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First-Year Service Learning Project: Engineering Education with a Broader Social Purpose

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Abstract

Freshman engineering students at our University take the First Year Seminar (FYS) course in their first semester to assist in the transition from high school to university life and education. The goals of the course include instilling motivation, and cultivating, within each student, a growing interest and passion for engineering, as well as developing the skills required for problem solving in engineering disciplines. A service learning project (SLP), which is included within the FYS taught at our institution, helps achieve some of these goals. Specifically, the students understand aspects of engineering design with cost and time constraints. They must work in teams, thereby contributing and acquiring not just technical skills but also communication and leadership skills. These skills are essential for the engineers of the future to be effective and competitive in the global workforce. For the past three academic years, the SLP focused on food security as stated in the United Nations Sustainable Development Goals. The objective of the project is to design and construct a functional model of a solar-powered food dehydrator (SFD) to remove moisture from produce and extend the shelf life of the produce. Significantly, a key requirement of the project is that the design and construction of the SFD be feasible for on-site construction; that is, without an over-reliance on technical construction techniques or hard-to-get materials. For the past three years, compact, portable and affordable designs have been targeted. This paper, which represents work-in-progress, will discuss the final product designs and the learning outcomes offered by engineering design projects, with service learning components, which are included as part of the FYS experience.

Introduction

Social responsibility and public wellbeing are essential aspects of all professions and, in particular, the engineering profession. The engineering profession is a form of service, as engineers use their skills and knowledge to help solve problems with innovative solutions for the betterment of society. Every engineering project has three major constraints: cost, scope, and time. In addition, design and construction of a solution with design constraints and very limited resources is highly challenging. Challenges like these require teams to have diverse skillsets, excellent communication, leadership, planning and delegation. One such challenge is encompassed in the United Nations Sustainable Development Goal (UN SDG) [1] on food security and nutrition, and sustainable agriculture. One key aspect of achieving this goal is to increase agricultural output and prioritize the strengthening and support of local and small farmers. Many factors such as climate change, volatility of food prices, and social factors such as conflicts, poverty, and education prevent the development and profitability of small farmers. In particular, in developing communities/countries where resources are minimal and farmers cannot purchase food processing and storage systems, low cost and low-tech engineering solutions such as a solar-powered food dehydrator can help resolve some of the problem. In short, use of a SFD can supplement the traditional methods of food preservation and thereby reduce food waste.

Service Learning as Part of FYS

Service learning (SL) in the academic curriculum emphasizes the integration of community service and enhances the learning experience of the students. In addition, SL provides students with opportunities to apply their knowledge to a real world environment. The University mission directs us to prepare our students to be global citizens by offering comprehensive, value-centered learning experience with emphasis on leadership, and social responsibility. To accomplish this mission, faculty are encouraged to incorporate service learning as part of the curriculum. Freshman engineering students are introduced to SL as part of FYS. During fall of 2019, the freshman engineering class was presented with a problem of constructing the SFD to help achieve the UN-SDG of food security, nutrition, and sustainable agriculture. The SFD, in addition to meeting the performance criteria defined below, should be feasible for on-site construction with simple tools and material that should be easily available. A maximum budget of $100 is allowed for each team to purchase all the materials necessary for the construction of the SFD. The freshman cohort was divided into four sections with 16 to 20 students in each section. Within each section, multi-disciplinary teams of 4 to 5 members were formed. Each team had approximately six weeks to develop a design proposal. During this time, teams were required to submit progress reports. At the end of the design phase, the teams presented their proposal for evaluation, and one design from each section was advanced to the construction phase. All materials specified in the winning proposals were then procured. Finally, the project leader from the winning team was responsible for assigning construction tasks to teams that were not part of the winning team. This phase required a lot of communication, planning, scheduling, and leadership skills.

Solar-Powered Food Dehydrator

Design requirements and constraints

Most fruits and vegetables have limited shelf-life due to a high moisture content which results in microbial activity and rotting over time. Drying or dehydration of fruits and vegetables inhibits microbial and biochemical processes thereby increasing the shelf-life; thus making them available during the off-season. Drying can be done in the open air or by using modern technologies such as hot air drying or dielectric heating. While open air-drying or sun drying of produce has concerns over the quality of the final product, modern drying technologies are expensive and, due to the lack of access to electricity in many developing communities/countries, make them hard to use. A solar-powered food dehydrator can address the economic and accessibility issues while providing a quality final product. For the dehydration of fruits and vegetables, the recommended temperature in the SFD should be in the range of 120-140 ^{o}F (49-60 ^{o}C) [2].

The SFD designs developed by the AY19 FYS class were designated as Phase 3 (as in seeking to improve upon the designs from the previous two years). The goal was to improve the feasibility for field implementation in developing regions. Therefore, the materials used in the design should be inexpensive and easily attainable, and construction techniques should be simple. After all, if successful, the design will have to be reproduced in order to handle the anticipated amount of food to be dehydrated. Several Phase 1 proof-of-principle SFD designs are discussed by Gee et al. [2], and a recently completed Phase 2 design addressed some of these goals (Malecki et al. [3]). One of the Phase 2 designs was tested on a summer day in the northeastern United States (43.2 ^{o} N, 77.6 ^{o} W) in 2019 and achieved internal temperatures approaching 115 ^{o}F (46.1 ^{o}C) for outside air temperatures ranging from between 88-91 ^{o}F. This temperature is ~5 ^{o}F below the recommended temperature range of 120-140 ^{o}F for the dehydration of fruits and vegetables. Against this backdrop, AY19 FYS student teams set out to improve upon the Phase 2 designs to enhance overall quality. During fall 2019, the FYS students designed and constructed four SFDs. These designs will be tested during summer 2020.

SFD Design Considerations

Broadly speaking, the crucial aspects of the design include the following:

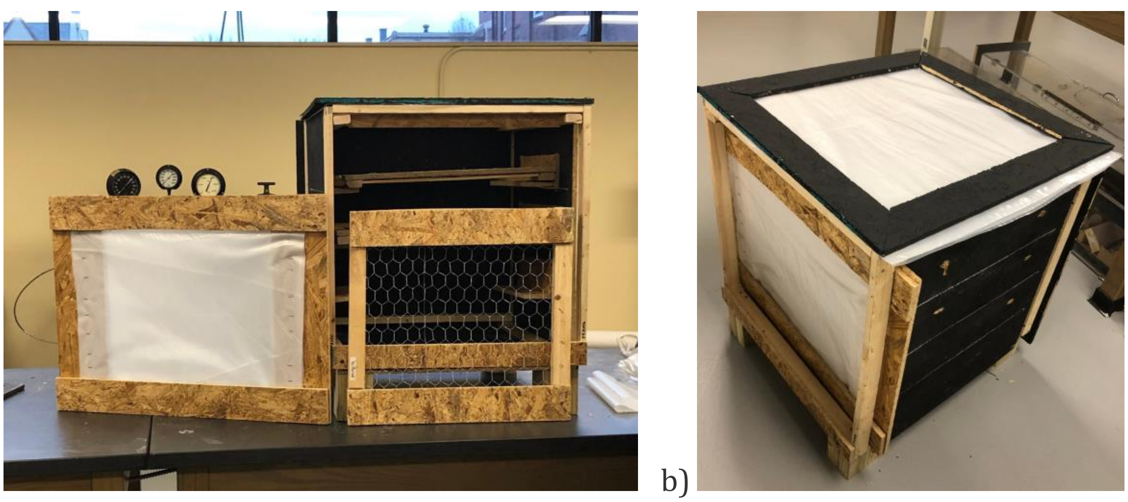
- Must dry food fairly quickly
- Be easy to operate, particularly in terms of loading, unloading, and cleaning
- Be easy to maneuver, set up, and put away
- Portable, durable, and sturdy
- Have venting controls to control temperature and airflow
- Weather resistant
- Pest (insects, rodents etc.) proof

2019 final SFD designs

The primary materials used in all four designs are black paint, nails, plastic sheet, plywood (varying thickness), 2x4 lumber, mesh screens and aluminum foil. All four designs were constructed within the assigned budget of $100. A detailed description the four designs is provided below.

Design 1:

The enclosure is formed from 7/16 inch plywood. The waste plywood was used to form the rails that hold up the 3 food trays. The trays themselves were framed using 1 in x 2 in furring strips, and chicken wire was used as the surface to hold the food (Figure 1 a). The sharp edges of the chicken wire were covered with waste plywood to prevent user injury. In the current design, screws and nails were used to fasten parts together. As can be seen in Figure 1 b), a receiving slot was designed into the two corresponding side walls as opposed to forming a groove into the walls, as was done previously. This was done to simplify construction. Air circulation through the unit occurs via natural convection as the relatively dry outside air can enter the drying chamber through several mesh covered holes located on the floor of the box (not shown). Warmer, moisture-laden air exits through construction gaps in the side walls. Both the exterior and interior surfaces were painted black in the final configuration. Finally, as was the case in the earlier design, plastic sheeting was used to cover the roof and the sliding door. Three food trays are included and the removable door slides in oppositely matched slots; roof and door are covered with semi-transparent plastic sheeting to enhance warming of the interior space.



a) b)

Figure 1: Phase 3 solar-powered food dehydrator design #1

Design 2:

Figure 2 a) illustrates the assembly of the SFD design. Figure 2 b) shows the assembled SFD. The solar thermal energy is collected in a hot box, which is covered by a transparent acrylic sheet. This energy heats up an inlet air which is directed into the interior space which contains two food storage shelves. The rising column of heated air serves to dehumidify food placed on the shelves prior to exiting the dehydrator through two vents located at the top of the sliding door.

The box component of the dehydrator is primarily made of plywood. Other materials that are used for construction of the box are: black matte paint, the lack of shine of which stops excess reflection of light to help absorb the solar energy, the legs are constructed of timber wood, and a screen material is used for the shelves to allow circulation of heated air. In order to minimize hardware such as hinges, the door to the dehydrator utilizes notching in the plywood to function as a sliding door. The second component of the dehydrator is the hot box, which is constructed of plywood and a transparent acrylic sheet. All materials are assembelled using wood screws.

a)

b)

Figure 2: Phase 3 solar-powered food dehydrator design #2

Design 3:

This design consists of an exterior and interior insulation with black tarpaulin lining for heat trapping (Figure 3 b). Drying racks were provided for proper ventilation and heat circulation to allow for moisture to leave. Non-solid trays with different lengths were used to maximize sunlight on each tray/rack and prevent moisture from dripping on lower trays/racks. Doors are provided for access to the interior. The shape and size of this design allows for easier transportation. The final design occupied approximately 0.23 cubic meters and could accommodate three drying racks (Figure 3 a) cut in half to hold at least six non-solid trays. The budget used for the materials was 75% of the available sum of one hundred dollars.

a)  b) 

Figure 3: Phase 3 solar-powered food dehydrator design #3

Design 4:

The fourth design consists of a drying chamber and a hot box. This design is raised off the ground with two ways of heating (Figure 4). First, is a plastic covered hot box that is placed at an angle to allow sunrays in and heat the air. The warm air moves through the drying chamber passing through the food trays. Second, two mirrors made with aluminum foil are placed along windows covered with plastic sheet this will reflect sunrays providing additional heat. Except for the plastic sheet, rest of the SFD exterior was painted black to retain heat. The drying chamber has space for three trays made with aluminum mesh for free movement of air and can handle large quantities of food. It is user-friendly; the door is attached using strings and can be completely removed for accessing trays or for cleaning purposes. The device is also very practical and was constructed from simple and easily accessible materials.

a)  b) 

Figure 4: Phase 3 solar-powered food dehydrator design #4

Learning Outcomes of the SLP

The SL components of the FYS address the following course learning outcomes:

- Become familiar with the engineering design process
- Demonstrate the ability to analyze what they learned from their service learning experience

These learning outcomes are measured by the SL design proposal document, oral presentations, and written reports. The SFD project, in addition to engaging the freshman students in a real-world engineering design problem, also offers these students with a glimpse of the working dynamics of engineering industry; i.e., alignment of individual tasks and contributions with team productivity, proper communication channels and effective leadership roles assumed by the chosen team members.

Future work: SFD Design Evaluation

The following criteria would be used to evaluate each design during the hot summer months.

- Performance in different temperature and humidity conditions
  - *Timing and effectiveness of the drying process*
  - *Throughput i.e. amount of produce dried in a fixed time interval*

- Ease of disassembly and assembly
  - *Extent of cleaning and disinfection of the interior*

- Portability and structural integrity
  - *Ease of relocation*
  - *Stability in harsh weather e.g. high winds, rainstorms etc.*

Conclusions

Overall, the 2019 FYS students were able to design and build four compact SFDs. Most designs met the requirement of compact design, use of inexpensive and easily attainable materials, and simple construction techniques. All the groups finished construction on time and under the allocated budget of $100. Although testing is still pending, the Phase 3 SFD designs show potential for field implementation. FYS students have gained valuable experience designing a product with challenging constraints.

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