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Eco-Friendly Dehydrator Machine for Food Recycling: A Waste Management System

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Abstract

Up to one-third of food intentionally grown for human consumption is wasted uneaten, with significant environmental, social and economic impacts. There is now a growing number of publications in the field addressing various aspects of this important issue, generally focusing on proactive approaches to reduce food waste and recommendations for more efficient waste management. Focuses on reactive solutions. In this context, this project aims to better understand different types of food waste and use this knowledge to support informed decision making for more sustainable food waste management. The decomposition of food waste produces methane, a powerful greenhouse gas that contributes to global warming. To that end, we take a holistic approach in this project, we proposed a food waste dryer machine using the thermal effect and sensor techniques to reach the required temperature and ensure good drying through a moisture and temperature sensor. Experiments have shown that the optimal temperature range for hydration is 70-127 °C. Food waste can be dried in the shortest possible time and with low energy consumption using the proposed dryer. Dehydrated food waste slightly affected soil pH. However, they significantly increase soil EC and repeated use can lead to soil salinity. Food waste also increased plant macronutrients (N, P, and K) in different soil types. Carbon and nutrients in dehydrated food waste increased microbial activity as measured by basal respiration. Sometimes, the dehydrated food waste may need to be composted before applying it to the soil or incorporated into the soil for a long period of time before planting. These processes will overcome the limitations of anoxic conditions, phytotoxins, salinity, and water repellency.

Keywords: *Food, Waste Management, Sustainable, Recycling*

1. Introduction

Now the most important priorities of countries in the field of Environment and Sustainability include prevention and recycling of wastes. Decomposable organic matter, mainly kitchen waste and agriculture waste, is the major waste generated around the world [1-2]. Encouraging homeowners and farmers to separate and dry organic waste is a promising project for food waste management to reduce significantly its volume. In general, dry bio waste is a fixed carbon source that can be used to produce green energy. Figure 1 shows that per person, wasted food varies around the globe. For Example, Tthe amount of food wasted by consumers in developed countries (222 million tons) is nearly equal to the total food supply in sub-Saharan Africa (230 million tons) [3]. Figure 2 shows the volumes of food waste produced by commodity groups in various regions.

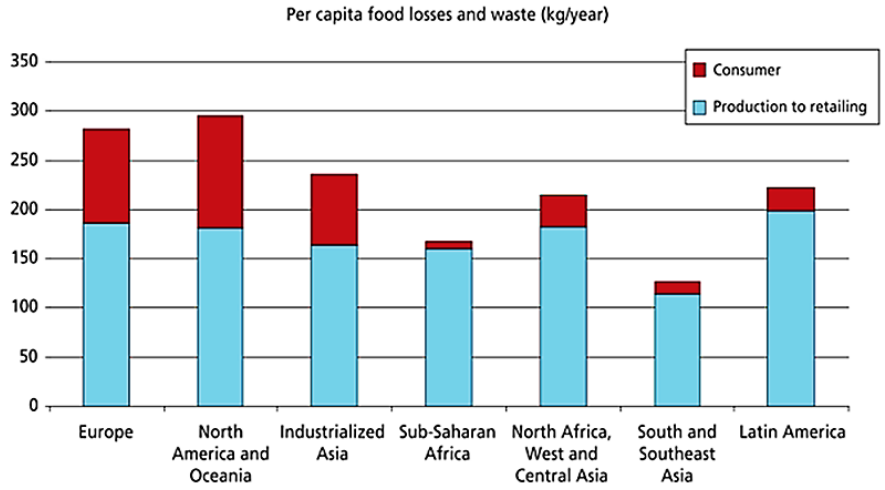

Fig.1. Food Losses and Waste Per Capita In Various Regions, At The Consumption and Pre-consumption Stages; (Blakeney, 2019).

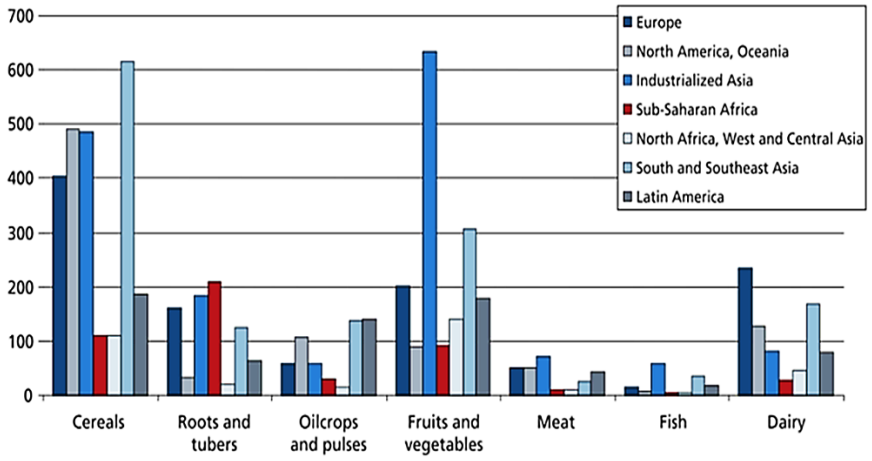

Fig.2. Commodity Groups Produce Volumes of Food Waste in Various Regions; (Blakeney, 2019).

Food waste has broad-ranging implications on both a national and international level. Up to 40% of all food produced in the US is wasted. and over 95% of food waste is disposed away in landfills [4]. At 21%, it makes up the majority of municipal solid trash. Only 5% of the food waste generated in 2014 was diverted from landfills and incinerators for composting, totaling more than 38 million tons [5]. Methane, a potent greenhouse gas that contributes to global warming, is produced when food waste decomposes. One-third of the food produced worldwide is thrown away uneaten, adding to the environmental load. More than 25 million Americans might be fed each year if food waste were reduced by 15% [6-10].

Further, up to one-third of food intentionally grown for human consumption is wasted uneaten, with significant environmental, social and economic impacts. According to Web of Science and Scopus databases; there is now a growing number of publications in the field addressing various aspects of this important issue, generally focusing on proactive approaches to reduce food waste and recommendations for more efficient waste management. Focuses on reactive solutions. In this context, this project aims to better understand different types of food waste and use this knowledge to support informed decision making for more sustainable food waste management. To that end, we take a holistic approach.

1.1. Work Motivations

The goal of the current study is to investigate why people behave in certain ways when handling food that contribute to reducing food waste. Finding any factors that might potentially obstruct or facilitate the alignment of food waste reduction with other (food-related) goals is of particular interest. Since consumers have the most influence over how food is handled at home, including control over meal planning, grocery shopping, and meal preparation, we concentrate on in-home food waste and ignore out-of-home food consumption and waste. This research presents the results of an in-depth analysis using focus groups of the wide array of variables that may underlie domestic food waste.

1.2. Work Aims

Food recycling is another way to conserve resources. It’s a natural way to turn food waste into usable products. Food waste includes all the edible and non-edible parts of food, including partially digested leftovers, spoiled fruits or vegetables, and animal products such as milk, cheese, or other dairy products. By food recycling this project aims to: (i) reduce food waste. (ii) increase rate of organic fertilizers. (iii) Save money. (iv) Produce less methane. (v) Improve plants health. (vi) Boost business’ reputation.

1.3. Work Contributions

The proposed system has many contributions as the following: (i) it can count how many times that the project act it’s work every week or mouth. (ii) The device work by an application or

through the internet. (iii) The device can't open before the heat become 30 degrees or less. (iv) When degree reach high degree the heater turned off and fun turned on. (v) Reduction and recycling of food waste By composting food wastes and reuse them, it is possible to reduce the amount of intermediate treatment and the final disposal sites, as well as food waste incineration which causes CO_2 emission. (vi) High durability and good maintainability Since the composting machine has been developed over many years, it can maintain high durability. In addition, it has a characteristic of simple maintenance system by reducing the number of parts and types of parts with high general versatility. (vii) Low power consumption and energy saving Food waste is mixing at a slow speed in composting machine. Then the power consumption is less than normal machines and it can save energy. (viii) Possible to use local composting enzyme developed in the country (ix) In order to encourage decomposition and fermentation of food waste, composting enzyme is used. Although we use composting enzyme made in Japan at the beginning of operation, but we can positively examine the use of local composting enzyme if conditions are satisfied. (x) Treatment of food wastes including high moisture, oil and fats, and salt Since the compost machine has a water sprinkler and dehydration mechanism, vegetable residue with high moisture content and food residue including salt and fat can be processed.

1.4. Major Features and Advantages

The proposed system has the following key features:

- **(i) Food waste can be utilized for resources**: Well Create Co., Ltd. recycles a variety of food waste to compost. We produce 80 tons of compost from 1300 tons of food waste per year. (Volume reduction through the dehydration and fermentation process).
- **(ii) Manufacture of stable quality compost**: The system can manufacture stable quality compost. All produced compost can be purchased and consumed by local farmers.
- **(iii) Simple operation method of the composting machine**: Anyone can operate the machine after short training for about 1 week.
- **(iv) No emit of bad odor in a composting center:** Deodorized equipment are not necessary, since composting machines do not generate bad odor in the fermentation process.
- **(v) Two methods of composting:** first, the customers collects food wastes via our website and carries them to the composting center and produces compost. Second, The customers installs composting machines to hotels, restaurants, hospitals etc. These on-site machines are operated by clients. The company also collects primary fermented compost from those machines and carries it to the composting center, around once a month.

1.5. Relation with Environment and Economic Benefits

Recyclable and compostable items are resources that have a market value. All Seattle customers benefit from the sale of those materials because the income generated keeps solid waste bills lower than they would otherwise be. When these materials are sent to the landfill, that value is

wasted. The costs of landfilling and transporting materials are higher than the costs associated with transporting, processing, and handling materials that go to a composting or recycling facility. The monthly bill that homeowners and landlords pay may be reduced if all the recyclables and food scraps are kept out of the garbage. Governments sets collection rates to incentivize recycling and composting, where garbage collection is the most expensive commodity, compost collection is provided at an affordable rate, and recycle collection is provided for free. The project has the following economic and environmental benefits: (i) Reduces food waste by 90%: The project reduces food waste weight and volume by 90% creating a sterile, odorless and nutrient-rich soil amendment to reuse for your plants or garden. (ii) Adding convenience to your routine: The project is strategically built to fit into your lifestyle, all year round. (iii) Feeding individuals garden, not your garbage: by starving the landfills, you're reducing your carbon footprint and the amount of methane generated from food waste. (iv) Creating a cleaner, greener home: The project eliminates smelly food waste and associated pests. Plus, it's energy efficient, which helps reduce your environmental impact.

1.6. Paper Organization

The rest of this work is organized as follows: the second is a work background including a discussion about food waste sources and management. Section three present a literature review followed by the proposed system in section four. Section five discusses the results followed by the challenges and future research direction in section six. Finally, the paper is concluded.

2. Work Background

The increasing global population growth of 7.6 billion has increased waste generation worldwide. It has enormously impacted the climate, animals, and human beings, recently attracting great global attention [11]. In 2016, the Food Aid Foundation announced that Malaysia lost almost 15,000 tonnes of food waste, including 3,000 tons of food per day [12] and around 15 million tonnes (234 kg/person/year or 50% of food) ware lost annually in the United Kingdom [13]. Food waste is one of the big problems in the world. Most developing countries lose billions of dollars per year due to food waste. This problem does not stop at the point where food is discarded. Around 95% of discarded food goes down in areas where anaerobic digestion processes nitrogen, carbon dioxide, or other gases, which has a catastrophic effect on global warming. Food waste exacerbates climate change. Because food waste produces methane, a gas that absorbs heat considerably more quickly than other greenhouse gases such as carbon dioxide, methane has a shorter lifetime than carbon dioxide, which results in the globe's rapidly warming [14].

Nowadays, significant factor considerations must be considered before implementing food waste disposal units as a wide-ranging solid waste management option, as solid waste is related to emissions of greenhouse gasses and other environmental damage. Continued research and development in food waste could better manage this choice to become a sustainable alternative to

landfilling, incineration, and composting. Food waste is a subset of food loss that consists of material meant for human consumption but not consumed. The border between food loss and food waste is not well defined [15]. Food loss is common in the food value chain before it reaches the customer. It can occur during growing, harvesting, processing, or transportation. However, food waste happens due to mismanagement in the supply chain. Food waste is typically regarded as avoidable food loss [16].

2.1. Food Waste

Now the most important priorities of countries in the field of environment include prevention and recycling of waste. Decomposable organic matter, mainly kitchen waste and agriculture waste, is the major waste generated around the world. Encouraging homeowners and farmers to separate and dry organic waste is a promising project for food waste management to reduce significantly its volume. In general, dry bio waste is a fixed carbon source that can be used to produce green energy. Figure 3 discusses the food waste problem. However, Dry bio waste is very light because most of the water is removed. This means that the cost of transporting dry final products is very low. In addition, it is odorless and can be stored for a long time. Therefore, it reduces the amount of garbage collection. In addition, it helps reduce methane and toxic leachate from domestic landfills. Many kinds of drying systems have been developed for biomass drying such as the conveyor dryers, solar dryer, fluidized bed dryer, and rotary dryer, among which rotary dryers are the most common [17-19].

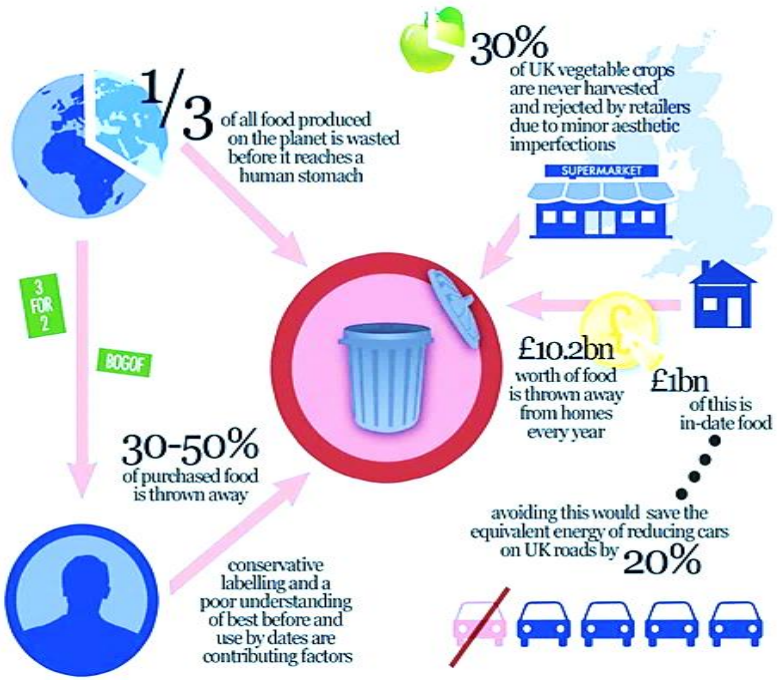

Fig.3. Illustration of Food Waste Problem, **Source:** Digest.

The core reasons and motivations of the people involved in food waste are now the significant variables distinguishing food waste from food losses [20]. Food is wasted at every step in the food supply chain (FSC); many points along the supply chain degrade or lose edible food mass (e.g., post-harvest handling, processing, distribution, and consumption). Food is wasted to a large extent in middle and high-income countries, both at the consumer and manufacturing levels. Food waste per capita is the most prominent in Europe and North America (95–115 kg/ year), while rock-bottom in Sub-Saharan Africa and South/Southeast Asia (6–11 kg/year) [21]. More than 40% of food losses occur in developing countries after harvesting and preparing the produce [22]. However, in developed nations, over 40% at the retail and customer levels, most of the food waste is generated.

Food waste is one of the most challenging issues humankind is currently facing worldwide. Currently, food systems are extremely inefficient: it is estimated that between one-third and one half of the food produced is lost before reaching a human mouth [23-24]. The Sustainable Development Goal 12 ‘Ensure sustainable consumption and production patterns’ established by the United Nations in 2015 includes a specific target for food waste reduction: halve per capita global food waste at retail and consumer levels by 2030 [25]. Figure 4 presents the different sources of food waste. Additionally, it also includes a more general goal to reduce food losses along food supply chains [26]. Therefore, it is expected that there will be an increasing number of initiatives, campaigns and legislative developments in order to reach the aforementioned objectives.

Nevertheless, reduction of the current levels of food waste must be accompanied by better management of the waste: inevitably there will always be some food waste. Furthermore, some parts of the food products are inedible and will unavoidably become a waste stream. There are countless alternatives to manage food waste, however the most common solution worldwide is still landfilling [27], which is highly damaging to the environment and poses a risk to human health, whereas it does not provide any benefit. In spite of the progress achieved in recent years to find alternative solutions, particularly in developed nations, better management of food waste in supply chains is still required.

Sustainable management of food waste is a momentous research area that has rapidly grown over recent years. Meritorious examples of research aiming to find sustainable solutions for food waste management are numerous, but they have been generally inclined to look into only one area of sustainability: environmental, economic or social ramifications [28].

Fig.4. Sources of Food Wastes.

Finally, The term "**wasted food**" describes food that was not used for its intended purpose and is managed in a variety of ways, such as donation to feed people, creation of animal feed, composting, anaerobic digestion, or sending to landfills or combustion facilities. Examples include unsold food from retail stores; plate waste, uneaten prepared food, or kitchen trimmings from restaurants, cafeterias, and households; or by-products from food and beverage processing facilities. EPA uses the overarching term "wasted food" instead of "food waste" for food that was not used for its intended purpose because it conveys that a valuable resource is being wasted, whereas "food waste" implies that the food no longer has value and needs to be managed as waste [29-30].

Also, variation of food waste composition had no effect on drying rate. Several studies on effective moisture diffusivity, energy of activation, and energy consumption were achieved in thin layer drying of vegetables and fruits. However, there is little information on the drying of food waste in cabinet dryers, which makes the current research necessary.

3. Related Work

Many researchers and developers have worked on many systems that aim to reduce food loss and dry it to be reused as animal food or organic fertilizer in agricultural operations. The following are the most prominent posts in this field. For example, Khalida, et al [21] explained that thermal drying quickly removes moisture from food waste and prevents hydrolysis and biodegradation. Thermal dryers, such as the GAIA GC-300 dryer, and cabinet dryers with standard pans is the best alternative to sun drying. Part 2 of this review found that dehydrated food waste was slightly

acidic (4.7-5.1), had high electrical conductivity (EC) values (4.83-7.64 mS cm1), and was high in nutrients due to low pH values. I am emphasizing that However, dehydrated food waste is not directly suitable as fertilizer for plants. Therefore, dried food waste should be composted before applying it to plants. Because the composting process governs the limits of plant toxins, oxygen deficiency, salinity, and water repellency. Ditch compost is suitable for decomposing dry organic waste as it relies solely on soil-degrading microorganisms and insects.

Ortiz-García-Carrasco, et al [31] studied the drying behavior of vegetable waste, a combination of cabbage and lettuce leaves, at temperatures between 50 and 150 °C. An air velocity of 0.6 m/s and he material thickness of 1–2 cm were selected. They extracted the drying curve. As a result, it was found that the drying time is seven times faster at 150°C than at 50°C, and the drying speed is faster under high humidity. Another study investigated the effects of sample size and different temperatures on the drying rate of MSW. The results showed that the drying rate increased with increasing temperature.

Lopez, et al [32] demonstrated (i) rehydration by designing a freeze-drying cycle that ensures product integrity (i.e., no collapse or swelling) and (ii) characterization of both freeze-drying and rehydration. To investigate the effect of highly cross-linked porous microstructure on the quality of sum tomato. Kinetics. Fresh tomatoes were first freeze-dried and then rehydrated to generate kinetic data.

Subsequently, regression analysis was used to fit the six thin-layer drying models and his four rehydration models to the experimental data. Goodness of fit was assessed using mean squared error, adjusted R2, Akaike information criterion, and Bayesian information criterion. The most accurate representations of system kinetics have been observed using the Page model for freeze-drying and the exponential and Weibull models for rehydration. The rehydration capacity and equilibrium water content of the rehydrated samples were found to increase with temperature and the corresponding activation energy values were calculated.

The food waste dried in [33] dryer is called FORBI. A dry food waste containing biomass with low water content and high calorie content, this product can be used to produce raw materials for animal feed and compost. The dryer he can process 50 kg of food waste every 8 hours. The GAIA GC-300 dryer is gaining popularity due to its affordable price. It works at 140 degrees and can eliminate existing microorganisms by drying food waste. The physical and chemical properties of kibble make it a useful raw material for value-added products such as compost and animal feed. becomes [34].

Food waste and leftovers contain carbohydrates, proteins, lipids and nutraceuticals and can be used as raw materials to manufacture important commercial compounds. Overall, this technique reduced food waste in the long run [35]. Dehydration has recently been investigated as a way to recycle food waste, especially animal feed. Dehydration of food waste resulted in 70% weight reduction and lower energy costs than traditional food waste treatment. The lower moisture

content of the material after dehydration results in slower decomposition, less odor, and less frequent waste disposal.

Further, the food dehydrator machine [36] is to make people aware that using machines can extend the shelf life of food. The machine also facilitates the process of drying food more efficiently. It also works great with meals. The method of tools used is for preserving food, using a food dryer to dry the food. This is intended to protect food from bacterial and yeast growth by removing moisture. The research results conclude that this food dryer can greatly reduce the burden on consumers, especially businesses that use food dryers to achieve sales results. Therefore, consumers using these food dryers can achieve higher quality and more durable food. Allowing retailers to last longer, process higher quality food, and save time can help our project financially.

In [37], an automated food dehydrator for the storage of fruits and vegetables is designed. The hot oven dryer demonstrated the capacity to dry agricultural goods with a sensible reduction in water content while simultaneously assuring the improved performance of the dried product. This hot oven dehydrator was designed using a PID controller to regulate the heat source, a heating filament (an electric bulb), a temperature sensor, and fans. In this specially constructed arrangement, the temperature that may be utilized to dry agricultural products ranges from 45°C to 55°C automatically.

Finally, all previous systems lack a user-friendly application that facilitates waste collection and recycling while having a small, easy-to-use home device for the general public.

4. Proposed Model

The three themes that were proposed for the framework were as follows: (i) Food security and surplus. (ii) Avoidable and unavoidable food waste. (iii) Waste prevention and waste management the food waste hierarchy is used to rank the options. The food waste categorization and management selection flowchart discussed in Fig. 5 that facilitates the selection of the most sustainable food waste management alternative, with the objective of minimizing environmental impacts and maximizing economic and social benefit.

The proposed overall framework recommends recycling system output (i.e. Dried Food Wastes) into animal feed or composting after all precautions have been exhausted. When recycling becomes impossible, the next best option is anaerobic digestion of food waste. Ultimately, when all other options are exhausted, only landfill disposal remains. This study investigated the drying process of food waste in cabinet dryers and identified the optimal drying conditions to reduce drying time and adjust energy consumption.

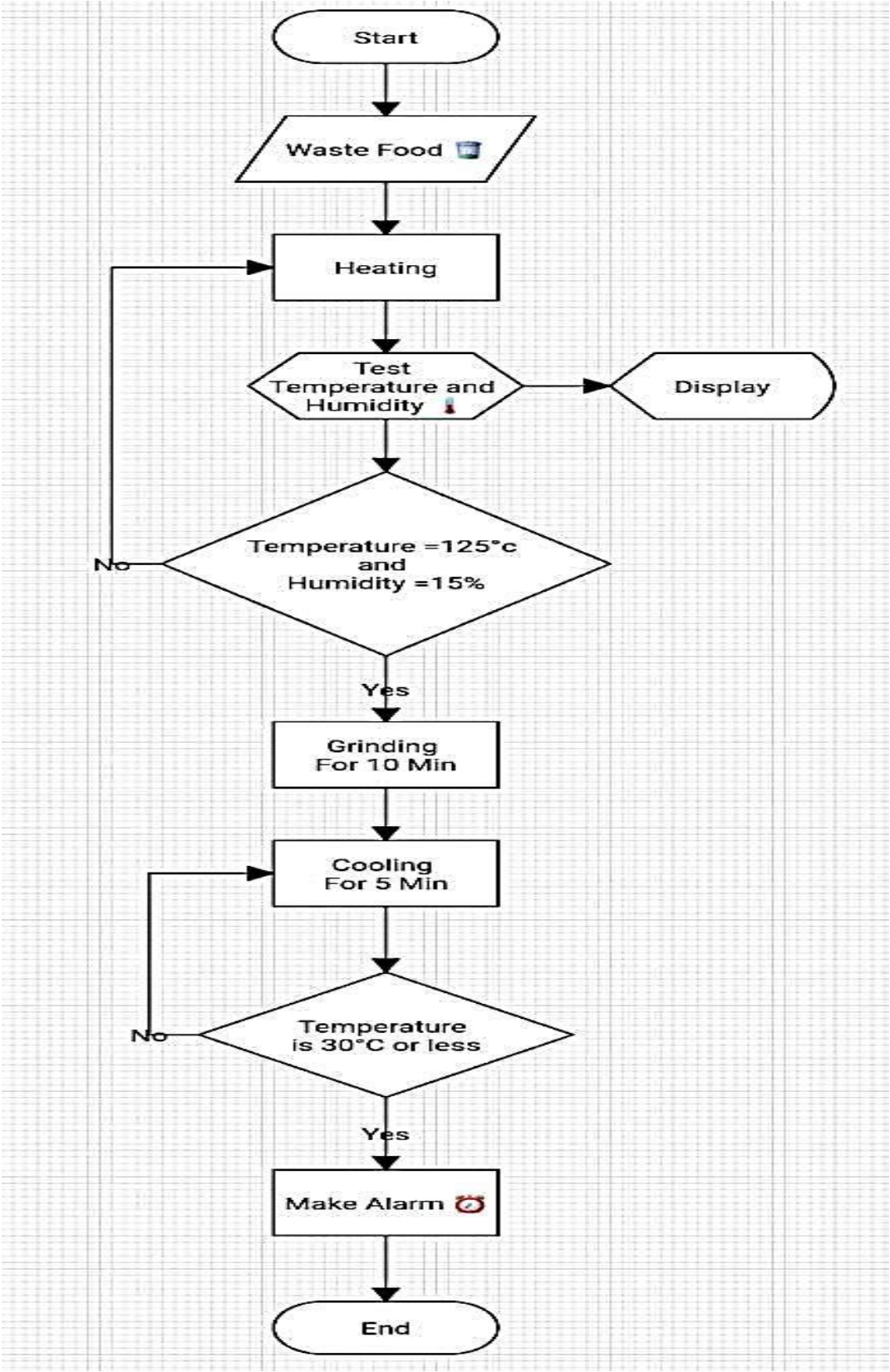

Fig.5. System Flowchart.

4.1. System Analysis and Design

The categorization of the proposed system is intended to be easy to apply, facilitating identification of the type of food waste generated, and its link with the most appropriate food waste management alternative. This methodology and hardware requirements have been illustrated as well in Fig. 6. The system is not limited to the machine only, but there is also a web application for easy waste collection and communication between consumers to enable people who do not have the device in their hands to donate or sell their waste to other people who have the device

The analysis described can be applied to every type of food waste from every stage of the food supply chain. However, this methodology is expected to be more useful in the early stages (agricultural and manufacturing) of the food supply chain, where separate collection is generally carried out more effectively, than in the retailing and consumer stages where waste is often sent to municipal solid waste. Additionally, it is recommended to adapt the categorization to each food sector or business and include more waste management alternatives in the analysis (e.g. extraction of compounds of interest from food waste).

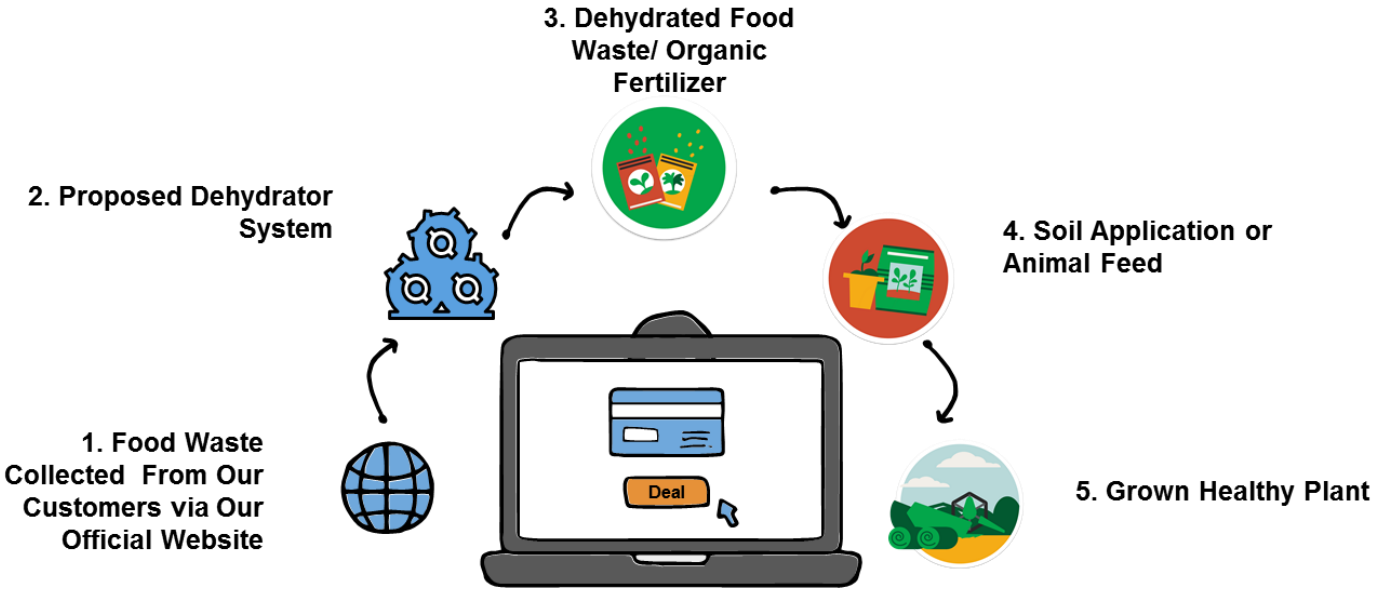

Fig.6. System Workflow.

4.2. Methodology and Hardware Requirements

In order to reduce the impact of food wastes; a food waste dryer is proposed in this project with a conventional tray was built, and drying of food waste was investigated. Power of 2.7 kW will be used as the heat source, and a centrifugal fan with an air volume of 1300 m3/h. The experiments will performed at 70-127 °C . Cabinet dryer with a conventional tray can be used for

drying food waste in the shortest time with low energy consumptions with the objective of minimizing environmental impacts and maximizing economic and social benefits. Moreover, Reducing food wastes disposed by incineration and landfilling have been an important issue in our daily life. To this issue, we provide an effective solution with carbon offset model, by constructing a community based composting system. The composting center equipped with food waste recycling facility operated by the collected food wastes discharged from hospitals, hotels, wholesale markets etc. and produces compost in the process of shedding, dehydration and fermentation in a composting machine. Table 1 discusses the required hardware for the proposed system.

Table 1. Hardware Requirements and Corresponding Cost in L.E.

Index	Required Hardware	Cost in L.E.
1	Control heat and humidity	600
2	Steel fan	300
3	Heater	250
4	Arduino mega	500
5	Ethernet	320
6	Chopper	400
7	Screen	500
8	Container	700

5. Results

After the experiment, the optimal temperature of the drying air supplied to the dryer was observed to be between 70 and 127 °C. It has also been found that the use of heated air to dry food waste with a high moisture content takes too much time. The machine could be for both home or enterprise use as composting center equipped with food waste recycling facility operated by the company collects food wastes discharged from hospitals, hotels, wholesale markets etc. and produces compost in the process of shedding, dehydration and fermentation in a composting machine. The output of the proposed machine could be used in many applications such as: animal feeding, soil compositing, land filling...etc. Thus, we have developed a web application to link consumers and the owners of the devices to obtain food waste, whether by buying and selling or donating. Figures 7 and 8 present the home page and our profile page. The website also contains pages to raise awareness of the dangers of food threats to the environment and the damage caused by methane gas. It also offers many home solutions for food recycling. Figure 9 presents the customer signup page to create his own profile on our database and get in touch with other online customers to buy, sell and donate food.

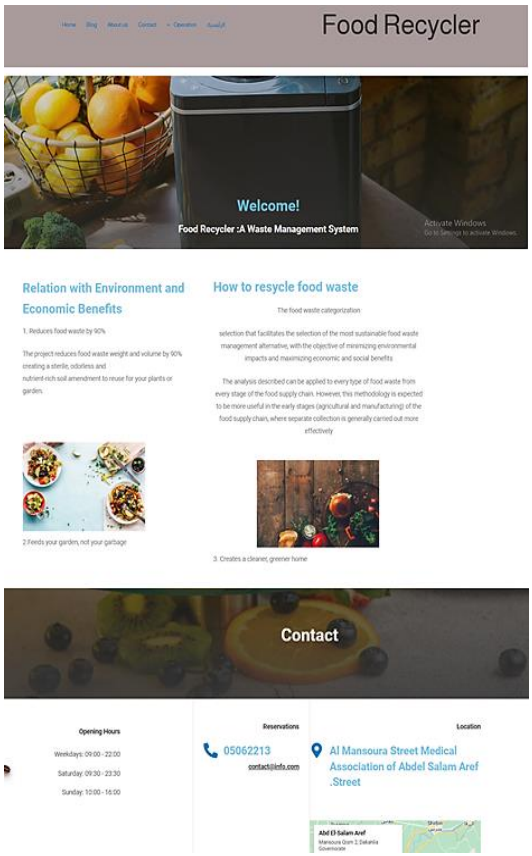

Fig.7. Official Website Homepage.

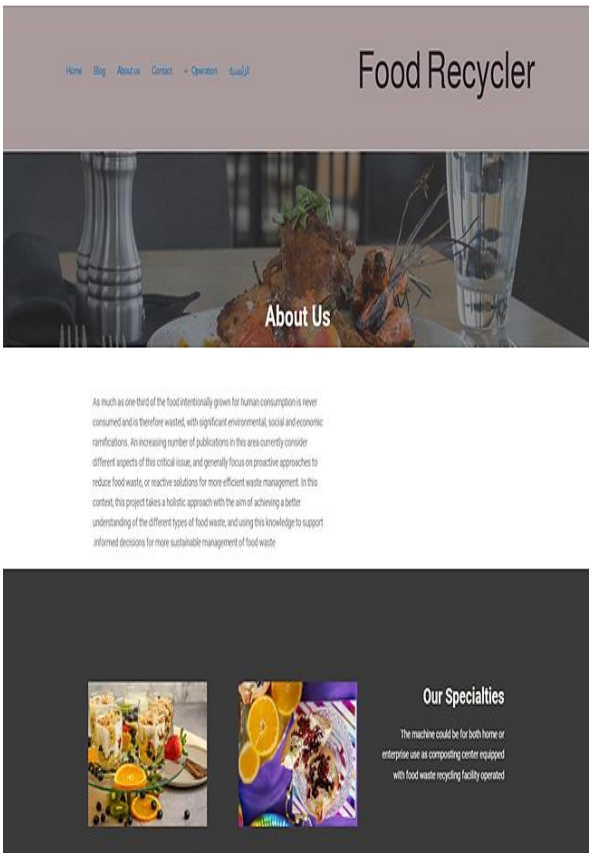

Fig.8. About The Project.

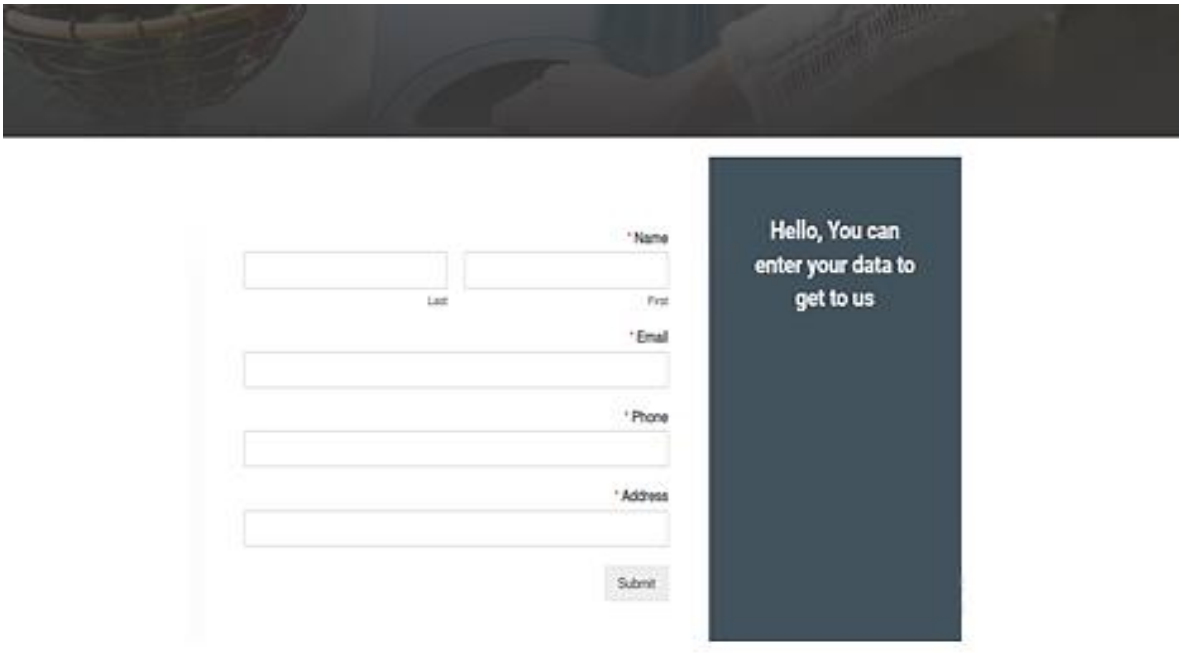

Fig.9. Customer Signup.

6. Challenges and Future Research Directions

Food Recycling and waste management still has many limitations [38-42] as follows: (i) Climate change: seven to eight percent of global greenhouse gas (GHG) emissions are lost or wasted from food production or management. This is a waste of our carbon budget. To make sure that the greenhouse gases produced by agriculture are justified, we need to reduce this waste. Feed the world, not landfills. (ii) Energy efficiency: Environmental Science and Technology, a journal of the American Chemical Society, calculated that if America stopped wasting food, it could save 2% of its total energy use annually. Since it produces energy, this waste means that we are not using our limited oil and gas supplies efficiently. (iii) Freshwater: about 70% of the world's freshwater is used for food production. Water scarcity and drought are major problems in many regions. When we waste food, we also waste water, a precious resource for many. We need to use scarce resources efficiently and reduce food waste to ensure that the water we use provides social benefits. Food waste has recently been linked to the plastic crisis in our oceans (think packaging). By solving food waste, we keep our oceans clean. (iv) Feeding the world: About one billion people worldwide suffer from hunger and malnutrition. (v) Rainforest and agricultural land use: by 2050, the world's population is expected to increase by two billion people. This puts a strain on our resources such as water, fossil fuels and land we need. For every hectare of rainforest cleared for agriculture, we damage ecosystems and further adversely affect the climate. Yet, if we can reduce food waste can provide many of these new global citizens with the resources we have today. Figures 10 and 11 summarize these food waste prevention challenges and future research directions.

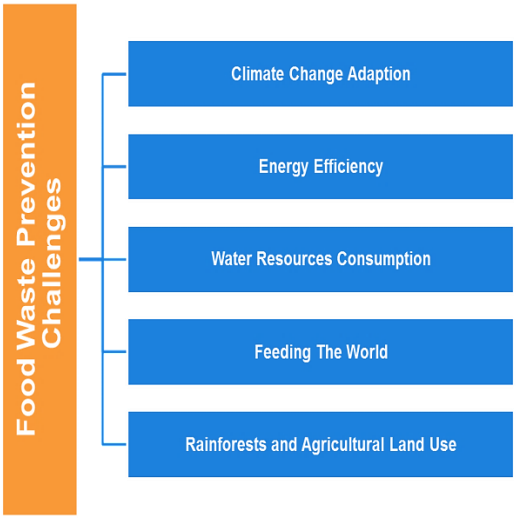

Fig.10. Food Waste Prevention Challenges.

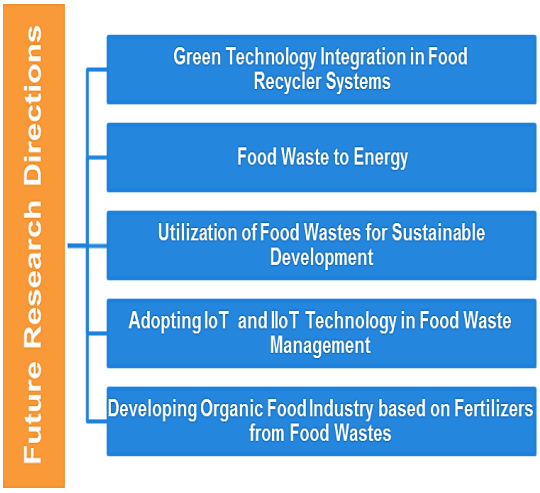

Fig.11. Food Waste Prevention Future Research Directions.

7. Conclusions

Food recycling is another way to conserve resources. It's a natural way to turn food waste into usable products. Food waste includes all the edible and non-edible parts of food, including partially digested leftovers, spoiled fruits or vegetables, and animal products such as milk, cheese, or other dairy products. By food recycling this project aims to: (i) Reduce Waste; (ii)

Introduce Home-made Organic Fertilizer; (iii) Cost Saving; (iv) Produce Less Methane; (v) Helps to Improve Plants' Growth; (vi) Saves Water Resources; (vii) Helps Boost Business' Reputation. Our proposed system has the following features: (i) The machine can work by an application or through the internet; (ii) The device can't open before the heat become 30 degrees or less; (iii) When degree reach high degree the heater turned off and fun turned on for safety purposes; and Can count how many times that the project act it's work every week or month.
Finally, using food dryer will lead to Reduce food wastes via composting and reuse them, it is possible to reduce the amount of intermediate treatment and the final disposal sites, as well as food waste incineration which causes CO_2 emission. It will also achieve high durability and good maintainability. In addition, it has a characteristic of simple maintenance system by reducing the number of parts and types of parts with high general versatility.

8. Acknowledgement

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