The Appropriate Technology Collaborative

and

Michigan State University

Solar Dehydrator
Drawings and Specifications
2020

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[SOLAR DEHYDRATOR]

[Final Report]

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Introduction

Researchers have identified the first 1,000 days of a child's life (from pregnancy through a child's 2nd birthday) as the most critical window of time; this time sets the stage for a person's intellectual and physical development, and overall health for the rest of their life. Ensuring a child has the right start to life during these precious first 1000 days begins most importantly with nutrition. Nutrition is the critical building block for physical growth, brain development, and health of the immune system. Once a child reaches approximately two years of age, the physical and mental results of the nutrition they have been provided are irreversible. Malnutrition not only stunts a child's development, but it is also responsible for almost half of all deaths of children under age 5. For these reasons, malnutrition in woman and children is particularly damaging to both the individuals, and whole societies as it damages the potential future leaders.

Malnutrition in Guatemala is a very serious issue; the rate for children under 5 is 49.8 percent, the highest in the area and the fourth highest in the world. According to the World Food Programme, Guatemala is one of the 36 countries that account for 90 percent of stunting in the world. This stunting can be directly attributed to the poor nutrition children receive during the first 1000 days of their life. Indigenous areas in particular are severely affected—the malnutrition rate is nearly 70 percent. Additionally, 53 percent of the population lives in poverty. The connection between malnutrition and poverty is prevalent in Guatemala. When children are stunted (both physically and mentally) they are unable to grow into productive members of society; they are often destined for a life of poverty before they even turn two. Women often have children very young, while they are malnourished themselves, and their children are born into the same cycle. In order to help prevent this poverty cycle, an important part of the answer is clear. As state by the World Bank in regards to Guatemala, "reducing child malnutrition is key to fight poverty in the country."

Located in a rural area of Guatemala is the community of Panyebar. Being a poverty stricken community, Panyebar suffers from “hungry months” when the local crops are not being harvested and the community’s ability to make money is temporarily halted. At these times in particular, the children of the community’s diet is negatively affected, as they cannot afford nutrient dense fruits and vegetables. Children in their first 1000 days of life during these hungry months suffer from stunted development, and older children struggle in school due to lack of energy. At the Panyebar Childcare and Nutrition Center, they are trying to combat this problem. Other nutrition centers in Guatemala have had success with dehydrating fruit, and Panyebar would like the tools to practice this in their community. The ability to dry fruit and vegetables would allow them to preserve the food, in order to provide essential nutrients the children need through the hungry months. Helping children in this essential time of their lives is very important to our Humanitarian Engineering team at Michigan State University. We have been able to see the smiling faces of the kids at Panyebar, and hear the story of the women working there to give the kids a better life, and we hope our solar dehydrator design will help provide them with a tool to give nutrients to the children of Guatemala and help combat malnutrition.

Design Parameters

Before beginning to develop a solution to this problem, the problem needed to be properly understood and defined. As Albert Einstein said, "If I had an hour to solve a problem I'd spend 55 minutes thinking about the problem and 5 minutes thinking about solutions." Taking this step was critical, because if the problem is not fully defined before moving forward, you run the risk of creating a solution to the wrong problem all together. If the design parameters have holes and some information is missing it can delay the design or worse the final result may be unusable to the client. Specifying design parameters was a key step in defining our problem; they were the building blocks that molded the project and kept it on the right track.

A comprehensive set of design parameters are listed in the left column of the table beginning on the next page. All parameters are not created equal, so we utilized a ranking scheme that allows for the differentiation between items that are absolutely critical to our project, and items that would be nice to have, but are not critical to success. Each design parameter is ranked on a scale from 0 to 3, 0 being of least importance and 3 being of upmost importance. These rankings will later be used to factor into our final design decision. A brief description of each parameter, and details and specifications of how they apply to our solar dehydration project in Guatemala are given on the right.

Table 1. Design Parameters

Design Parameters	Rank	Description
Function/Performance	3	The function of this product will be to dehydrate fruit to a certain level of moisture in a given amount of time. The goal is between 1 and 2 days.
Product Cost	3	The cost of this dehydrator will include all materials and labor to create the product, as well as any maintenance required. It is essential that the product be cheap to produce, and utilize only locally accessible materials.
Delivery Date	2	For this project in particular, the delivery date may not be applicable, but rather the due date for the final product, which is April 29, 2015.
Quantity	1	The number of dehydrators should be able to provide enough dried food to satisfy the need, while also providing the most manageable situation possible. The goal is that 1 dehydrator will be able to meet the needs.
Environmental Issues	3	For this specific location, there are a few environmental issues that need to be addressed. There are ants and bugs that will try to eat and contaminate the fruits, as well as dust in the air that could enter the drying chamber. The device will need to be as air tight as possible, and slightly elevated to combat these issues.
Safety	3	Safety is important, as the dehydrator will be located in an area where children will be running around it, and it is important to keep the women operating it safe as well. It will be designed with no sharp edges and a stable structure.
Quality	3	A key aspect of the quality of a dehydrator is to eliminate the growth of mold during the drying process. This is of extreme importance.

Spatial Constraints	0	Because the dehydrator will be outside, there is no specific spatial constraint. Further details will be discussed in size/weight.
Aesthetics	1	While this does get a low weight because it will not affect the function of the device, we will shoot for the best aesthetics we can as we understand it is still important to provide an appealing product.
Transportation & Packaging	0	The dehydrator will be stationary near the playground at the Nutrition Center, so transportation should not be relevant.
Personnel	3	The personnel usually using the dehydrator will be the women who work at the nutrition center. We have attempted to take them into account in any other design parameter that will affect them.
Service Life	2	We would like to design a dehydrator that will last as long as possible without needing part replacements. The goal is a service life of longer than 5 years.
Noise Radiation	0	Noise radiation should not be a relevant factor in a solar dehydrator.
Operating Instructions	3	Not only will the workers at the nutrition center need clear instructions on how to operate the dehydrator, but it is also important that we provide very thorough instructions on how to build the dehydrator that we design so it can be reproduced.
Energy Consumption	3	While in some cases it might be useful to use electric energy to aid dehydration, it is important that we do not do this. We will need to rely on the free and abundant energy of the sun to power this product.
Reliability	3	The dehydrator must be reliable in order to function properly. Human interaction should be kept minimal similar to maintenance.
Maintenance	3	The women working at the nutrition center are very busy, and should not need to worry about doing regular maintenance on the dehydrator.

Mechanical Loading	1	There are no moving parts or substantial loading occurring. We will only have to ensure the structure is stable, and the weight of the thermal mass can be supported.
Size/Weight	2	The dehydrator will be stationary, so limiting the weight is not crucial, but it must be an appropriate size to be fully accessible to the women working with it, and also dry the amount of fruit desired.
Health Issues	3	Materials chosen must be safe for direct food contact.
Government Regulations	0	Government regulations will not be a relevant factor in this project.
Shelf-Life Storage	0	This product will not be sold in a store, so shelf life is not applicable. Although, it is important to note that the dried fruit does need to be stored properly.
Operating Costs	2	Depending on our final design, the operating costs should be almost, if not zero.
Environmental Conditions	3	The conditions in Panyebar include a Dry season from November - April/May where it barely ever rains. The air is dry, and it is sunny most of the day (sun should hit directly around 7:30am-5pm). Lows at night are around 40 degrees, highs during the days in the 70s. These conditions play a large role in the design as we attempt to create a device that will maintain higher temperatures well into the night.

Design Concepts

Following defining the problem in terms of design parameters, the next step was to begin developing design concepts. This began with research about solar dehydration methods already in existence. Throughout the world, there are many methods for drying fruits and vegetables. In our research, we found that in general terms, solar dryers can be classified into two main categories based on how the air is moved through the system:

1. Active Solar-energy systems- Airflow is forced.
2. Passive solar-energy systems- Airflow is created by natural convection.

Within these two types of drying systems, there are three main subtype categories that are based on how the contents are heated (in relation to the sun):

1. Direct heating
2. Indirect heating
3. Mixed mode (both direct and indirect)

Figure (1), on the next page, summarizes these six different possible combinations with simple images showing both the airflow, and the solar radiation.

We specifically looked into each of these conceptual designs except for the mixed mode type of active dryer. We felt that between the consideration of the indirect active system, and the mixed mode passive system, we could accurately measure the pros and cons of the individual aspects that it would provide. We also did consider direct sun drying and oven drying as methods of fruit and vegetable dehydration, but quickly deemed these would not be viable solutions to the problem presented because they deplete the nutritional value if not done properly and did not spend time further analyzing them.

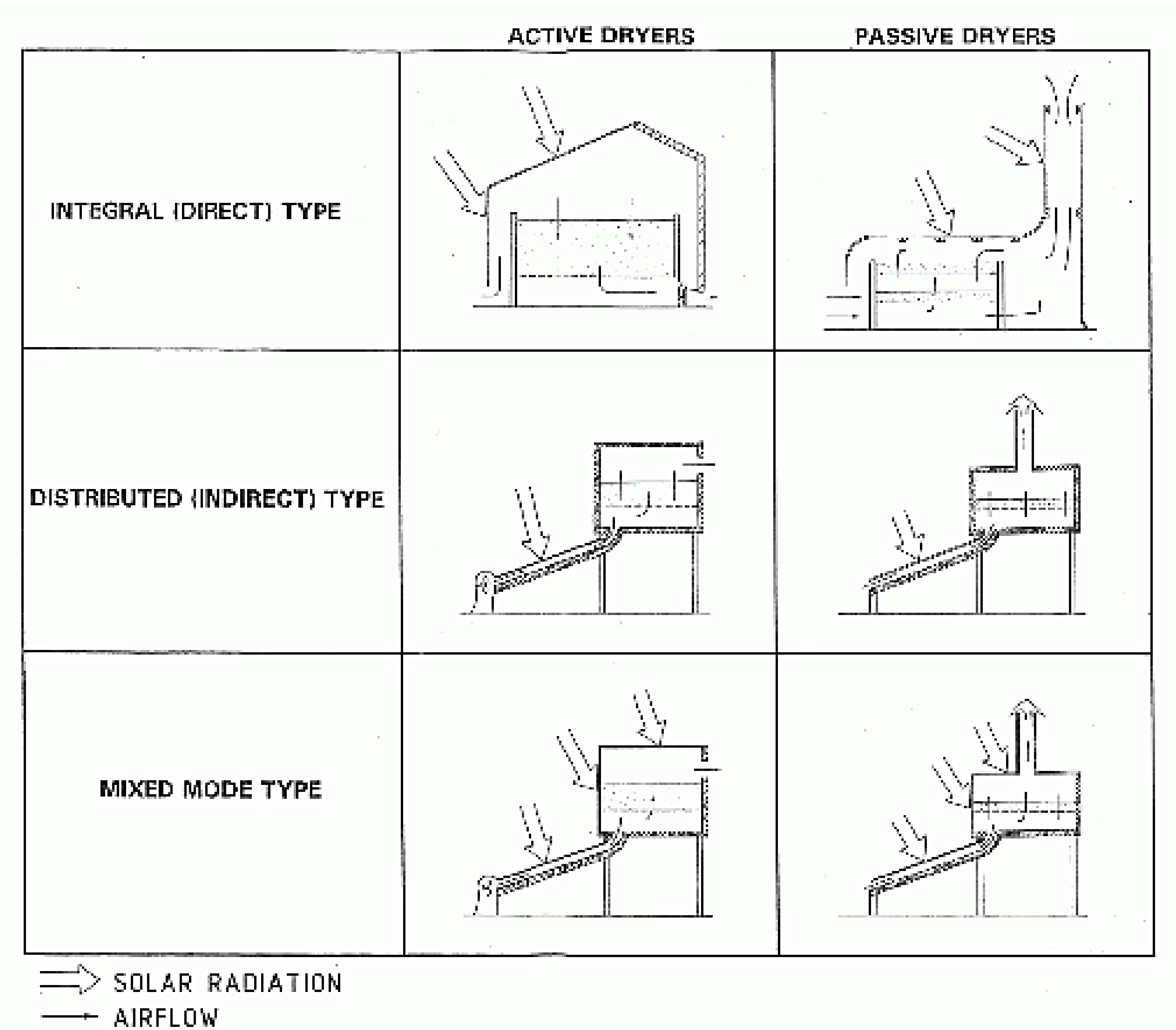

ACTIVE DRYERS
PASSIVE DRYERS
INTEGRAL (DIRECT) TYPE
DISTRIBUTED (INDIRECT) TYPE
MIXED MODE TYPE
SOLAR RADIATION
AIRFLOW

Figure 1

Design 1: Solar Dehydration (direct/active)

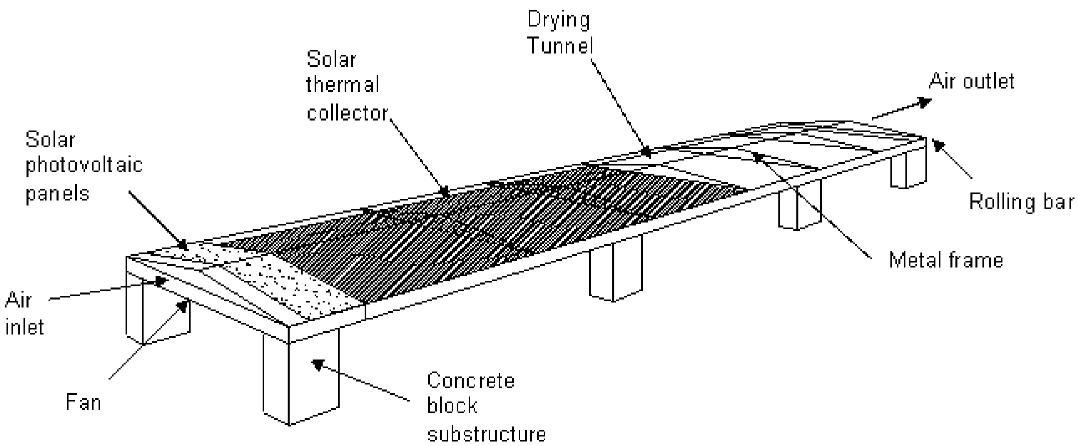


Figure 2

Figure (2) depicts and example of a direct and active solar dryer. A transparent top allows the sun to radiate directly to the contents. Generally this type of system has a wide area, and a small height, allowing the sun to quickly heat it. Because of this set up, there is no natural convection, so fans are used to force airflow (hence: active system). Creation and operation is relatively simple, as it is a single chamber with the addition of fans. Airflow can effectively function in many conditions, but the heating element is completely weather dependent and it cools down very quickly at night. Direct sunlight can also cause depletion of nutrients in the fruits and vegetable, along with discoloration that is not desirable. A single layer limits the throughout to only be effective for very small operations.

Design 2: Solar Dehydration (direct/passive)

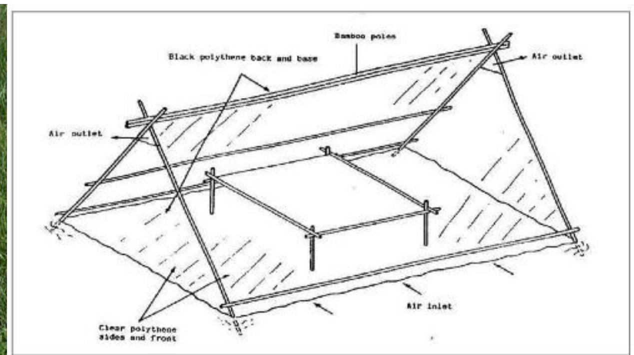


DIAGRAM OF TENT SOLAR DRYER

Figure 3 **Figure 4**

Above, two different types of direct and passive solar dehydrators are shown. Figure (3) is a cabinet style, and Figure (4) is a tent style. These are two similar concepts that both utilize direct sunlight as the source of heat for the contents as the top is transparent. Passive airflow is created by convection, as each have either holes in Figure (3) or a vent Figure (4) on the bottom, and small outlets at the top to allow the hot air to rise and then escape. Both are very simple, having only a single area where the food is held. They are a cheap method for dehydration that is not only simply to construct, but also very simple to operate, and also easy to see when the contents are dried. Direct heating can be efficient and produce fast drying when the sun is able to quickly heat the fruit. This type of design, however, does not promote abundant airflow, immediately cools down when the sun sets, and cannot performance in conditions with cloud coverage. The direct sunlight can also cause depletion of nutrients in the fruits and vegetable, along with discoloration that is not desirable. They also are limited in size, and therefore cannot generate a large amount of output

Design 3: Solar Dehydration (indirect/active)

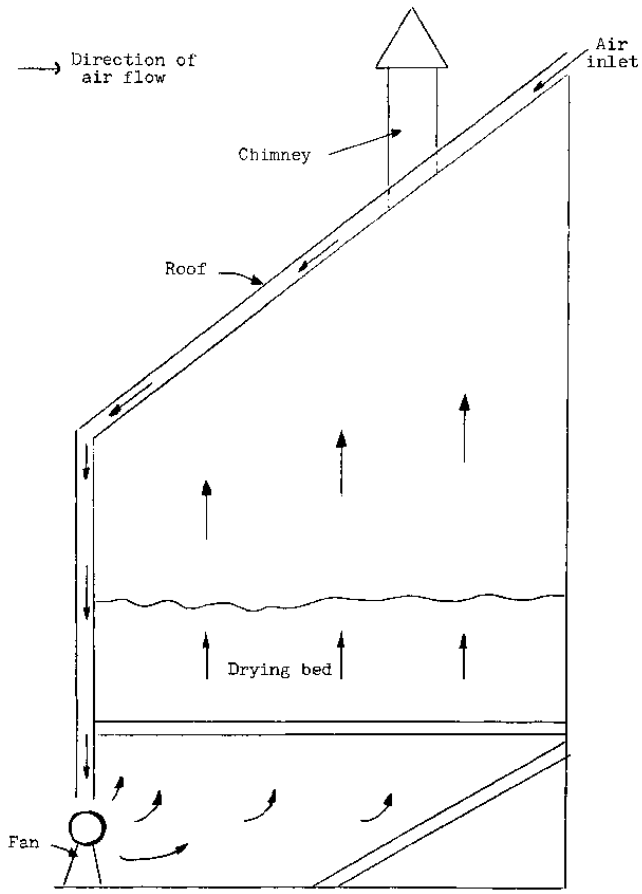


Figure 4

An example of an indirect and active solar dehydrator is shown in Figure (5). A key component of this type of design is the fan, usually located near the bottom of the chamber, causing air to cycle through and aid in the drying of the fruit. Heat inside the chamber is achieved through insulated walls that are heated by the sun throughout the day. The size of this type of system is taller than any of the direct systems because it can be more than one layer deep inside the chamber, meaning a larger quantity of food can be dried. Nutrients of the food are also better preserved without the direct sunlight and the airflow is not dependent on the weather, and it is able to hold the heat slightly longer into the night. Disadvantages include a higher cost, risk of electrical issues, and safety with the fans.

Design 4: Solar Dehydration (indirect/passive)

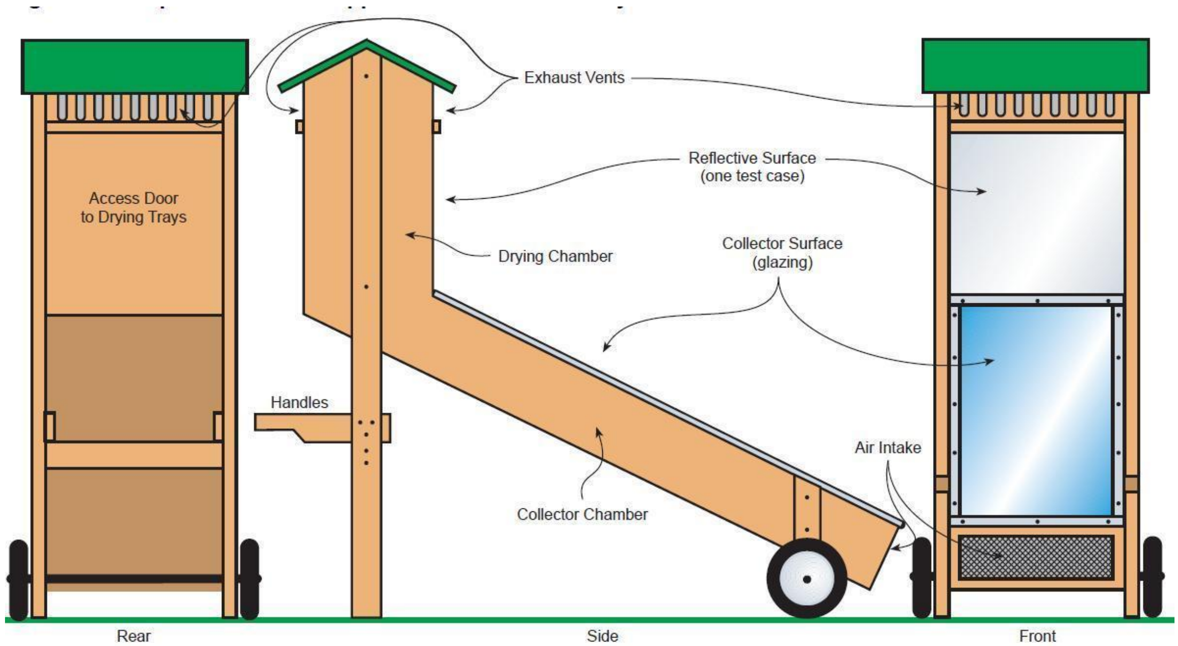


Figure 5

Indirect and passive systems for dehydration are perhaps the most widely used, and also the type that is currently successfully in use at the nutrition center near Panyebar. Figure (6) shows an example of this system that went through extensive testing of different variables at Appalachian University. The heat collector heats the air, which then travels through the drying chamber by convection and then rises out of the vents at the top of the system. This type of system is still able to function when there is some cloud coverage because it is not completely dependent on direct sunlight, but it does struggle to stay warm into the night hours. It can output a larger amount of content than the direct methods for the same reasons Design C, and the fruit also is not at risk of losing nutrients in the chamber, as it would be in a directly heated system. Additional disadvantages associated with this design are higher costs than direct (but lower than Design C) and it is more complex to assemble.

E. Design 5: Solar Dehydration (mix/passive)

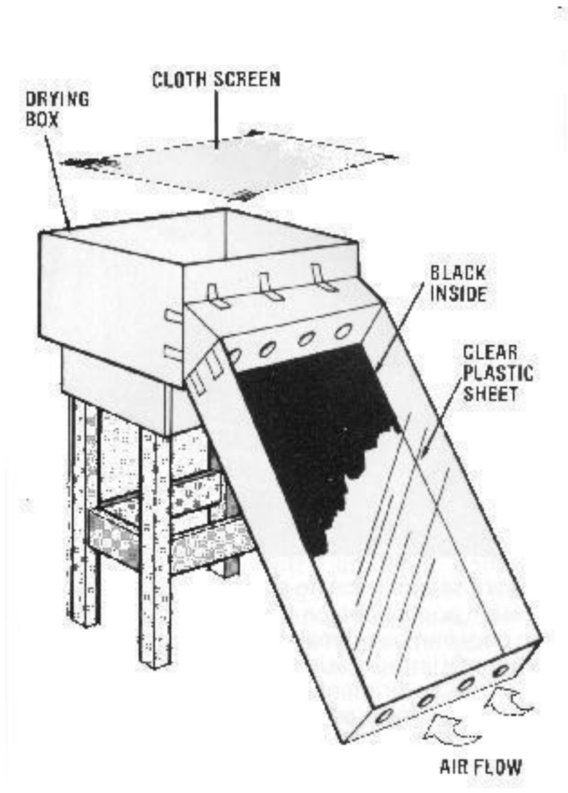


Figure 6

A mixed solar dehydrator seen in Figure (7) represents using direct sun to dry the fruit and a heat collector attached. This method utilizes the energy from the sun more efficiently by collecting it on more surfaces, one of the surfaces being the fruit directly. Utilizing the heat collector can help create more air flow through natural convection moving from the heat collector and through the heating chamber. This design adds little complexity to the previously discussed passive direct solar dryer while adding more efficiency. With a greater absorption of solar rays the drying time can be greatly decreased. There would be limitations placed on the amount of racks put in the drying chamber because racks below would not be getting direct sunlight and would dry much slower. Direct sunlight to the fruit can once again cause the depletion of some essential nutrients to the fruit.

Decision Matrix

Table 2

		Conceptual Design										
		Rating (1-5)					Rating X Weighting Factor					
Evaluation Criteria	Weight Factor	SD A	SD B	SD C	SD D	SD E	SD A	SD B	SD C	SD D	SD E	Ideal
Function	3	2	2	4	3	3	6	6	12	9	9	15
Cost	3	3	5	2	3	2	9	15	6	9	6	15
Delivery Date	2	5	5	5	5	5	10	10	10	10	10	10
Environment	3	5	5	5	5	5	15	15	15	15	15	15
Safety	3	3	5	3	4	4	9	15	9	12	12	15
Size	2	3	3	3	3	3	6	6	6	6	6	10
Aesthetics	1	3	3	4	4	4	3	3	4	4	4	5
Personnel	3	3	3	4	4	4	9	9	12	12	12	15
Service life	2	2	4	2	4	4	4	8	4	8	8	10
Noise	1	4	5	4	5	5	4	5	4	5	5	5

Energy	2	4	5	4	5	5	8	10	8	10	10	10
Reliability	3	2	1	4	4	3	6	3	12	12	9	15
Maintenance	3	3	4	3	4	4	9	12	9	12	12	15
Quality	3	3	2	4	4	4	9	6	12	12	12	15
Human factors	1	3	3	4	4	4	3	3	4	4	4	5
Health Issues	3	2	2	4	3	2	6	6	12	9	6	15
Operating Instructions	3	5	5	5	5	5	15	15	15	15	15	15
Operating Costs	2	4	5	3	5	5	8	10	6	10	10	10
Totals							139	157	160	174	165	215

Table (2) shows a complete rating of each of our potential designs. The left column describes our design parameters considered for this project and then the weighting factor that determines which parameter is more highly valued. Each design, A-E, is then ranked on a scale from one to five. Weighting factor is then considered in the following five columns with the ideal scores in the far right column. One design with the highest score can be seen highlighted in green with a total score of 174. This design was the indirect/passive solar dehydrator also in Figure (6). Based on our design parameters this design has shown to balance being the most effective and yet cost efficient.

Looking at the most important factors, it can be seen that concept C was the best functioning dehydrator. Although this should make it the best choice for us, the given parameters like availability to power and safety does not make this choice the best. Concept A was a simple design that allows heat to quickly get to the fruit. There is no natural convection making this the worst choice because of the type of crops that will be dehydrated. moist fruit and vegetables contain a lot of moisture and this is why fruits and vegetables mold quickly. Concept B was the simplest and most cost effective concept on our list. This dehydrator does its job, but only in certain conditions. There must be ample sun and the concept can quickly heat up, but this means that it can quickly cool down. This does not make it effective during the night where there is not thermal energy coming from the sun. Lastly, concept E also does its job effectively and is simple. The problem here is the amount of crop that can be dehydrated at a given time, so concept E is not favorable.

Mathematical Model and Analysis

Fruit and Vegetable drying is a process of removing moisture to preserve the food; it is a complex process that involves a combination of heat and mass transfer. A schematic diagram of food drying showing both transport of heat and mass is shown below if figure (7).

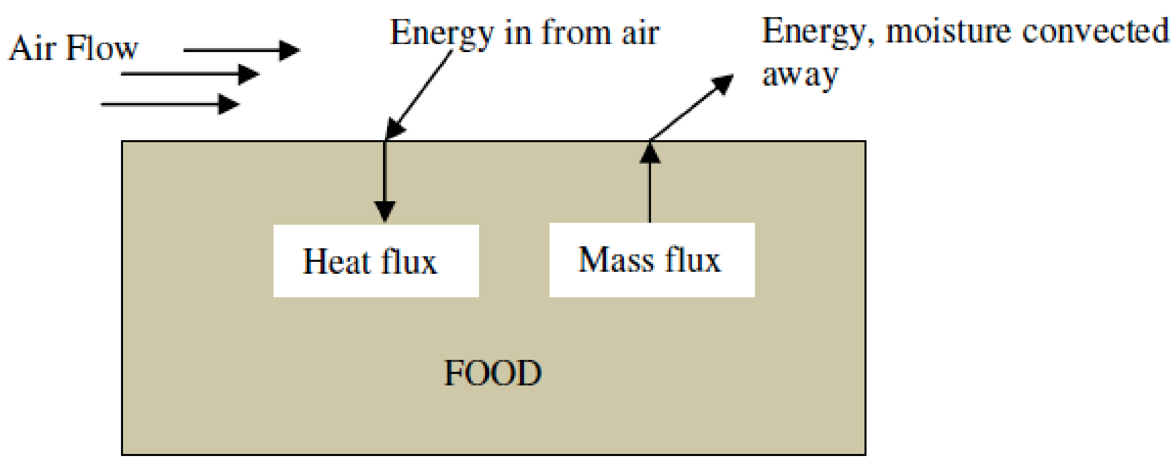


Figure 7

As seen in the diagram, heat is being transferred into the food from the warm air, while simultaneously being transferred out of the fruit via evaporation. This process is expressed using equation (1) with the heat transfer coefficient (h), the surface area (A), and mass flow ($\dot{m}$).

$$hA(T_b - T_\infty) - \dot{m}h_{fg} = \dot{m}C_p(T_b - T_\infty) \tag{1}$$

In order for the design to function properly by natural convection the material properties and geometry of the heat collector are important when considering the flow of heat. The ideal Tilt angle is found from the known latitude of the location for collecting solar radiation seen in equation (1).

$$\text{Tilt Angle} = \text{Latitude} \times 0.87 \tag{2}$$

This produces a desired tilt angle of approximately 12 degrees. We then decided to elevate the tilt angle up to 26 degrees in order to assist with the flow of heat into the drying chamber. Another task is to contain the heat through the night when there is lower temperatures. Thermal mass will absorb heat energy from the sun during the day and retain heat longer into the night. Materials with high heat capacities such as rock and sand will be utilized as thermal mass. Heat capacity is calculated by the following formula seen in equation (2). The contributing variables for specific heat are the mass (m), specific heat (C), and temperature (T).

$$H = mC(T1 - T2) \tag{3}$$

The heat capacity of a thin bed of rock vs. a sheet of steel shows that the rock will be able to hold approximately seventeen times more heat energy. (Hs = 366BTU, Hr = 6,390BTU). Insulation will then be vital in directing and maintaining the heat into the drying chamber. Knowing the thermal resistance can be used to find the effectiveness of the insulation and can be found by equation (3).

$$R = L / kA \tag{4}$$

Thermal resistance (R) is found by the length (L), or thickness of the material, divided by the multiplication of the conductivity (k) and the area (A) of the wall. Putting a quarter in layer of plywood and inch inside for insulation increases the thermal resistance by six. This calculated increase is not even considering the plastic bags inserted in the insulation space.

Building/Instructions

The dehydrator was manufactured using electric tools and some modern machines. A full list of tools is listed in Appendix A. Some of our features include space for thermal mass, double walls for space for insulation on the side panels, and vents that slide to adjust air flow. Most of the dehydrator was built with availability of materials in mind. All of the features on our dehydrator can be built in Guatemala.

Building the dehydrator out of wood made for better insulation during the time where there is no sun, where metal would quickly cool down the drying chamber. This is also why we incorporated space for thermal mass to contain heat during that time. A lot of the materials we used to build our dehydrator can be swapped out for different materials that are readily available in Guatemala. The aluminum sheet that covers the thermal mass can be changed with metal roofing and the Plexiglas can be exchanged out with any clear plastic sheet. The dehydrator is mostly made out of pine but in Guatemala there is an abundance of cedar which would be an improvement because bugs to not like cedar wood. Our design is the model that other dehydrators should be based on.

The manufacturing of the dehydrator was somewhat difficult. As we added more features onto our design it got heavier and at the end of building, two people were needed to move the dehydrator around. Our design can be modified to fit the environment it is placed in, meaning the materials can be interchanged as stated above. The design took about a month to go from stock to a working dehydrator and it was well worth the wait. Our design and prototype created delicious dried bananas.

Testing

Once the dehydrator was built, testing was the next step. The dehydrator was placed in greenhouses for the initial test, and successfully dried banana slices in less than 24 hours. During this time the sky was very cloudy, and accurate temperature measurements were not collected due to lack of access in the greenhouse facility. The next test was completed outside, and temperature measurements were taken every hour in both the heat collector, and the fruit drying chamber as well as the ambient temperature. The results of this test are graphed below.

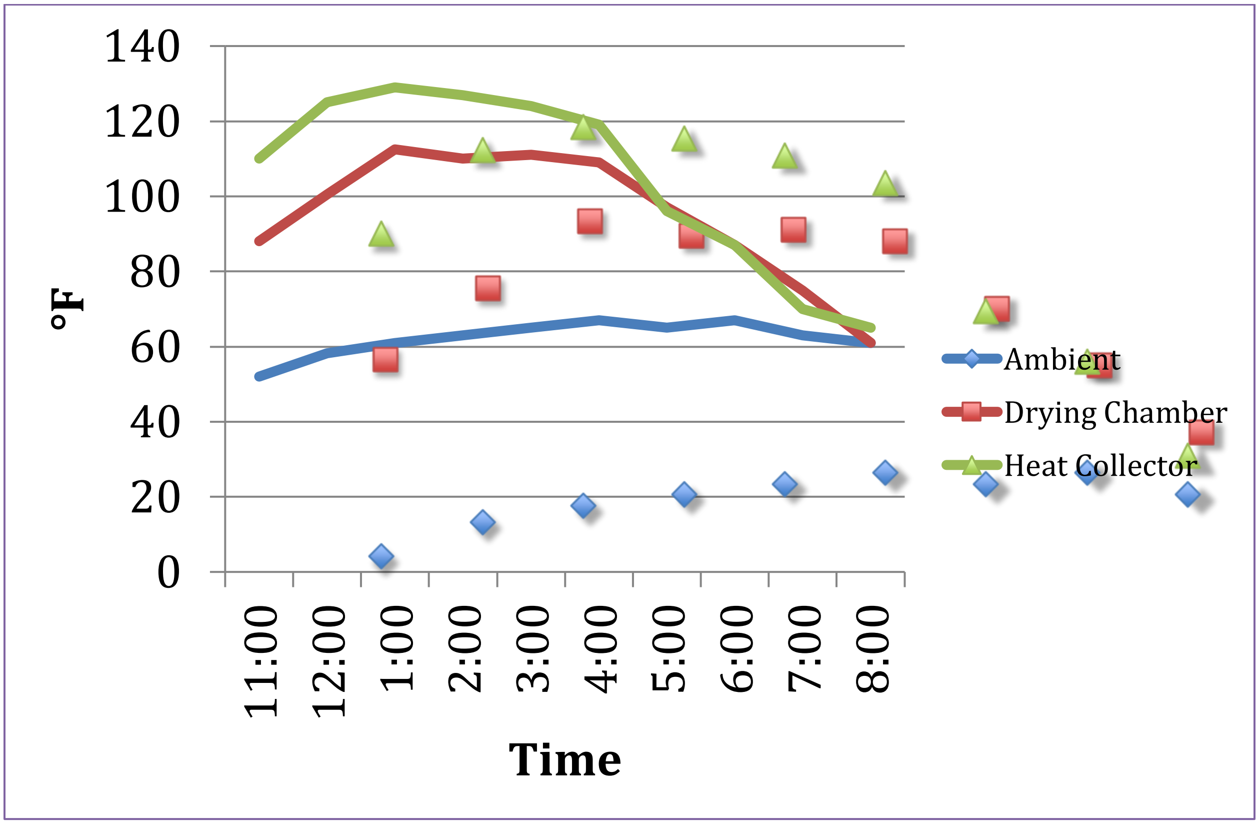


Figure 8. Temperature of the dehydrator during a trial

Direct radiation stopped hitting the heat collector at about 4pm as the surrounding buildings began to block the sunlight from reaching the dehydrator. Measurements were concluded when all the temperatures were the same, which occurred at 8pm. At the end of this time, a majority of the banana slices (aside from the thicker ones) were dried to a firm, but not yet brittle level. This leads us to believe that our projected time of between 12 and 13 hours will be an accurate approximation in the conditions in Guatemala. For best results, proper fruit preparation must be completed. Included in the appendix are directions for how thick to cut, and how to prepare many different types of food for the best results with dehydration.

Options for Improvement

There are many options that can be added to our design to make it function better. Most of the options needed to be tested to make sure they work better. Lists of possible improvements are important in any project big or small. When you stop thinking of possible improvements you stop progress. Unfortunately our group was not able to test many of the options that we have thought of because of our time constraint.

The idea of reflective panels was tossed around. What would the reflective material be? Are they going to be able to build this in Guatemala? What angle should the reflectors be set at? Does the angle need to be changed throughout the day? This idea posed many questions that we could not answer without extensive testing.

Different insulation could improve the heat stored in the dehydrator at night. Our double panel design could be incorporated on all of the outward facing sides of the dehydrator not just the sides. A different type of clear plastic could be used instead of the Plexiglas to improve insulation as well. But the Plexiglas does have a drawback. It starts to warp and bulge when it heats up creating gaps in the top of the heat collector. It expands so our group recommends cutting slots in the Plexiglas so it has room to move; adding rails to hold down the sides might be beneficial; or using something like a clear shower curtain material that is flexible.

Painting the inside of the heat collector flat black could increase solar absorption. This one needs to be tested because if a temperature inside the drying chamber reaches over 140 degrees Fahrenheit, cooking starts and the nutrients can be depleted. The aluminum sheet that covers the thermal mass could be replaced with metal roofing and painted black to maximize the surface area touching the thermal mass.

The application of heat could extend the drying time throughout the whole night. Hot stones could be added to the thermal mass. This may cause some problems with the wood so trial and error testing could be done with a test sample to make sure the dehydrator does not burn.

We were unable to dry different types of fruit other than bananas. We only tested bananas because they have a low moisture content compared to an apple or mango. This meant our drying time was reduced. We are very interested in finding out what fruit dries the best in our design. Maybe it is an apple or pineapple.

These options are just what we could come up with while building the dehydrator. With another set of eyes, so to speak, there may be different options that we have not thought of. There is always room for improvement and progress should not stop with us.

Conclusion

Solar dehydration is an effective and useful tool for preserving food. In Panyebar, Guatemala at the Childcare and Nutrition Center, they will utilize this tool in order to preserve fruit through the hungry months the community suffers. Many designs were considered including both direct and indirect heating in combination with passive and active airflow. Each different combination was analyzed in a decision matrix that showed that given specific design parameters, an indirect and passive system would be most effective for Panyebar. Beyond the classic design, a double layer for added insulation as well as a large compartment for thermal mass were included in order hold the heat longer and extend the drying time into the night. Testing in country will provide a better gage for exactly how successful these additions were, though it was able to dry fruit in relatively cool Michigan temperatures in about 10 hours, and stay warmer than the ambient temperatures between 3 and 4 hours past the time direct radiation concluded. The building instructions provided will allow this device to be recreated and utilized in Panyebar, and potentially many other areas. We hope this will be one small step in the fight to end child malnutrition.

Appendix

A. Step By Step building Instructions

Tools Required

Tape measure
Straight edge
Pencil/pen
Jigsaw
Table Saw
Circular Saw
Electric drill
1” Hole saw bit
Saw horses/table
Protractor
Staple gun
Caulk gun
Paint brush
Wrenches
Tin snips
Router
Clamps

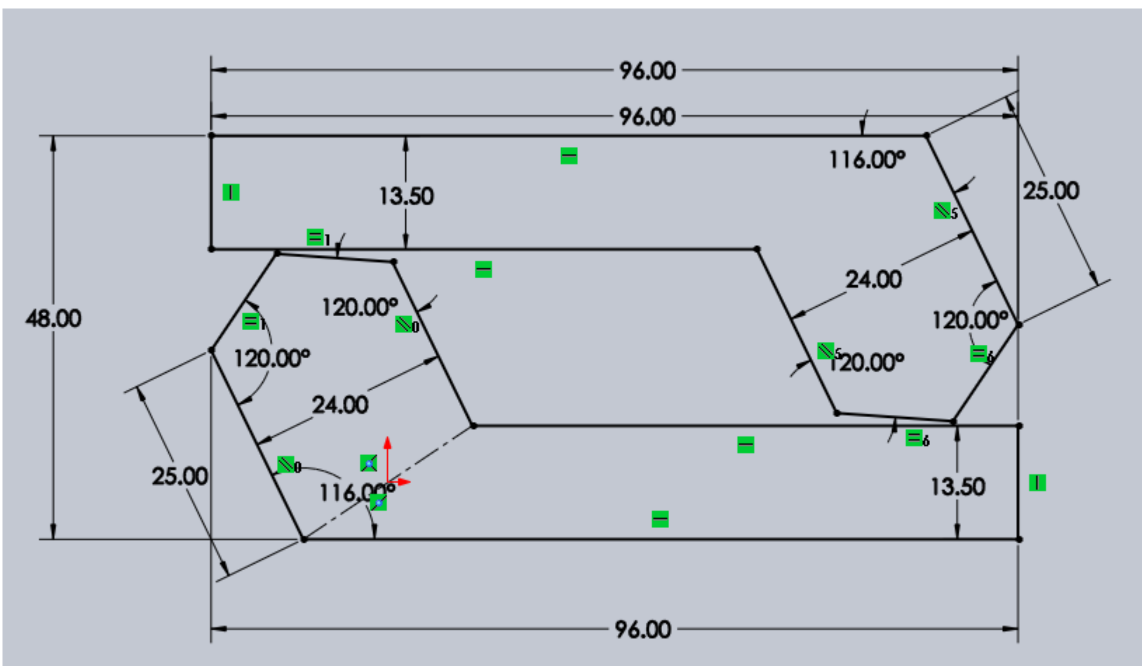
*Note: All cuts can be done with hand tools and no electricity

Materials

-2 sheets of 4x8 ¾” exterior Plywood	-Staple gun
-2 sheets of 4x8 ¼” Plywood	-8 bolts ½” x 5”
-Four 8’ 2x4s	-8 nuts (goes on bolts)
-One 8’ 2x3s	-16 washers (goes over bolts)
-Two 8’ 2x2s	-Two 8’ 4x4s (exterior grade)
-Four 8’ 1x2s	-3 door hinges
-Matte black paint	-Flat black spray paint
-Water Sealant	-Food safe screen
-2 tubes of silicone caulk	-Plexiglas or clear plastic sheet(must be large enough to lay over heat collector)
-1 ½” wood screws	-Metal lattice/mesh
-3” wood screws	-6 screw hooks
-1” wood screws	-Plastic bags

-Metal sheet(must be large enough to cover length of heat collector to drying chamber and width of the heat collector)	

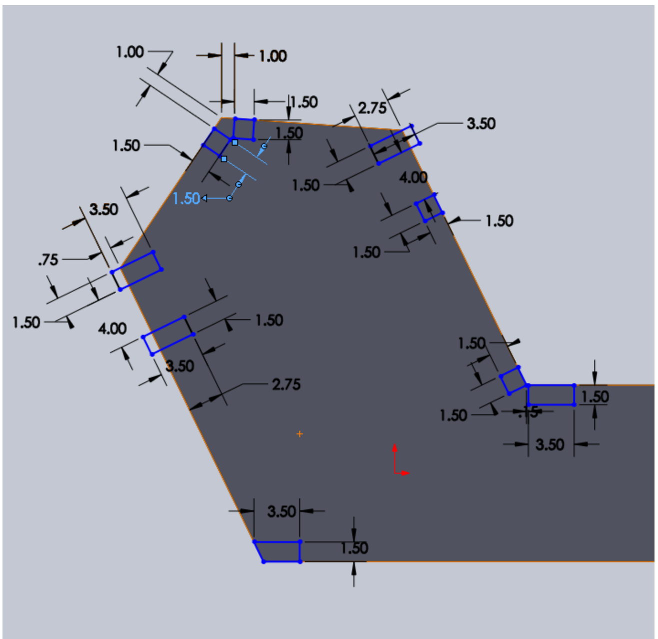
<u>Step 1:</u> Cut the outer panels out of ¾” plywood, and inner walls out of ¼” plywood

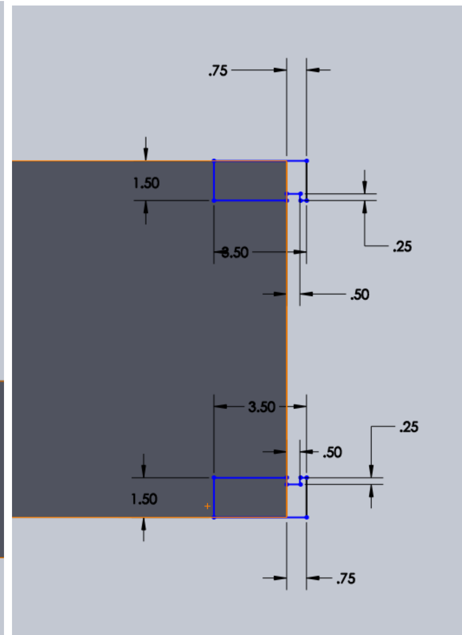


Details: Cut two sides out of ¾” plywood and two sides of ¼” plywood, all of the exact same dimensions (from the diagram, or altered to meet your desired size and production.) First, use a ruler and straight edge to mark the dimensions on the board. Then proceed to cut out the pieces using whatever method is readily available (we used a jigsaw and were careful to cut straight lines). After completing each additional piece, lay it on top of the previous piece to make sure they are the same size. Cut away any excess material.

*Note: Be careful to factor in the width of the blade when you are cutting.

<u>Step 2:</u> Cut holes in ¼” plywood sides for the 2x4 and 2x3 supports





Details: Referring to the diagram, using a ruler and a straight edge, draw the dimensions that need to be cut to fit the supports. Then carefully cut them out (again we carefully used a jigsaw.) These cuts do not have to be as precise. But a more precise cut the better, because these holes will potentially allow the warm air to escape from the inner drying chamber.

<u>Step 3:</u> Cut seven 30 in. segments 2x4s as well as three 30 in. 2x3s

Details(1): Do not measure all segments and then cut all at once. This will result in segments that are not the same length of 30”

Details(2): Some of the supports need to have at least a ½“ slot cut in them to allow the vents to slide back and forth. The supports that need to be cut are the ones that stick out.

Step 4: Waterproof all sides and supports using sealant

Details: Sealing/waterproofing the wood is important to the lifespan of the dehydrator. Water is a dehydrators worst enemy as the wood absorbs more moisture, the quicker it will warp. Simply paint on any type of wood sealant/water proofer to all sides of the wood. (Paint can also be used as a sealant if it is more easily accessed.)

*Note: Make sure that the sealer/water proofer allows it to be painted after it dries

Step 5: Connect the sides using 2x3 and 2x4 struts in the appropriate places.

Details: Follow the diagram in step 2 for proper placement of the supports. In order to avoid splitting the wood, predrill the holes into the plywood and supports Then proceed to screw all the supports together using 3” wood screws.

*Note: The ¼” in panels need to be put into place before screwing on the supports.

Step 6: Cut 1" wide blocks out as many as deemed necessary.

Details: 1" 2x2s were cut to separate the ¼"plywood from the ¾" plywood to make room for the insulation. Use 1 ½"nails to secure the ¼"plywood through the spacer to the ¾ "plywood.

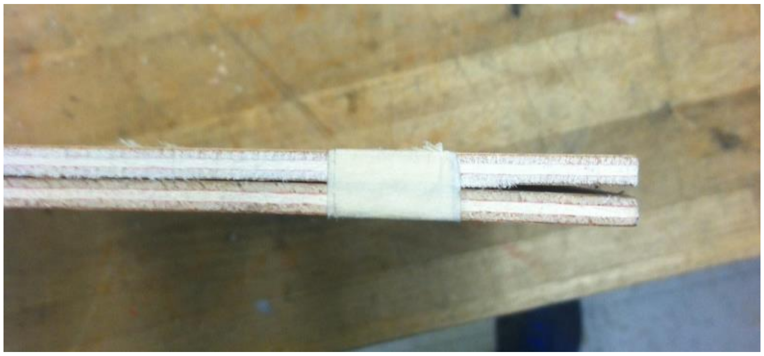
*Note: Depending on how well you cut the ¼" side panels, you might need to sand the ¼" to make sure all of the panels cut in later steps fit flat on the ¾".

Step 7: Installing the bottom of the dehydrator

Details: Using a straightedge and a ruler, mark the dimensions of the bottom on your ¾ inch plywood. Measure the full width of the dehydrator and the length of the bottom. Then cut the shape out (again we used a jigsaw.) Finally, pre drill holes every 6 inches and screw into the ¾ inch plywood.

Step 8: Cut the front and back of the dehydrator

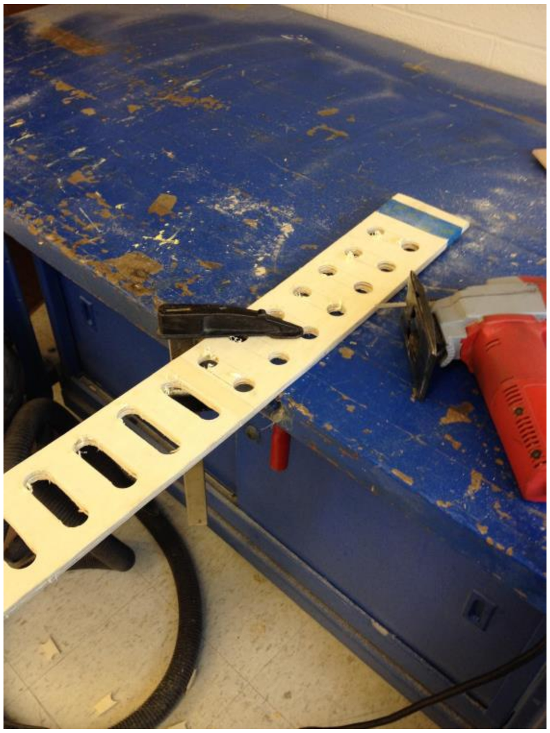
Details: Using a straightedge and a ruler, mark the dimensions of the front on your ¾ inch plywood from the bottom of the vent to the top of the heat collector. Then cut the shape out. Do the same thing for the back and measure from the bottom of the back vent to the bottom of the dehydrator. Then cut the shape out, but do not attach the front panels. We will attach them later.



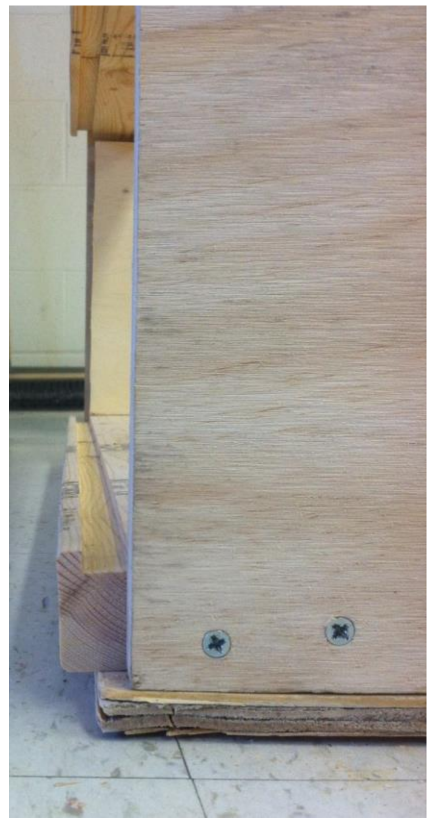
Step 9: Create and install vents for bottom and top and install the front panel.

Details(1): Take two pieces of ¼” plywood for each vent and measure out the width of the dehydrator and the height of the desired vent. The vent should overlap the height of the opening because they are designed to slide. Cut out the overall shape of the vent.

*Note: Bond the overall vent shape with tape. It makes the later processes easier.



Details(2): Drill “ holes as pictured left. Each hole needs to be in line with each other. Cut the slots to create the vents. Cutting two at a time allows for identical holes with no gaps when you slide them. Sand to remove rough edges.



Details(3): ½ “Slots must be cut in the supports to allow the vents to slide. This is why the vents are cut larger than the opening on the top and bottom. Last, cut/sand to allow the vents to slide with minimal force.

*Note: The top front vent uses the front ¾ “ panel as the bottom slide.

Details(4): We temporarily nailed in the front panel to install the top front vent. After you have the front vent sliding, 1” screws are used to attach the front panel to the ¾” side panels. One screw every 6” around the perimeter of the front panel. Attach knobs to all sliding portions of the vents.

Step 10: Installing screen for vents.

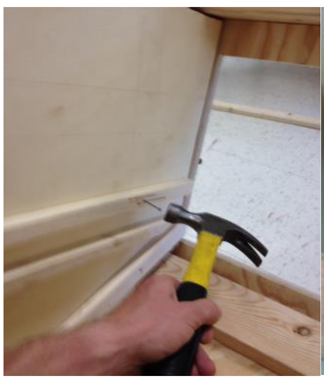
Details: Before nailing in the fixed portion of the vents wrap the backside in window screen to prevent bugs from entering the dehydrator. Make sure you cut the screen larger than the vent.

*Note: There are different ways to do this. We placed two pieces of wood on the top and bottom and glued them down on the screen.

Step 11: Install metal sheet supports with 1x2s.

Details: Measure the length of the heat collector from the bottom of the large vent to the back of the drying chamber. Cut two 1x2s and nail them into the ¼" side panels. Make sure the rails are at an angle to allow room for thermal mass. When nailing in the rails be sure to have your 1" spacer so the rails have something to be nailed to.

Step 12: Install shelf supports with 1x2s.



Details(1): Cut 1" strip to allow shelf supports to be nailed to the ¼" side panels. We cut a 2x2 lengthwise to 1" thick. Nail in the 1" spacers before nailing in the shelf supports to hold the spacers into place.

Details(2): Measure the length of the drying chamber and cut 1x2s according to your measurements. Make sure you have room for 5 trays that will be spaced out about ¾" to 1". Keep in mind the rails for the metal sheet.

*Note: Mark with pencil with all the projected placements of the tray supports to make sure they are evenly spaced.

Step 13: Cut and install the door.

Details(1): Measure out a 2" border inside of the back panel. Drill holes in the corners of the border using a wood drill bit that is large enough to accommodate a jig saw blade.

Details(2): Using a jig saw cut the door out keeping in mind that there will be no waste on this cut.

Details(3): Measure out the placement for the hinges and locking mechanism. We marked all the holes for the screws first, pilot drilled the holes, then attached the hardware.

Details(4): Using 1” screws spaced 6” around the perimeter attach the door and frame to the back of the drying chamber.

*Note: After the door is cut sanding may be necessary for the door the open and close smoothly. Also it is not necessary to use three hinges.

<u>Step 14:</u> Installing the metal sheet for above the thermal mass.

Details(1): Measure the width and length of the heat collector going all the way to the door to the drying chamber. Cut a metal sheet to fit inside to separate the thermal mass from the rest of the dehydrator.

*Note: If a large enough sheet is not found, like with our dehydrator, one must be put together is pieces.

Details(2): The pieces must overlap to be bolted together. Line up your metal and drill holes 3” to 4” apart through both sheets. The holes should be just large enough so small bolts are able to fit through the holes.
Details(3): Attach the two sheets with small bolts and nuts to create a large enough sheet to be placed on top of the thermal mass rails. Lay the sheet on the rails you installed in the previous step. Drill holes in the metal sheet about 6” apart from each other. Take 1” screws and attach the metal sheet to the rails.

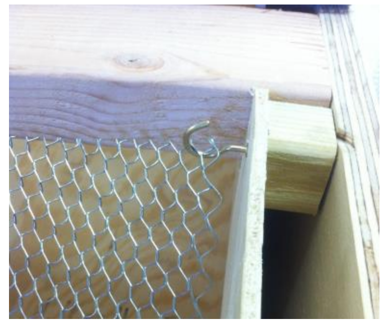
<u>Step 15:</u> Installing legs.

Details(1): Measure and cut 2 legs at 5 ½ feet and 2 legs that are 2 ½ feet for the dehydrator to stand. The length of the legs needs to be tall enough for the dehydrator to be off the ground.

Details(2): Drill holes through the 4x4s and all the way through the side panels. Using ½“bolts and nuts attach the legs.

Step 16: Installing metal mesh.

Details: Measure the from the bottom corner of the vent to the top of the heat collector. Cut the metal mesh to fit inside. Cut as many pieces as desired (we used 4).Take 6 screw hooks (3 on each side) and hand screw them into the sides of the ¼" plywood. Before installing the mesh, spray paint each layer of the mesh flat black to allow for better heat absorption.



Step 17: Create the drying racks.

Details: This dehydrator can fit 5 racks. To create these, we split 1x4 wood in half, and cut them to the two needed lengths (27.5 inches long and 22.5 inches long.) Once you have the wood cut to size, create an overlapping joint for strength. This requires cutting halfway into both ends of each piece so they can lock together as shown. We did this using a table saw, but it could also be done with any sort of hand tools. Then, use waterproof glue and screws to secure the corners. Last, staple food safe screening down to the wood.

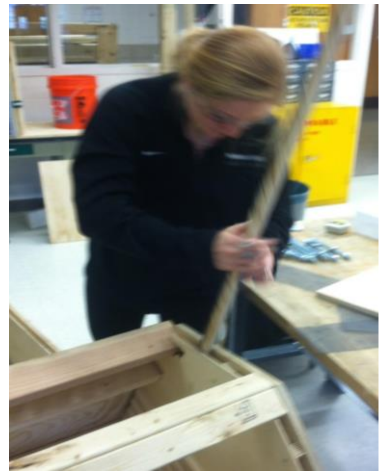
Step 18: Paint the dehydrator and caulk outside in

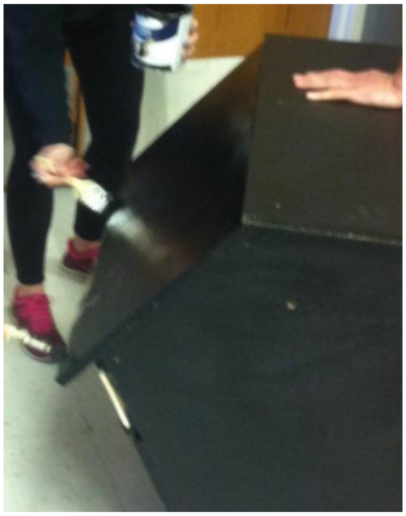
Details: All the sun facing panels need to be painted black and all gaps need to be caulked to weather the dehydrator.

*Note: You do not need to paint the underside. We also caulked the metal sheet to protect the thermal mass

Step 19: Insert plastic bags/insulation.

Details: Insert plastic bags. We used grocery bags.





Step 20: Installing roof.

Details: Measure two roof panels to go on both sides of the top of the drying chamber. The measurements should be from the peak the vent supports. Make the roof larger than the space that needs to be covered in order for rain to be directed away from the dehydrator.

Step 21: Installing the Plexiglas cover.

Details: Measure the top of the heat collector from each edge. Cut your cover accordingly and lay on top to make sure it fits. Drill holes for screws to fit into about every 6” on the perimeter. Use 1” screws to fix the covert to the dehydrator.

*Note: We used screws with little to no bevel head on them so as not to crack the Plexiglas.
**Note: If you do not have a full sheet like we did not. Section the Plexiglas and caulk to finish weathering.

Step 22: Cut fruit and enjoy.

Details: You now have a dehydrator built. Place your trays inside with fruit cut. Angle your dehydrator in direct sunlight wait for about 10-16 hours, depending on the fruit type and thickness, and enjoy.

Bibliography

"Why the First 1,000 Days Matter." HMHB RSS. N.p., 06 Mar. 2014. Web. 07 May 2015.

"World Food Programme." Guatemala. N.p., n.d. Web. 07 May 2015.

"Solar Dryer." Solar Dryer. N.p., n.d. Web. 07 May 2015.

"| Practical Action." | Practical Action. N.p., n.d. Web. 07 May 2015.

"Small-Scale Maize Milling: CHAPTER II. GRAIN PREPARATION: III. DRYING: III.2 Drying Methods." Small-Scale Maize Milling: CHAPTER II. GRAIN PREPARATION: III. DRYING: III.2 Drying Methods. N.p., n.d. Web. 07 May 2015.

"News." Guatemala: My Future in My First Centimeters. N.p., n.d. Web. 07 May 2015.

Eurotherm Seminar 77 – Heat And Mass Transfer In Food Processing, and June 20-22 2005 Parma Ita. June 20-22, 2005 Parma, Italy EXPERIMENTAL DETERMINATION OF HEAT TRANSFER COEFFICIENTS IN BANANA PUREE (n.d.): n. pag. Web.

"How to Find the Best Solar Panel Angle or Tilt Angle - Solar Panels Photovoltaic." Solar Panels Photovoltaic. N.p., 05 Dec. 2013. Web. 07 May 2015.

Building Instructions

Tools Required

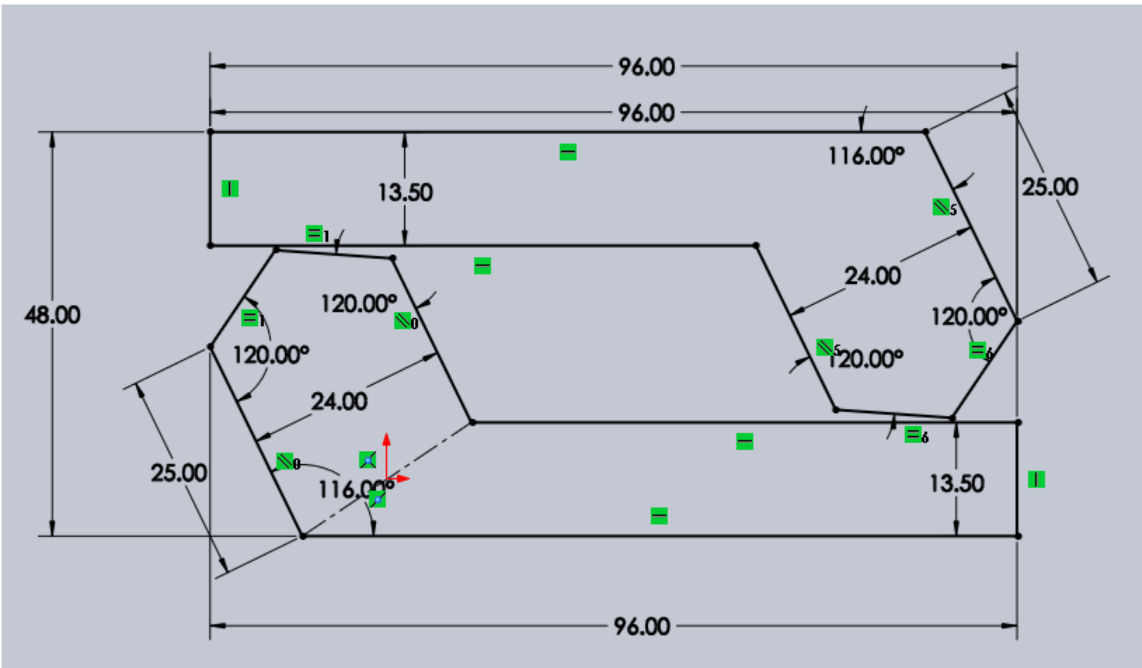
Tape measure
Straight edge
Pencil/pen
Jigsaw
Table Saw
Circular Saw
Electric drill
1” Hole saw bit
Saw horses/table
Protractor
Staple gun
Caulk gun
Paint brush
Wrenches
Tin snips
Router
Clamps

*Note: All cuts can be done with hand tools and no electricity

Materials

-2 sheets of 4x8 ¾” exterior Plywood	-Staple gun
-2 sheets of 4x8 ¼” Plywood	-8 bolts ½” x 5”
-Four 8’ 2x4s	-8 nuts (goes on bolts)
-One 8’ 2x3s	-16 washers (goes over bolts)
-Two 8’ 2x2s	-Two 8’ 4x4s (exterior grade)
-Four 8’ 1x2s	-3 door hinges
-Matte black paint	-Flat black spray paint
-Water Sealant	-Food safe screen
-2 tubes of silicone caulk	-Plexiglas or clear plastic sheet(must be large enough to lay over heat collector)
-1 ½” wood screws	-Metal lattice/mesh
-3” wood screws	-6 screw hooks
-1” wood screws	-Plastic bags
-Metal sheet(must be large enough to cover length of heat collector to drying chamber and width of the heat collector)	

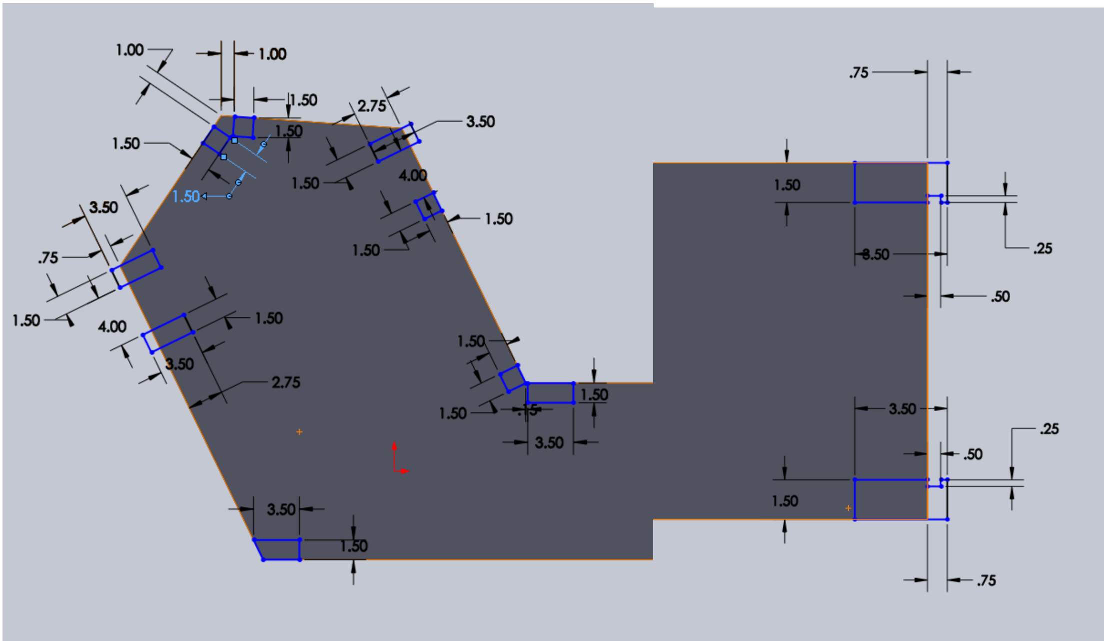
Step 1: Cut the outer panels out of ¾” plywood, and inner walls out of ¼” plywood



Details: Cut two sides out of ¾” plywood and two sides of ¼” plywood, all of the exact same dimensions (from the diagram, or altered to meet your desired size and production.) First, use a ruler and straight edge to mark the dimensions on the board. Then proceed to cut out the pieces using whatever method is readily available (we used a jigsaw and were careful to cut straight lines). After completing each additional piece, lay it on top of the previous piece to make sure they are the same size. Cut away any excess material.

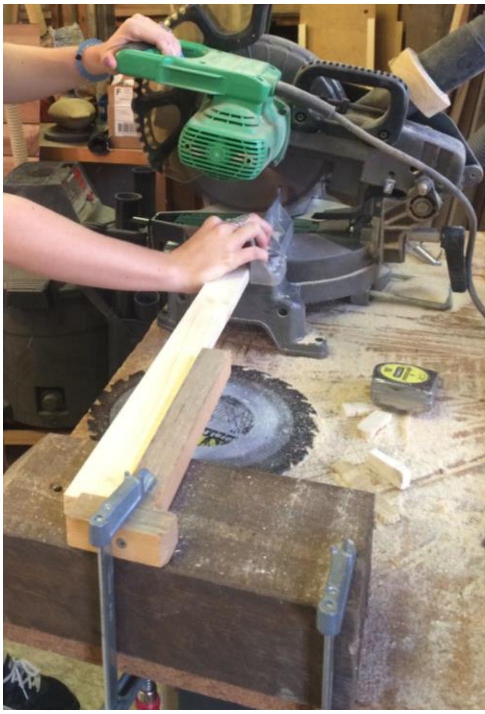
*Note: Be careful to factor in the width of the blade when you are cutting.

<u>Step 2:</u> Cut holes in ¼” plywood sides for the 2x4 and 2x3 supports



Details: Referring to the diagram, using a ruler and a straight edge, draw the dimensions that need to be cut to fit the supports. Then carefully cut them out (again we carefully used a jigsaw.) These cuts do not have to be as precise. But a more precise cut the better, because these holes will potentially allow the warm air to escape from the inner drying chamber.

<u>Step 3:</u> Cut seven 30 in. segments 2x4s as well as three 30 in. 2x3s



Details(1): Do not measure all segments and then cut all at once. This will result in segments that are not the same length of 30”

Details(2): Some of the supports need to have at least a ½“ slot cut in them to allow the vents to slide back and forth. The supports that need to be cut are the ones that stick out.

Step 4: Waterproof all sides and supports using sealant

Details: Sealing/waterproofing the wood is important to the lifespan of the dehydrator. Water is a dehydrators worst enemy as the wood absorbs more moisture, the quicker it will warp. Simply paint on any type of wood sealant/water proofer to all sides of the wood. (Paint can also be used as a sealant if it is more easily accessed.)

*Note: Make sure that the sealer/water proofer allows it to be painted after it dries

Step 5: Connect the sides using 2x3 and 2x4 struts in the appropriate places.

Details: Follow the diagram in step 2 for proper placement of the supports. In order to avoid splitting the wood, predrill the holes into the plywood and supports Then proceed to screw all the supports together using 3” wood screws.

*Note: The ¼” in panels need to be put into place before screwing on the supports.

Step 6: Cut 1” wide blocks out as many as deemed necessary.

Details: 1” 2x2s were cut to separate the ¼“plywood from the ¾” plywood to make room for the insulation. Use 1 ½“nails to secure the ¼“plywood through the spacer to the ¾ “plywood.

*Note: Depending on how well you cut the ¼” side panels, you might need to sand the ¼” to make sure all of the panels cut in later steps fit flat on the ¾”.

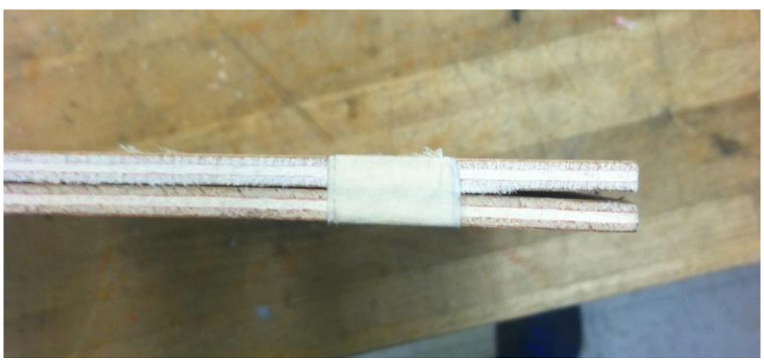
Step 7: Installing the bottom of the dehydrator

Details: Using a straightedge and a ruler, mark the dimensions of the bottom on your ¾ inch plywood. Measure the full width of the dehydrator and the length of the bottom. Then cut the shape out (again we used a jigsaw.) Finally, pre drill holes every 6 inches and screw into the ¾ inch plywood.

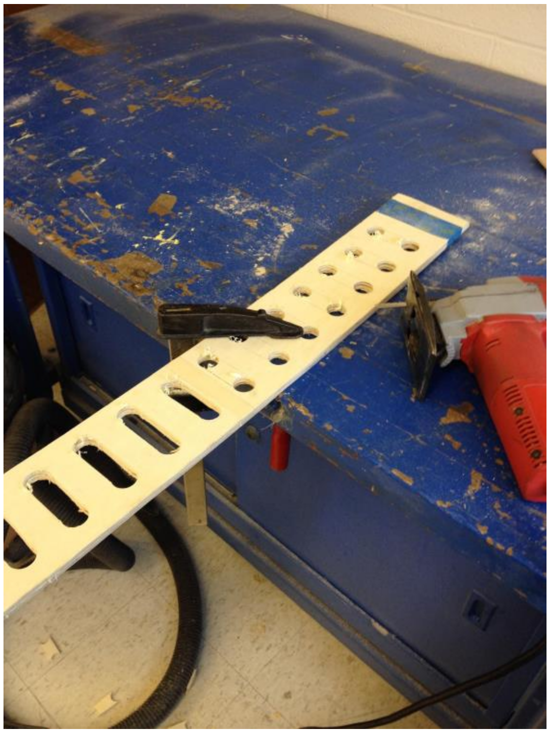
Step 8: Cut the front and back of the dehydrator

Details: Using a straightedge and a ruler, mark the dimensions of the front on your ¾ inch plywood from the bottom of the vent to the top of the heat collector. Then cut the shape out. Do the same thing for the back and measure from the bottom of the back vent to the bottom of the dehydrator. Then cut the shape out, but do not attach the front panels. We will attach them later.

Step 9: Create and install vents for bottom and top and install the front panel.



Details(1): Take two pieces of ¼" plywood for each vent and measure out the width of the dehydrator and the height of the desired vent. The vent should overlap the height of the opening because they are designed to slide. Cut out the overall shape of the vent.



*Note: Bond the overall vent shape with tape. It makes the later processes easier.

Details(2): Drill “ holes as pictured left. Each hole needs to be in line with each other. Cut the slots to create the vents. Cutting two at a time allows for identical holes with no gaps when you slide them. Sand to remove rough edges.

Details(3): ½ “Slots must be cut in the supports to allow the vents to slide. This is why the vents are cut larger than the opening on the top and bottom. Last, cut/sand to allow the vents to slide with minimal force.

*Note: The top front vent uses the front ¾ “ panel as the bottom slide.

Details(4): We temporarily nailed in the front panel to install the top front vent. After you have the front vent sliding, 1” screws are used to attach the front panel to the ¾” side panels. One screw every 6” around the perimeter of the front panel. Attach knobs to all sliding portions of the vents.

<u>Step 10:</u> Installing screen for vents.

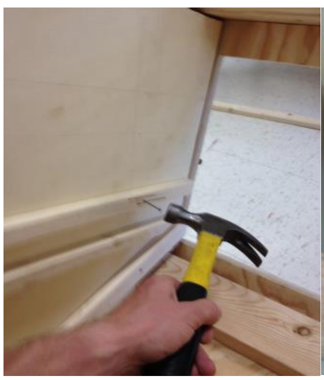
Details: Before nailing in the fixed portion of the vents wrap the backside in window screen to prevent bugs from entering the dehydrator. Make sure you cut the screen larger than the vent.

*Note: There are different ways to do this. We placed two pieces of wood on the top and bottom and glued them down on the screen.

<u>Step 11:</u> Install metal sheet supports with 1x2s.

Details: Measure the length of the heat collector from the bottom of the large vent to the back of the drying chamber. Cut two 1x2s and nail them into the ¼" side panels. Make sure the rails are at an angle to allow room for thermal mass. When nailing in the rails be sure to have your 1" spacer so the rails have something to be nailed to.

<u>Step 12:</u> Install shelf supports with 1x2s.

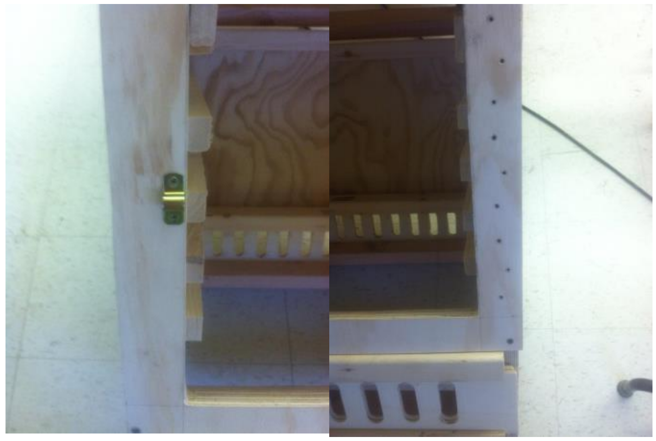


Details(1): Cut 1" strip to allow shelf supports to be nailed to the ¼" side panels. We cut a 2x2 lengthwise to 1" thick. Nail in the 1" spacers before nailing in the shelf supports to hold the spacers into place.

Details(2): Measure the length of the drying chamber and cut 1x2s according to your measurements. Make sure you have room for 5 trays that will be spaced out about ¾" to 1". Keep in mind the rails for the metal sheet.

*Note: Mark with pencil with all the projected placements of the tray supports to make sure they are evenly spaced.

<u>Step 13:</u> Cut and install the door.



Details(1): Measure out a 2” border inside of the back panel. Drill holes in the corners of the border using a wood drill bit that is large enough to accommodate a jig saw blade.

Details(2): Using a jig saw cut the door out keeping in mind that there will be no waste on this cut.

Details(3): Measure out the placement for the hinges and locking mechanism. We marked all the holes for the screws first, pilot drilled the holes, then attached the hardware.

Details(4): Using 1” screws spaced 6” around the perimeter attach the door and frame to the back of the drying chamber.

*Note: After the door is cut sanding may be necessary for the door the open and close smoothly. Also it is not necessary to use three hinges.

<u>Step 14:</u> Installing the metal sheet for above the thermal mass.

Details(1): Measure the width and length of the heat collector going all the way to the door to the drying chamber. Cut a metal sheet to fit inside to separate the thermal mass from the rest of the dehydrator.

*Note: If a large enough sheet is not found, like with our dehydrator, one must be put together is pieces.

Details(2): The pieces must overlap to be bolted together. Line up your metal and drill holes 3” to 4” apart through both sheets. The holes should be just large enough so small bolts are able to fit through the holes.

Details(3): Attach the two sheets with small bolts and nuts to create a large enough sheet to be placed on top of the thermal mass rails. Lay the sheet on the rails you installed in the previous step. Drill holes in the metal sheet about 6” apart from each other. Take 1” screws and attach the metal sheet to the rails.

<u>Step 15:</u> Installing legs.

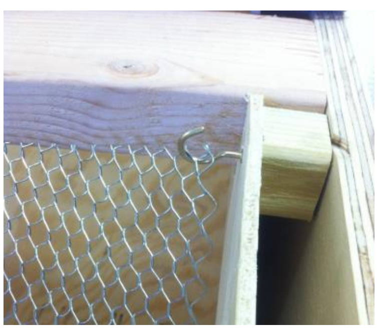
Details(1): Measure and cut 2 legs at 5 ½ feet and 2 legs that are 2 ½ feet for the dehydrator to stand. The length of the legs needs to be tall enough for the dehydrator to be off the ground.

Details(2): Drill holes through the 4x4s and all the way through the side panels. Using ½“bolts and nuts attach the legs.

*Note: You may need more than one person for this.

<u>Step 16:</u> Installing metal mesh.

Details: Measure the from the bottom corner of the vent to the top of the heat collector. Cut the metal mesh to fit inside. Cut as many pieces as desired (we used 4).Take 6 screw hooks (3 on each side) and hand screw them into the sides of the ¼“ plywood. Before installing the mesh, spray paint each layer of the mesh flat black to allow for better heat absorption.



Step 17: Create the drying racks.

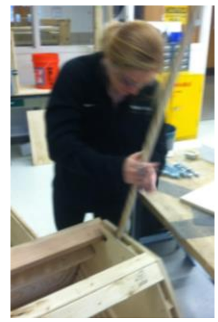
Details: This dehydrator can fit 5 racks. To create these, we split 1x4 wood in half, and cut them to the two needed lengths (27.5 inches long and 22.5 inches long.) Once you have the wood cut to size, create an overlapping joint for strength. This requires cutting halfway into both ends of each piece so they can lock together as shown. We did this using a table saw, but it could also be done with any sort of hand tools. Then, use waterproof glue and screws to secure the corners. Last, staple food safe screening down to the wood.

Step 18: Paint the dehydrator and caulk outside in

Details: All the sun facing panels need to be painted black and all gaps need to be caulked to weather the dehydrator.

*Note: You do not need to paint the underside. We also caulked the metal sheet to protect the thermal mass

<u>Step 19:</u> Insert plastic bags/insulation.



Details: Insert plastic bags. We used grocery bags.

<u>Step 20:</u> Installing roof.

Details: Measure two roof panels to go on both sides of the top of the drying chamber. The measurements should be from the peak the vent supports. Make the roof larger than the space that needs to be covered in order for rain to be directed away from the dehydrator.

<u>Step 21:</u> Installing the Plexiglas cover.

Details: Measure the top of the heat collector from each edge. Cut your cover accordingly and lay on top to make sure it fits. Drill holes for screws to fit into about every 6” on the perimeter. Use 1” screws to fix the covert to the dehydrator.

*Note: We used
no bevel head on
crack the Plexiglas.
**Note: If you do
like we did not.
and caulk to finish

screws with little to
them so as not to

not have a full sheet
Section the Plexiglas
weathering.

Step 22: Cut fruit and enjoy.

Details: You now have a dehydrator built. Place your trays inside with fruit cut. Angle your dehydrator in direct sunlight wait for about 10-16 hours, depending on the fruit type and thickness, and enjoy.