Solar Fruit Dryer

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Objectives

The aim of this project is to design a full-scale solar fruit dryer based on a computational analysis of the air speed, temperature, and humidity through the entire dryer system.

Requirements

The analysis and final design needs to include the following:

- Use resources available to Afghani farmers including shipping containers.
- Maintain 43°C as closely as possible
- Produce the same amount or more raisins than a Kishmish Khana (Fig. 1) in a season
- Have variable air speed
- Evaluate if dust and pest filters are needed
- Determine the value of a thermal storage unit, and if useful, find the best material
- Determine optimal solar collection design

Background

Sean Currans is an agronomist who served as an agricultural advisor in Iraq and Afghanistan where he came up with the idea of a solar fruit dryer made out of a shipping container.

Currently, grapes are dried using a Kishmish Khana (Fig. 1). Many of the Kishmish Khanas were destroyed during war and are expensive to replace. They help produce a higher quality raisin that is not affected by direct sunlight. Direct sunlight can deteriorate the taste and color of raisins causing them to be worth much less. A typical open-sun dried raisin is worth 10 cents per pound where a Kishmish Khana raisin is worth $2 per pound. Along with cost, the downside to a Kishmish Khana is that a single batch of grapes takes the entire 3 month drying season to become raisins. This time is due to grapes only being dried during the heat of the day. In addition, Kishmish Khanas are not able to keep out insects, which negatively affects the quality of the grapes.

Utilizing the sun as a heat source, Currans' hope is to use available shipping containers as drying and thermal storage units (TSU). The TSU would provide heat during nighttime hours, reducing the overall drying time. This system could help drying grapes become more efficient and profitable for Afghani farmers, allowing more raisins to be produced with the same or better quality of a Kishmish Khana.

Figure 1. A typical Kishmish Khana found in Afghanistan.

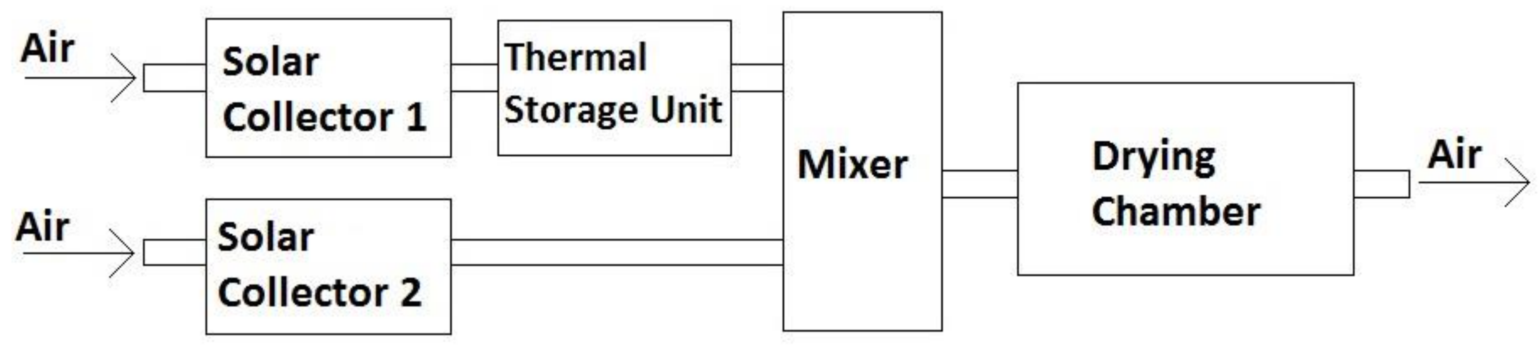

Figure 2. Block diagram of the system.

Final Design

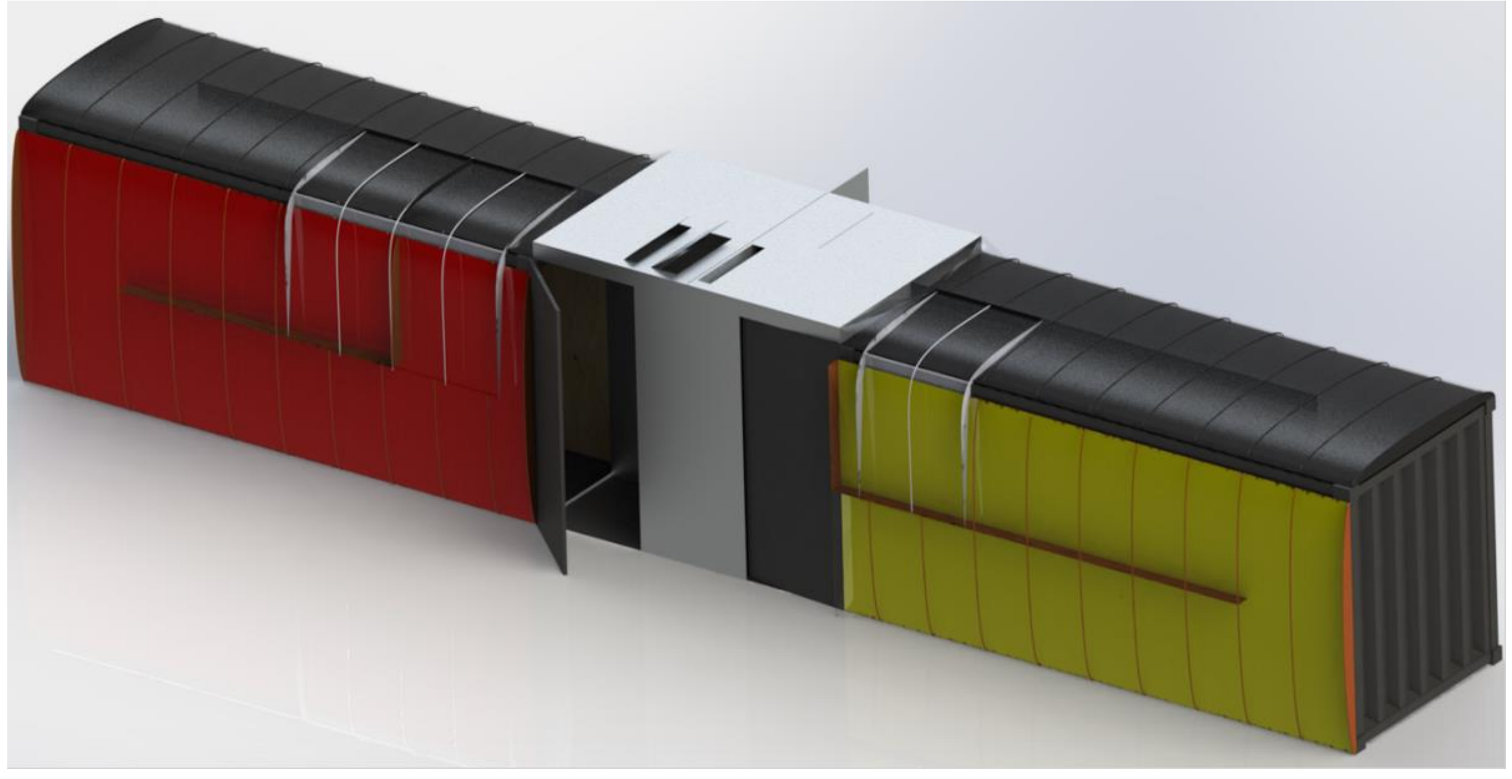

Figure 3. The final design of the solar dryer system, which includes the thermal storage unit (left, in red), the mixer unit (center, in grey), and the drying chamber (right, in yellow).

The design utilizes two standard 40 ft shipping containers (Fig. 3, on either end) for the thermal storage unit and drying chamber. Affixed to the top and the south facing sides are the solar collectors. In this render, the solar collectors are shown as metal ribs with plastic sheeting stretched taut over the top. The two containers are attached in the middle via the mixer unit shown in Fig. 4.

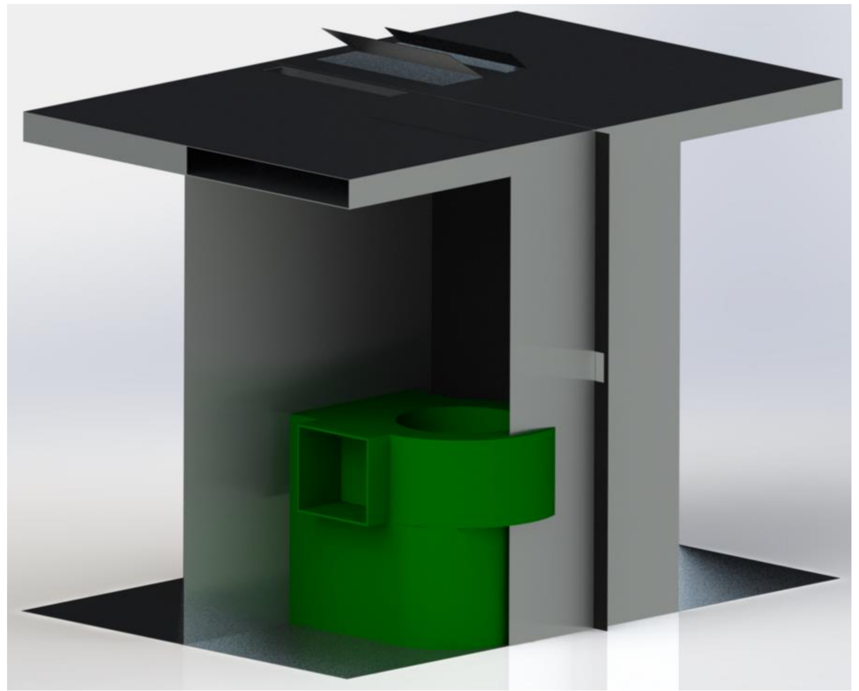

Figure 4. The mixer that is located between the two containers.

The purpose of the mixer (Fig. 4) is to vary the air inputs from the solar collectors, thermal storage unit, and outside to maintain the desired 43°C air temperature in the drying chamber or, if the desired temperature cannot be reached, the highest possible temperature. In the center, controllable dividers side closed (as shown in Fig. 4), separating the thermal storage unit from the dryer during the day and are opened at night to allow air to pass from the thermal storage unit to the dryer.

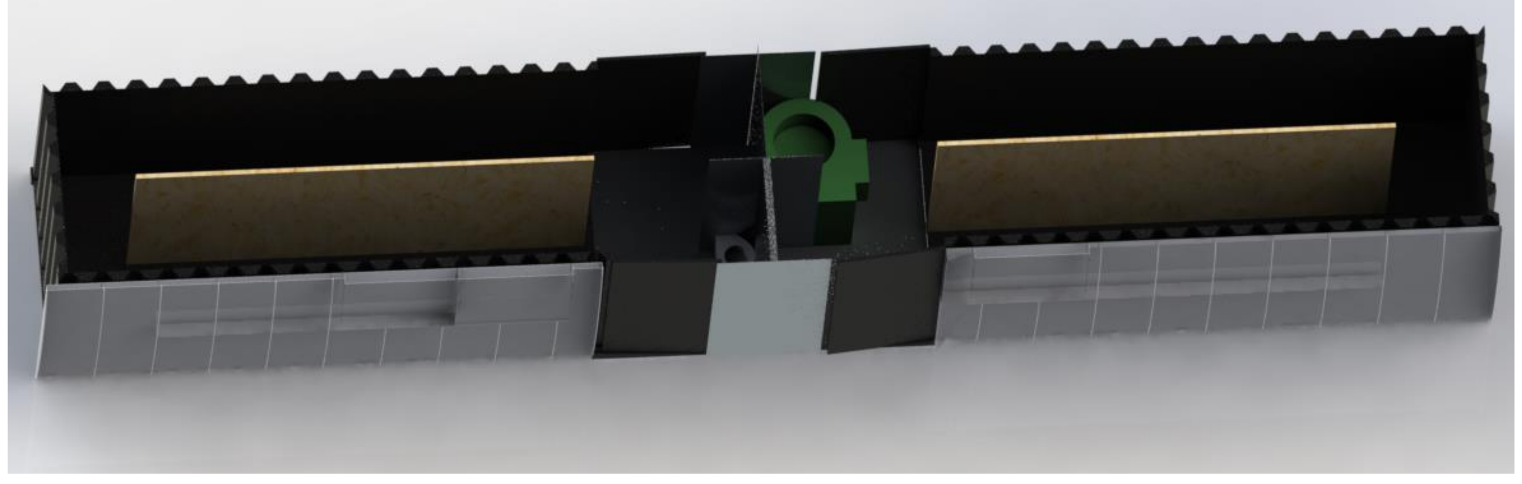

Figure 5. Top view cutaway of the design showing the inside layout.

The dividers in the centers of the thermal storage unit and drying chamber (seen in Fig. 5) are walls that direct the airflow to the end of each chamber and then back toward the mixer. The dividers are made out of plywood in the model but could also be made out of other materials. The doors of the shipping containers are used to connect the mixer with the two containers and allow access to the units between runs.

Analysis

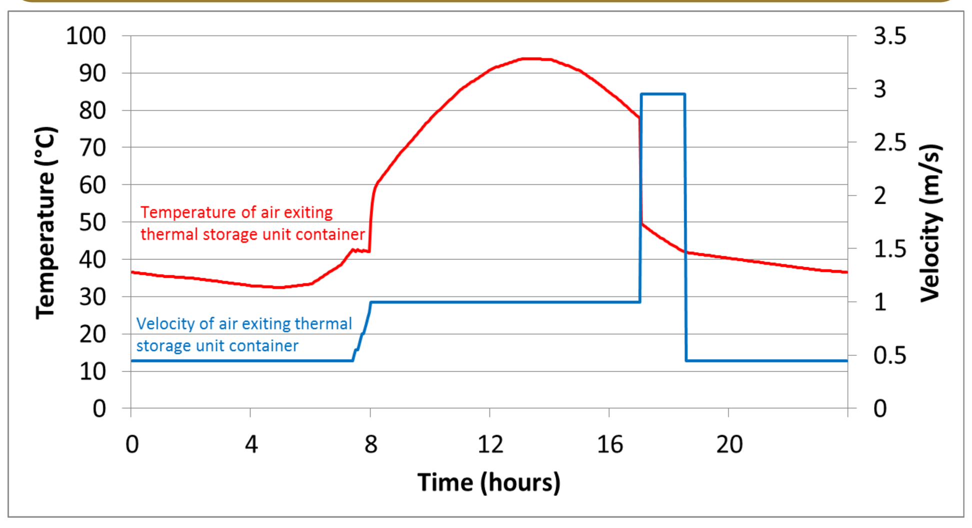

Figure 6. Temperature and velocity exiting the TSU. Zero hours corresponds to midnight.

Figure 6 shows how the thermal storage unit heats and cools over the course of a day, starting at midnight. The higher the temperature that can be achieved during the day when inactive, the longer a higher temperature can be held in the dryer. The fluctuation in velocity is what controls the constant temperature during the night.

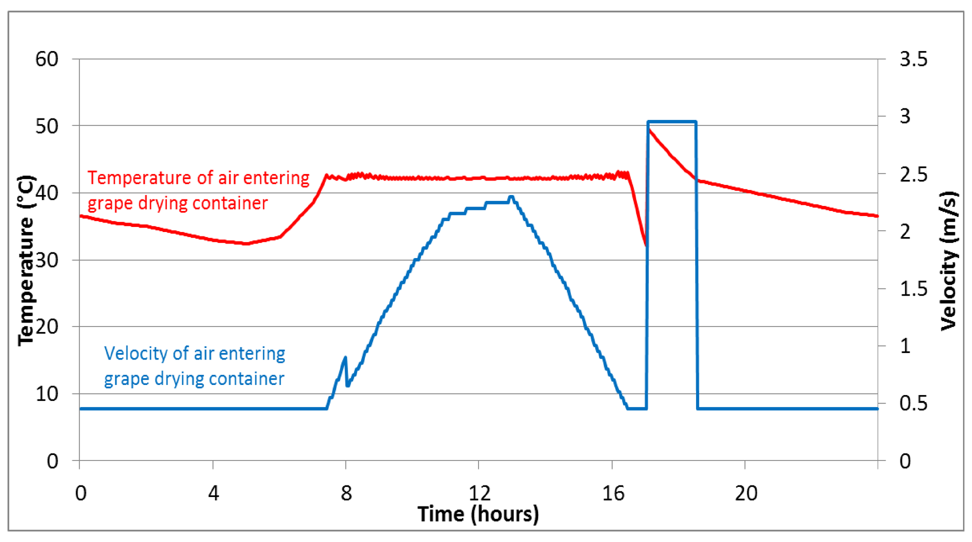

Figure 7. Temperature and velocity of the air entering the drying chamber. Zero hours corresponds to midnight.

Figure 7 shows the temperature and velocity of air in the drying unit. At times where the temperature of the air entering the dryer is higher than the desired 43°C, the air velocity must be raised to lower the temperature. Increased air velocity with constant temperature decreases grape drying time.

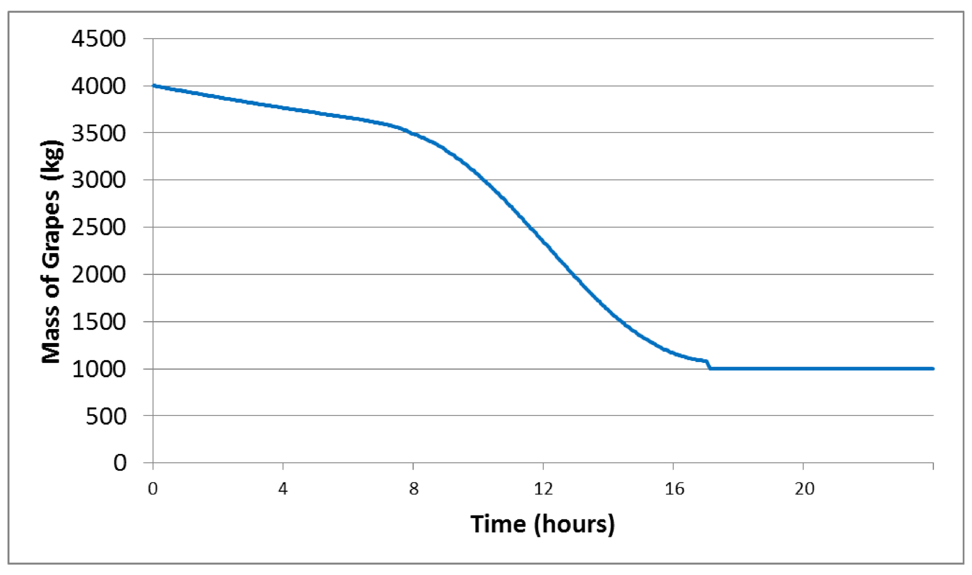

Figure 8. Mass of grapes in the drying chamber. Zero hours corresponds to midnight.

Figure 8 shows the mass of the grapes as they dry over the course of a day. For the grapes to be fully dry (i.e., raisins), they must lose 75% of their mass. For example, 4000 kg of grapes will be fully dried when their mass has decreased to 1000 kg overall.

From left to right: Kyle Harris, Shawn Kirby, Matthew Mansfield (PM), Caitlin King (TM), Karina Stephenson