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Efficient Method to Reduce Weight and Volume of Food Waste at Home by Creating a Powered Dry-Grinding System

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ABSTRACT

Almost 330 million pounds of food are wasted in the United States every day. This waste ends up in landfills and emits a harmful chemical called methane. According to the Environmental Protection Agency (EPA), food waste is directly responsible for two percent of carbon emissions [1]. Throwing away food waste into green trash bins at high temperatures can bring about fetid rotting. Our project goal is to reduce the amount of food waste and demonstrate an eco-friendly and efficient disposal method by optimizing the blade for a dry-grinding system. We developed a dry-grinding system with the inside temperature of the container maintained at 80°C ± 3°C for dehydration for 3.5 hours. To reduce moisture, we installed a fan in the system and activated it for 5 hours. We designed 4 different types of blades, tested them in the same condition, and selected the best blade type to reduce food waste. We quantified the food waste reduction with 7 different foods and dairy food waste. Our method demonstrated an average food waste reduction of 76% weight and 67% volume. Ultimately, processed food waste is a natural and sustainable alternative as it enriches soil with essential nutrients that can be used as compost.

Introduction

Almost 330 million pounds of food are wasted in the United States every day. This waste ends up in landfills and emits a harmful chemical called methane. According to the Environmental Protection Agency (EPA), food waste is directly responsible for two percent of carbon emissions, or half of all aviation emissions [1]. It wastes a significant amount of water. According to the World Resources Institute, 24% of all the water used for agriculture is lost through food waste every year. That's 45 trillion gallons (about 170 trillion liters) [15].

Food waste must be separated from general trash. Beginning from 2022, Senate Bill (SB) 1383 began to require every jurisdiction to provide organic waste collection services to all residents and businesses [2]. Additionally, California state law will fine those who contaminate their organic waste starting from 2024. The first offense can cost up to $50~$100 and subsequent offenses can cost up to $500. However, separating food waste is a challenge. For example, summer lasts for 3.6 months, from May 31 to September 16, with an average daily high temperature above 78°F. The hottest month of the year in California is July, with an average high of 86°F and low of 71°F [3]. These high temperatures cause recycled food waste to spoil easily, resulting in poor hygiene and appearance.

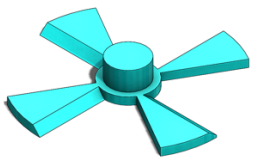
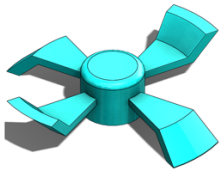
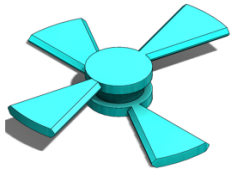
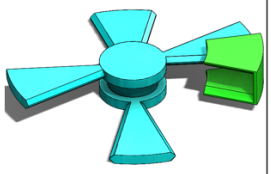
Food recycling doesn't solve everything. No matter how much recycling you do, nothing can be better than fundamentally reducing the amount of waste. Individual efforts have the greatest impact; this includes throwing away expired food or not overly buying food in the first place. Everyone needs to figure out why food is wasted in their kitchen and discover ways to avoid it.

Again, in California, the average temperature in July is 86°F, and throwing away food waste at high temperatures will inflict fetid odor and rotting. Hence, we will demonstrate an efficient method to reduce weight and volume of food waste at home by creating a powered dry-grinding system.

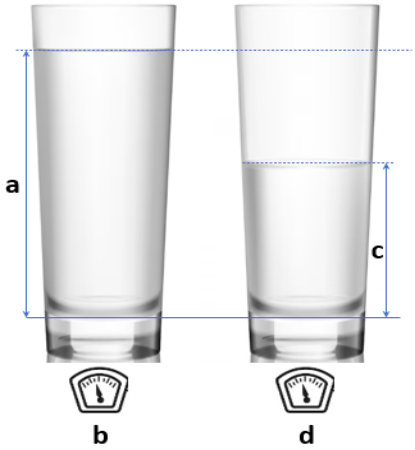
Method

Both volume and weight of food waste needed to be reduced. We hypothesized that following the traditional principle of drying food waste under low heat and steady air flow could remove enough moisture and help to significantly decrease the waste's weight. We also hypothesized that if food waste is cut into smaller pieces, both its volume and the drying duration could decrease. Consequently, we formulated an idea that the waste's volume can be reduced efficiently with the optimum blade. Thus, we evaluated 4 different types (as shown on Table 1) with the same motor (12V direct current high torque and low speed [40 revolutions per minute]) and found the best one. After careful consideration, we hypothesized that type 4 could be the best for our prototype. Type 2 was a normal blender blade, which was a possible design for a high-speed motor. After testing each type, we selected the best design with the most reduced volume and weight.

Table 1. Design of the tested blades

Type 1	Type 2	Type 3	Type 4
One layer & no bending	One layer & bending	Two layers without chopper	Two layers with chopper
			

We designed 4 different cutter blades and manufactured them through a metal 3D printing service. Starting off, we put the food waste into a transparent cup and measured the weight and volume. After 5 hours of operation, we placed the processed food into the same transparent cup and measured the weight and volume again. A detailed method to quantify efficiency is shown in Figure 1.



How to quantify volume and weight reduction

Step 1: Put food into transparent cup and take picture

Step 2: Measure it on scale and log weight(**b**)

Step 3: process on prototype

Step 4: Put processed food into transparent cup and take picture

Step 5: Measure it on scale and log weight(**d**)

Step 6: Place and compare height(**a** & **c**) with taken pictures from Step 2 and 5

	Volume	Weight
Before	a	b
After	c	d
Reduced(%)	(a-c)/a*100	(b-d)/b*100

Figure 1. How to quantify volume and weight reduction

Our system included a stainless container, a base body, a motor, a gear, a bearing, a heater, a temperature sensor, and a cutter. To control temperature, motor, and operation duration, we used Arduino. Table 2 includes details of our prototype.

Table 2. Details of Components

Description	Picture	amount	Unit price	source
Mainstays Brushed Nickel Metal Bathroom Wastebasket - Silver		1x	$12	walmart
trash can-plastic		1x	$9	walmart
S SYDIEN 4Pcs 8mm/0.31" ID Silver Zinc Alloy Pillow Block Flange Bearing Self-Alignment KFL08		4x	$8.99	Amazon
BRINGSMART 12V 40rpm DC Worm Gear Motor 40kg.cm Self-locking Reversed Engine Mini Turbine Geared Motor for DIY Robot Rotating Table Door Lock Curtain Machine (12V 40rpm)		1x	$28.99	Amazon
Harissess 5PCS Round Silicone Heating Pad,12V 30W Electric Rubber Heat Wrap Hot Heating Mat for Industrial Equipment (Φ100mm)		5x	$20.59	Amazon
Bringsmart 370 Mounting Bracket with Screw Worm Gear Motor Fixed Fastener DIY Parts DC Motor Holder (Single-Side Bracket)		1x	$8.99	Amazon
Othmro 2Pcs 108-8 Mechanical Shaft Seal Replacement, 8mm/0.31" ID Alloy Plastic Shaft Seal for Pump Shaft Water Pumps Shaft Mechanical Sealing for Swimming Pools Spa Pumps		2x	$9.99	Amazon
2PCS 8mmx 400mm (0.32" x 15.75") Case Hardened Chrome Plated Linear Motion Rods Linear Rail Rod Shaft for 3D Printer, DIY, CNC - Metric h8 Tolerance		2x	$13.99	Amazon
Zeberoxyz 2PCS 8mm to 8mm Aluminium Plum Flexible Shaft Coupling Diameter25mm Length30mm 8x8mm Motor Connector Flexible Coupler for 3D Printer CNC Machine and Servo Stepped Motor (8x8mm)		2x	$12.99	Amazon
Box for Base		1x	$9.99	walmart
DC 12v 24v to 5v Step Down Converter		1x	$12.99	Amazon
2 pcs 5V 2 Channel DC 5V Relay Module with Optocoupler High/Low Level Trigger Expansion Board		2x	$5.69	Amazon
LM YN DC 12V Digital Thermostat Module -58°F to 257°F Fahrenheit Temp Display Temperature Controller Board with 20A Relay Waterproof Sensor Probe Dual LED Display Red Blue		1x	$11.99	Amazon
Arduino Uno R3 Development Board, Kit Microcontroller Card		1x	$16.99	Amazon

Design Criteria

Although the entire nation wastes about 2.5 billion tons of food annually, the United States discards more food than any other country in the world with 60 million tons wasted per year. This is estimated to be almost 40 percent of the entire US food supply, and it equates to 147 kg of waste per person or 400g per person/day [4]. Our design goal was to reduce 50% of this daily waste to 200g.

Here was our design criteria:

1. The maximum food waste that can be put in our system is 1408 grams (400 x 3.52(Average family size [5])).
2. When the lid is open, the motor and fan must be turned off immediately.
3. The system operation voltage is 12V.
4. Our system needs to be for indoor usage and the total size of the system must be 300x400x400mm.

Constraints

Our system could not process all foods. For hygiene reasons, we used meat or fish only when boiled or cooked. Below shows a list of acceptable and unacceptable food inputs:

Acceptable food waste: Fruits, Cheese, Meat, Fish, Noodles, Rice, Pizza, Sausage, Cookies, Bread, and Cooked Egg.

Not acceptable waste: Bone, Shell, Plastic, Metal, Glass, and any Wooden Materials.

Our Final Design

We designed the inside temperature of the container to maintain 80°C ± 3°C for dehydration for 3.5 hours. There were 3 different operation modes: slow mode, high mode, and stop mode. The stop mode was activated when the lid opened. A fan was installed in the system and activated for 5 hours to reduce moisture. Details about operation to control temperature and motor are shown in Figure 2. Figure 3 is a close and detailed view of our system.

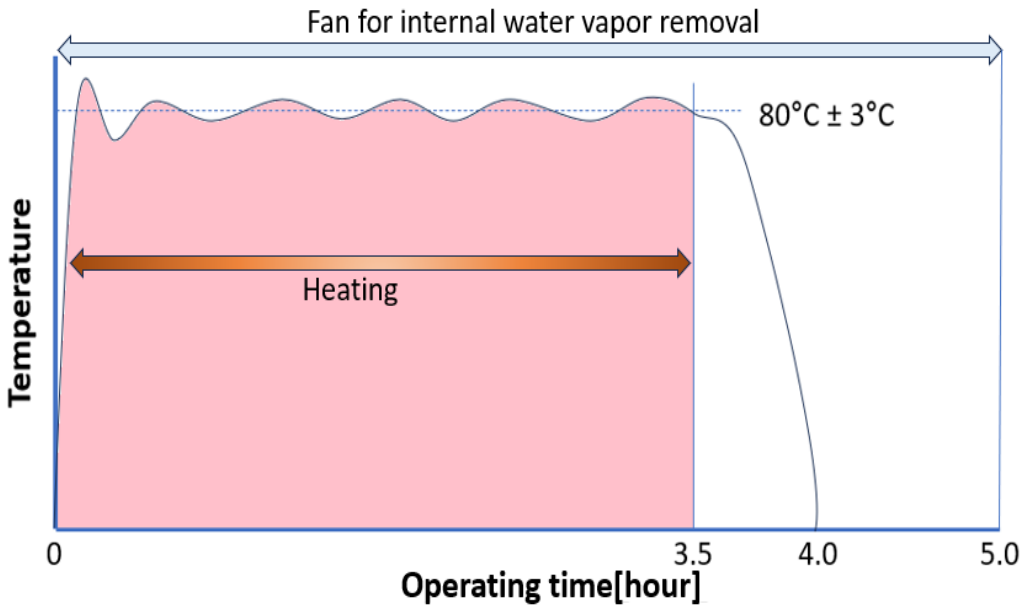


Figure 2. Operating time and temperature/motor control for dehydration

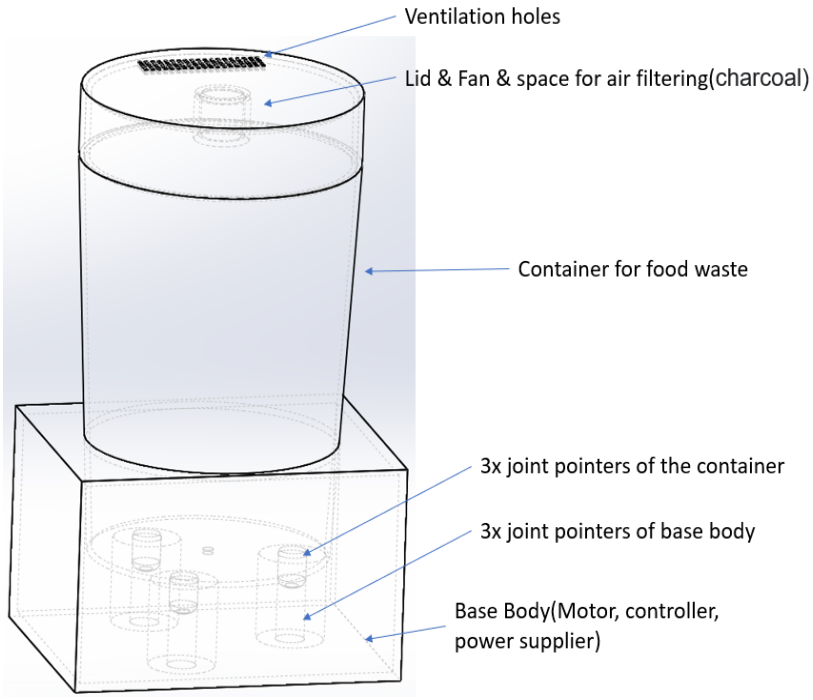
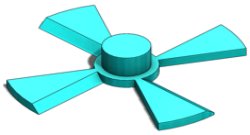
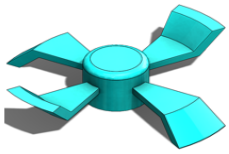
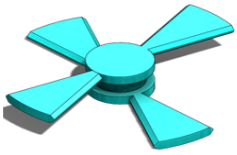
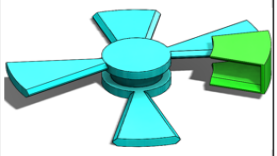


Figure 3. Design of prototype and components

We used the method described in Figure 1 to quantify efficiency of food reduction. Comparison results are shown on Table 3.

Table 3. Summary of result per type and picture of residual.

Before	Type 1	Type 2	Type 3	Type 4
	One layer & no bending	One layer & bending	Two layers without chopper	Two layers with chopper
Test food : Vegetable Weight :				
760 g	68 g	50 g	32 g	18 g
				
Remark	Both big & small pieces	More fine piece than Type 1 but still big piece.	More fine piece than Type 1 and 2.	Cut into small pieces evenly. The most fine piece

Based on Table 3, we concluded that type 4 was the best, as expected. The chopper cut food into small pieces at a slow motor speed. But during the test, we figured out that it was not easy to access the bottom of the

container for cleaning purposes. So, we decided to remove one blade in the upper layer as this change facilitated access to the bottom of the container. Figure 4 shows the final optimum blade for the prototype that we chose.

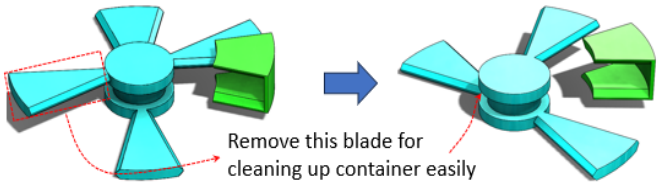


Figure 4. The final optimized blade based on type 4.

The system's internal diagram with the final design among 4 blade types is like Figure 5.

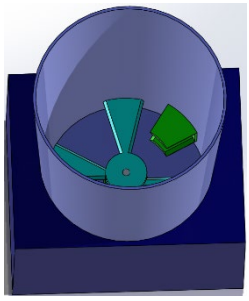
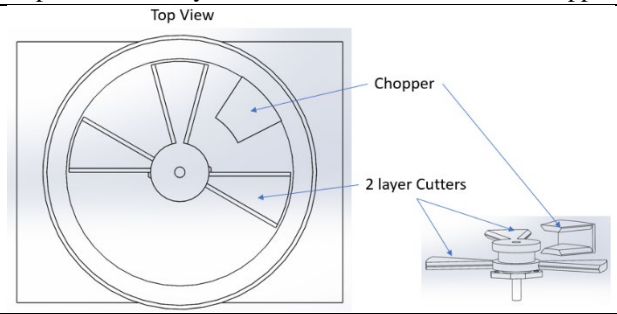
3D view of the inside of the system	Top view of the system inside with cutters and a chopper
	

Figure 5. The System's Internal Diagram

Before assembling the prototype, we initially developed 3 main modules shown in Figure 6, 7 and 8 to check the basic function per module.

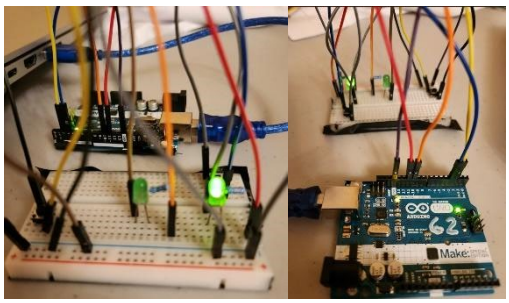


Figure 6. Module to test basic function for (Start, 5 hours operation, Stop when lid opens)

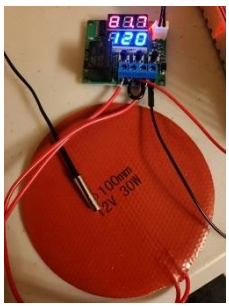


Figure 7. Module to control Heating & Temperature

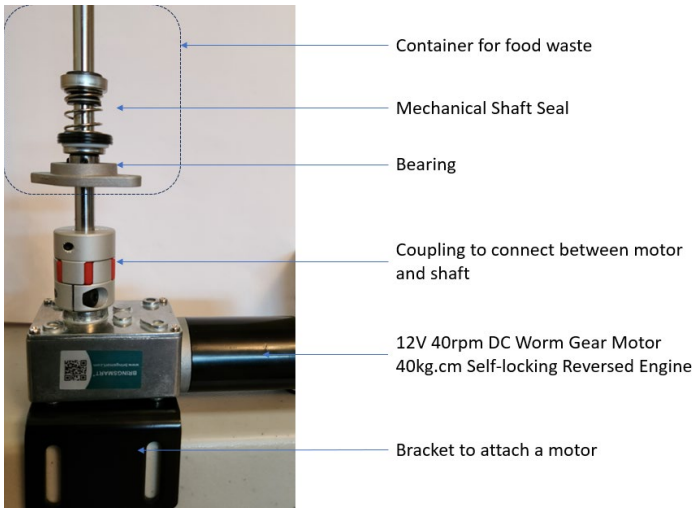
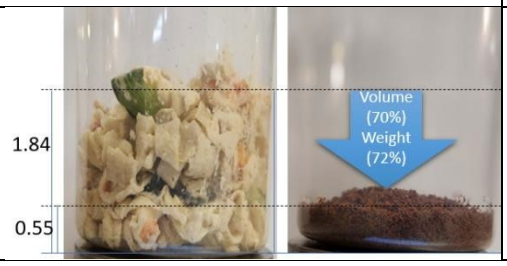


Figure 8. Module of the Motor, Coupling, Bearing, Shielding, and the 8mm Shaft

Results

We tested our prototype with different types of food and the test results are shown in Table 4. Based on the test results, we calculated the food waste that can enter into our system and verified whether it reduced 50% of the entered amount. During the operation, we checked whether the system turned the motor off when the lid opened.

Table 4. Test results with the our prototype

Test#	Content	Picture Before/after	Reduced Volume/Weight
1	Vegetable		Mode / Volume / Weight Before / 2.92 / 500g After / 0.55 / 27g Reduced / 81% / 94.6%
2	Pasta		Mode / Volume / Weight Before / 1.84 / 760.5 After / 0.55 / 210.1 Reduced / 70% / 72%

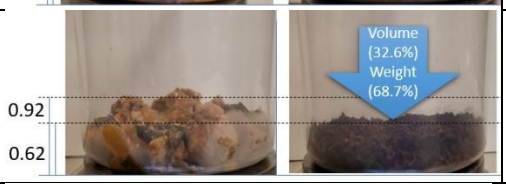
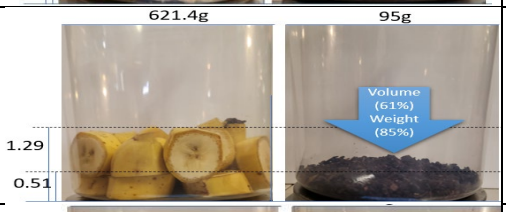
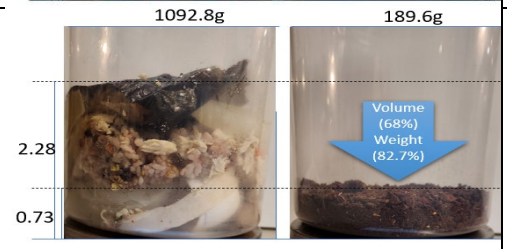
3	Shrimp (Fish)		Mode / Volume / Weight Before 2.1 437.5 After 0.64 98.2 Reduced 69.5% 77.6%
4	Chicken (Beef, pork, or chicken)		Mode / Volume / Weight Before 0.92 219.7g After 0.62 68.7g Reduced 32.6% 68.7%
5	Bread		Mode / Volume / Weight Before 2.15 320.5 After 0.69% 200.5 Reduced 67.9 37.4%
6	Fruits(Banana)		Mode / Volume / Weight Before 1.29 621.4 After 0.51 95 Reduced 60.5% 84.7%
7	Fruits(Apple)		Mode / Volume / Weight Before 1.7 280 After 0.42 69.7 Reduced 75.3% 75.1%
8	Daily waste food (rice,potato,onion,green onion)		Mode1 / Volume / Weight Before 2.43 631.0 After 0.59 97.6 Reduced 75.7% 84.5%
9	Daily waste food(Tofu, kimchi, rice, etc)		Mode / Volume / Weight Before 2.02 766.8 After 0.6 147.8 Reduced 70% 80.7%
10	Daily waste food(lunch, vegetable, rice)		Mode / Volume / Weight Before 2.28 1092.8 After 0.73 189.6 Reduced 68% 82.7%

Table 4. Summary of the test results

	Before		After		Reduced			
	Volume	Weight[g]	Volume	Weight[g]	Volume	Weight[g]	Volume	Weight[g]
Apple	1.7	280	0.42	69.7	1.28	210.3	75%	75%
Bread	2.15	320.5	0.69	200.5	1.46	120.0	68%	37%
Banana	1.29	621.4	0.51	95	0.78	526.4	60%	85%
Chicken	0.92	219.7	0.62	68.7	0.3	151.0	33%	69%
Shrimp	2.1	437.5	0.64	98.2	1.46	339.3	70%	78%
Pasta	1.84	760.5	0.55	210.1	1.29	550.4	70%	72%
Vegetable	2.92	500	0.55	27	2.37	473.0	81%	95%
Rice,tofu,kimchi,etc	2.02	766.8	0.6	147.8	1.42	619.0	70%	81%
Rice,Potato,onion,etc	2.43	631	0.59	97.6	1.84	533.4	76%	85%
Rice,Lunch,Vegetable	2.28	1092.8	0.73	189.6	1.55	903.2	68%	83%
				Average	1.38	442.6	67%	76%

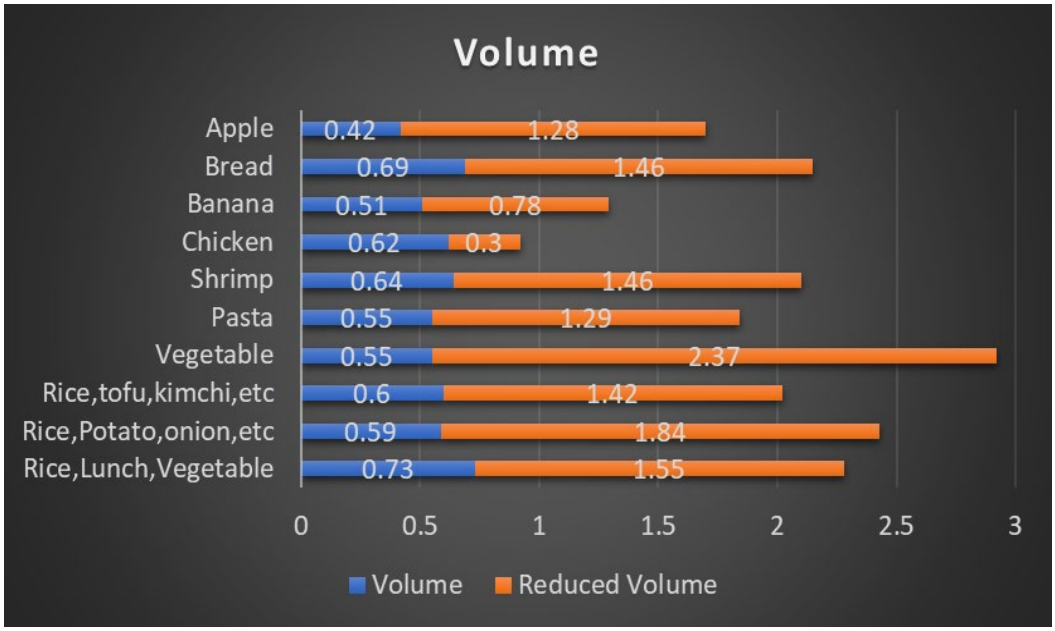


Figure 9. Graph to volume comparison

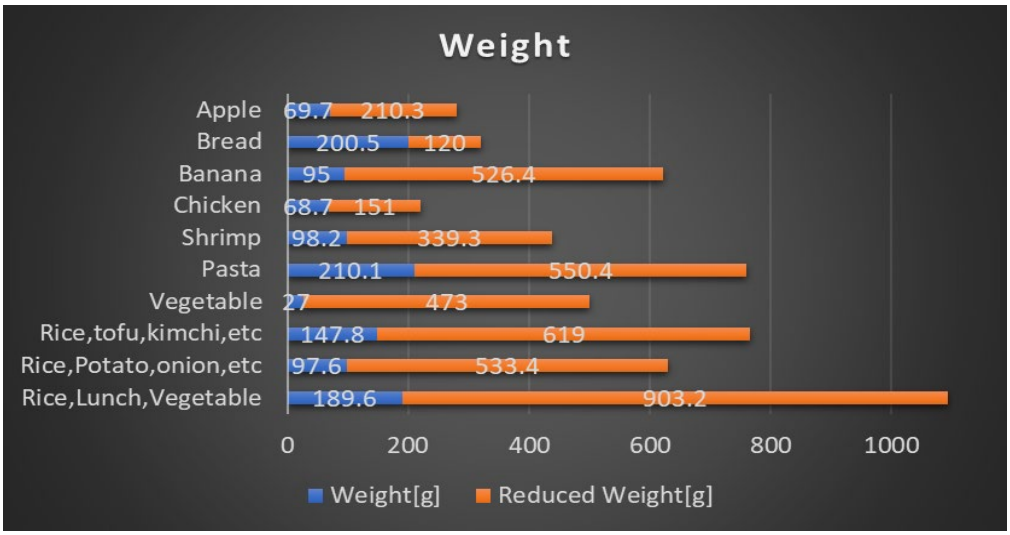


Figure 10. Graph to weight comparison

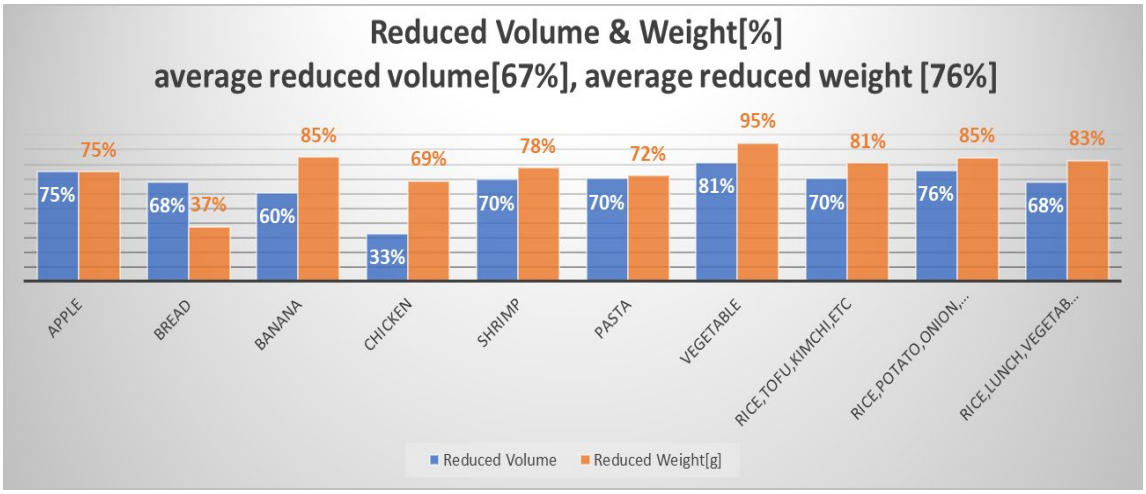


Figure 11. Percent of reduced volume and weight

Conclusion

Our method demonstrated an average food waste reduction of 76% weight and 67% volume. With our design of the most optimal blade, fan, and other components, we were able to successfully reduce the weight and volume of food waste in the premises of our home.

Discussion

Additionally, we compared the advantages and disadvantages of different food waste disposal methods. Food grinders in sinks are used in more than 50 percent of American homes and in countless food-service operations [6]. Although quick and clean, the installment costs are expensive and the social treatment costs are rapidly increasing due to microorganisms. Moreover, it is not an environmentally-friendly method. Thus, we concluded

that a “dry-grinding method” or a home composter with microbes would be the best eco-friendly and efficient way to reduce waste at home.

Table 5. Summary of pros and cons per food waste disposal method

Method	Pros	Cons
Food grinder in sink 	Quick and clean	* Water usage increases * As the occurrence of microorganisms increases, social treatment costs increase.
Food Waste Disposal Cycler 	Quick and efficient	Must frequently replace filter
Home Composter using microbes 	*Efficient way to reduce volume and weight of food waste *Reduces unpleasant odors	* Must rinse food with water to remove salt * Slow: takes 24 hours to handle for 800g food waste
food waste refrigerator 	Slows down food spoilage Cheapest method	No reduction for food waste

Table 5. Simulated results in Santa Clara county and California

Yearly	Santa Clara county	California
Housing units, July 1, 2022	697,052	14,627,460
Estimated food waste	=697052*3.52[1]*400[2]*365/1000000=358,229 ton	=14627460*3.52[1]*400[2]*365/10000000=7,517,344 ton
Cost for landfill	358,229 * $4.1[3]=$1,468,739	7,517,344 *$4.1[3]= $30,821,110
If 76% weight reduce		
Cost save for landfill[$]	1,468,739*0.76=$1,116,241	30,821,110*0.76=$23,424,043
Reduced food waste[ton]	358,229*0.76 =272,254 ton	7,517,344*0.76=5,713,181 ton
when food ends up in landfill, it generates methane	=272,254*2.5[4]*25[5]/1million =17 million tons	5,713,181*2.5[4]*25[5]/1million = =357 million ton
Target in 2030 :226[6] million tons	7.5%	158%

1) Average family number in California : 3.52 [5]
2) Average food waste daily : 400g = 147,417/365 ← 325 Pounds=147,417g [4]
3) Cost price for landfill :$4.1/ton [12]
4) CO2 emission per 1kg of food waste : 2.5kg [13]
5) Generates methane, a GHG 25 times more potent than CO_2 : 25 times more [13]
6) Target greenhouse gases emit in 2023 in California 14]

Acknowledgments

I would like to thank my advisor for the valuable insight provided to me on this topic.

Reference

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