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Addressing Global Food Security through First-Year Engineering Service Learning Projects

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Full Paper: Addressing Global Food Security through First-Year Engineering Service Learning Projects

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Abstract - First-year engineering students recently participated in a service learning project with potential for global reach. In response to a United Nations Development Programme Sustainable Development Goal for zero hunger, first-year engineering students were tasked with designing and building a solar-powered food dehydrator that could be built on location with minimal resources other than the primary building materials and some basic tools. 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, in practice, food dehydration makes it possible to extend the period for which freshly grown food can be prepared and stored for later consumption when food sources are more scarce. Starting from a previous year's design, several new features were implemented in an attempt to increase the efficiency of the dehydrator design. Most significantly, for a similar interior volume the redesigned dehydrator used walls that were 1/2 the thickness –as compared to the previous design– to enclose the interior space. Thus, along with using less material the overall weight was reduced by nearly 29%. In the previous design, testing on a sunny 91 °F day revealed that the internal air temperature T_{int} was approximately 5-6 °F below the recommended minimum temperature for dehydration of fruits and vegetables (i.e., 120 °F $\leq T_{int} \leq$ 140 °F). Under similar test conditions, the internal air temperature for the new design reached 122 °F, exceeding the recommended minimum temperature. Since the intent of the project was to introduce the dehydrator into regions of sub-Saharan Africa where average temperatures in the hottest months can exceed 103 °F, efficient designs can therefore extend periods of the day –and of the season– during which the dehydrator can be used to safely process food.

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. In AY2017-18, first-year engineering students participated 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 extend the period for which freshly grown food can be prepared and stored for later consumption when food sources are scarcer. The initial designs were considered proof-of-principle in that they were not intended for field application.

In AY2018-19, 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 dependence on access to a fully equipped machine shop. In this way, it was reasoned that student teams would be able to travel abroad to demonstrate construction and use of the dehydrator. In that design, the energy collecting and dehydrating chambers were merged into the same volume and sunlight entered the drying chamber via a roof that was covered with semi-transparent plastic sheeting [5]. Incident solar radiation striking the walls of the dehydrator (painted black in order to help the structure to retain heat) also contributed to the energy input. Air circulation through the device was via natural convection as relatively dry outside air entered the drying chamber through several mesh covered holes located on the floor of the unit. Moisture-laden air exited through a mesh-covered roof vent. In tests conducted in early summer 2019 in the northeastern United States on sunny and/or partly sunny days with outside air temperatures in the 88-91 ^{o}F (31.1-32.8 ^{o}C) range, internal air temperatures were seen to approach 115 ^{o}F (46.1 ^{o}C) in the shaded regions of the dehydrator (i.e., out of direct diffused sunlight). This was between 5-25 ^{o}F below the recommended range (depending on the product) for dehydration of fruits and vegetables [6-10]. It should be kept in mind, however, that food drying can be accomplished anytime the outside air temperature exceeds about 98 ^{o}F [11].

As mentioned above, a simple modification to the previous design was recently implemented with the overall objective to determine if the redesigned dehydrator could achieve the recommended drying temperatures. By reducing the wall thickness, the redesigned dehydrator should allow for greater warming since the thermal resistance of the structure would be decreased. This should result in increased heat transfer to the interior space yielding higher temperatures, all other things being equal. Testing of the redesigned dehydrator in fact revealed this to be the case. One other modification was that the box-type structure of the dehydrator is now completely fastened together using 5/16 in wood dowels.

2. Service Learning as Part of FYS

In early fall, the freshman cohort is assembled together in order to introduce and discuss the need and opportunity for community engagement through service projects. 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% [12]. As a result, approximately 75% of children in the Erie City School District qualified for the National School Lunch program [13].

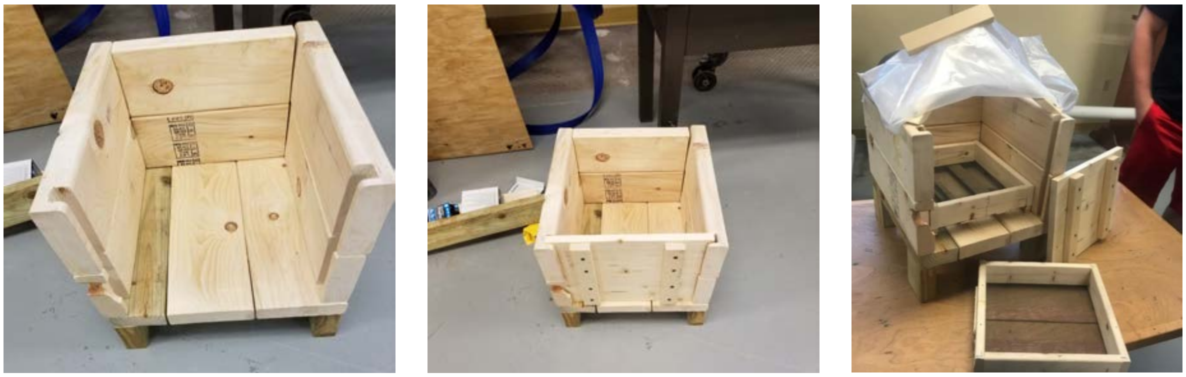
At GU, the freshman engineering cohort is typically divided across three sections. Within each section, students are assigned to multidisciplinary teams comprising between 5-6 team members and including, where possible, ME, BME, ENV, EE, and/or IE majors. Once the teams are formed, a team leader and 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. 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 competition 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. It should be noted, however, that 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 community service projects.

All section faculty are involved in the process to ensure that timely progress is made and to provide guidance, as necessary. By the end of fall semester the project is completed and the design is typically delivered to the stakeholder. However, in the current project a local stakeholder has not been identified since, as mentioned, this service project was specifically initiated with the idea of being implemented in regions of emerging development.

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 moisture content of the food item. 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 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 along with some basic tools; i.e., with minimal-to-no reliance on access to a machine shop.

The Phase 2 SFD design which preceded the current one is shown in Fig. 1. The design was implemented at 1/3 scale since it was not intended for actual use. In constructing the walls and floor of the drying chamber (Fig. 1a), wood dowels were used to fasten many of the 2x6 in planks together. While a drill was used to create the mating holes, a manual hand drill could be used on location. Similarly, a chisel can be used to create the grooves that receive the sliding door (Fig.



(a) (b) (c)

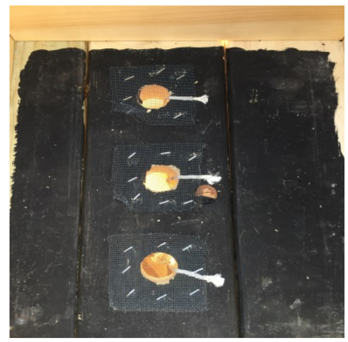
Figure 1. Phase 2 solar-powered food dehydrator: (a) interior volume is framed by walls fastened together with wood dowels; (b) door slides in oppositely matched grooves; (c) completed design showing stackable food trays and a roof composed of four angled slats to which semi-transparent plastic sheeting is attached.

1b). The completed design showing two stackable food trays and the sliding door is indicated in Fig. 1c. As may be seen, angled slats form the support structure for the roof which is covered in semi-transparent plastic sheeting to allow sunlight to enter. Incident solar radiation striking the walls of the dehydrator (painted black in order to help the structure to retain heat) also contributed to the energy input. Air circulation through the device was via natural convection as relatively dry outside air entered the drying chamber through several mesh covered holes located on the floor of the drying chamber. Subsequently, moisture-laden air exits through a mesh-covered roof vent. Testing of the design in early summer 2019 in the northeastern United States (43.2 ^{o} N, 77.6 ^{o} W) indicated that on sunny and/or partly sunny days with outside air temperatures between 88-91 ^{o}F (31.1-32.8 ^{o}C), the dehydrator could achieve internal air temperatures approaching 115 ^{o}F (46.1 ^{o}C) in the shaded regions of the dehydrator (i.e., out of direct diffused sunlight). This was approximately 5-25 ^{o}F below the recommended range of 120-140 ^{o}F (49-60 ^{o}C) for the dehydration of fruits and vegetables.

A modification to the earlier design by using walls that were 1/2 the thickness –as compared to the previous design– to enclose the interior space was implemented in order to determine the warming capabilities of the redesigned dehydrator. Using 1x6 in pine to construct the walls, the redesigned dehydrator enhances heat transfer to the interior space by way of lowered thermal resistance of the structure. The sections of the enclosure were fastened together using 5/16 in wood dowel (Fig. 2a-b) and the walls were attached to the floor also using wood dowels. Dry outside air enters thru several mesh-covered holes drilled into the floor (Fig. 2c). The redesigned dehydrator –for similar interior volume– also uses less material. Compared to the earlier design, the overall weight has been reduced by nearly 29%. One other modification was to the sliding door design. Instead of cutting slots to receive the door (Fig. 1a), channels were created from waste wood. These can be seen in Fig. 2d which also shows the angled roof and the two food trays; the sliding door is in place in Fig. 2e. Testing of the redesigned dehydrator was recently conducted on a sunny to partly sunny 91 °F day (Fig. 2f). Table 1 gives test data for the outside air temperature, inside air temperature, and relevant test conditions. It can be seen that under similar conditions compared to the previous design [5], the internal air temperature in the modified design reached 122 °F. This is above the recommended minimum temperature for dehydrating fruits and vegetables.


(a)


(b)


(c)


(d)


(e)


(f)

Figure 2. Phase 3 SFD: (a)-(b) walls redesigned using 1x6 in pine; sections attached together using wood dowels; (c) mesh covered holes allow outside air to enter the drying chamber; (d) waste wood was used to form channels for the sliding door; angled roof and food trays also visible; (e) sliding door in place; (f) completed dehydrator instrumented for data collection.

Table 1. Test data for the Phase 3 solar-powered food dehydrator (SFD).

Day	Time (EST)	$T_{outside}$ (°F)	T_{inside} (°F)	Comment
7/6/20	12:00p	88	108	sunny w/ breeze
	1:00p	89	117	sunny w/ breeze
	1:30p	90	120	sunny w/ light breeze
	2:00p	90	122	sunny w/ light breeze
	2:30p	91	122	partly sunny w/ freshening breeze
	3:00p	90	118	mostly sunny w/ breeze
	3:30p	89	114	mostly sunny w/ light breeze
	4:00p	89	114	sunny w/ light breeze

4. Conclusions

Given the project task of designing and building a solar-powered food dehydrator, a student-led team generated a unique and simple design. 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 some basic tools. Applying basic thermodynamic properties (e.g., decreasing wall thicknesses in order to decrease wall insulative effect), an updated design was generated. Compared to an earlier design from which it was based off of, the new design was able to achieve internal air temperatures higher than the minimum recommended temperature for dehydrating fruits and vegetables. Since the intent of the project was to introduce the dehydrator into regions of sub-Saharan Africa where average temperatures in the hottest months can exceed 103 °F, efficient designs can therefore extend periods of the day –and of the season– during which the dehydrator can be used to safely process food. Efforts of the first-year engineering student teams demonstrate their capability in addressing one of the global issues –zero hunger– identified and targeted by the United Nations Development Programme in their series of Sustainable Development Goals.

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