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DRYING COFFEE WITH THE HORTICULTURE INNOVATION LAB'S PALLET DRYER - REPORT

November, 2022

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UC DAVIS UNIVERSITY OF CALIFORNIA

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Drying coffee with the UC Davis 'Pallet' dryer report

November 2022

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COVER PHOTO:

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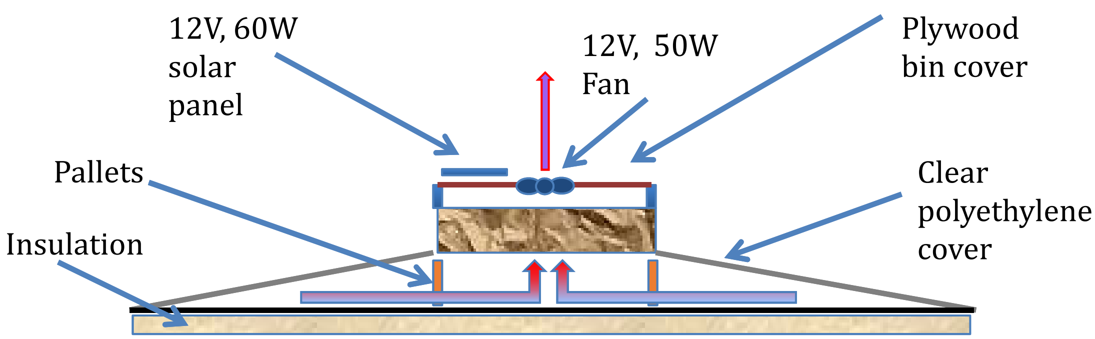
INTRODUCTION

Aflatoxin and fumonisin contamination of basic grains and pulses is widespread in the developing world, and is suspected of being a primary cause of high levels of childhood stunting in the humid tropics. Although some contamination occurs in the field, a major source of aflatoxin is storage of grain at high moisture content. The UC Davis DryCard is a simple tool that allows farmers and traders to determine whether grain is dry enough to store. The problem for many farmers, particularly smallholder farmers, is that they do not have a satisfactory means of drying grain that is not yet dry enough for safe storage. Present technologies are either very simple or relatively sophisticated. Simple solutions, such as drying on the ground or the roof leaves grains and pulses susceptible to contamination, to moisture from rain and dew, and to insect, bird and rodent attack. More sophisticated solutions, usually dryers using electricity, gas, or biofuels, are expensive and only appropriate to larger-scale commercial farming operations.



Cut away view of the Pallet Dryer demonstrating airflow of heated air through bin with drying product inside

THE PALLET DRYER

Aware of the need for a simple and efficient dryer for grains and other bulk-handled commodities, we wondered if we could develop a modification of the UC Davis chimney dryer, which has proved to be so successful for drying of fruits, vegetables, and even fish. The requirements that we felt should be met by such a dryer are that it needs to have relatively large capacity (100 kg minimum), provide protection from rain, birds, and rodents, be portable, inexpensive, and constructed, as much as possible, with locally-available materials and technologies. To meet these requirements, we designed the UC Davis Pallet Dryer, a solar-heated bin dryer.

The dryer comprises a layer of insulation on the ground, then a black substrate (plastic or fabric). At the center of one end are stacked two pallets (widely available in all but the poorest or most isolated communities). Over the pallets is placed a sheet of clear polyethylene that stretches to the edges of the black base sheet, and is held taut at the corners with elastic ropes attached to stakes. The clear plastic over the center pallet is cut out, so that heated air can flow through it from the solar collector. The pallets supports a bin containing the product to be dried. The bin is constructed from another pallet, and a sheet of plywood or similar material that is cut to make the sides and lid of the bin. The lid, sized to cover the bin, is fitted with a 60 watt solar panel and a 59 watt, 12V fan (rated at 300 cfm) that pulls air from the solar collector through the product being dried.

ADVANTAGES OF THE PALLET DRYER

The dryer provides a low-cost but efficient solar dryer for use with grains, pulses, and other agricultural commodities that need to be further dried after harvest and before storage. It is well suited to use with crops such as maize, peanuts, chick-peas, beans, and even specialty items like coffee and cacao.

As an example of the effectiveness of the dryer, the data below show temperatures, humidities and bean moisture content during an experiment testing the dryer for drying green washed coffee beans. The bin was loaded with ca. 50 kg of coffee beans with a moisture content of 48%. The control comprised beans on a raised bed covered with a hoop greenhouse structure, mimicking what is commonly used in production areas.

Placing bin on solar collection area

RESULTS OF COFFEE DRYING EXPERIMENT WITH THE PALLET DRYER

The data show (see Figures 1, 2, 3, 4) that the collector raised the inlet temperature as high as 140 F, with a corresponding reduction in RH to 20%. During the first day of drying, the air exiting the bed of drying coffee was at moderate temperatures and very high RH, but during the second day the exit RH fell rapidly and the exit temperature increased. These changes correlated with the moisture content of the beans, which had reached the 12% target by 30 h. In contrast, the beans in the raised bed control treatment took over three days to reach the target moisture content.

In this experiment, MC was determined by oven drying (at 220 F, until constant weight, ca. 48 h)(see Figure 5). At the time the samples were taken, we also used the Dickey-John moisture meter to determine MC, using the 'maize' calibration. It turns out that this is a satisfactory tool for measuring MC in coffee, although with limited range (it does not measure below 10% MC nor above 30% MC). The graph below shows the highly significant linear regression of MC determined by the two methods.

Coffee beans inside of the bin

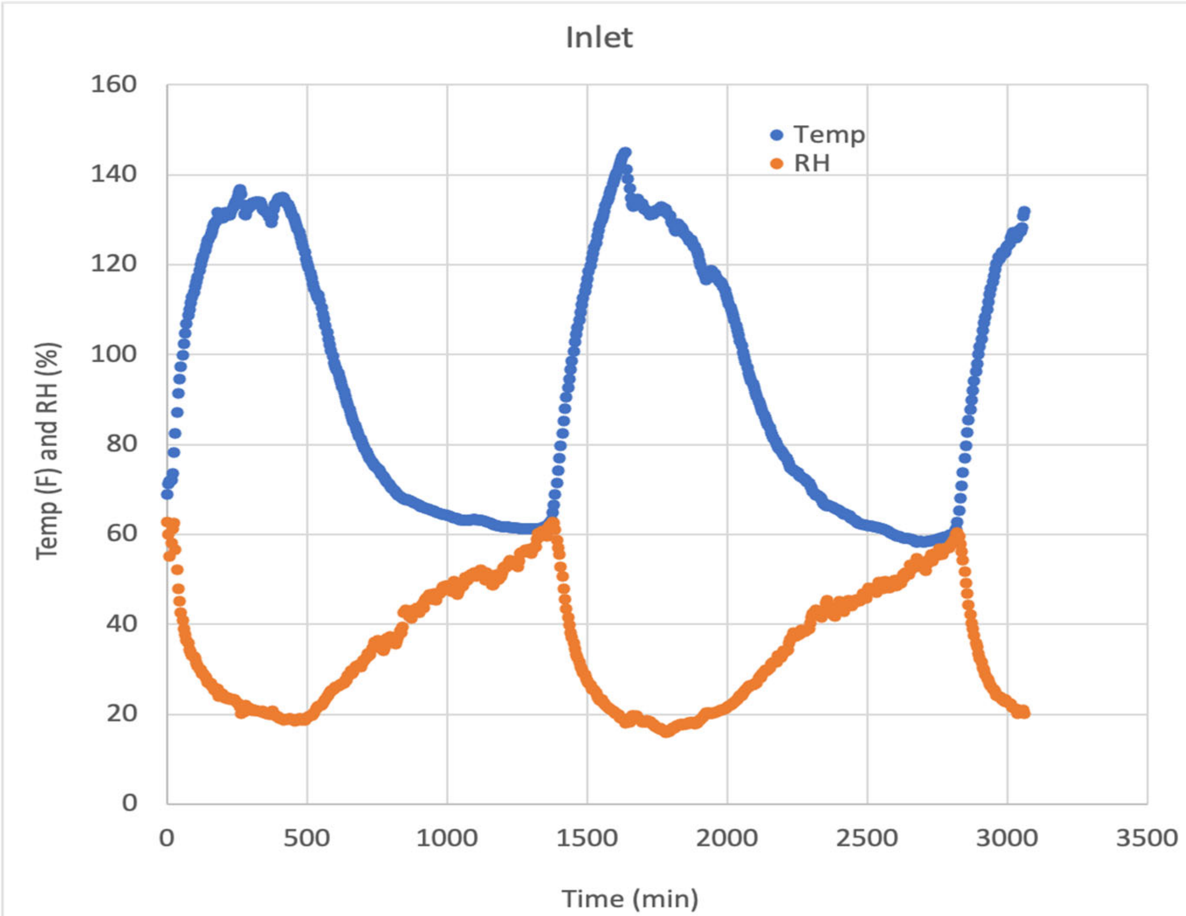


Figure 1: Inlet temp and RH during the course of the trial

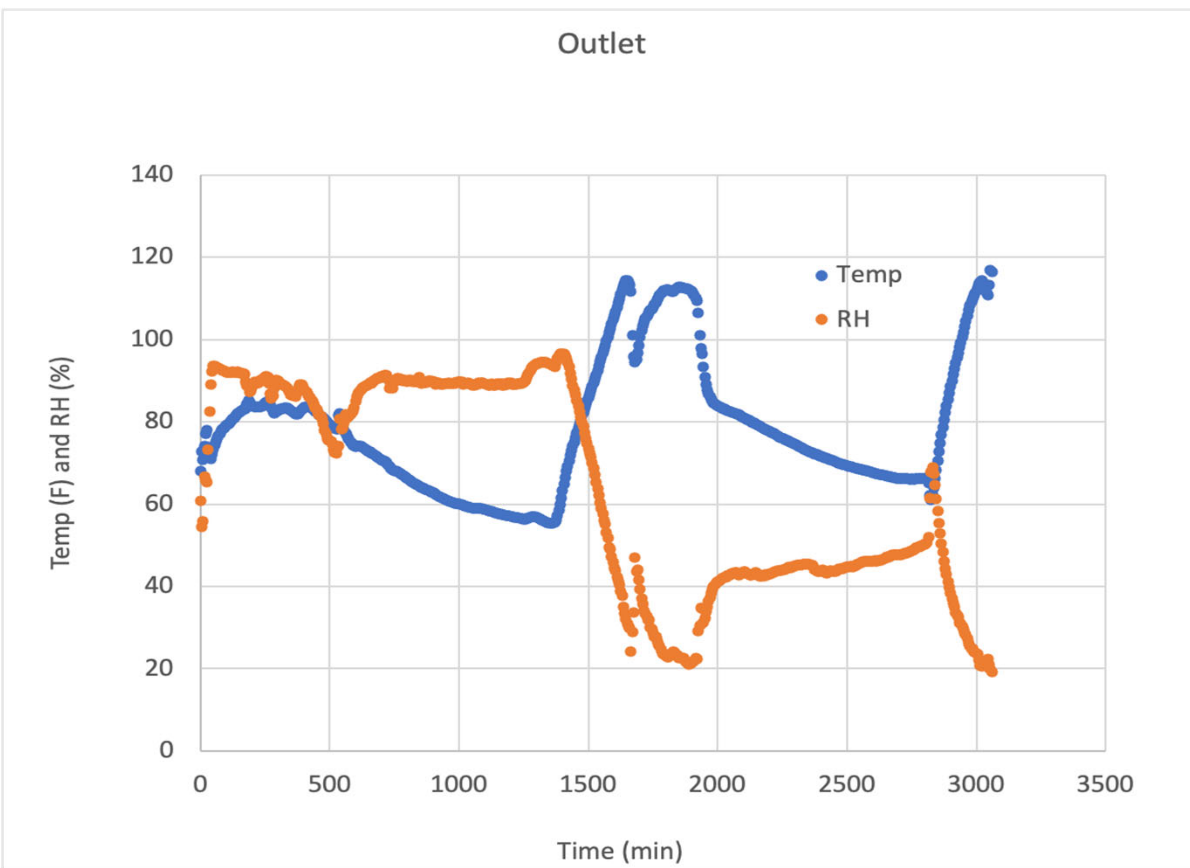


Figure 2: Outlet temp and RH during the course of the trial

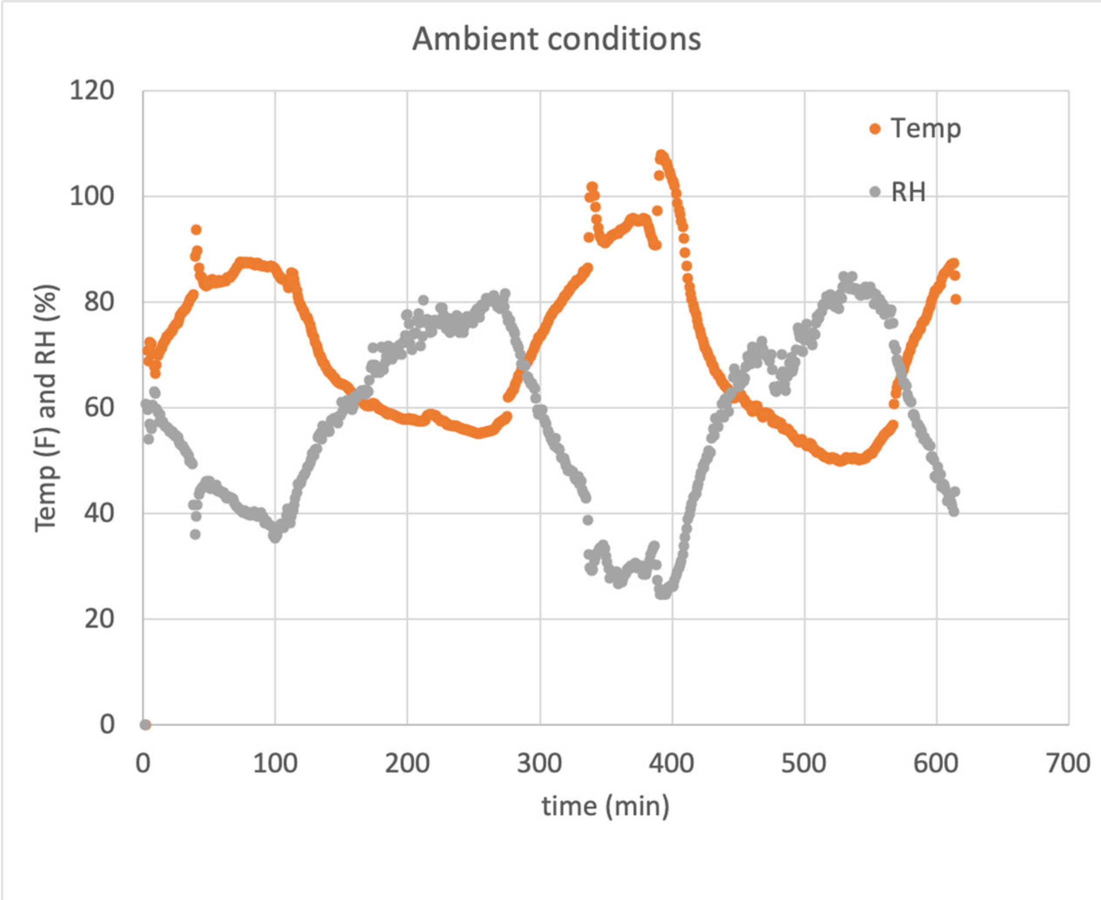


Figure 3: Ambient temp and RH during the course of the trial

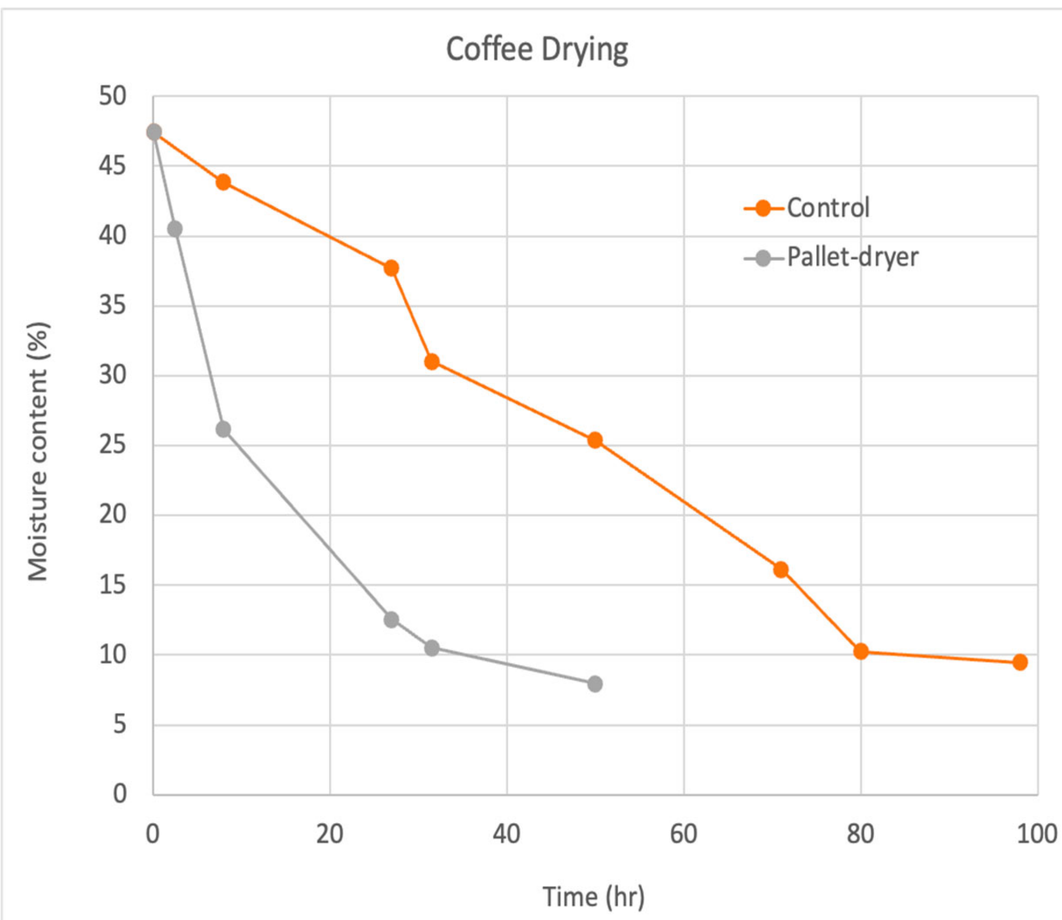


Figure 4: Rate of coffee drying control vs pallet dryer

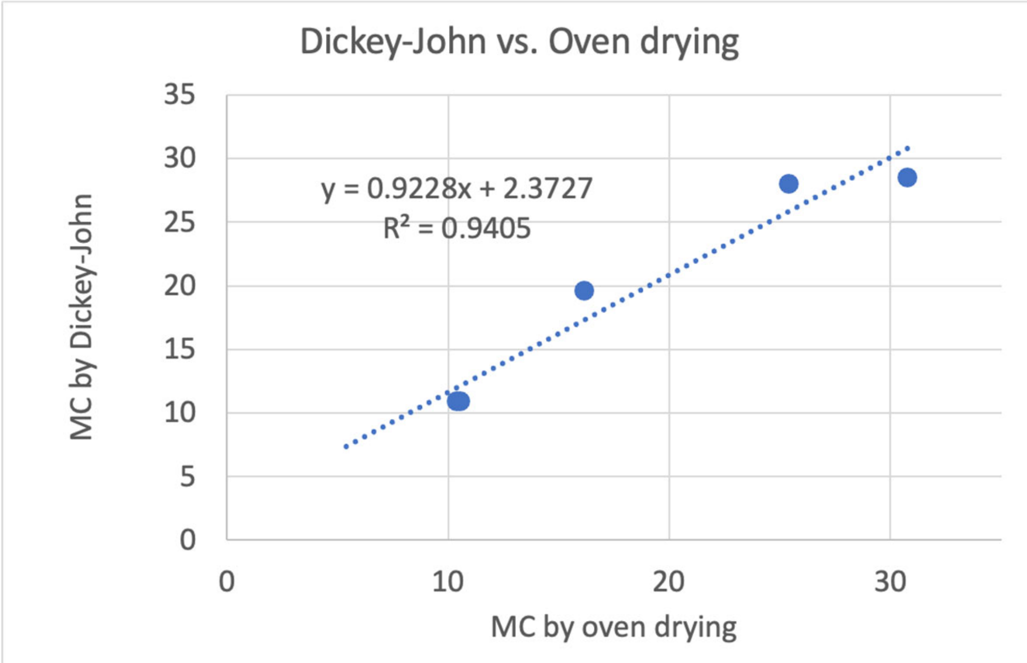


Figure 5: Comparing a Dickey-John MC vs oven drying method

COFFEE DRYING IN THE PALLET DRYER USING SERPENTINE METHOD

As an alternative to bin drying, and particularly for drying coffee cherries, we tested the use of the pallet dryer in the 'serpentine' configuration, in which the coffee is placed on trays, three inches shorter than the bin, that are stacked in the bin on spacers, and at alternate ends of the bin, forcing the air to follow a serpentine path over the product that is being dried. This system has successfully been demonstrated with products that cannot be dried in a bulk bin, like sliced tomatoes, and sliced bananas. The photograph shows the interior of the bin with two of the trays, and the sensor for the Hobo datalogger in place.

Interior of the bin with datalogger in place. Coffee beans placed in bin using serpentine method

Beans were hydrated overnight with water containing 200 ppm hypochlorite to prevent fungal growth. The water content of the rehydrated beans, determined by oven-drying samples at 220 F to constant weight, was 48%. Then the beans were placed on three trays in layers approximately 1 cm deep, and a mesh bag containing 130 g of beans was placed on each tray as seen in the photograph. Dataloggers at the inlet, at the end of the first tray, and at the end of the third tray provided a record of conditions during drying. A heavy weight was placed on the cover tray to ensure that the air flow was maintained through the serpentine system. As control, beans were placed 5 cm deep in a raised bed covered with a hoop/supported plastic cover.

Additional image of coffee beans placed in bin using serpentine method

After the first day of drying, the beans from the pallet dryer were held in buckets overnight, then placed on the trays in reverse order, since the beans in the bottom tray were much drier than those in the top tray.

RESULTS OF COFFEE DRYING IN THE PALLET DRYER USING SERPENTINE METHOD

Changes in weight of the sample bags showed that the beans in the pallet dryer dried rapidly (See Figure 6). At the end of the second drying day, the moisture content of the beans, determined with the Dickey-John meter, was below 10% (the lower limit of the device). The control beans took another 24 hours to reach the same dryness.

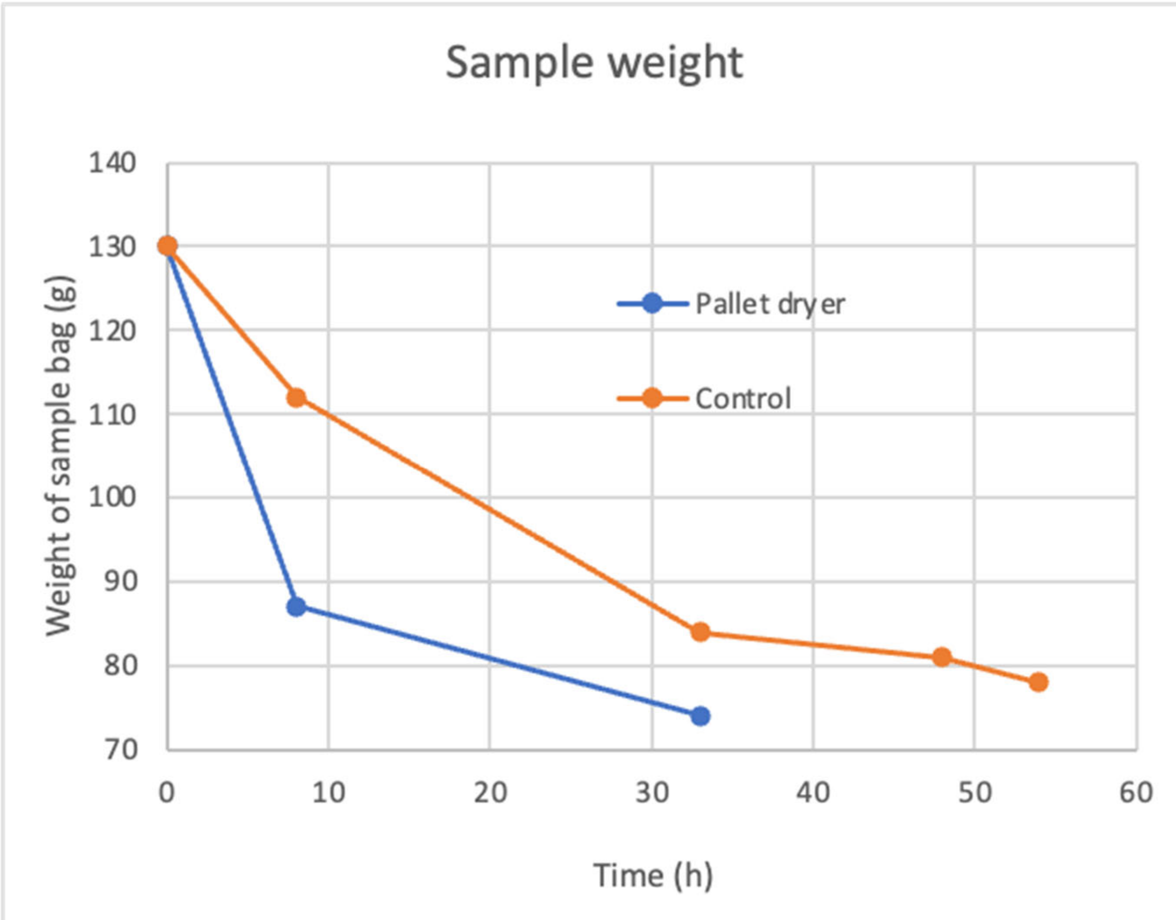


Figure 6: Weight of sample bags during the drying trial using serpentine method

These data show that the serpentine system performed about the same as the much simpler bin drying system, with the beans being fully dried within the first two days. The additional handling and complexity of the serpentine configuration of the dryer suggests that it should be used only for products that cannot be dried in the bin system.

The temperature and humidity profiles in the serpentine dryer suggest less efficiency than the bin system (see Figures 7, 8, 9, 10). The temperature and humidity profile at the outlet indicates water removal in the system (lower temperature, higher humidity), but was much less striking than the profile seen in the bin system (where humidities were very high and temperatures low at the outlet during the first day of drying).

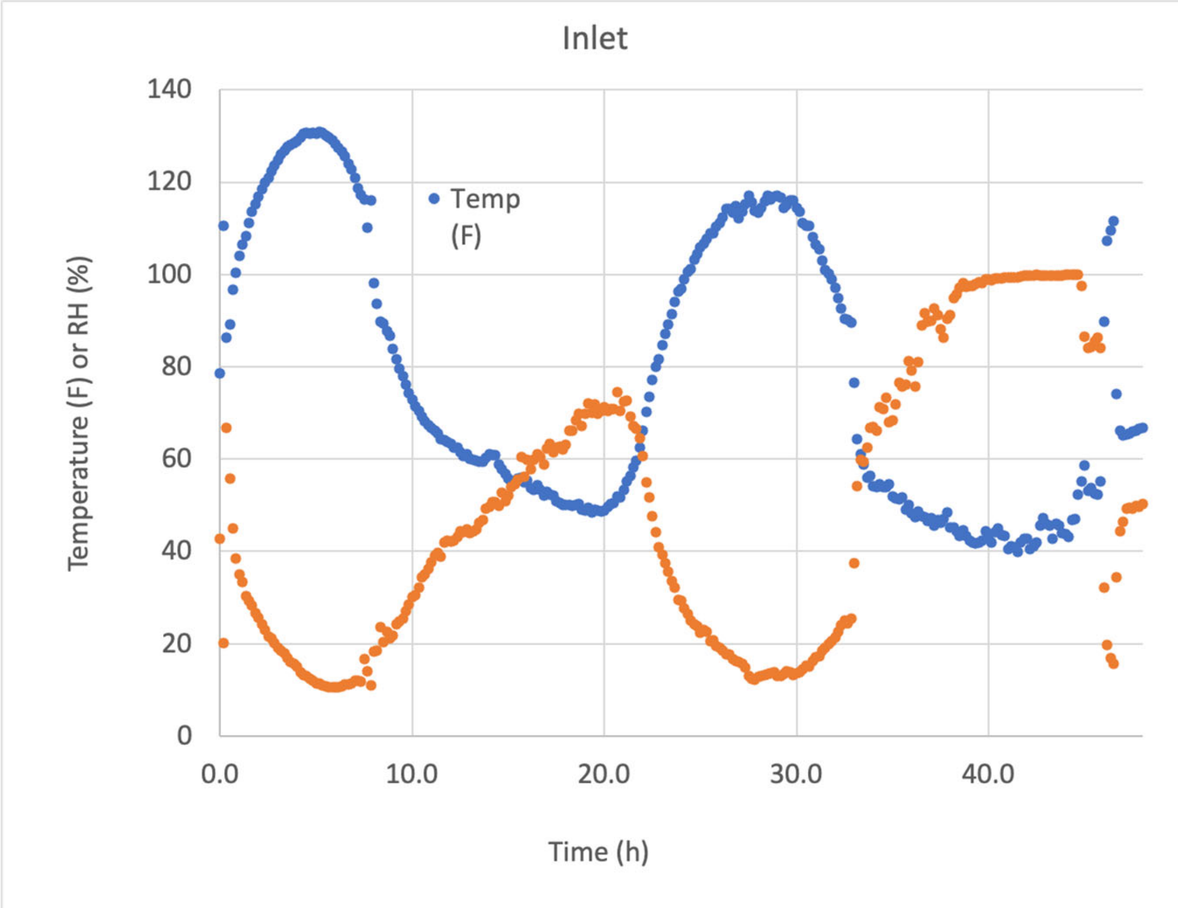


Figure 7: Inlet temp and RH using serpentine method

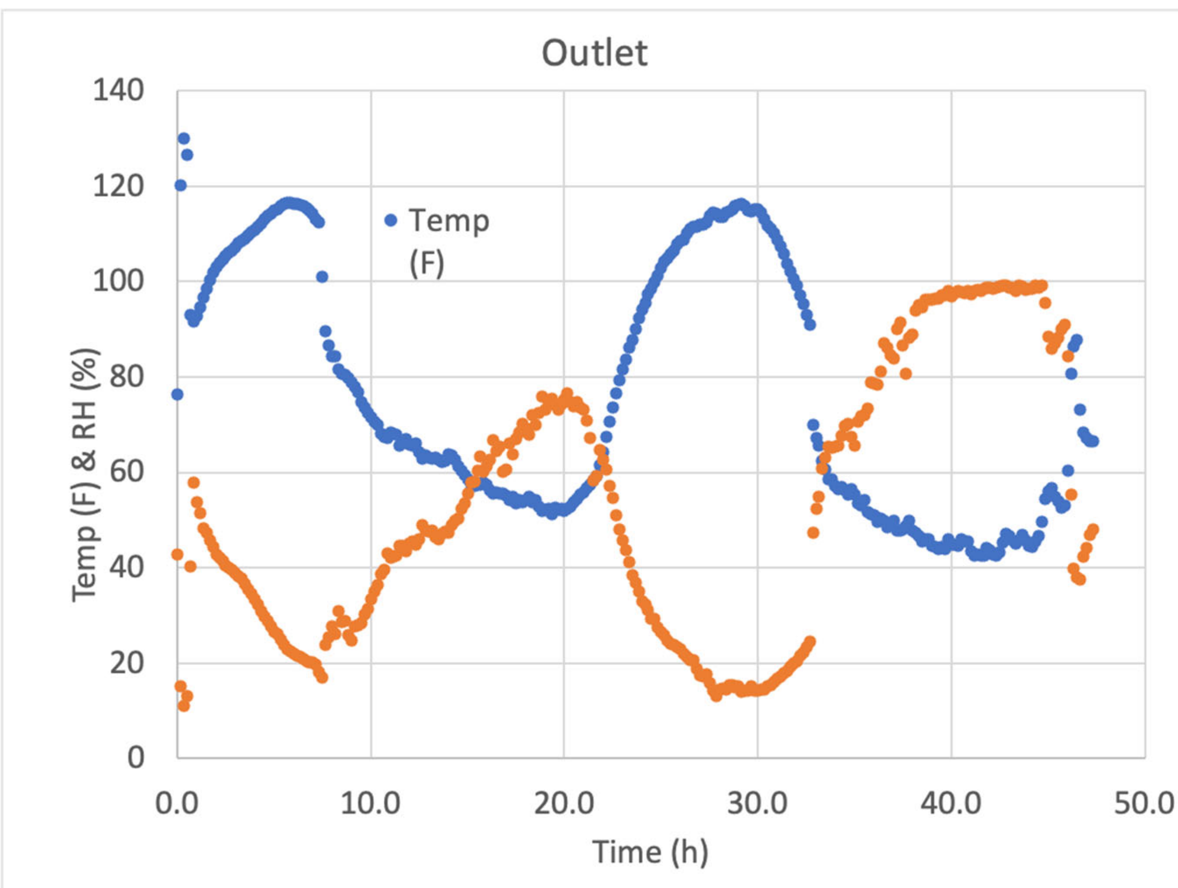


Figure 8: Outlet temp and RH using serpentine method

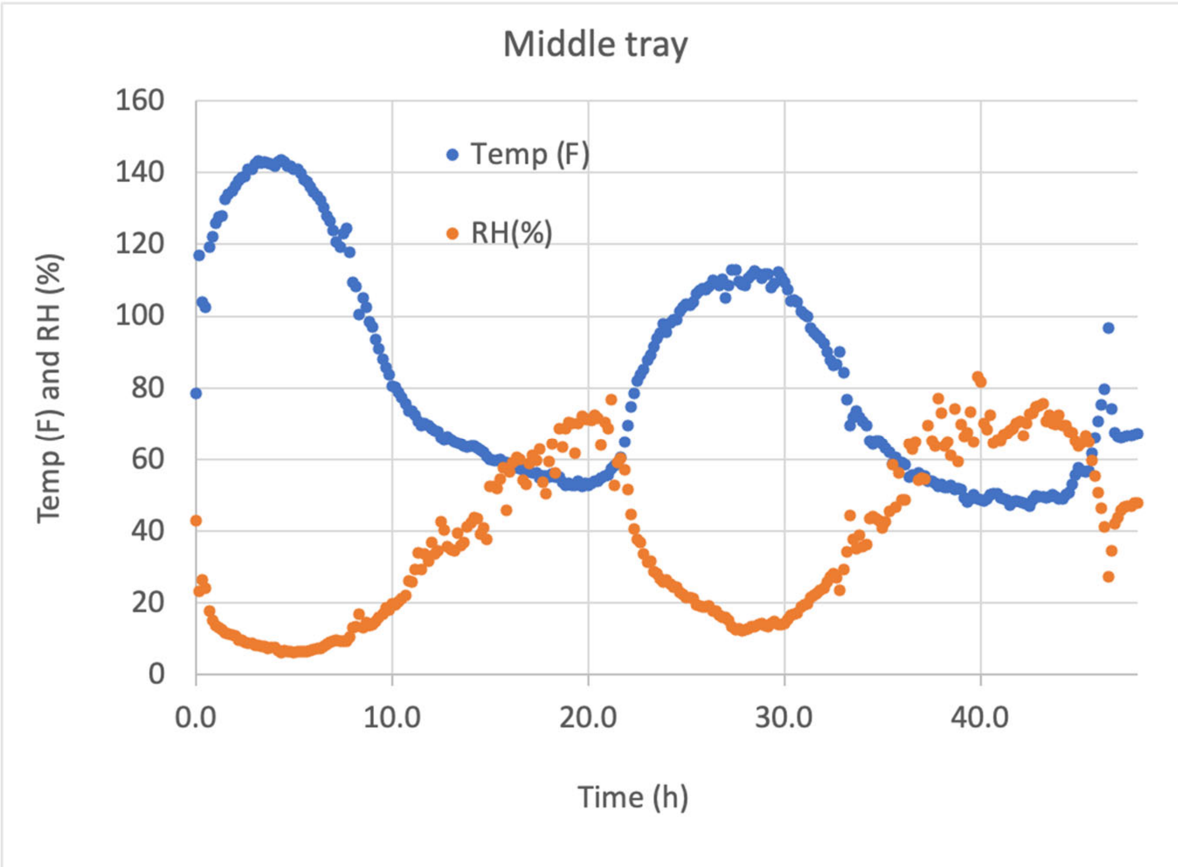


Figure 9: Temp and RH of middle tray during serpentine method trial

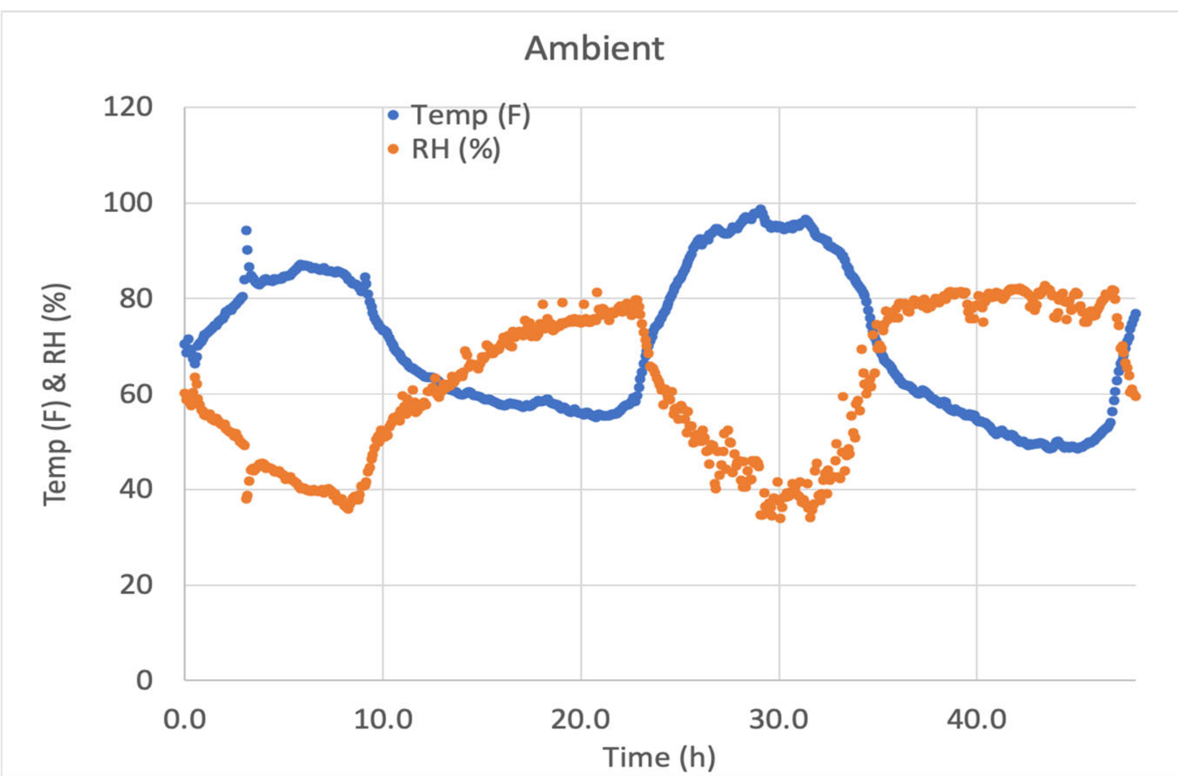


Figure 10: Ambient temp and RH during serpentine method trial

CONCLUSION

The pallet dryer was very effective in drying green washed coffee beans, and the direct bin system was probably\ faster, and certainly less complex than the ‘serpentine’ arrangement. Both systems dried the beans considerably faster than the raised bed system that was used as a control. The temperatures that were produced by the solar collector were greater than what is considered desirable for washed coffee (110 F), although research has shown that higher temperatures are safe for ‘natural’ coffee. Recent testing under field conditions in Colombia and Dominica suggest that under the lower ambient temperatures and sporadic insolation experienced in those locations, the warm air generated by the collector will not usually exceed the safe (110 F) level. Temperatures can be adjusted simply by lifting the corners of the collector sheet, or by using a programmable thermostat to modulate the speed of the fan.

Natural coffee might be dried in the ‘bin’ system as long as the weight of the cherries does not cause excessive crushing in the lower fruit, but this needs to be tested. Alternatively, cherries could be dried (albeit slightly less efficiently) using the ‘serpentine’ system.