InterEGR 160 Solar Dehydrator Design Report

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Abstract

Solar dehydration is a food preservation technique that has been used for many years. The three main factors that need to be taken into account in order to dehydrate food correctly are an optimal temperature range, good airflow, and the use of food grade materials. In order to get to this temperature, you need to have the dehydrator face south, have an optimal angle, and utilize a conductive material. The optimal temperature range should be roughly between 120^{o}F and 140^{o}F and the angle should be 15^{o} in the morning and evening and 45^{o} at noon. However, it is not enough for the food to just get hot; the moisture needs to be carried away. To do this, you need to have the vents open between 3 and six inches. Lastly, in order to not contaminate the food, all materials need to be food grade. We were tasked with building a reproducible dehydrator. We initially broke down into three small groups and made prototypes that focused on the clients' needs of reproducibility, aesthetics, and nature troubles. After consolidation, we arrived at a design that combined the best elements of both, which were the efficient properties of the reproducible design and the innovative aspects of the other designs. We developed a simple way to construct it and got fairly positive test results despite the conditions. Overall, this design did not meet all of our quantitative expectations but, qualitatively it performed well and this is an effective, functional design, which can be used, tested and serves as a solid foundation for the construction of future dehydrators in a reproducible fashion.

Executive Summary

Brian Emerson from WMARS needs an easily reproducible solar powered food dehydrator to demonstrate the process of dehydrating fruits and vegetables. The design should appeal to market growers and home gardeners and convert excess produce into profit while combating current environmental problems including wind and wildlife. The client would prefer the use of passive solar energy to dry the produce within an optimal temperature range. There have been many dehydrators built over the years. Most are either updraft designs or horizontal designs. However, we consolidated and combined the two and utilized the ease of the horizontal design with the efficient properties of vertical designs and utilized certain innovative ideas to arrive at a compact, functional solar dehydrator. Our design is primarily made of wood. This includes 2’’x 6’’ pressure treated wood that makes up the frame held up by 4’’x 4’’ legs that are also pressure treated. The top consists of an acrylic panel, 2’x2’ sides and a middle support. Aluminum flashing on the bottom of this panel re-radiates the heat into the drying chamber. This chamber has 4 food trays made of 2’’x 2’’s, 1’’x 2’’s and food grade wire mesh. It allows for different distances between foods to accommodate numerous food drying needs. It also utilizes a dark chamber that keeps the food away from direct sunlight, which preserves the nutrients. There are also vents to ensure optimal airflow that passively carries moisture away from food. Also, there is weather stripping and bug netting to protect it from the elements of nature and to keep the temperature high. It is also raised from the ground just enough to load food comfortably and it is not high enough for wind to be a problem. Overall, this design is vertical, wind resistant, portable, able to hold thirty pounds of food, functional, easily cleaned, aesthetically pleasing, food grade, keeps an optimal temperature range, has removable racks, passive solar energy, a dark chamber, is wind and wildlife proof, and most importantly, it is reproducible.

Background of Solar Dehydration

Solar food drying has been used for many years partly because it offers a unique way to preserve food. It prevents waste, changes perishable food into a storable product, and it may add value to the produce which could turn it into a marketable product (Compatible Technology

International). In addition, dried foods retain nutrients and concentrate flavor (Compatible Technology International). Since solar dehydration uses the sun's "free energy, this provides unique opportunities for people in places who do not have access to conventional methods of dehydration offering them a chance to preserve their fruits, vegetables, nuts, herbs, and grains that would have otherwise spoiled.

There are many factors to take into account when dehydrating food. There needs to be good airflow, an optimal temperature range to function in, and equipment to combat the elements. These elements include humidity, bugs, loss of nutrients, and sanitation. Humidity can be combated by utilizing the natural flow of air. Humid air is less dense than dry air since water vapor makes up more of the mixture of humid air than in dry air. Dry air is made of about one fifth oxygen and four fifths nitrogen, which ends up having a molecular mass of 29 atomic units (The Engineering Toolbox, 2005). Since humid air is made up of a mixture of nitrogen, oxygen, and water vapor, this new combination yields a molecular mass of 18 atomic units (The Engineering Toolbox, 2005). Therefore, humid air will rise above dry air. In addition, it is important to take advantage of the other properties of warm air and how it can contribute to drying. Warm, dry air moves over the surface of produce, absorbs moisture, and is ultimately what dries it (Privette, 2005). Also, the higher the temperature of the air, the more moisture it will absorb, and the greater the air movement the faster the moisture will be carried away (Privette, May, 2005). For example air that is 130^{o}F has over eight times the moisture carrying ability of air that is 82^{o}F (Privette, 2005). To create the best airflow, the vents should be opened between 3 to 6 inches (Scanlin, Renner, Domermuth, & Moody, 1999). The loss of nutrients can be reduced and/or eliminated with the use of a dark chamber. The dark chamber prevents the loss of color and nutrients in the produce (Kerr, 1998). It is also important to use food grade materials in this process. If copper is used, even though it is a highly conductive material, it would destroy the vitamin C (Troftgruben). It is also important to shift and rotate pieces of produce periodically so they dry evenly (Troftgruben). These pieces should be cut to between an eighth of an inch and a quarter of an inch thick (Doityourself, 2010). This cut size allows for more surface area to dry, thus the produce will dry faster. However, the produce should not be dried too quickly. This can result in crusting which means that if something dries too fast, the outside will be dry but, the inside will still have too much moisture (Sadler, 2009). Thus, it will not be properly dehydrated and the interior will still be a favorable medium for the growth of bacteria and fungi (Sadler, 2009). This is why it is important to have optimal airflow. One may think that the use of active solar energy would be best for this due to the use of fans. However, it was shown that the drying performance between active solar energy and passive solar energy in dehydrators similar to one we would want to build are negligible (Scanlin, Renner, Domermuth, & Moody, 1999). In order for passive solar energy to work, the temperature needs to be kept between 120^{o}F and 185^{o}F (Sadler, 2009). Ideally, it is best to have the temperature between 150^{o}F and 160^{o}F until the surface moisture is gone. Then, it is best to lower the temperature to around 135^{o}F (Troftgruben). In order to get to this optimal temperature range, it is best to have the solar collector facing south so that the sun's light can be captured during the entire day (Scanlin, Renner, Domermuth, & Moody, 1999). In addition, it is important to have a conductive material to radiate the heat back to the food. Accessible conductive materials include copper and aluminum flashing (Scanlin, Renner, Domermuth, Moody, & 1999). Furthermore, the collector needs to be at an optimal angle. Optimally, it is best to have the angle be at 15^{o} in the morning and evening and 45^{o} at around noon (Scanlin, Renner, Domermuth, Moody, & March, 1999). Another way to help evenly dry fruit is by spacing vertical trays an inch to an inch and a half apart so there is room for airflow (Troftgruben). At the end of the drying process, a fruit should still be composed of around 15% water (Answers Corporation, 2010). However, a vegetable should be composed of around 3% water (USA Emergency Supply, 2009).

Client Needs/Constraints

In a perfect world, one would tackle every single issue perfectly regardless of the resources. However since we have scarce resources, we have constraints. These constraints include the design being vertical, wind resistant, portable, able to hold thirty pounds of food, functional, easily cleaned, aesthetically pleasing, food grade, keep an optimal temperature range, have removable racks, passive solar energy, a dark chamber, wind and wildlife proof, and most importantly, be reproducible. Tackling all of these issues while keeping the design reproducible is a unique challenge. However due to the client's personal situation, there are some things that need to be addressed more than others. For one, the client will only need to dry grapes, tomatoes, miscellaneous berries, and peppers. In addition, these foods will be dried at different times throughout the year so; the fumes and issues regarding the interactions of the foods are not that big of a problem. However, he would like to preserve the nutrients as much as possible which makes a dark chamber necessary. In addition to problems with the fruit, there are specific problems related to the elements around it. It is extremely windy there so, the design needs to combat that. Also, raccoons, squirrels, chipmunks, mice, moles, and bugs need to be combated. There also needs to be a barrier against rotting for the wood. As issues related the community around the dehydrator, a staff will always be there to rotate and tend to various things and security is not a problem due to this. However, the design needs to accommodate the need to be able to be cleaned. Since it is in a public garden, it is important that the design look and be clean.

Besides more micro aspects of the design, it needs to fulfill macro needs. The design can be around 300 pounds but, it needs to be mobile. This means that it needs to be collapsible. Brian has said wheels are not a must if a few people can carry it around. The design does not need to be too adjustable but, it would be nice. It is also a must that the dehydrator has a thermometer of some sort to regulate temperature. While tackling all of these issues, it is important to keep the design reproducible. Durability versus reproducibility was a crucial design issue. Also, the process of making the design adjustable needed to be easily reproducible. There is a $300 budget to work with so, we need to use our resources effectively. Overall, it is most important to get a functional design out there to trial and test. Metaphorically, it is important to get a "foot in the door." This design is a stepping stone for future food preservation and needs to have a solid foundation for making functional, reproducible dehydrators alike.

Small-group prototypes

In order to make sure we met the client's main needs related to reproducibility, aesthetics, and wildlife obstacles, we broke into smaller groups to focus individual designs on these aspects. The group concerned with reproducibility created a design called Simply Solar, which can be seen in Appendix A. It was a basic updraft design, which would have utilized the solar catcher to generate heat. The catcher would have been at an angle of around 45^{o}. In this prototype, a large piece of Plexiglas would create a big area to catch sun; a piece of aluminum would re-radiate heat up. Hot air would travel to the dark chamber. Vents on the bottom of the sun catcher would allow for optimal airflow. The air would rise in the box and exit through a plastic chimney at the top. The dark chamber would have had removable grill grates coated in polypropylene to hold food. The box would have had a door that had a thermometer in it. This thermometer would be visible from the outside of the door because there would have been a precise cut for the thermometer to rest in. The box would have been supported by legs made of wood. The legs would have had stakes to allow for anchoring the design. There would also be wheels for portability. There would have also been a prep table fastened to the back. The pros of this design were that it was a simple, reproducible design, it was tried and true, and it provided the best airflow in comparison to the other designs. However, there were a few draw-backs to this design. Due to its unwieldy sun-catcher, it is not visually pleasing. Also, it is large, catches wind, and compared to the other designs it is not original.

The next group focused on aesthetics. They came up with a cube design. One side of it would be a window that collects the sunlight and the trays would be in a dark chamber behind this. There would be a layer of aluminum flashing that would radiate the heat to the food. The pros of this design were that it was aesthetically pleasing, it utilized its compact design to achieve innovation, and it had more than one heat source. The cons of this design were that it was low to the ground, the shelving was awkward due to its shape, it did not have efficient airflow capabilities, and due to its lack of history, its functionality would have been suspect.

The final group focused on the battles against nature. Their design was titled the Vertical Cylinder or the Sunflower. A window would collect the sunlight and the heat would travel up from the bottom into a dark chamber which heats the food and exits through the top. The advantages of this design were that it was vertical, aerodynamic, aesthetically pleasing, original, portable, weather resistant, and the window would have covered 360^{o} to catch sun at all times. If there was not a window spanning 360^{o}, a prep table would have been in its place. However, some drawbacks were that the awkward shape of the trays made the chambers tough to load and it was not easily reproducible.

Consolidation/choice of materials/design

In order to make the best design possible, we were forced to consolidate our preliminary ideas into the final design. By combining the reproducibility of the Simply Solar design, the aesthetics of the Cube, and the portability of the Sunflower, we devised a final plan. Overall when in action, our design combines the sun catcher and drying chamber from simply solar into one and uses the heat re-radiating aluminum flashing aspect to heat the food from the cube design. These of course were coupled with the prior parameters of maintaining simplicity, general efficiency, a large drying area, and heating without direct sunlight.

In order to optimize the functionality of our design, the right materials and design basics needed to be used. Initially we brainstormed a list of materials to use. These included: Wood, Plexiglas, stainless steel, PVC, mirrors/glass, steel, string, aluminum, ceramics, brick, clay, rain bucket/ water, mesh, bug zapper, mesh, bug zapper, heat absorbent paint, flat black paint, weather stripping, bio degradable, hinges, joints, nails, and a car battery. In addition there have been many solar dehydrators made over the years so, we had many options and designs to draw from. We brainstormed many possible design ideas such as: table design, large or short legs, no legs, cutting, wheels, portable, curves/pleasing to eye, funnel, reflectors, magnifying glass, oven, grills, fans, heated water compartment, regulate temperature, water proofing, radiation always face sun, insulation, passive solar energy, active solar energy, and good airflow.

Eventually we settled on optics acrylic for the solar window. Like Plexiglas, optix acrylic is a polycarbonate. This window has the highest light transmittance physically possible, which is 92% (RPlastics, 2010). It is 6 to 17 times more impact resistant than ordinary glass. It is also weather resistant and its U-factor is 20% lower than ordinary glass % (RPlastics, 2010). A Lower

U-factor means a greater resistance to heat flow and better insulation. As a way of transforming that light into heat, we decided to use aluminum flashing. When the light hits the clear acrylic, the wavelength of the light is lowered to make it more infrared, which fuels a greenhouse effect that generates more heat (Geopathfinder, 2002). The light then hits sheets of black aluminum flashing. This absorbs the heat and radiates it onto the food below. In addition, aluminum flashing on the bottom above the plywood re-radiates the heat up, improving efficiency (Geopathfinder, 2002). Aluminum flashing is extremely conductive and optimizes heat while keeping cost in mind. When the heat is eventually re-radiated on the food itself, moisture is given off while keeping sunlight off of the food itself. The moisture given off by the food passively flows up the sloped air channels (Geopathfinder, 2002). These sloped air channels also take advantage of the natural properties of air, such as moist air rising more than dry air.

We painted the dehydrator with flat black spray paint because it will absorb more sunlight, which will create heat that rises up and over foods that are being dried (Doityourself, 2010). In addition, since it is spray paint, it makes assembly faster and easier. However, we did not paint anything in the inside so we kept everything as food grade as possible. In the inside, we ended up making 4 separate, removable, horizontal racks on which one would place the food. These racks have handles made from nylon rope and are easily removable. This solves one of the biggest concerns which was sanitation. With this design, it is simple to remove the racks and clean the interior. As for the screens that food rests on, we originally wanted to use stainless steel mesh but, the cost of those became an issue so, we instead used trays made from PVC (Vinyl). One concern with these are whether they are food grade or not and it turns out they are. Vinyl, commonly recognized by this symbol, ♵, is food grade (The Virtual Web Bullet, 2004). It is often used to package fresh meats and other types of food (The Virtual Web Bullet, 2004).

Overall, our four racks are cheap, reproducible, and allow for the diversification of produce. When placing food in them, we use a 2''x 6'' piece of wood that fits in-between the trays and props open the dehydrator. Our drying chamber has 9.5 ft^2 of area to dry food. This is plenty of room to fulfill our clients' space needs. We ended up building the box and legs out of wood. Building the legs and box out of cheap and durable materials adds to the structural integrity and reproducibility of our design. With this box, we drilled four circles 3 inches in diameter on the bottom and four more at the back for airflow. From our research, we learned that the vents should be between 3 and 6 inches wide (Scanlin, Renner, Domermuth, & Moody, 1999). We ended up choosing the low end of that in order to keep the temperature higher. In order to get to that optimal temperature range, we needed to make the dehydrator as airtight as possible. Additionally, the dehydrator is at a comfortable height that provides an easy way to load the food while still combating the wind. Also, since it does not have wheels, it is sturdier, and also combats wind. We caulked the acrylic on the top, used weather-stripping where the box opens up, and we used bungee cords on the side in order to keep the dehydrator closed as tight as possible. In addition, we covered the vents with bug screening to keep insects from getting to the food. Overall, this design is airtight enough so raccoons, squirrels, chipmunks, mice, moles, and bugs should not be a problem. These screens are on the inside of the dehydrator in order to provide adjustability in the form of closing off the vents in order to get the temperature hotter. The angle of our dehydrator is about 14.4^o. This angle is set and is not adjustable. It was not a main concern of Brian's to make it too adjustable so, we decided to focus our resources elsewhere. However, we did make the design portable. The legs are held on by bolts which can be removed with a wrench. After they are removed, the box can be hauled around by two people. The box weighs roughly 60lbs. Since there are multiple people that will be operating this dehydrator, this is an effective solution to portability. Lastly, we have a digital thermometer that reads the temperature from the inside but, can be read from the outside. We just drilled a hole in the side and placed the thermometer in the hole. It is also completely airtight and is an efficient solution to reading the temperature but is not disrupting to the dehydration process.

Budget

We had a budget of $300 but, it was important to keep the price below that because the main goal of our project was to make a solar dehydrator that was reproducible and cost is an important aspect of reproducibility. Initially, we ended up spending $243.65 on the project. However, we ran into a problem at the end and needed to purchase more aluminum flashing which brought the final cost to 282.64. Wood made up a cost of $56.69 of the price. The cuts of wood consisted of 18ft of 2’’x 6’’, 8ft of 2’’ x 2’’, 8ft of 2’’x 1’’, 8ft of 4’ x 4’’, and plywood. All of the fasteners cost $72.17. These included 8 1/2" Bolts, 8 1/2" Bolts (HEX), 8 1/2" Nuts, 8 1/2" Washers, 3 3/4" Screw (10 per bag), 2 1/2" Screws, 1 5/8" Screw, and 4 6" Hinges. The sheeting cost a total of $120.11. The sheeting consisted of 2 aluminum flashing sheets, another roll of aluminum flashing, 2 acrylic sheets, 1 insect screen, and 2 hardware cloths for trays. The accessories cost $29.17. These included: sealant, weather-strip tape, flat black spray paint, nylon rope, and a thermometer. Miscellaneous shipping for that was a total of $4.50. We also used small spare bungee cords to seal the box better which are not included in the budget. You can buy a pack with a few of these are most hardware stores for around 99 cents. It is important to keep in mind that all of our aluminum flashing needs could have been satisfied with our final purchase of aluminum flashing and we also had miscellaneous expenses that did not need to be incurred with other parts. With all of this taken into account, we figured it would cost someone $229.43 to build this. This keeps with the reproducible aspect of our design and most of the materials can be purchased from Home Depot. In addition, one may think we spent a lot on fasteners however; these are what held our entire project together and were crucial to the stability of it. Furthermore, we used high quality materials for these. For example, our screws have a weather resistant coating. Therefore, the higher cost is justified. The complete breakdown of the materials, budget, and the revised farmer's budget can be seen in Appendix B.

Construction process

We had numerous setbacks during the construction process such as materials not arriving on time and other things but, we developed a simple process to building this dehydrator. When assembling the frame, we took 4' 2" x 6" boards and two 5' 2" x 6" boards and arraigned them to form a square with 6" off the end of each 5' board. We then inserted two screws into each 'T' made between the 4' boards and 5' boards. They were inserted at the top of the 'T' starting in the 5' board and through the 4' board. We then took the plywood and lined it up to match the square frame created by the 4' and 5' boards. With the plywood on top, we inserted three screws at every corner of the square. There was one screw in the direct center of the corner and one about an inch and a half away from the direct center, with one in either direction, forming a corner. Next, we cut out blocks of wood from the remaining 2" by 4". There were four 2 ½" by 2 ½" pieces, four 2 ½" by 5" pieces, and one 5" by 5" piece. Screw in one 2 ½" by 2 ½" piece in each corner of the inside of the box. This was done starting from the plywood side. The 5" by 5" square was screwed into the direct center of the square, the center of the block lined up with the center of the square frame. Each 2 ½" by 5" block was screwed in each side of the box. They had to be directly in between each corner 2 ½" by 2 ½" block. These blocks of wood became the resting point of the trays and provide ample airflow for dehydration.

When assembling the legs, we attained 14 feet of 3 ½ " by 3 ½ " pressure-treated lumber and cut these into two 4' pieces and two 3' pieces. When assembling the cover, we cut 2 pieces of 48" and 3 pieces of 45" of 1 ½" by 1 ½ "lumber using a compound miter saw. We then arranged the 48" pieces and two of the 45" pieces in the shape of a 48" by 48" square, with the 45" pieces bridging between the ends of the two 48" pieces. After that, we screwed them together using a drill. Next, we put the last 45" piece in the middle, bisecting the square into two 48" by 47 ¼ "rectangles, again screwing this piece in place. We then spray painted the top sides of the lumber frame, which is the side that faces the sun, and then we let it dry. After that, we put both of the two 24" by 48" pieces of acrylic over each of the two rectangles so, the whole thing was covered by acrylic. Then we screwed the acrylic into the cover frame with one screw in each of the four corners of both pieces of acrylic, for 8 total. On the underside (the side opposite the acrylic), we attached the pieces of aluminum sheeting. This aluminum sheeting covered the bottom, so the total dimensions should add up to 48" by 48".

When assembling the trays, we cut 8 pieces of 21 and a half inches and 18 and a half inches each from the one by two and two by two boards using a compound miter saw. We had a total of 32 pieces of wood. Next, we cut out 21 ½ by 21 ½ inches squares of the mesh netting. Then, we assembled boxes by using the 21 and a half one by two pieces with an 18 and a half between the two pieces, making a square with the flat side down. Then, we put the square mesh on top of the one by two square and stapled it down as needed. Next, we made a square out of the two by two pieces of wood and assembled that on top of the mesh as an outline. The 21 ½ inch side should be on top of the 18 ½ inch one by two side to make for a better support. After, we secured the two by two pieces of wood to each other by using two screws at every end point. Then, we secured the two by two frame to the one by two frame by inserting a screw from the bottom of the tray to the top, from the one by two side to the two by two side. Then, we cut out four 20" by 20" squares of mesh wire and used a staple gun to staple each of the squares onto one of the ½ " by 1 " tray frames. Finally, we screwed each of the ½ " by 1 " squares onto each of the 1" by 1 " squares, with the wire mesh in between the two pieces of wood.

Finally, we combined the parts. We began by setting aside the four legs (two four foot other two are three foot) and placed two holes, half inch hex screw size, in each. The first hole in each needed to be two inches down from the top of the leg and one inch in. The second hole needed to be three inches down from the top of the leg and one inch in from the opposite side as used from earlier. The body of the dehydrator needed to have two holes on each extending piece of board to connect to the legs. The first hole needed to be one inch down from the top of the legs and one inch form the side. The second hole needed to be four inches from the top and one inch from the side, the opposite side that was used for the first hole in the body. The holes were half an inch thick, big enough to fit a half inch thick six inch long hex screw. Then, we drilled four 3 inch in diameter vents at the back of the dehydrator and in the bottom at the front of it. After that, we attached the solar window to the frame. This was done by the use of hinges. Later, we put weather stripping all around the frame. Then, we attached bungee cords on the sides in order to keep the cover tighter. Finally, we cut two sheets of bug netting and stapled them over our vents using ¼'' staples.

As for constructing it optimally, some things need to be taken into account. When putting on the aluminum flashing, it is best to sand it in order for the paint to stick more efficiently. It is also better to staple it from one side to the other side sequentially so it does not bubble. In addition when putting on the bug screen, it is important to hold the screen tight and staple using ¼'' staples. This way, there is little room for bugs to get in and the screening is held on tighter.

Also, it is better to paint the parts before assembly. This way, it looks better and since we used spray paint, drying times are not an obstacle. Moreover, it is important to have more than enough spray paint (around 8 cans) so that you do not run out. When using the acrylic, it is common for it to crack. We tried using a propane torch to melt the plastic together, however, that did not work as effectively as we had hoped. Perhaps it would have worked with a butane lighter but, we learned that caulking the broken pieces on works just fine. Additionally, it is important to not paint anything in the inside of the chamber in order to keep it food-grade and to eliminate fumes that would pollute the food. When making the frames, it is important to measure the diagonals of all of the boxes and squares made to ensure the end results are square. Overall, much of the cutting can be done with a handsaw and the rest of assembly can be accomplished with standard tools that are accessible to many people. As a whole, the assembly of this dehydrator took roughly 12 hours of work. This includes the numerous setbacks we had, which included accidentally painting the trays and then sanding the paint off. This turned out to be incredibly time consuming. With these tips, the assembly time of this dehydrator can be greatly reduced. People could essentially build their dehydrator one day and have it ready to dry food the next.

Testing

In order to be sure of our design, we did some testing of the dehydrator. The first test that we conducted was creating different textures on the aluminum. We were trying to see if the different textures would cause a difference in the ability to capture the energy of the sun. We tried 3 different textures during the testing: a smooth, a moderate, and a rough texture. These three textures were attained by the amount a time that was spent rubbing the aluminum with sandpaper. We found no appreciable difference between the three textures. However, we did notice that the spray-paint was able to stick much better to aluminum when the texture was more rough. Therefore, we decided that the rough texture would be best for our design.

Eventually, we tested it on April 23rd. The area that the design was placed in was behind a housing co-op near the capitol. The area did not allow for sunlight all day because of shade produced by nearby buildings. In addition, it was a fairly cold, around 58^{o}F, and it was a cloudy day. We just decided to get temperature readings for the first test. The test began on the right track. Between noon and 1:00 P.M. the temperature was rising steadily and you could feel the acrylic and the dehydrator begin to get hot. The temperatures ranged from 84^{o}F to 93.3^{o}F. However, it then began to get incredibly cloudy and the temperature dipped to 82^{o}F at 2:00. Some sources of the problem could have been that the vents were too big, the acrylic expanded due to the heat and bubbled, or the thermometer could have been too low to accurately read the temperature.

After that, we wanted go beyond the theory of our design and actually see if it would fulfill its purpose of drying food. We placed sliced bananas in our dehydrator on a partly sunny day when the temperature was around 65^{o}F. We were able to see that the bananas were almost dry after just one day of being in the dehydrator. We consider this a success because of several factors that limited the productivity of the dehydrator. One of these was the weather. The temperature was not as hot as it will be in the summer months. Also, the dehydrator was not able to receive direct sunlight for the duration of the day because of the clouds. The other factor was the location of testing. At the client's site, the prototype will be in an open field where it will receive sunlight for the entire day. This will allow for the dehydrator to collect more of the sun's energy and create a higher temperature inside the food chamber.

Also when we placed the food outside, we gained some temperature readings from inside the food chamber. On the same day as the banana testing several temperatures were recorded. The highest temperature was recorded at around 85°F. This is about 20 degrees above the air outside. The temperature inside the box was rising until the sun was covered for an extended amount of time. Then the temperature peaked at 85°F and then continued to fall. We concluded that in a different setting and different weather, the temperature inside the box could have reached the desired range.

Unfortunately, we ran out of time to do a more comprehensive test. But, for future testing, it would be best to weigh the produce before testing, let it dry and then weigh again after and determine the final moisture content of the produce. For example, apples are composed of 84% water, bananas 74%, and tomatoes are made of 94% water before drying to name a few (University of Kentucky Department of Agriculture, 1997). After drying, fruits should have a moisture content between 15% and 20% (Answers Corporation, 2010). Also, vegetables should be composed of around 3% water at the end of the process (USA Emergency Supply, 2009). By knowing the initial weights, final weights, and appropriate moisture contents one could determine how efficient the dehydrator is.

In order to fix the problems associated with our dehydrator during testing, we made a few adjustments. We noticed that during testing the plywood on the bottom got extremely hot and absorbed a lot of heat. We decided to fix this problem by buying more aluminum flashing and placing it on top of the plywood inside so that more heat can be re-radiated up to the food. In addition, we noticed that the size of the vents could have been a contributing factor to our lower temperatures and that since they were on an angle, rain could potentially seep into the drying chamber. So, we added an exhaust vent cover from the aluminum flashing to adjust temperature in the chamber and to protect from weather.

Results/Recommendations

Overall, our design tackles the client's main needs of reproducibility and weather resistance while keeping the design easily accessible. It also meets our client's needs of it being vertical, wind resistant, portable, able to hold thirty pounds of food, functional, easily cleaned, aesthetically pleasing, food grade, keep an optimal temperature range, have removable racks, have passive solar energy, a dark chamber, be wind and wildlife proof, and most importantly, be reproducible. Although, the design did not live up to the quantitative expectations we had for it qualitatively it performed well. We also believe that with the adjustments we made, the dehydrator will perform its job in its setting. This is because despite the obstacles, the overall process worked. The bananas we had actually were dehydrated. This design is a good "foot in the door" for future dehydrators. It combines what has worked in previous designs and by combining the drying chamber and solar catcher into one space, it puts it into an accessible, compact form. This serves our client's purpose of being a dehydrator that is a functional design that can be used and tested in order to serve as a solid foundation for the construction of future dehydrators. For future building or when weighing alternatives for the trays, it is important not to use plastic that is denoted as ♴ because some of it is not food-grade (The Virtual Web Bullet, 2004). In order to improve our design it would be best to use stainless steel mesh for the trays if cost permits, glass for the paneling due to the bubbling we encountered with the acrylic, metal edges around the lid for better insulation, wheels if solution can be found to keep it sturdy, a better latching mechanism, and adjustable angle for the solar window, and vents that are not angled so they do not collect rain.

References

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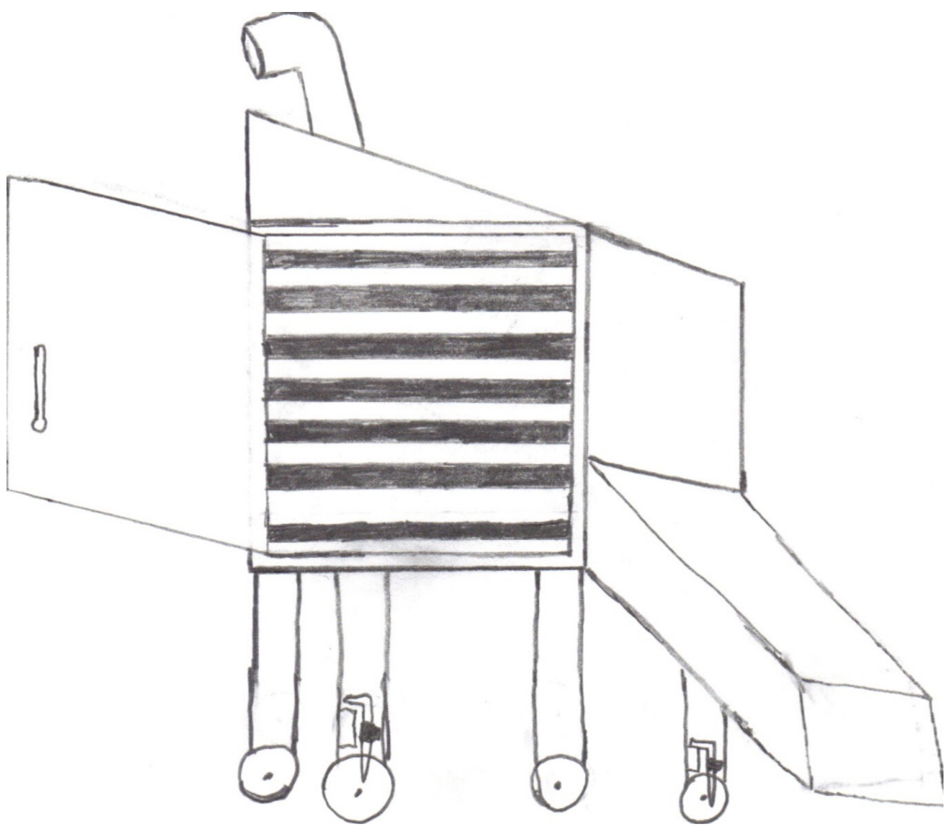
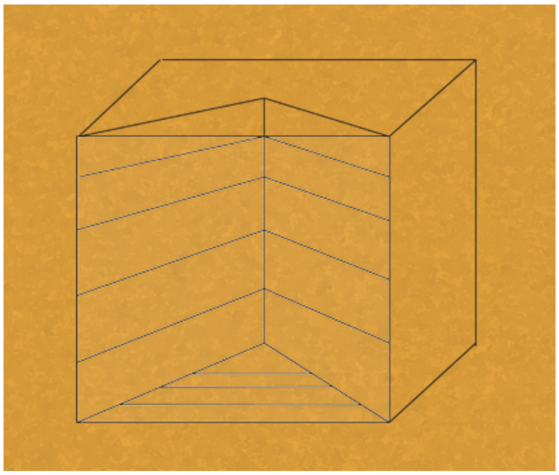
Appendix A

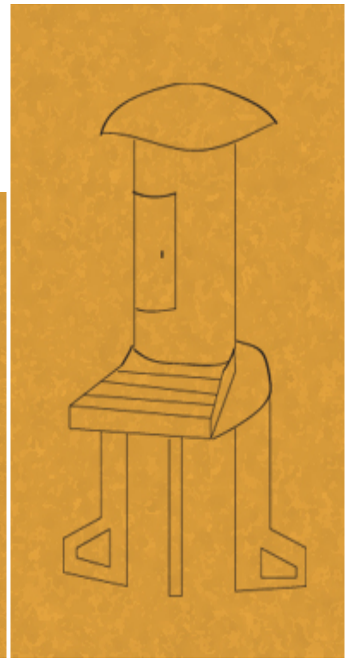
Simply Solar



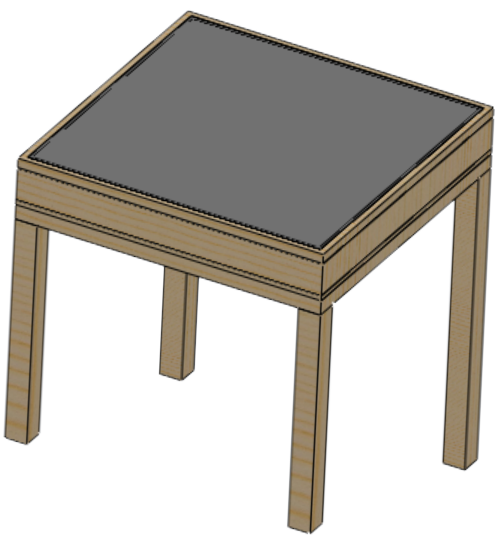
The Cube



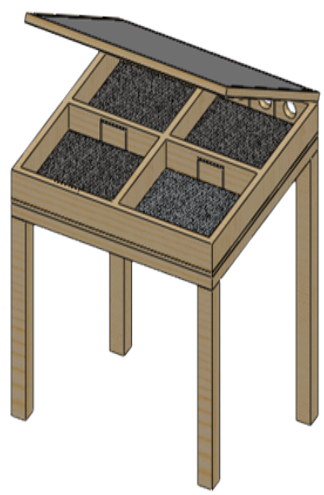
Sunflower/Vertical Cylinder



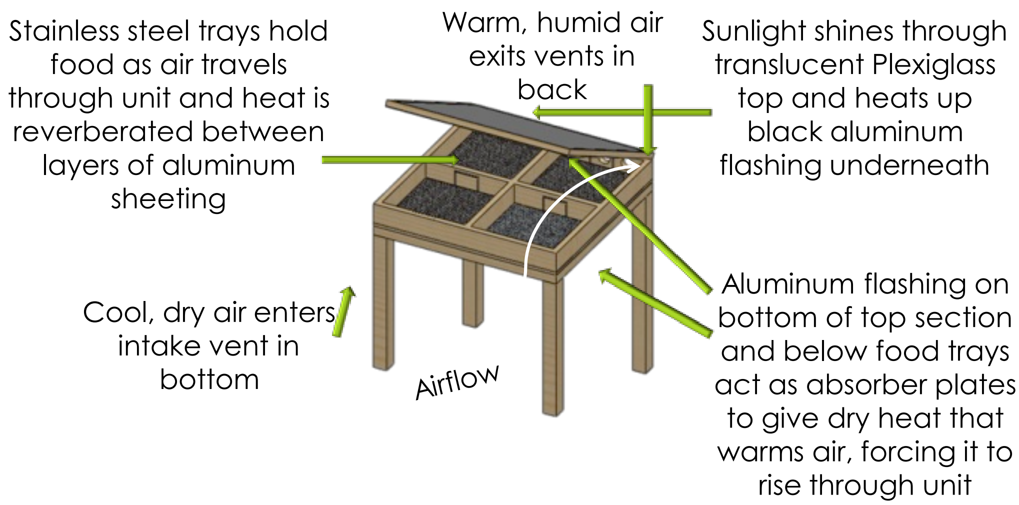
Final Design (Top/closed view)

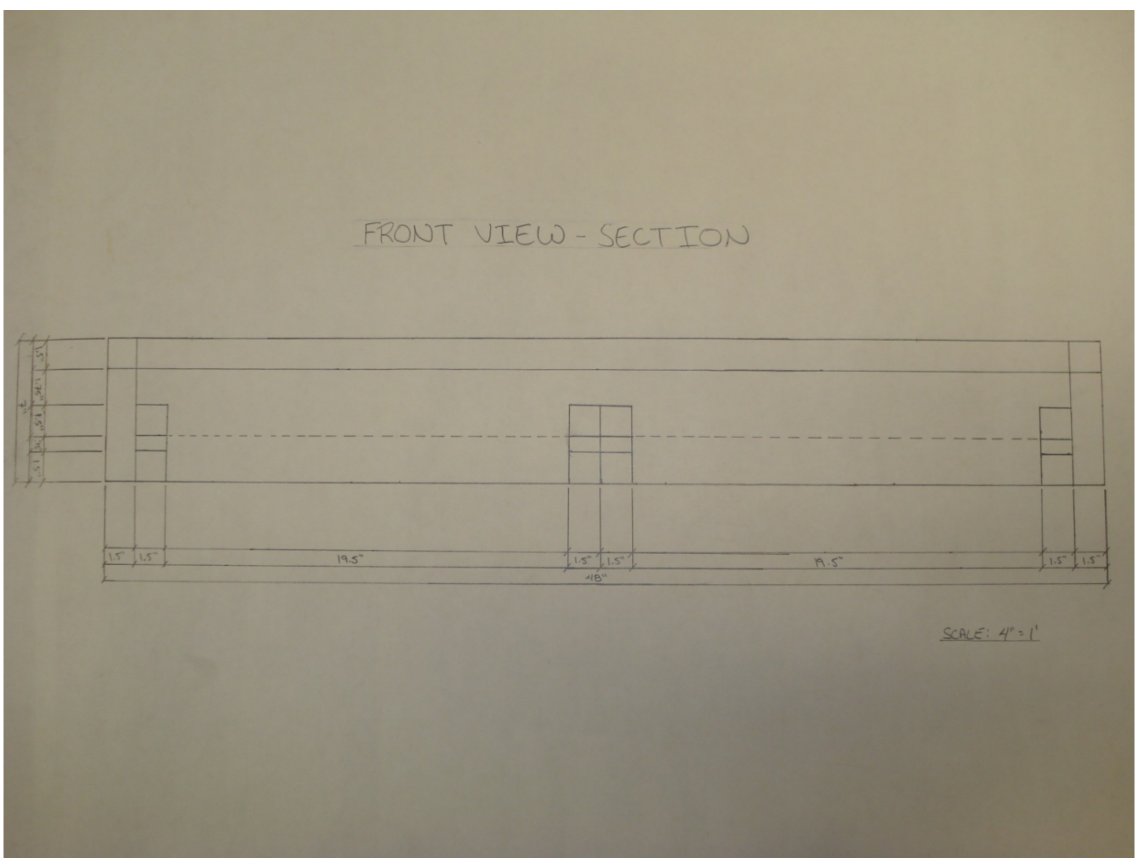


Top open view



Design


Stainless steel trays hold food as air travels through unit and heat is reverberated between layers of aluminum sheeting
Warm, humid air exits vents in back
Sunlight shines through translucent Plexiglass top and heats up black aluminum flashing underneath
Cool, dry air enters intake vent in bottom
Airflow
Aluminum flashing on bottom of top section and below food trays act as absorber plates to give dry heat that warms air, forcing it to rise through unit


FRONT VIEW - SECTION
1.5"
19.5"
48"
SCALE: 4" = 1'

Appendix B

InterEGR 160- Solar Group 2010 Budget/Materials Breakdown

Wood

Size/Type	Cost per Unit	Quantity Ordered	Total
2x6 (8ft)	$4.32	2	$8.64
2x6 (10ft)	$4.57	1	$4.57
2x2 (8ft)	$1.49	8	$11.92
2x1 (8ft)	$0.92	5	$4.60
4x4 (8ft)	$5.97	4	$23.88
Plywood	$7.65	1	$7.65
Total Wood Cost			$56.69

Fastners

Type	Cost per Unit	Quantity Ordered	Total
1/2" Bolts	$1.11	8	$8.88
1/2" Bolts (HEX)	$1.51	8	$12.08
1/2" Nuts	$0.19	8	$1.52
1/2" Washers	$0.19	8	$1.52
3/4" Screw (10 per bag)	$0.98	3	$2.94
2 1/2" Screw	$8.69	2	$17.38
1 5/8" Screw	$8.69	1	$8.69
6" Hinge	$4.79	4	$19.16
Total Fastner Cost			$72.17

Sheeting

Type	Cost per Unit	Quantity Ordered	Total
Aluminum Flashing	$8.72	2	$17.44
Extra Aluminum Flashing	$38.99	1	$38.99
Acrylic Sheet	$19.79	2	$39.58
Insect Screen	$4.14	1	$4.14
Hardware Cloth for Trays	$9.98	2	$19.96
Total Sheeting Cost			$120.11

Accessories

Type	Cost per Unit	Quantity Ordered	Total
Sealant	$5.24	1	$5.24
Weatherstrip Tape	$2.42	1	$2.42
Flat Black Spray Paint	$0.97	8	$7.76
Nylon Rope	$3.77	1	$3.77
Thermometer	$9.98	1	$9.98
Total Accessories Cost			$29.17
Shipping	$4.50		$4.50
Total Project Cost			$282.64

Farmer's Budget

Wood

Size/Type	Cost per Unit	Quantity Ordered	Total
2x6 (8ft)	$4.32	2	$8.64
2x6 (10ft)	$4.57	1	$4.57
2x2 (8ft)	$1.49	7	$10.43
2x1 (8ft)	$0.92	5	$4.60

4x4 (8ft)	$5.97	2	$11.94
Plywood	$7.65	1	$7.65
Total Wood Cost			$43.26

Fastners

Type	Cost per Unit	Quantity Ordered	Total
1/2" Bolts (HEX)	$1.51	8	$12.08
1/2" Nuts	$0.19	8	$1.52
1/2" Washers	$0.19	8	$1.52
3/4" Screw (10 per bag)	$0.98	3	$2.94
2 1/2" Screw	$8.69	2	$17.38
1 5/8" Screw	$8.69	1	$8.69
6" Hinge	$4.79	2	$9.58
Total Fastner Cost			$53.71

Sheeting

Type	Cost per Unit	Quantity Ordered	Total
Extra Aluminum Flashing	$38.99	1	$38.99
Acrylic Sheet	$19.79	2	$39.58
Insect Screen	$4.14	1	$4.14
Hardware Cloth for Trays	$9.98	2	$19.96
Total Sheeting Cost			$102.67

Accessories

Type	Cost per Unit	Quantity Ordered	Total
Sealant	$5.24	1	$5.24
Weatherstrip Tape	$2.42	1	$2.42
Flat Black Spray Paint	$0.97	4	$3.88
Nylon Rope	$3.77	1	$3.77
Thermometer	$9.98	1	$9.98
Total Accessories Cost			$25.29

Shipping	$4.50		$4.50
Total Project Cost			$229.43

Name of Part	**Part Number/Store SKU**	**Quantity**	**Total Cost ($)**	**Provider**
2x6(8ft, wood)	161713	2	8.14	Home Depot
2x2(8ft, wood)	165360	8	11.92	Home Depot
2x1(8ft, wood)	160954	5	4.60	Home Depot
Plywood	386081	1	6.36	Home Depot
Aluminum flashing	566810	2	17.44	Home Depot
¾ in screw	760428	25	13.25	Home Depot
2 ½ in screw	734838	2	17.38	Home Depot
1 5/8 in screw	734821	1	8.69	Home Depot
				Provider
Name of Part	**Part Number**	**Cost per Unit**	**Cost per Unit**	
WeatherShield 4X4-8 #2 PT	256276	1	$5.97	Home Depot
Crown Bolt 1/2 In. x 4 In. Carriage Bolt Coarse Thread Zinc Plated	654256	8	$1.11	Home Depot
Crown Bolt 1/2 In. Nut Hex Coarse Thread, Zinc Plated	655465	8	$0.19	Home Depot
Crown Bolt 1/2 In. Washer Cut Zinc Plated	655589	8	$0.19	Home Depot
Optix .093 In. x 24 In. x 48 In. Acrylic	453221	2	$19.79	Home Depot

Sheet				
OSI Pro Series 10.2 Oz. Clear Window, Siding and Roof Sealant	506553	1	$5.24	Home Depot
MD Building Products 3/16 In. x 3/8 In. x 17 Ft. Gray High Density Foam Weather-strip Tape	616028	1	$2.42	Home Depot