

Comparison of the Performance of Three Cocoa Bean Drying Techniques in Bafia, Southwest Region, Cameroon

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Abstract: This research compares the performance of a wood-fuelled oven, a greenhouse solar dryer and open sun drying techniques for drying of fermented cocoa beans, under the same weather conditions. The tests were implemented in Bafia, in the Southwest Region of Cameroon, during the month of November 2017. Performance in drying time (number of days) and quality of the resulting beans were measured (determined using sensory measurements, sight, smell and taste). Data were also collected on the progression of weight and moisture loss in the beans during the drying process, and the ambient temperatures and relative humidity levels of the environment. Also, solar radiation levels were measured for the greenhouse solar dryer and open sun drying techniques. Results showed that during dry weather conditions the wood-fuelled oven was the fastest drying method (1 day), followed by open sun drying (4 days) and the greenhouse solar dryer (5 days). The quality of beans produced through open sun drying and in the greenhouse solar dryer had a good colour, and a pleasant chocolate smell and taste. However, the beans from the wood-fuelled oven had an overly dark colour and their smell and taste were smoky due to contamination by smoke from the oven.

Keywords: Drying techniques, Bafia, cocoa beans.

1. Introduction

In 2012 Cameroon gave itself the year of 2020 to reach the target of producing 600,000 tons of good quality cocoa beans. Table 1 shows the national cocoa production figures over the past 5 seasons and indicates that there is a stagnation of national cocoa bean production at between 210,000 and 240,000 tons/year.

Unless fundamental changes occur in all aspects of cocoa production and post-harvest operations, it seems unlikely that the target of 600,000 tons can be reached by 2020. The required changes are many and include application of good agricultural and post-harvest practices by farmers. Important post-harvest practices include fermentation, drying and bagging which have

to be carried out to a high standard to ensure production and maintaining of high quality cocoa beans. For post-harvest practices, Cameroon has yet to set standards.

Economic and environmental conditions determine the drying techniques applied by cocoa farmers. Common drying techniques include use of wood-fuelled ovens (especially where pluviometry is high) and drying on tarred roads, cemented floors and tarpaulins (on sunny days and in areas receiving relatively more sun and less rain). In Bafia, located in the South-west

Table 1 Cameroon national cocoa production figures between 2012-2103 and 2016-2017.

Season	National cocoa bean production in tons/year
2012-2013	225,000
2013-2014	211,000
2014-2015	232,000
2015-2016	211,000
2016-2017	240,000

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Region of Cameroon, the main drying technique used is that of the wood-fuelled oven. While there are different types of wood-fuelled ovens, the vast majority of the ovens produce “smoky cocoa”. Smoky cocoa is the result of smoke contamination due to leakage of smoke from the oven. Smoky cocoa has a smoky flavour. To remove this flavour manufacturers have to apply a special process before processing the cocoa beans. At the international level, smoky cocoa has resulted in significantly tarnishing the image of cocoa originating from Cameroon.

In recognition of the need to improve the quality of cocoa originating from Cameroon, SNV Cameroun took the initiative of seeking ways to improve post-harvest practices. One initiative was the construction of “Greenhouse Solar Dryers”. Under the Cameroon Eco-Cocoa & ProCISA-CBSC¹ projects a total of 8 such solar dryers were constructed: 4 in the Centre Region (in Ngomedzap & Ayos) and 4 in the South-west Region (in Bafia and Konye).

In November 2017, an experiment was conducted to compare the quality of cocoa beans produced through application of three different drying techniques: the greenhouse solar dryer, the wood-fuelled oven and open sun drying on a tarpaulin. This paper describes the experiment and determines the performance of the different drying techniques.

2. Description of the Three Drying Techniques

The three drying techniques described in this section are the wood-fuelled oven, open sun drying and the greenhouse solar dryer.

2.1 The Wood-fuelled Oven

As mentioned earlier, in the South-west Region in general and in Bafia in particular, WOs (wood-fuelled ovens) are the most common drying technique used by

farmers. This is because the region receives particularly high levels of rainfall, the technology is affordable, timber resources are available, and the technique allows for quick drying.

The WO consists of a tunnel in which wood is burned (see Fig. 1) and an air-filled casing around the tunnel. The heat generated from combustion of the wood travels to the enclosed space around the tunnel through convection. The beans, which spread on a bamboo mat on top of the oven, are dried by the heated air travelling through the mat and the beans spread on top. A good WO will have a chimney to evacuate smoke from the tunnel and thus avoid contamination of the beans; in practice, the chimney may be lacking and contamination by smoke becomes an issue. The WO is mostly applied at the level of individual or a group of households.

Wood is generally obtained from the farm but may also be bought in Bafia. The drying time using this technique is from 18-24 hours for 5 to 6 bags of cocoa beans. When the moisture content of the cocoa beans has reached 9.5%² the beans are removed from the bamboo mat and transferred to jute bags. In the jute bags, the beans will remain hot for a considerable time longer which allows completion of the drying process.



Fig. 1 WO (Wood-fuelled oven) © WF.

¹ The Cameroon Eco-Cocoa Project was funded by the Dutch Government and implemented in 2014 and 2015. The ProCISA-CBSC project was funded by the German Cooperation and implemented in 2016 and 2017.

² This is according to the standard set for the WO; in practice, few farmers have equipment to measure the moisture content and they rely on their experience.



Fig. 2 Open sun drying © WF.



Fig. 3 Greenhouse solar dryer © WF.

2.2 Open Sun Drying

OSD (open sun drying) is mainly applied at household level. Under this technique the beans are taken out early in the morning to spread on a tarpaulin or mat near the farmer's house. Throughout the day, a person is present to turn the beans to ensure that they all receive comparable amounts of sunlight. In the evening, the beans are gathered and (ideally) put in jute bags. The next day and following days, the process is repeated until the farmer considers the beans to be dry³. Depending on the weather conditions, drying using the OSD technique takes 3 to 5 days.

2.3 The Greenhouse Solar Dryer

The GSC (greenhouse solar dryer) technique was brought to Bafia by the SNV under the ProCISA-CBSC project. The GSC design was an adaptation of a model used in Nicaragua where it has proven its effectiveness.

The GSC consists of a wooden frame, the sides of which are covered with translucent UV-resistant plastic film and a roof of translucent corrugated plastic sheets. The floor consists of a layer of gravel. The surface area of the structure measures 10×15 meters. It is furnished with raised wooden drying boxes giving

³ Few if any farmers have access to equipment to measure moisture content of cocoa beans; therefore, they depend on their own experience.

a drying area of 111 m^2 . The drying tables are sectioned into 68 compartments (or drying beds) where the beans spread out for drying. Depending on weather conditions, one drying bed dries up to 22 kg of cocoa beans in 4 to 5 days.

3. Methodology

This section presents the methodology of the experiment under separate sections relating to performance indicators and the types of measurements made, equipment used, how overall consistency in the cocoa beans at the start of the experiment was ensured, the sampling method and the measurements taken.

3.1 Performance Indicators

The following indicators were used to determine performance of the drying techniques: overall drying time, colour, odour and moisture content of the finished dried bean.

3.2 Measurements and Data Gathering

The overall drying time was measured in days while colour and odour of the beans were measured using the senses of sight and smell of three persons who evaluated the beans independently. The beans were considered "dry" when the moisture content measured 8%, the recommended value for cocoa bean moisture content in Cameroon.

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Table 2 Type of measurements and frequency for each drying technique.

Measurement	Frequency	No. of days	Drying technique
Ambient solar radiation	Hourly between 07:00 and 18:00	4 days	All 3 techniques
Ambient temperature	Hourly between 07:00 and 18:00	4 days	All 3 techniques
Ambient relative air humidity	Hourly between 07:00 and 18:00	4 days	All 3 techniques
Cocoa sample drying temperature	Hourly between 07:00 and 18:00	4 days	OSD and GSD
Cocoa sample weight	Daily between 17:00 and 17:30	4 days	OSD and GSD
	At the beginning and end of drying	1 day	WO
Cocoa sample moisture content	Daily between 17:00 and 17:30	4 days	OSD and GSD
	At the beginning and end of drying	1 day	WO
Colour	At the end of the drying process	1 day	All 3 techniques
Smokiness (odour)	At the end of the drying process	1 day	All 3 techniques

Measurements were taken of the solar radiation, ambient temperature and relative humidity, as well as the drying temperature, weight and moisture content of the cocoa beans. To ensure that the measurements were comparable, the experiments using the three drying techniques were done in the same place on the same days; thus weather conditions were the same for all three experiments.

Table 2 shows the daily frequency and number of days in which the data were gathered for each drying technique.

3.3 Equipment Used

As mentioned earlier, the drying methods used were the WO, OSD and GSD. The WO was located in Bafia town in “Quarter Two”, a 10 min motorcycle from Bafia centre. This WO is a typical one for farmers in the Bafia area. It was constructed in December 2016 with private funds (around 300,000 FCFA) but the chimney had already been destroyed. The oven is operational every day, rented by farmers to dry their cocoa beans. On average, the system can dry 2 tons of cocoa beans per week at a cost of 2,000 to 2,500 CFA per bag.

For OSD, a woven plastic bag was used (this material is commonly used by farmers to produce large mats for sun drying). The plastic bag was placed on top of a wooden board to ensure a flat surface. The GSD used was the one located at the Cocoa Business

Service Centre of the cooperative BAFIACOOP. To gather the data, the equipment listed in Table3 was used.

3.4 Standardising the Cocoa Beans

The beans used for this study were purchased from Mr. Yamnyong Jonathan, a registered farmer of the cooperative BAFIAFCOOP. The beans had been fermented using cascade fermentation boxes⁴ located at the CBSC (Cocoa Business Service Centre) of BAFIAFCOOP. By taking beans from the same farmer, who applied “good agricultural practices”, and that had been fermented in the same batch using an improved fermentation technique, the maximum possible consistency was ensured.

3.5 Sampling and Sample Placement

On Friday night, the 24th of November, between 20:00 and 22:00, the fermented beans to be used in the experiment were removed from the fermentation unit and taken to the GSD where they were placed in the drying beds. On the following Sunday morning, at 07:00, after 33 hours of initial drying, the beans were taken from the same drying bed and divided into samples for subsequent use in the three different drying techniques. Table 4 details the weight and

⁴ Cascade fermentation boxes allow for standardized conditions and are an improved method for cocoa bean fermentation. The fermentation process takes 6 days. The resulting beans are considered “quality cocoa”.

Table 3 Equipment and specifications used for data gathering.




Equipment		Specifications
Relative humidity and temperature recorder		TROTEC brand with measurement ranges from 0 to 100% at temperatures from -40°C to +70°C, and an accuracy of ±3.5% and ±2.0°C
Solar radiation meter		VOLTGRAFT brand with a measurement range of 0 to 1,999 W/m ² , reading frequency of 4/sec and an accuracy level of ±10 W/m ²
Moisture content meter		DRAMISKI, TWISTGRAIN model, with measurement range for cocoa from 6% to 20% and accuracy of ±0.5% for normalized grain
Weighing scale		Electronic, with range from 200g to 40 kg, graduation of 2g

Table 4 Number and weight of samples taken, and placement for each drying technique.

Drying technique	Sample (no. and weight)	Sample placement
Wood-fuelled oven	1 sample of 3 kg	The sample was split into two and spread on opposite sides of the bamboo mat
Open sun drying	1 sample of 0.5 kg	The sample was put on a plastic bag on a wooden board and placed out in the sun
Greenhouse solar dryer	4 samples of 0.5 kg each	For random placement of the 4 samples the GSD was divided into 4 parts length-wise, with each part receiving one sample; in its width the GSD was divided into 2 with each part receiving 2 samples

number of samples taken and how they were placed for each drying technique.

4. Results and Discussion

This section presents the data gathered during the period 26th-29th November 2017 for the GSD and OSD techniques and on 26th November 2017 for the

WO technique. Analyses for the three drying techniques are also presented.

4.1 Solar Radiation, Ambient Temperature and Relative Humidity

The hourly data gathered during the 4 days of the experiment were averaged giving the figures

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shown in Table 5.

The data were graphed resulting in the graphs shown in Fig. 5.

It must be noted that during the 5 days of the experiment the weather conditions were very good: there was no rain and bright sunshine daily.

The above data show that the solar radiation was highest between 09:00 and 16:00 while the highest

temperatures were recorded between 11:00 am and 14:00 pm when they were between 40 and 44°C. From 09:00 to 11:00 the relative humidity level was below 60%, after which it dropped to 40% until 14:00 when it rose again but did not pass the 60% mark until 17:00. This shows that the optimum time for both OSD and GSD, in good weather conditions, is between 09:00 and 17:00.



Fig. 1 Placement of samples on the WO, OSD and GSD.

Table 5 Average solar radiation, temperature and relative humidity at hourly intervals between 07.00 and 18.00

Time [h:m]	Average solar radiation [W/m^2]	Average temperature [$^{\circ}C$]	Average relative humidity [%]
07:00	77.77	22.07	91.03
08:00	146.20	27.87	75.87
09:00	154.28	32.93	62.88
10:00	155.50	37.18	52.88
11:00	155.90	40.65	43.95
12:00	156.05	42.95	38.68
13:00	155.70	42.80	37.33
14:00	155.20	44.03	35.78
15:00	154.38	40.53	42.33
16:00	154.05	36.68	50.03
17:00	127.93	32.63	59.95
18:00	8.55	28.60	73.93

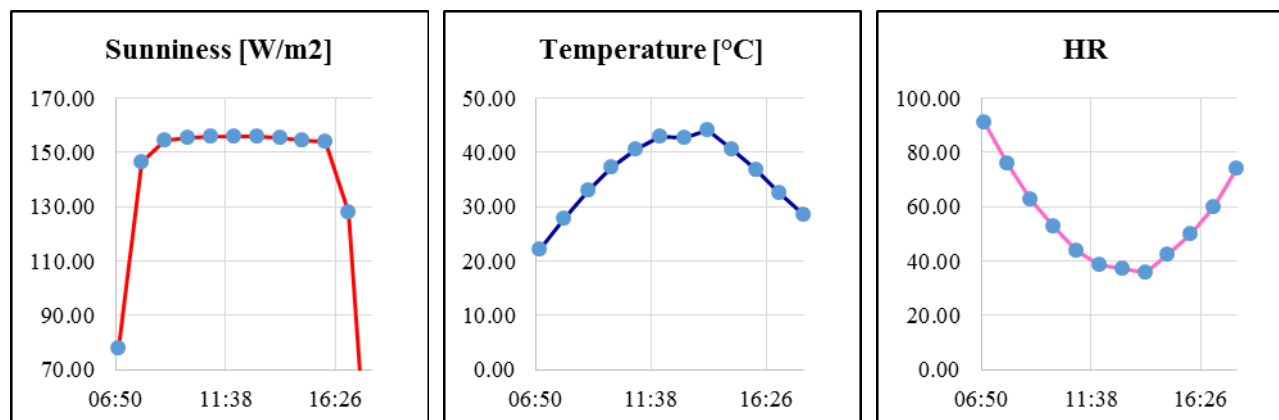


Fig. 5 Graphs showing average solar radiation, temperature and relative humidity at hourly intervals between 07:00 and 18:00 during the period 26-29 November 2017.

4.2 Drying Temperatures and Relative Humidity for the GSD and OSD Techniques

Table 6 gives the average hourly drying temperature and average relative humidity of the samples of the OSD and GSD techniques between 07:00 and 18:00.

The data show that OSD reaches 40-44°C in the middle of the day while the GSD reaches only 39°C. Lowest relative humidity was measured at 14:00, for OSD the measurement was 35%, for the GSD it was 46%.

4.3 Daily Weight and Moisture Content of the Samples

Table 7 summarizes the average daily weight and moisture content of the samples.

The data show that it took the GSD 5 days to reach the 8-9% moisture content needed for quality cocoa but only 4 days for the OSD. The data also show that cocoa beans lose water quicker using the OSD than

the GSD. However, the WO is the fastest method. Even though the result for all the techniques was < 9% of cocoa bean moisture content, the loss in weight was not the same for the three drying techniques. The WO technique resulted in a weight loss of 28%, while the GSD and OSD resulted in a significantly higher weight loss at around 40%.

4.4 Comparing Measurements for the Three Drying Techniques

In this section the progression of moisture content and weight are compared as well as the drying temperatures and relative humidity of the air.

4.4.1 Evolution of Cocoa Bean Moisture Content and Weight

The graphs below compare the weight and moisture content of samples in the three drying techniques during the five days of the experiment.

The weight and moisture curves exhibit the same trends. Both parameters decrease during the drying

Table 6 GSD and OSD average hourly drying temperature and relative humidity.

Time	GSD		OSD	
	Temperature (°C)	RH (%)	Temperature (°C)	RH (%)
07:00	21.93	93.8%	22.07	91.0%
08:00	26.53	83.3%	27.87	75.9%
09:00	32.43	67.4%	32.93	62.9%
10:00	34.59	62.5%	37.18	52.9%
11:00	37.04	54.4%	40.65	44.0%
12:00	38.29	50.4%	42.95	38.7%
13:00	39.44	46.5%	42.80	37.3%
14:00	39.04	46.5%	44.03	35.8%
15:00	37.53	49.4%	40.53	42.3%
16:00	35.38	55.7%	36.68	50.0%
17:00	32.37	62.8%	32.63	60.0%
18:00	28.99	73.0%	28.60	73.9%

Table 7 GSD, OSD and WO average daily weight and moisture content of the samples.

Day	GSD		OSD		WO	
	Weight (kg)	Moisture (%)	Weight (kg)	Moisture (%)	Weight (kg)	Moisture (%)
Day 1	0.500	> 20%	0.500	> 20%	3.000	> 20%
Day 2	0.405	18.5%	0.396	14.4%	2.160	9.0%
Day 3	0.340	12.9%	0.328	10.1%	-	-
Day 4	0.311	11.4%	0.312	8.2%	-	-
Day 5	0.295	8.6%	0.304	7.2%	-	-

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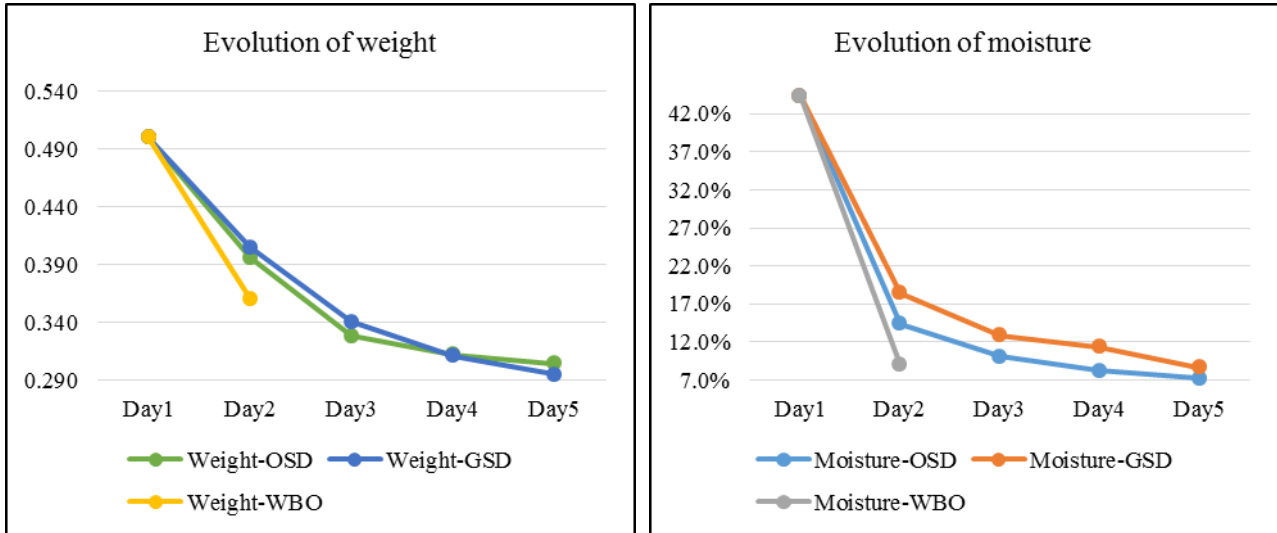


Fig. 6 Graphs showing the evolution of the weight and moisture content of the samples.

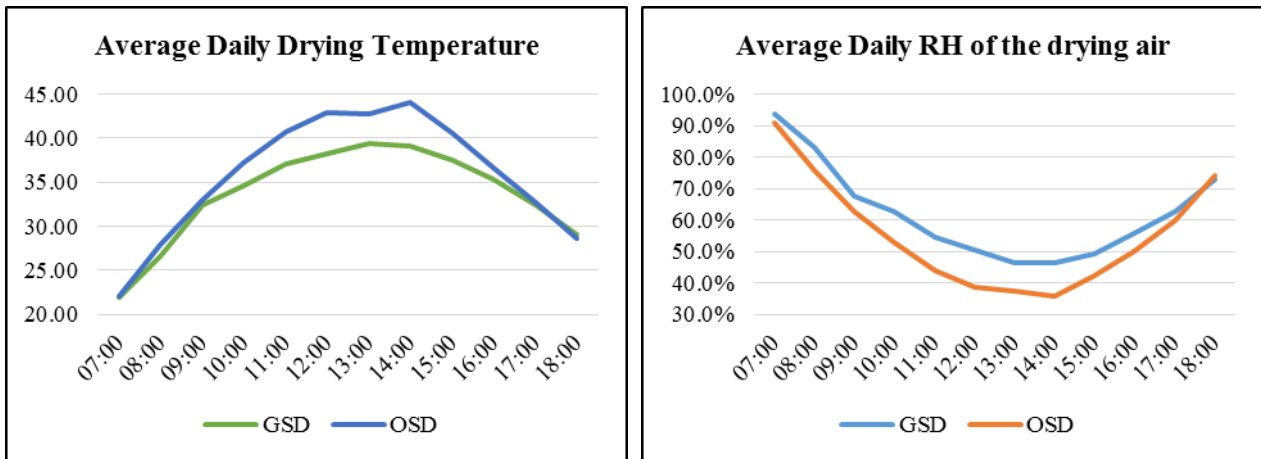


Fig. 7 Graphs of average daily drying temperature and relative humidity of the samples.



Fig. 8 External appearance of samples from OSD, GSD and WBO.

process irrespective of the drying technique. Cocoa in the WO dries fastest, followed by cocoa in the OSD technique, the GSD taking a little longer. The loss in weight was calculated to be 28%, 41% and 39% respectively for the WO (after 1 day), OSD (4 days) and GSD (5 days). The WO took less than a day to dry the beans to 9% moisture content, whereas the drying durations to reach a similar level of moisture content were 4 days for the OSD and 5 days for the GSD.

It is possible that the difference observed in drying duration between the GSD and OSD can be explained by the fact that cocoa beans in the solar dryers are exposed to a higher relative humidity of the air, approaching 100% when the drying process stagnates. However, OSD beans are taken indoors at 17:30 pm till 7:00 am the next day, avoiding the rising humidity outside at night and benefitting from the lower humidity indoors..

4.4.2 Evolution of Cocoa Bean Drying Temperature and Relative Humidity

The graphs below compare the average ambient drying temperature and relative humidity of samples in the OSD and GSD.

The ambient drying temperature and relative humidity exhibit opposite trends. Temperature and relative humidity are respectively higher and lower for the OSD technique. This explains why the drying duration is shorter for the OSD technique than the GSD technique.

For both the OSD and GSD, the drying temperatures do not exceed 45°C unlike the WO where the drying temperature reached above 60°C. With a higher temperature, the drying process is faster but results in poor cocoa quality because at drying temperatures above 60°C, cocoa beans become acid (reduced pH and high free acidity level).

4.5 External Appearance, Smell and Taste of the Beans

The colour and external appearance of the beans differed for each drying technique used: the WO

produced a darker bean, the GSD a lighter bean and the OSD a bean with colour in between the two others.

Beans from the OSD and GSD had a chocolate aroma whereas the beans from the WO had a smoky odour. The three evaluators independently reached the same conclusions.

5. Conclusion

The purpose of this study was to determine the performance of three drying techniques used for fermented cocoa beans in Bafia, under the same weather conditions. The performance indicators were: drying time (in days) and quality of the resulting bean measured in colour, odour and flavour.

The WO was the fastest drying technique (1 day) but produced a poor quality bean (overly dark in colour and smoky in smell and taste). Under the same good weather conditions the OSD took 4 days to produce a good quality bean while the GSD took 5 days. Both the OSD and GSD produced beans of the right colour and without a smoky odour and flavour.

In Bafia, which receives high annual rainfall levels (3,500-4,000 mm), weather conditions are often not favourable for sun drying. Therefore, the greenhouse solar dryer, which still functions on rainy days, is a good solution for farmers to be used in combination with OSD. An additional advantage of the GSD is that it does not require a family in constant attendance to turn the beans (this is taken care of by the personnel of the GSD).

To further test the performance of the cocoa drying techniques it would be interesting to repeat the experiment:

- Under different weather conditions (e.g., under different levels of cloud cover and during intermittent rain);
- In different cocoa producing areas where weather conditions are different;
- Determine bean quality through other than the rather subjective sensory measurements (e.g., through chemical analyses).

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After installation of a forced ventilation system in the GSD to evacuate humid air, thereby we can improve drying efficiency and reduce the drying time.

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