 54.2 °C. Overall, the temperature was relatively similar between SBD and FSD on day one until day three when there was heavy rain. From day four onwards when the weather cleared, the temperature in the SBD tended to be slightly higher (Figure 2). This indicated that the SBD's surface did in fact raise the temperature inside the dryer, however there were some unusual circumstances that contributed to these results.

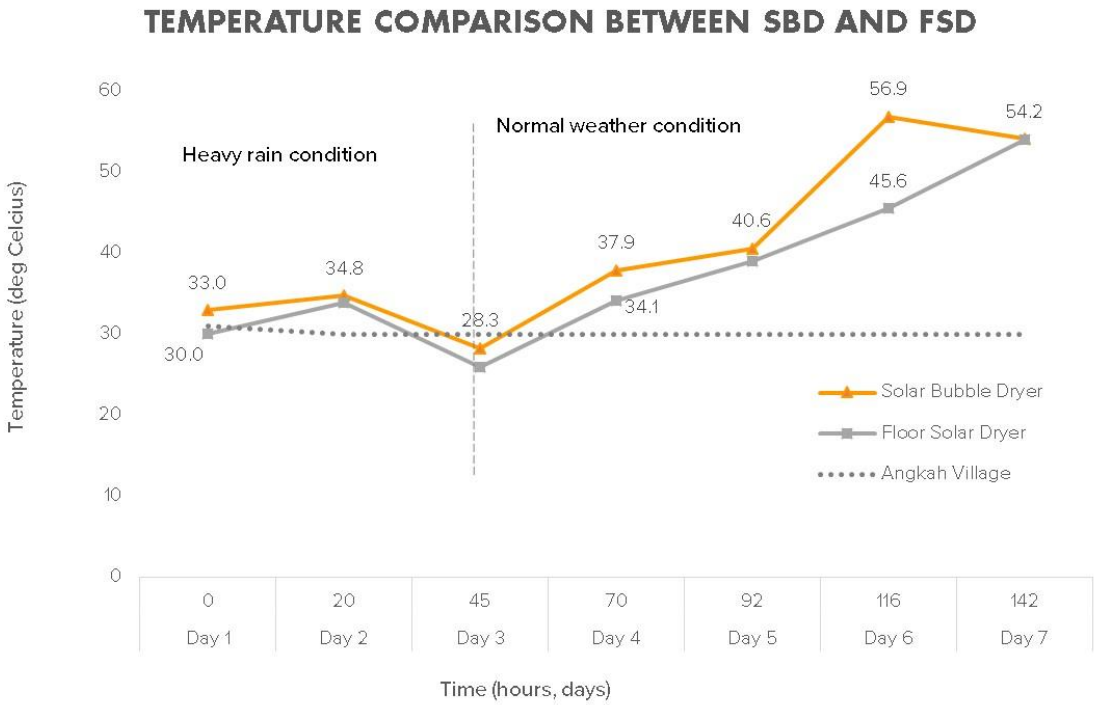


Figure 2. Temperature comparison between SBD and FSD during the drying period

The heavy rain conditions on days one to three had two effects on the drying process for the SBD. While the product was designed to minimize the effects of unpredictable weather, the rain entered the bubble through the mounting of the fan which was located too low (Image 1). This affected the temperature inside the SBD and also affected the moisture content of the cacao beans as they became damp (Image 2), reducing the effectiveness of the drying process.

[4] *Food and Agriculture Organization (FAO). Recommended International Practice for Cacao; International Cocoa Organization: Drying for Cocoa Beans.*



Image 1: The placement of the fan outlet was located too low so additional stones were needed under the fan outlet to overcome flooding during heavy rain



Image 2: Water infiltrated the bubble from heavy rain causing the beans to become damp

Furthermore, the lack of sun during this initial rainy period meant the solar panel for the SBD did not store enough energy to power the fan. The solar-powered batteries' capacity was too low to store enough power to cover a three day cloudy period resulting in the deflation of the bubble. This also directly affected the drying effectiveness of the SBD evident in the poor drying results during the first four days of the experiment.

Another contributing factor, which may why the FSD method was competitive despite the rain, is that our local partner did not fully reflect the true experience of farmers during rainy weather. The usual practice is that cacao beans drying on the ground would be collected and brought inside when it is raining, halting the drying process and extending the number of days taken to complete the process. However, instead of doing this, the farmer we worked

with protected his beans with polycarbonate boards, allowing the beans to continue to dry outside while minimising the effect of rain on the speed of the drying process. While this scenario meant that the comparison is not perfectly representative of the usual practice, Kopernik validated the number of days taken on average to dry the beans using the FSD method as seven days, the same result the farmer achieved, even with polycarbonate boards.

As recommended by the Food and Agriculture Organisation of the United Nations (FAO) and the International Cocoa Organization, the optimum moisture content for cacao beans is 7 - 7.5 percent.[5] Meeting and retaining this optimum moisture content helps to prevent beans from over-fermentation, mold contamination and damage during storage.[6] Despite the conditions explained above, both of the drying methods reached the target level of 7 percent on day seven. Once the weather cleared, the moisture content dropped faster for the FSD method on day four and the SBD began to catch up from day five onwards after the flooding and deflation had been rectified (Figure 3). On day five Kopernik recorded that the SBD dried the cacao beans 2.5 times faster than the FSD method showing the potential for the product without the issues we had faced.

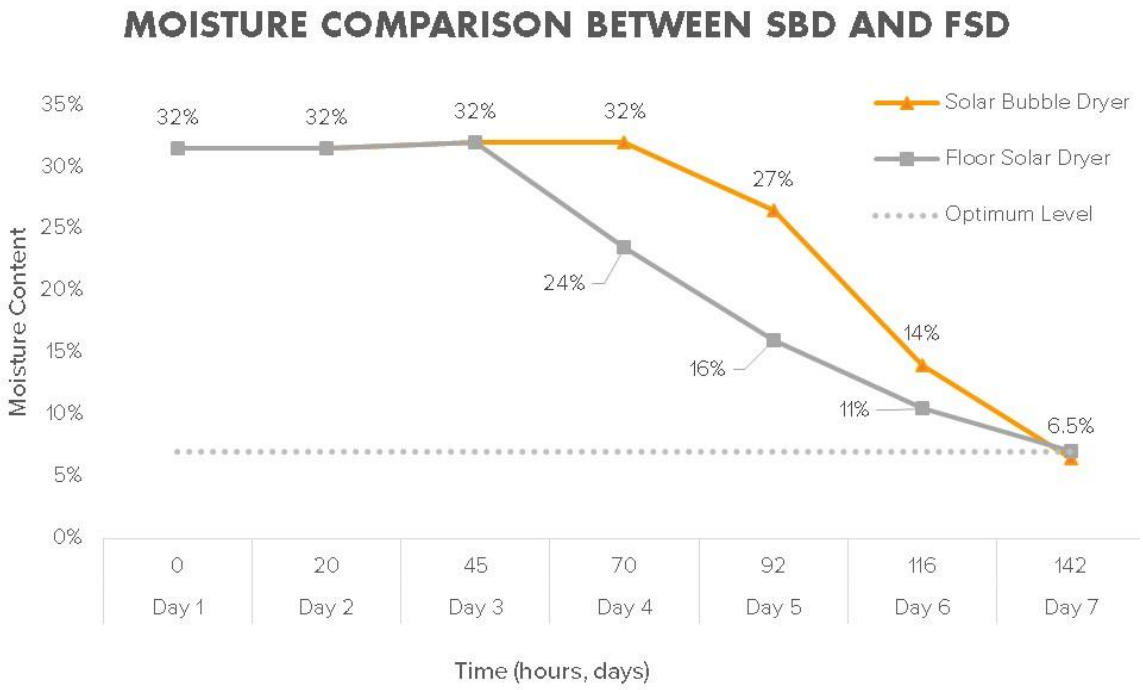


Figure 3. Moisture content comparison between SBD and FSD during the drying period

Quality of the Bean

Kopernik arranged an interview with an independent cacao expert from a Bali-based chocolate factory to assess the quality of the dried fermented cacao beans resulting from the two drying methods. During the assessment, the cacao beans were evaluated based on appearance and taste - the two factors influencing the quality of chocolate made from cacao beans.

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[5] *Food and Agriculture Organization (FAO). Recommended International Practice for Cacao; International Cocoa Organization: Drying for Cocoa Beans.*

[6] *Aprotosoaie, Luca, and Miron (2015). Flavor Chemistry of Cocoa and Cocoa Products - An Overview. Comprehensive Reviews in Food Science and Food Safety retrieved from http://onlinelibrary.wiley.com/doi/10.1111/1541-4337.12180/full*

In regards to the appearance, a well fermented cacao bean is characterized by a brown to dark red color with a fragile kernel with a pure and bitter flavor.[7] Compared to high quality fermented cacao beans, the beans from SBD as well as the FSD method were dark in appearance (Image 4).

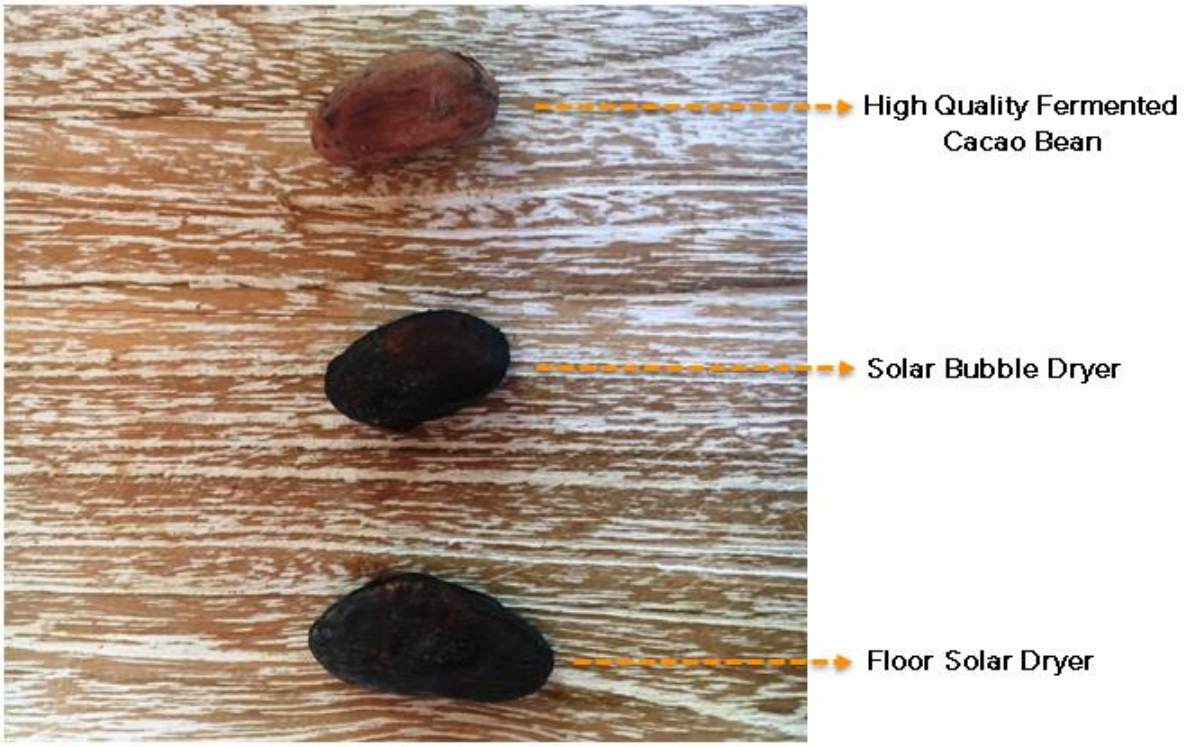


Image 4: Outer appearance of cacao beans from SBD and FSD compared to a high quality fermented example from the chocolate factory

A cut test was also performed to look inside the cacao bean. Based on the opinion of the independent cacao expert, the cacao beans from both the SBD and FSD method were under-fermented as characterized by a solid appearance with a lack of cavities in the kernel (Image 5).



Image 5: Reference for partially fermented cacao beans compared to well fermented beans. Source: On the Cocoa Trail

[7] *Cocoa/Cocoa Beans, Transport Information Services from German Marine Insurers, retrieved from http://www.tis-gdv.de/tis_e/ware/genuss/kakao/kakao.htm*

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Image 6: Comparing the Inside appearance of cacao beans from the SBD to a well fermented example from the factory

The cacao expert explained to Kopernik that under-fermented beans usually have a purplish color but that the beans used in the experiment looked dark (Image 6). Based on the opinion of the cacao expert, the dark color may have been caused by the drying process being too fast. He argues that a high quality bean is produced by a gradual drying process and that over-dried beans do not produce enough oil whereas under-dried beans become mouldy.

Detailed information regarding the quite complicated process required for producing the highest quality beans was not fully understood by our local partner. This highlighted to Kopernik a clear disconnect between smallholder producers and their buyers. During the period of the experiment, Kopernik met with farmers who had a lack of knowledge on a clear standard which farmers should follow to achieve the highest price for their produce.

Further assessment on the taste of the cacao beans demonstrated that both the beans from the SBD and FSD methods had a dense bitterness with no citrus flavour. A well fermented cacao bean has a delicate bitter flavor with some citrus flavor from the fruit acid generated through a successful fermentation process. Overall, Kopernik's cacao beans were classified by this expert as low-quality dried fermented cacao beans that would achieve a market value of IDR32,000 per kg (~US$2.35). As a comparison, high-quality cacao beans can reach a market value of up to IDR45,000 per kg (~US$3.30).

Market Prices

Conducting productive post-harvest activities is one channel for farmers to earn higher profits for their commodities. Figure 4 below describes the price difference per kilogram of cacao with post-harvest and without post-harvest activities (raw cacao) according to our local partner and an independent chocolate producer purchasing cacao in Bali.

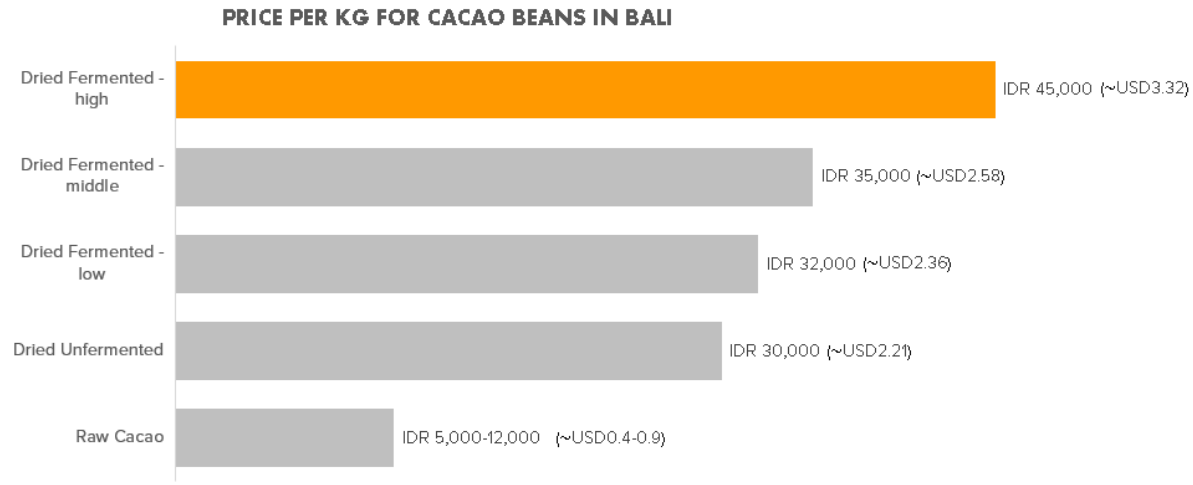


Figure 4. Price difference for cacao beans in Bali. Source: Interview with two cacao farmers and one chocolate factory owner in Bali

Most farmers in Angkah Village do not perform the fermentation or drying process. The majority of the farmers don't have direct access to the market and sell raw cacao beans to middlemen in Java who export the product abroad. They can achieve between IDR 5,000 - IDR 12,000 per kilogram for the raw beans. The middlemen will only pay IDR5,000/kg (~US$0.40) while if they can access the market directly, they may be able to achieve IDR 12,000/kg (~US$0.90).

Striving for a higher price, and thus committing to the fermentation and drying processes, can be a risk to farmers. Farmers living in the last mile often do not have the sufficient knowledge or facilities to implement effective post-harvest processes that meet the standards required for the high quality dried fermented beans. Meeting the high standards for fermentation and drying that result in the optimal bean for selling is a complicated process. Farmers need to invest time and money, first to understand the fermentation process and to further build a fermentation box. They must also invest their time to wait for the process to be completed, allowing 6-10 days for the fermentation process and then a further 5-10 days for the drying process, dependent on weather conditions[8].

There is relatively high demand for dried unfermented cacao beans from buyers in Java who export the product abroad, with the United States as the largest export market.[9] However, if the product is low quality, the price difference between raw and dried fermented beans and dried unfermented beans does not always work out favourably for the farmer (Figure 5). The calculation on price must take into account shrinkage after fermentation and drying. When we fermented and dried 50 kg of raw beans, the end result was reduced by 67% to 16kg. So the farmers often have a difficult decision to make on whether to sell the products raw, sell them dried, or sell them fermented and dried.

[8] *FAO. Processing Cocoa Beans, retrieved from http://www.fao.org/docrep/006/ad220e/ad220e06.htm*
[9] *From interview with a cacao farmer in Angkah Village*

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PROCESS	DERIVED WEIGHT	PRICE/KG	TOTAL PRICE
Raw Cacao (middleman)	50kg	IDR 5,000 (~US$0.40)	IDR 250,000 (~US$20.00)
Raw Cacao (direct)	**50kg**	**IDR 12,000 (~US$0.90)**	**IDR 600,000 (~US$45.20)**
Dried Unfermented	16kg	IDR 30,000 (~US$2.20)	IDR 480,000 (~US$35.20)
Dried Fermented (low quality)	16kg	IDR 32,000 (~US$2.35)	IDR 512,000 (~US$37.60)
Dried Fermented (mid quality)	16kg	IDR 35,000 (~US$2.60)	IDR 560,000 (~US$42.20)
Dried Fermented (high quality)	**16kg**	**IDR 45,000 (~US$3.30)**	**IDR 720,000 (~US$52.80)**

Figure 5: The investment in the fermentation and drying process does not always result in the best price for the farmer

CONCLUSION

The solar bubble dryer we installed in Angkah Village to aid the drying process did not perform as expected. The SBD did not accelerate the drying process and did not produce better quality beans.

Kopernik believes the result would have been more favourable if we did not experience technical problems related to flooding. However, Kopernik believes the evaluation of the product is valid given that the rainy weather is typical of the region. The SBD design would be much improved if the position of the fan outlet is raised and the low capacity of the solar battery is increased.

We do note however that on a sunny day, without any technical issues, the SBD did dry the produce 2.5 times faster than the FSD method.

Kopernik is also mindful of the advice provided by the cacao expert who is a buyer of high quality cacao that often fetches the highest sales price for farmers such as our local partner. While we were seeking a dryer that would increase efficiencies for smallholder farmers, we learned during this experiment that making the process too fast, can have a detrimental effect, reducing the quality of the beans. Similarly, while we were not testing the fermentation process during this experiment, perfecting this process alongside drying would be required to gain the highest price for the *UPH*.

Pricing and access to the market are also important considerations for farmers when deciding whether to commit to drying and/or fermenting their produce. If smallholder farmers have direct access to the market and can find a buyer to purchase their raw beans at IDR12,000/kg, it is not necessarily more profitable to undergo complicated post-harvest processes. However, if their only choice is to sell to a middleman at IDR5,000/kg, processing the beans, even if only drying them without the fermentation process, would gain them a higher price.

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TESTIMONIAL :

The Solar Bubble Dryer is good enough to help the drying process of cacao beans. The black material on the surface makes the temperature inside much warmer and the fan helps the air circulation to maintain the moisture content for the cacao. - Pak Adi, Cacao farmer, Angkah Village, Tabanan Regency, Bali.

RECOMMENDATION

Based on the data collected, Kopernik recommends that:

1. The manufacturers of the Solar Bubble Dryer, GrainPro, consider a design with the fan outlet positioned higher and with a higher capacity solar battery so the fan does not stop during bad weather (Kopernik has provided this feedback to GrainPro but have not to date received a response);
2. Kopernik retests this technology to see if there are better results without the technical issues we experienced;
3. Kopernik retests this technology to learn how the process could be improved in relation to fermentation and drying to attain the highest quality cacao beans;
4. Kopernik investigates further the lack of knowledge amongst farmers regarding the quality standards required for their produce and experiments with solutions to address this;
5. Kopernik retests this technology to assess the portability and the financial viability of this technology. Portability and financial viability were not the focus of our first phase project but are a consideration regarding adoption of this technology as it is an expensive choice that has not yet proven its effectiveness.

Kopernik will review all data collected through five projects related to solar drying to compile a report collating our findings and insights before embarking on future solar drying initiatives.

LEARN MORE

Kopernik has published the project report for the Improving Processing Technologies: Cacao Beans Phase One and Phase Two projects and for the Increasing Farmer Incomes: Solar Drying Solutions Phase One project which all experiment with different solar dryer designs.

In early 2018, Kopernik will also publish the project report for the Increasing Farmer Incomes: Solar Drying Solutions Phase Two project.

Furthermore, in early 2018, our Solar Dryer Manual will be available for all to access, illustrating a “How To” guide to build a small-scale 300kg capacity solar dryer from locally available materials.