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A First-Year Engineering Service Learning Project That Impacts Global Food Security

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Full Paper: A First-Year Engineering Service Learning Project That Impacts Global Food Security

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Abstract - In response to a joint UN/IEEE Humanitarian Technology Challenge Sustainable Development Goal to achieve food security, students were tasked to design and build a solar-powered food dehydrator that could be built on-location with minimal resources other than the primary building materials. Materials and construction techniques not anticipated to be native to the region were excluded from the design. The project was targeted for implementation in regions of emerging development with unstable food supply and simultaneously lacking infrastructure, including access to electrical power. In practice, using a food dehydrator makes it possible to store summer-grown fruits and vegetables for consumption at a later time when sources of food are scarcer. The design discussed here includes an externally attached box-like conduit designed to warm environmental air and funnel it into the main drying chamber. The drying chamber is topped with a sloped, plastic-covered roof which allows moist air to vent to the outside. Air circulation inside both the dehydrator chamber and the warm air conduit is via natural convection. An earlier design was tested and found to have achieved the targeted temperature goal for safe dehydrating of fruits and vegetables. The current design significantly improves the main performance goal by generating internal air temperatures far above the external ambient air temperature (ΔT ~50 ^{o}F). This implies that the redesigned dehydrator will generate and maintain minimum safe drying temperatures over longer sustained periods of a given day. Finally, students gained valuable experience designing and building a structure using only the simplest of tools and construction techniques.

Keywords: zero hunger, solar-powered food dehydrator, freshman year experience, UNDP

1. Introduction

Freshman at GU take a mandatory First Year Seminar (FYS) course which includes a service-learning project. Participation in service projects directly supports the fundamental mission of the university to prepare students to be global citizens through programs grounded in the liberal arts and sciences via a comprehensive, values-centered learning experience that emphasizes faith, leadership, inclusiveness, and social responsibility. A recent survey found that a clear majority of students were willing to volunteer for weekend community service projects post-graduation [1]. A smaller majority were even willing to forgo some salary as a professional engineer working at a company known for its support of community activism.

Engineering FYS students lean on their background and/or inclination in engineering design and construction to help carry out their particular service project. In past years, engineering students have designed and built rooftop rainwater collection systems for garden use, vertical vegetable planters for efficient space utilization, and composters for community gardens. Recently, first-year engineering students had the opportunity to participate in a service-learning project with potential for global reach. In response to the United Nations Development Programme Sustainable Development Goal for zero hunger [2-3], first-year engineering students were tasked with designing and building solar-powered food dehydrators [4]. The project was targeted for implementation in regions of emerging development including areas with chronic widespread hunger and, simultaneously, lacking in material resources and infrastructure - including access to electrical power. In these regions, farming is the single largest source of income and jobs. Hence, food dehydration makes it possible to store summer-grown fruits and vegetables for consumption at a later time when sources of food are more scarce. The initial designs were considered proof-of-principle in that they were not intended for field application.

In AY2018-19, this project was continued and requirements were added to include the feasibility of implementing the design on-site. Construction techniques were also to be considered in that there was to be no over-reliance on access to a machine shop. In this way, student teams would be able to travel abroad to demonstrate design, construction, and use. In the design, the energy collecting and dehydrating chambers were merged into the same volume and sunlight enters the drying chamber through a plastic covered roof [5]. Incident radiation striking the walls of the dehydrator also contributes to the heat energy input. Air circulation occurs via natural convection as relatively dry outside air enters the drying chamber through holes drilled into the floor. Moisture-laden warm air exits through a mesh-covered roof vent. Testing on sunny and/or partly sunny days with outside air temperatures in the 88-91 ^{o}F (31.1-32.8 ^{o}C) range revealed internal air temperatures approaching 115 ^{o}F (46.1 ^{o}C) in shaded regions of the dehydrator; approximately 5-25 ^{o}F below the recommended 120-140 ^{o}F (49-60 ^{o}C) range for dehydration of fruits and vegetables [6-10]. However, food dehydrating can be accomplished anytime outside air temperatures exceed about 98 ^{o}F [11].

A simple modification to the previous design was implemented to determine if internal air temperatures greater than 120 ^{o}F could be achieved. By reducing wall thicknesses, the redesigned dehydrator would allow for greater warming due to incident radiation. Under similar test conditions, the internal air temperature in the new design reached 122 °F, exceeding the recommended minimum temperature [12].

Most recently, a new attempt was made to produce a simple design that could achieve the recommended drying temperatures for longer periods of the day. Additionally, construction was now strictly limited to hand tools that did not require electrical power. Both requirements were deemed critical for overall project success. The majority of surfaces were attached together using 1/4 in wood dowels placed into mating holes hand-drilled into the respective parts; nails and staples were used in some places. The major design modification called for a detachable conduit that could be used to funnel warm air into the drying chamber. The conduit was covered with semi-transparent plastic sheeting to mitigate convective heat losses. Using this design, internal air temperatures exceeding 120 ^{o}F were achieved on a partly cloudy summer day with the external ambient air temperature only in the low 70’s here in the U.S. northeast.

2. Service Learning as Part of FYS

In early fall, the freshman engineering cohort is assembled together in order to introduce and discuss the need and opportunity for community engagement through service projects aimed at communities and neighborhoods in need. In Erie, the need is particularly acute. For example, in 2016 the estimated poverty rate in the city of Erie was 27.3%, compared to the national rate of 14.0% [13]. As a result, approximately 75% of children in the Erie City School District qualified for the National School Lunch program [14].

At GU, the first-year engineering cohort is divided across multiple sections. Within each section, students are assigned to multidisciplinary teams typically comprising between 5-6 members. Once the teams are formed, a team leader and co-team leader are selected and the teams subsequently spend the next 6 weeks developing their proposal. Along the way, multiple interim progress reports are submitted and evaluated. All course section faculty are involved in the process to ensure that timely progress is made and to provide guidance, as necessary. At the end of 6 weeks, stakeholders are invited to attend in-class team presentations in order to score the competing designs. At the end of the design phase, a winning design from each section advances to the construction phase. At this point, materials are acquired and the team leader blends in students from non-winning teams. In this way, they learn valuable aspects of project management: scheduling tasks and assigning talent to those tasks. The GU Office of Service Learning plays a direct role by providing project funding. However, previous teams have successfully engaged corporate or private sponsors to donate both materials and expertise in support of these projects. Thus, in addition to developing some useful networking skills, this process also serves to advertise the service-learning project to the community which, in turn, provides one small way for the company to engage in support of service projects. By the end of fall semester, the project is completed and delivered to the stakeholder.

3. Solar-Powered Food Dehydrator

The solar-powered food dehydrator (SFD) was developed using this model. As envisioned, use of a SFD can extend the shelf life of fresh foods by using solar energy to help lower the food's moisture content. This helps to preserve food by slowing down bacterial growth. Concept proof-of-principle (POP) SFD designs were initiated in AY2017-18 [1, 4]. The competing designs were largely unconstrained –except for budget– and thus many of the designs closely resembled commercially available models and were constructed using parts and materials available from local home goods stores. These designs were never intended to be constructed on site due to an over-reliance on materials, hardware, and shop skills.

It was felt that a SFD design that could truly impact global hunger would be one that could be mass produced on location with minimal resources other than the primary building materials, and with minimal-to-no reliance on machine shop access. This constraint led to the AY2018-19 Phase 2 design which was implemented at 1/3 scale [5]. In constructing the walls and floor of the drying chamber, wood dowels were used to attach many of the planks together. While a drill was used to create the mating holes, a manual hand drill could be used on location. The roof structure was formed using angled slats and the roof was covered with semi-transparent plastic sheeting to allow sunlight to enter and, simultaneously, mitigate convective heat losses.

In AY2019-20 a modification calling for walls that were 1/2 the original thickness of the previous design was implemented. Using 1x6 in pine to construct the walls, the redesigned dehydrator sought to enhance heat transfer by way of lowering the thermal resistance. Sections were fastened together using 5/16 in wood dowels (Fig. 1a), and the walls were similarly attached to the floor. The redesigned dehydrator –for similar interior volume– used less material and achieved a 29% overall weight reduction [12]. The door design was also modified. Instead of cutting slots to receive the door, channels were created from waste wood (Fig. 1b). The completed design showing the angled roof and two food trays is shown in Fig. 1c. Testing of the redesigned dehydrator on a sunny to partly sunny 91 °F day produced internal air temperatures of 122 °F, above the recommended minimum temperature for dehydrating fruits and vegetables.

(a) (b) (c)

Figure 1. Phase 3 SFD: (a) walls redesigned using 1x6 in pine; sections attached together using 5/16 in wood dowels; (b) waste wood was used to form channels for the sliding door, shown in place; (c) completed design showing the angled roof covered in plastic, and two food trays.

A Phase 4 design has recently been implemented with the overriding design goal to limit tools and resources to only those anticipated to be available in an emerging region. For example, a hand drill was used to create the mating holes for the dowels which were used to fasten the wall planks together. 1x6 pine was used to construct the main drying chamber, and the side walls and floor were fastened together using 1/4 in dowels (Fig. 2a). The legs of the drying chamber –made out of 2x4s– were attached in a similar manner. Due to its widespread availability, plywood was used for several parts of the structure. This included the door which featured two 1/2 in thick pieces that were glued together (Fig. 2b). Plywood was also used to create the slots for the sliding door. The roof was constructed using several strips of plywood stapled together and covered with semi-transparent plastic over the opening (Fig. 2a). The roof was elevated along one edge to redirect any accumulated water. While the side sections of the roof were also covered with plastic, there are sufficient paths for warm humid air to escape the drying chamber.

The major modification in the Phase 4 design was the implementation of a conduit used to heat and direct warm air into the drying chamber. This component was made using 1/2 in plywood and 2x4 pine fastened together using dowels (Fig 2c). Plastic sheeting was stapled over the top to complete the conduit enclosure and the staples were reinforced with tape to prevent tearing. The conduit makes a 25-degree angle with respect to the horizontal, yielding a 30 in conduit length (Fig. 2d). To attach the conduit to the drying chamber, a slot was formed in one of the side walls (Fig. 2a,e) and the conduit was attached using dowels. Two food storage trays are shown in the dehydrator, the first being set on the beams connecting to the conduit, and the second resting on four rectangular pieces of scrap wood glued to the inside wall (Fig. 2f). Additional food storage trays can easily be designed into the enclosure.



(a) (b) (c)



(d) (e) (f)

Figure 2. Phase 4 SFD: (a) walls constructed using 1x6 pine pieced together using 1/4 in dowels; roof constructed using plywood strips stapled together and covered with plastic; (b) plywood used to construct the door and door slots; (c) conduit constructed out of plywood and 2x4s; (d) conduit makes a 65-degree angle with the vertical; (e) slot for attaching the conduit, dowels visible in image; (f) food trays in the main drying chamber.

The current design was tested outdoors to determine the temperature rise inside the drying chamber relative to the external ambient conditions. In addition to an interior mounted bulb thermometer, two K-type thermocouples (one internally mounted, and one for external ambient conditions) were used to gather temperature data. Temperature readings were made by connecting the thermocouples to an external display.

Test data indicate that the internal air temperature approached 122 ^{o}F (Table 1); this is above the recommended safe drying temperature for dehydrating fruits and vegetables. More significant is the fact that this was accomplished on a partly cloudy day when the external ambient air temperature was only 71 ^{o}F; a temperature rise, above ambient, greater than 50 ^{o}F.

Table 1. Test data for the Phase 4 solar-powered food dehydrator (SFD)

Day	Time (EST)	$T_{outside}$ (ºF) Thermocouple	$T_{outside}$ (ºF) Weather App.	T_{inside} (ºF) Thermocouple	T_{inside} (ºF) Thermometer	Comment
7/10/21	9:30a	67.8	66	70	70	very cloudy
	10:30a	69.5	68	79.1	77	very cloudy, slight breeze
	11:30a	68.7	70	109	107	partly cloudy, slight breeze
	12:30p	70.8	70	113.4	116.5	mostly clear, slight breeze
	1:30p	71.3	71	121.8	121	mostly clear, periodic wind
	2:30p	73.4	71	120.6	121	mostly clear, periodic wind
	3:30p	71.9	73	118.2	117	mostly clear, periodic wind
	4:30p	73.3	73	105.7	101.5	overcast, periodic wind

4. Conclusions

Given the project task of designing and building a deployable solar-powered food dehydrator, a student-led team generated a unique design that was powered by solar energy. Simple construction techniques (e.g., using dowels in place of nails and screws to fasten sections together) were required as well, implying that the design could be built on location in remote communities and with minimal resources other than the primary building materials and hand tools. Modifying a previous design, the students were able to implement a Phase 4 design that significantly improved upon previous results. In particular, air temperatures inside the redesigned dehydrator can now reach recommended drying temperatures (i.e., > 120 ^{o}F) on days when the external ambient air temperature is only in the low 70’s. This result implies that on the warmer days as might occur in many regions of sub-Saharan Africa, this simple dehydrator can achieve safe drying temperatures for much longer periods of the day, thus enabling a larger volume of food handling. Projects like this, initiated in a first-year engineering course, demonstrate the capability of student-led teams in addressing one of the global issues –zero hunger– identified and targeted by the United Nations Development Programme as part of their Sustainable Development Goals.

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