Towards Sustainable Society: Design of Food Waste Recycling Machine

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Abstract

Qatar is one of the top 10 countries in the world in terms of per capita food waste; which ranges from 584 to 657 kilograms per year. The combination of high food consumption rate and very low food waste recycle rate, results in mountains of food dumped into landfills where they get burned and produce harmful gases. In this paper, we are introducing a practical solution to recycle food wastage at home. The solution is to design an eco-friendly machine that converts food waste to fertilizer. The use of recycled food waste as compost improves the soil health and structure, increases drought resistance and reduces the need for supplemental water, fertilizers and pesticides. The composting process is fully automated, it consists of several steps under controlled environmental conditions to fasten the process. A mechanism is designed to reduce food waste volume and experiments were conducted to figure out the best conditions of temperature, moisture content and the bulking agent that would result in a high-quality homemade fertilizer within hours. We constructed a prototype of the machine where we focused on the aesthetics aspect by designing an elegant machine with a suitable size to be placed in any kitchen.

Keywords: Recycle, Composting, Food Waste, Design, sustainability

1. Introduction

Food waste is becoming a critical global problem due to the continuous increase in the world population. Figure 1, shows that If food wastage were a country, it would be the third largest emitting country in the world (WRI'S Climate Data Explorer). It is stated that one-third of the food produced in the world for human consumption every year — approximately 1.3 billion tons — gets lost or wasted (UN reports). While in Qatar, around 3,002 tons of domestic waste is generated on a daily basis (ministry of development planning and statistics reports, in 2015). Aside from the social, economic, and moral implications of that waste—in a world where an estimated 805 million people go to bed hungry each night—the environmental implications of food waste to climate change is catastrophic. Thus, there is an urgent need to take appropriate actions to reduce food waste burden by adopting new combating practices. The benefits for the environment and agriculture are represented in protecting the quality of groundwater and reinstating the structure of soil after the natural soil. In addition, disposing food waste into the landfill can cause the organic matter to react with other materials and create toxic mixtures (Risse and faucette, 2006). Thus, recycling food waste to compost is preferred more. Moreover, composting food waste will reduce the volume of the disposed waste and the disposal cost (A Guide to Composting Yard & Food Waste, 2013). In addition, it has a big environmental benefit, which is the absence of synthetic chemical fertilizers in compost. Thus, with all the benefits that the compost we get when recycling food waste holds makes it healthier for human usage than the man-made compost sold in the market.

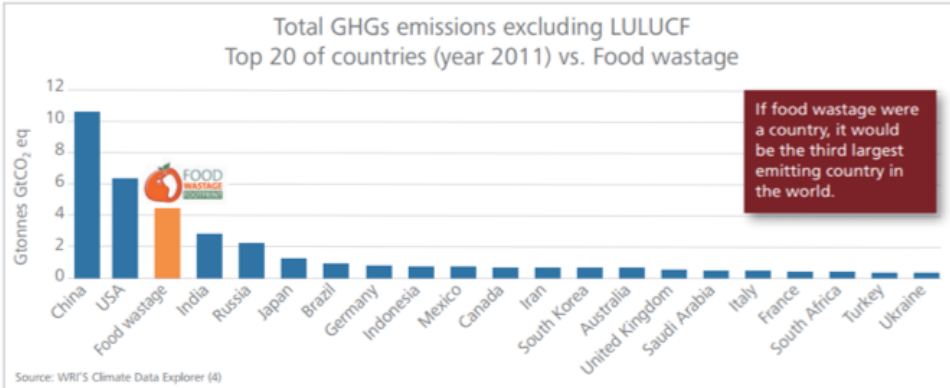

Figure 1. GHGs Statistics from the UN report (WRI'S Climate Data Explorer)

Qatar generated 8,000 tons of solid waste daily in 2012. With an annual growth rate of roughly 4.2%, this number is predicted to reach 19,000 tons per day in 2032. Most of the food waste in Qatar ended up in landfills. "Composting in Qatar is mainly done at the Domestic Solid Waste Management Centre (DSWMC) in Mesaieed, which houses the largest composting facility in the country and one of the largest in the world. The waste that enters the plant initially goes through anaerobic fermentation, which produces biogas that can power the facility's gas engine and generators, followed by aerobic treatment which yields the final product". Moreover, in the coming years Qatar is more likely to increase noticeably the solid waste as the country plans to host the World Cup in 2022. Qatar has a goal to sustain local waste generation at 1.6 kg per capita per day, which will possibly encourage the efforts to recycle and reuse waste. Where "composting can also be an attractive source of income" (Valarini, 2009). However, the factors effects the process of composting is briefly described in the following lines.

1- **Material factor:** The Carbon and Nitrogen levels differ with different organic material. The ideal combination of C: N ratio is between 25:1 and 30:1, if it was higher than 30:1 the heat production will slow down and the decomposition will get slower (Smith and Friend, n.d.) "The C/N content of organic materials varies not only with the type of organic matter, but also with different samples of the same matter." the higher the content of carbon in used materials, the more matter will be needed of high-nitrogen (Swarthout, 1993).
2- **Air factor:** A key environmental factor is the proper aeration. Many microorganisms, including aerobic bacteria, need oxygen. They need oxygen to produce energy, grow quickly, and consume more materials… Natural aeration occurs when air warmed by the composting process rises through the pile, bringing in fresh air from the surroundings (Smith and Friend, n.d.). The absence of oxygen will cause odors and make the process slower that can be fasten by adding cornstalks to deliver oxygen cost (A Guide to Composting Yard & Food Waste, 2013). In aerobic composting the target is maintain 8% or greater of oxygen level (Anon, 2017).
3- **Moisture Factor:** The materials need to constantly have the moisture level of a damp sponge in order for the microbes to break down everything in the compost pile while too much moisture will slow down the decomposition (Anon, 2017).The moisture content should be in the range of 40-60% by weight. A lower moisture levels will limit bacterial activity, and a higher level will likely make the process anaerobic and foul smelling (Smith and Friend, n.d.). However, "there is no universally applicable optimum moisture content for composting materials. This is because each material has unique physical, chemical, and biological characteristics, and these affect the relationship between moisture content and its corollary factors water availability, particle size, porosity, and permeability." (Makan, 2013).
4- **Temperature Factor**: Rapid decomposition's temperatures is between 90º and 140ºF, Lower temperatures signal a slowing in the composting process while high temperatures greater than 140º F reduce the activity of most organisms. The mixture should be rotated constantly so the materials can always get into the warm center (A Guide to Composting Yard & Food Waste, 2013). "Decomposition occurs most rapidly during the thermophilic stage of composting (40-60°C)" they also added "U.S. Environmental Protection Agency specify that to achieve a significant reduction of pathogens during composting, the compost should be maintained at minimum operating conditions of 40°C for five days, with temperatures exceeding 55°C for

at least four hours of this period. Most species of microorganisms cannot survive at temperatures above 60-65°C" (Trautmann, 1996).

5- **Particle size:** The more surface the easier it is for microorganisms to work and decompose the organic waste that is because activity occurs at the interface of particle surfaces and air. With smaller pieces of materials, microorganisms are able to generate sufficient heat and digest (Smith and Friend, n.d.). To accomplish this, the practitioner should need to go through some process, which are shredding, chipping, chopping, or cutting composted materials (A Guide to Composting Yard & Food Waste, 2013).

In the market, there are a number of food waste recycling machines; they all do the same job of turning food waste into compost. For examples, ZERA Food Recycler, The FoodCycler™ and Earth System Organic Waste fertilizer maker.

Table 1. Comparison between Similar machines characteristics in the market (Zera food recycler, 2017. Food Recycler, 2017. Erth system, 2017)

Specifications	ZERA	FOOD CYCLER	EARTH SYSTEM
Capacity	3.5 kg	1 kg	2 kg
Food waste volume reduction	Reduced by 70%	Reduced by 90%	Reduced by 85%
Recyclable food waste types	All types	All types except hard bones/shells	All types except hard bones/shells
Process time	24 hours	2-6 hours	24 hours
Additive	Coir and baking soda	No additive	No additive
Consumed power	6KWh per cycle	1KWh per cycle	Not motioned
Dimensions	28*56*86 cm	38*33*44.5 cm	50*44*61 cm
Weight	53.8 kg	10 kg	17 kg
Automation	Fully automated	Fully automated	Fully automated
control	Control panel and mobile App	Control panel	Control panel
Price	1199 $	394 $	580

1.2. Objectives

The aim of this work is to reduce the amount of food wastage at households in Qatar. The Objectives are:

- Explore the current used practices.
- Study the intended customers (Households) via conducting a survey.
- Design a solution to the problem.
- Build a prototype of the solution.
- Use behavioral science tools to raise the awareness of food waste reduction among people.

This paper will present the machine design process including the customer requirements, design specifications, internal and external constraints, technical risk management, and cost-benefit analysis. Three alternative designs will be proposed and evaluated to obtain the final design of the food waste recycling machine.

2. Methodology definition

2.1. Engineering design process

The engineering solution will be deployed using the illustrated steps in figure 2. The first phase requires the identification of the need and the definition of the problem. Then, find the global optimum solution, after that, constraints and criteria of success will be identified. Accordingly, within the identified constraints, solutions and ideas will be generated. Therefore, a literature review and benchmarking will be conducted to have an insight of the existing technologies.

In the second phase "Synthesis and Analysis", the three potential design solutions will be analyzed and an evaluation matrix will be used to choose the best solution. In the third phase "Communication", a final design solution will be documented to discuss the final design in details. Issues like material, dimensions, tolerances, and sketches will be included. In addition, sensitivity analysis will be done through computer simulation (Solid works) to help in constructing the prototype. In the fourth phase "Construct the Solution", a prototype will be constructed from the previously provided document. Finally, the prototype will be tested to determine whether the product is meeting the design specification.

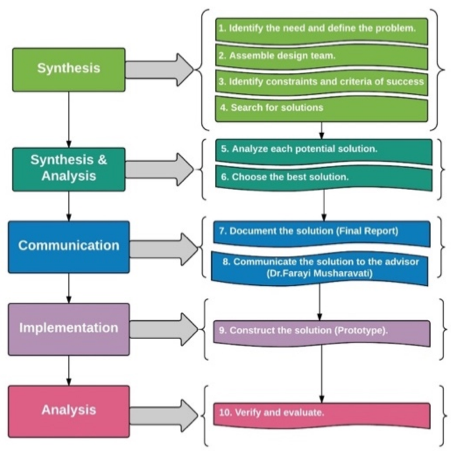

Figure 2. Design Process of Food waste recycling Machine

2.2 Customers identification

Customers are important because they play a significant role in the success of organizations. In any project, there are two types of customers: external customers and internal customers. The external customers provide the revenue stream because they are usually the end-user of the provided service or product. In our project, there are many potential customers to our proposed food waste recycling machine such as restaurants, school cafeterias, universities' food court, etc. However, our intended customers are the households. Thus, our design tends to meet their requirements.

2.3 Understanding customers' needs

The first step in any new product development is to find out what customers want and what they are prepared to pay for. If the new product is not better than existing alternatives in some way, then it will be difficult to compete and to generate a return on investment. Thus, any feature that is added, it must be valued by the customer. A survey was conducted and reviews for similar product were analyzed.

2.4 Customers' feedback/ survey

To begin with, everyone agreed on recycling food-waste in general rather than dumping it to landfills, which indicated that people are interested in helping the environment and find solutions to recycle their food-waste. Then when we asked about turning food waste into compost to use in gardening the majority 94% of people liked the idea, and 79% of people liked the idea of having a food-waste composting machine at home. This helps us to know that there are customers willing to buy our product and use it in their residence. We asked about the approximate food waste amount they throw daily it is important because it helps in the machine design as we can estimate the amount of food-waste recycled per cycle. Moreover, 53% of people did not mind if the machine was not fully automatic but 28% did mind and the rest did not care. The reason of asking such question is to determine the level of automation for the proposed machine.

Since the main goal of our project is to design, build, and use a machine in Qatar, we asked the people if they would buy the machine if it was made in Qatar, 86% said yes.
Finally, when asked if they would buy a machine that costs 300$ or more, 48% of the people agreed, 46% did not and the rest did not care. So, knowing that people are willing to buy our machine will promote our responsibility to make this machine efficient, elegant and produce good compost to convince the majority of people to buy it.

2.5 List of customer needs

To set the preferences for the requirements, 200 reviews were analyzed and the total number of individuals who mentioned this need or requirement were counted. Accordingly, the most mentioned need will have a higher priority. The priority is an integer on 1 to 10 scale, based on the customer feedback.

Table 2. List of Customer Needs

Customer Need	Number of Reviews	Priority
Easy to use and to harvest compost.	100	5
Get the compost as fast as possible.	85	4.25
Take a lot of scraps.	50	2.5
Worth the money.	95	4.75
It doesn’t stink or smells	160	8
Don’t attract flies or maggots	150	7.5
Not flimsy door mechanism.	112	5.6
Nice design.	45	2.25
Easy to tumble (i.e. turn) when it is full.	88	4.4

2.6 Product design specifications

Quality Function Deployment is used to translate customer needs into specifications. Furthermore, a product design specification (PDS) is constructed to show how the design is made, what it is intended to do, and how far it complies with the requirements. However, it is important to note that the priorities of customer driven specifications were set using house of quality and the priorities of the benchmarking and group decision driven specifications were set relatively by the team members.

2.7 Product design constraints

Every project has constraints and limitations. These are the applicable constraints for this project:

- **Realistic External Constraints:** Economical, Environmental, Health and Safety, Manufacturability, Political, Social, Sustainability, Ethical.
- **Internal Constraints:**

1. There should be a separate chamber to collect the final compost.
2. The composting process should be finished in not more 24 hours
3. The machine should be fully automated
4. The volume of the collecting food waste chamber should be adequate according to the amount of food that will be placed in it.

2.8 The product design standards

- Ethical Codes and standards by “National Society of Professional Engineers, Code of Ethics for Engineers”.
- Guidelines for Compost Quality by “National Standards of Canada CAN/BNQ 0413-200, Canadian council of Ministers of the environment”
- Minimum practical wall thickness by “ASME BPV Code Sec, VIII D.1”

2.9 Food waste characterization in Qatar

The management of the feedstocks depends on the type of the food waste. Because, the various physical and chemical properties can affect significantly the final product (i.e. compost) characteristics and it can influence odor production. Due to the lack access of data in Qatar, a regional characterization study was taken.

According to food and agriculture organization of the united nations (2011), the estimated amounts of food waste at household levels in North Africa, west and central Asia are shown in figure 3. It will be assumed that Qatar's food waste will have similar percentage.

2.10 Assumptions of Food waste amounts

According to environmental reports from ministry of development planning and statistics (2015) in Qatar, the daily per capita domestic waste generation is 1.23 kg. Also, they stated that the average family consists of 5 members. So, the daily waste production for a regular family equals 6.15 kg/day. However, a study of waste management in Qatar revealed that the amount of organic food waste is about 60% of the total domestic waste (Ahmed, 2016). Thus, it can be assumed that the amount of wasted food by typical family is 60% of 6.15 which equals 3.69 kg/day

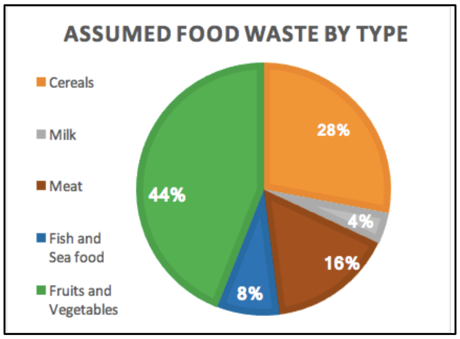

Figure 3. Assumed types and percentages of food waste

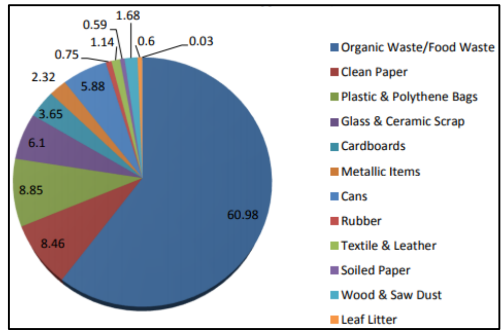

Figure 4. Household's waste types in Qatar

2.11. Cost-Benefit analysis

Cost benefit analysis tool used to determine whether the eligibility of the project. This tool can estimate the equivalent money value of the project benefits' and compare it to the expected costs to spend. Costs were estimated based on the production of one unit of food waste recycling machine and B/C (i.e. Benefit to Cost ratio) was calculated to be 1.9.

3 Developing design solution

3.1 The conceptual design

Functions of the machine:

- Reduce the volume of the food waste by 80%.
- Compost any form of food except bones, meat and chicken.
- Provide warning labels to ensure that customers are using the machine safely.
- Quite working to avoid noise problem to the user.
- Have an attractive design to encourage recycling.

Figure 5. The machine's conceptual Design

3.2 The generated design alternatives based on three engineering principles

- **Alternative 1 (Principle of Inclusivity)**: most food waste recycling machines can't process bones, so we wanted to introduce an alternative which can. This alternative uses high performance two-shaft shredders that are able to cut very hard materials. This would allow for a more universal and convenient solution for the users.

- **Alternative 2 (Principle of Automation)**: this alternative eliminates any manual operations that the user would have to carry out, and involves automatic features and controls that would make the food recycling process easier for the user and allows for a much more enjoyable experience.

- **Alternative 3 (Principle of Sustainability)**: this alternative doesn't require a power source, and is completely powered by solar energy. The solar energy generates the electricity required for carrying out all the machines processes. This alternative is considered efficient and cost aware.

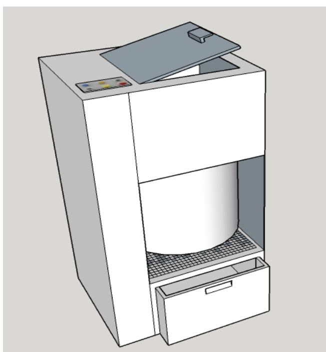

Figure 6. Alternative 1

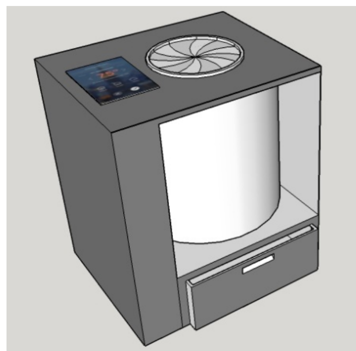

Figure 7. Alternative 2

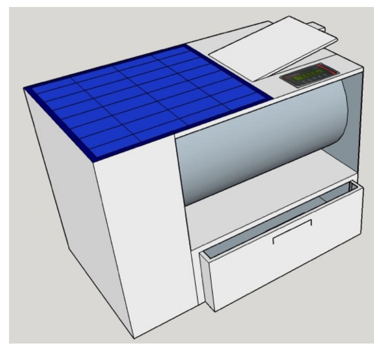

Figure 8. Alternative 3

Table 4. Comparison between the three design alternatives

		Alternative 1	Alternative 2	Alternative 3
1	**Feeding mechanism**	Top/vertical	Top/vertical	Top/vertical
2	**Appropriate environment**	Indoors	Indoors	Outdoors
3	**Power supply**	Required	Required	Not required
4	**Food types it can process**	• All food items including bones • All food containers except for plastic	• All food items except for bones • All food containers except for plastic	• All food items except for bones • All food containers except for plastic
5	**Inlet design**	Automatic lid that opens upwards	Automatic spiral panels that slide outwards	Manual lid that opens upwards
6	**Outer shell material (body)**	Acrylic	Acrylic	High-performance plastic
7	**Movement of material**	Horizontal (right and left)	Vertical (downwards)	Vertical (downwards)
8	**Mixing chamber orientation**	Horizontal	Vertical	Vertical
9	**Cutting mechanism**	Shredding using a two-shaft shredder	Shredding using individual sharp convex blades	Grinding using a one-piece continuous spiral blade
10	**Mixing mechanism**	using a rotating rod (Shear Mixing mechanism, i.e. involves thorough incorporation of material passing along forced slip planes in a mixer)	using a rotating rod (Diffusion mixing mechanism, i.e. slow blending mechanism, so after a long time the mixture will be homogenous)	using a rotating rod (Convection mixing mechanism, i.e. gross movement of particles)
11	**Heating mechanism**	Convection using heating gun	Convection using heating coil	Convection using
12	**Automation level**	Semi-automatic	Fully automatic	Semi-automatic

13	**Measuring features (sensors)**	Sensors for temperature and moisture. (measuring temp. of Air)	Sensors for temperature, moisture, and proximity. (Contactless sensor and measure food)	Sensors for temperature and moisture. (Contact and measure food)
14	**Control panel**	Simple buttons (on/off)	Advanced touch screen technology	LCD screen and buttons
15	**Number of chambers**	Five: 1- Electrical components chamber 2- Motor chamber 3- Mixing chamber 4- Cutting chamber 5- Collecting chamber	Four: 1- Electrical components chamber 2- Motor chamber 3- Mixing and cutting chamber 4- Collecting chamber	Four: 1- Electrical components chamber 2- Motor chamber 3- Mixing and cutting chamber 4- Collecting chamber

3.3 The alternatives design evaluation process

The criteria used to evaluate the three alternatives are:

1- Performance: as it is the product's main operating characteristics such as process speed and effectiveness.
2- Features: the additional characteristics that enhance the appeal of the product and attract the customers .
3- Sustainability: to reducing any harmful impact on the environment and reducing the economic impact of high-energy costs.
4- Automation: it is important as it reduces the process time, reduce human error, and increase safety.
5- Control: it is important because the machine will be used is houses it should be user friendly and easy to control.

An evaluation matrix is used where each criterion has a weight from 1-5 where 1 refers to less importance and 5 refers to highest importance. The weight of each criterion is assigned based on the designer's experience and relative scoring method used to score the alternatives from 1 to 5. Results from the evaluation matrix was as follows: Alternatives 1 and 3 got close results with a difference of only 2 points, which make them on the same level. While Alternative 2, which is the one, designed based on the automation principle got the highest score with a deference of 13 points compared to the second highest score. Thus, it is reasonable to choose the alternative design 3 as the best design solution.

4 Final design

Through an intense research process of existing technologies and designs, we were able to develop the following machine components and characteristics.

4.1 Material Selection

Stainless steel was selected to manufacture the blades, shaft and chamber. Because it has low density (i.e. light), it's strong (i.e. young's modulus 203 GPa) and it noted for excellent welding characteristics and formability. Along with that, it has a good corrosion resistance as the operating conditions such as the humidity level (55%) may cause corrosion. Also, it is important to note that stainless steel is 100% recyclable with no degradation (British Stainless-Steel Association). So, these parts can be recycled at the end of the product life cycle and hence reduce the environmental impact of the proposed machine production process.

4.2 Design the Chamber

The worst scenario was taken into consideration which is that the machine is going to cycle about 18.45 kg of food waste once a week. According to INFOODS density database (2012), the average density of food waste is about **1** g/ml. The maximum allowable chamber size was determined from the stated information and using the following equation $Density = \frac{mass}{volume}$. In addition, The ASME BPV Code Sec VIII D.1 was used to specify the minimum wall thickness such that the proposed chamber is withstanding its own weight and any incidental loads.

4.3 Design of the feeding system

To make easier to the user an automatics Iris mechanism door is designed. It involves panels that slide open towards the outside revealing circular opening (see figure 9). It includes a proximity sensor that detects approaching obstacles (users hand, food plates, foot items) and the panels open automatically, if the obstacle is within a specific range.

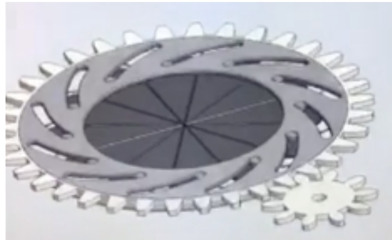

Figure 9. Iris mechanism door designed by Solidworks

4.4 Design the Cutting and Mixing

The optimal cutting blade design is the one that provide maximum contact with feed ingredient and hence maximize the amount of the processed materials (Saravacos & Kostaropoulos,2002). Also, the blade with linear edge shape can be the sharpest one as it will require less force to cut than other blades So, it can be said that the finer a cutting blade and the narrower a wedge angle, the finer is the cut (Debao & McMurray,2011). Based on these considerations, a tilted multi-level blade with fine geometry was developed (Figure 10). The blades were designed to be replaceable to enhance the maintainability of the design. Since the performance factors in Cutting mechanism differ from mixing mechanism, an additional part was added to the design to enhance the mixing process as the fine blades are not efficient in mixing. In order to determine the final allowable dimensions of these parts, free body diagram and principal stresses equation $\sigma_{max} = \frac{\sigma_y + \sigma_x}{2} + \sqrt{(\frac{\sigma_x - \sigma_y}{2})^2 + \tau_{xy}{}^2}$ were used to analyze the applied forces.

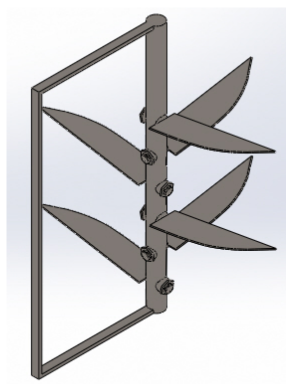

Figure 10. Mixing and Cutting Hand Design using SolidWorks

4.5 Design the Shaft

The main function of the mixing shaft is to hold the blades and the mixing hand jwhich are used to cut and mix the food waste during the composting process. Thus, it should be designed to withstand the torsional and shearing stresses. Also, two bearings are suggested to support radial loads and hence reduce unnecessarily vibrations.

4.6 Design of the Motor

From solid mechanics calculations, the maximum torque on the shaft = 89 N.M and the required speed is 56 rpm which was determined by reverse engineering by taking Panasonic chopper as a reference. By doing the proper conversion and following equation this equation $\mathrm{Power} = \mathrm{Torque(N/m)} \times \omega\ \mathrm{(rad/s)}$, motor was sized. But, it is important to note that the maximum efficiency of exiting motors is about 75% U.S. (Department of Energy, 2014). So, the actual required power input will equal to $\frac{\text{Power Output}}{\eta_{\text{ Motor}}}$,which was found 700 Watt.

4.7 Design of Heating System

Heating rods have been chosen for the final design of the machine because it suits the orientation of the machine, it is safer compared to the heating gun and the heating coil because it has low possibility of causing hazards (i.e. less risk).

4.8 Validation of the Design

To validate the design, finite elements test using Solidworks software was applied to the proposed parts as shown in figure 11, 12, 13. The test results matched the theoretical calculations, as the maximum obtained stresses from the software equaled the theoretical ones. However, in the additional mixing part design, it is important to note that although the static test has confirmed our results, a dynamic deflection or (dynamic test) is recommended because the accumulated energy absorbed by the part during mixing stage may cause the failure of the part. So, doing such test will show this information and hence we may get an insight about the reliability of the designed part.

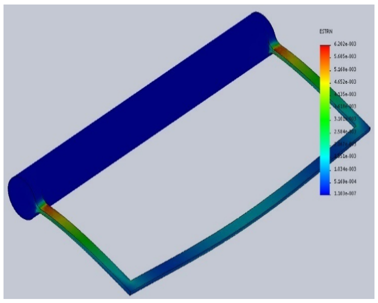

Figure 11. Stress analysis of the mixing hand

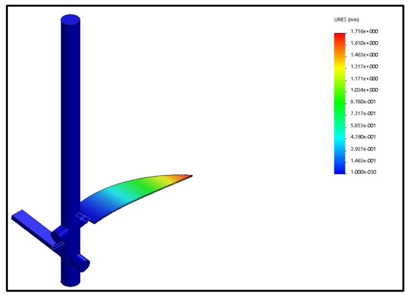

Figure 12. Stress analysis of a cutting blade

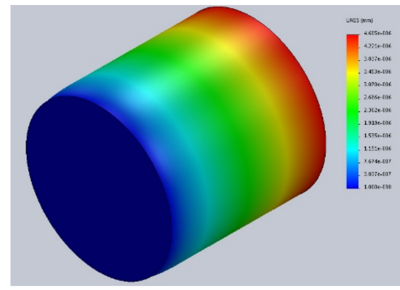

Figure 13. Stress analysis of the chamber

Solidworks simulation software subdivided the model into smaller pieces of elements, connected at common points called nodes. Then, it predicts the behavior of the model as a network of these interconnected elements. This process is called meshing. So, the smaller the mesh size (i.e. element size), the more accurate are the obtained results. In figure 14 and 15, various mesh sizes were specified and the resulted stress values were plotted and compared to the calculated stress.

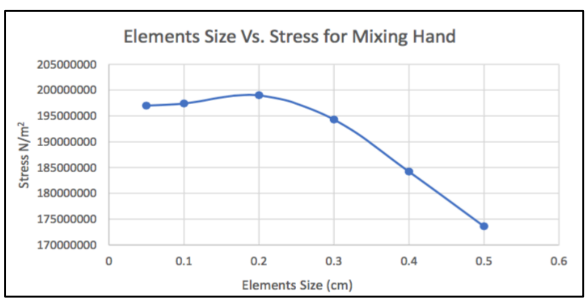

Figure 14. Graph of Element Size Vs Stress-Mixing Hand

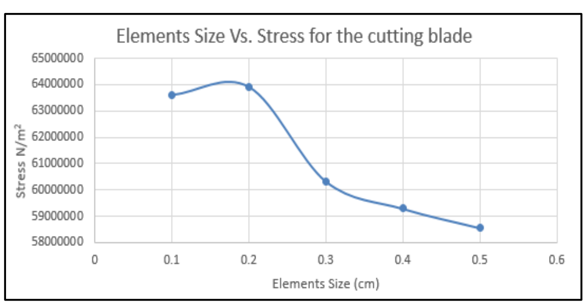

Figure 15. Graph of Element Size Vs Cutting Blades

4.9 Integrated Machine Design

Figures 16, 17 and 18 illustrate different views of the 3D design of the proposed food waste recycling machine. The dimensions of the machine are: height 30cm, width 40cm and depth 30cm.

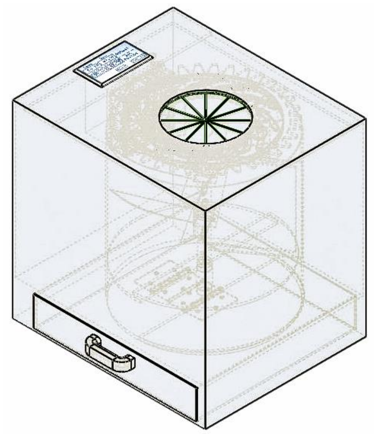
Figure 16. Oblique View

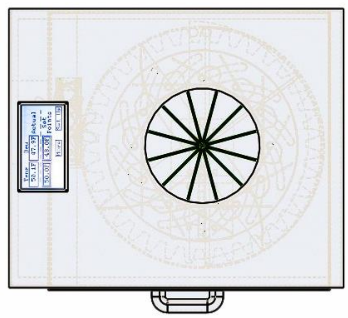
Figure 17. Top View

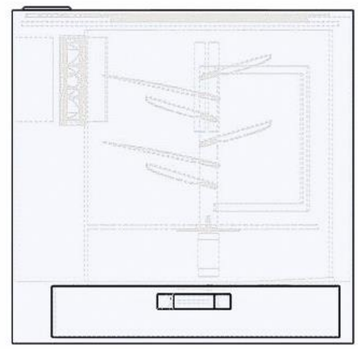
Figure 18. Front View

4.10 Control System

The proposed machine is automated as the critical factors like the temperature and moisture level will be controlled. Also, the opening lid will be controlled via proximately sensor. In order to do that Arduino microcontroller is going to be used. An initial simulated circuit design was created using TinkerCad Software to validate the system. In this circuit, analog and digital pins were used. Also, information from the technical data sheet of the sensors was used to do the calibration.

4.11 Display Design (Touch Screen User Interface Design)

Based on Donald Norman's Book, *the Design of Everyday Things*, (Norman, 2002) these are the user interface principles that have been applied to design the user interface of the touch screen (see figures 19 and 20) that control the machine:

1. **Visibility:** Good visibility indicates that it should obvious for the user what the control is used for. The controls on the touch screen allows the user to turn on, turn off or stop the machine to add more food waste. the function of each control is written on their touch buttons as shown in figure18.
2. **Affordance:** It means that it should be obvious how to operate a control. The user should know how to use a control just by looking at it. To design the touch screen with high affordance the touch buttons looks like real buttons with 3D design.
3. **Feedback:** Indicated that once the user has used a control, the system should clearly communicate what has just been accomplished. The feedback on the touch screen consists of four parts. First, when starting the machine, it shows on the screen that the machine started processing the food waste. Second, if the user pressed the pause button after 15 minutes of starting the machine it will be shown on the screen that the machine cannot be opened until it finishes the composting process. Third, when turning off button is pressed a conformance message will appear on the screen to ask the user if he is sure want to turn off the machine, if the user confirms turning off a feedback message will appear on the screen to inform the user that the he will not be able to open the machine until it cools down. Lastly, when the machine finish composting the food waste a message appear on the screen along with a peeping sound to notify the user that he can pull out the compost container. The temperature degree inside the machine will be always shown on the screen.

For children protection, turning the machine on and off or pause it, requires the user to enter a small four numbers password.

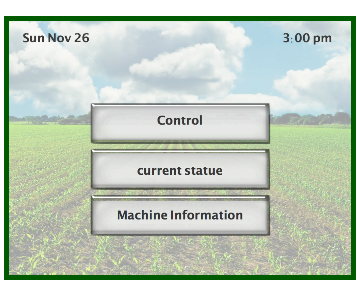

Figure 19. Touch screen user interface design

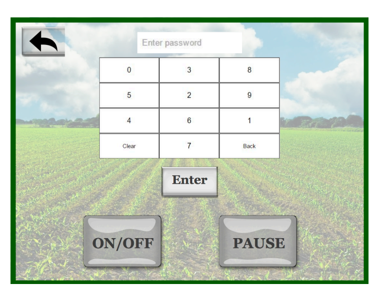

Figure 20. Touch screen display after clicking on

4.12 Prototype Construction

Prototype construction is the last part of the product design process, because it helps engineers in testing theories and confirming performances to the specified PDS (i.e. product design specifications). In this project, various design iterations were done to come up with the finalized mechanical and electrical systems of the prototype. It is important to note that the prototype is scaled one to one which is shown in figure 21.

Figure 21. proposed prototype

5. Conclusion

All in all, this paper aim is to show the importance of recycling food waste and helping the environment by building a machine that converts food waste into compost. The machine is completely manufactured in Qatar. This food waste recycler machine is to be built and used at home safely. The design methodology and the engineering solutions that will be used in this project were explained in the engineering design process. Followed by the identifying the customers, knowing their needs and taking their feedbacks, which are considered important since our purpose is to satisfy the customer's needs. Furthermore, a quality function deployment was used to translate customer needs into design specifications. In addition, the external and internal constraints and the design standards were identified. Moreover, the conceptual design for the machine, the design alternatives, alternatives evaluation, and the machine's final design all were discussed briefly and shown in detail in this paper. Since the world is seeking sustainability, our machine aims to lessen the food waste that is thrown into the landfills, which pollute the environment by recycling the food waste and turning it, in less than 24 hours, to compost that can be used in fertilizing the soil to plant healthy and organic food, and contributing in creating a safe and sustainable world.

Acknowledgement

Our special thanks of gratitude go to our professor Dr. Farayi Musharavati, who gave us the opportunity to do this project on the topic "Design of an Eco-Smart Food Recycling Machine for Qatar" and for his nonstop support for the project. Secondly, we would like to thank our supervisors in this project, Dr. Samer Gowid and Eng. Mohammed Rashwan, for their continuous help and support throughout the project, who also encouraged us in doing a lot of research on the topic to come up with the best solution.

Also, we would like to thank all the professors and teaching assistants in the department of Mechanical and Industrial Engineering for giving us the help whenever we ask for it. Furthermore, our thanks go to the technicians in the mechanical workshop for their assistance in the manufacturing part of the project. Lastly, we thank Dr. Jalal Abdullah for his helping and guidance in writing this paper.

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