Converting food waste into organic fertilizer

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Abstract:

Food waste is one of the global issues that needs to be considered and taken seriously since 1.3 billion tonnes are wasted annually, and this discharge of waste costs about $410 billion per year. Mainly food is thrown into the garbage which leads to environmental problems all around the world such as water and air pollution due to dumping in landfills and incineration as it is the largest contributor of solid waste in the national landfills which harms land, biodiversity, and release toxic gasses into the atmosphere. Therefore, the best way to convert this issue into an opportunity is by converting food waste to organic fertilizer that is nourished with nutrients that have plenty of benefits to the soil as it is the best food for the soil and to crops as well as it reduces the environmental issues and considers a sustainable way. This study aims to investigate the effect of different types of composting on plant growth and test the quality of the compost. Converting food waste into organic fertilizer through composting of food waste both aerobically (with the presence of oxygen) and anaerobically (in the absence of oxygen) that is collected from the university's canteen and houses. The findings of this study will be reported after completing the study.

Introduction:

Due to the population growth in the last decades where it reached 7.8 billion people in 2021 (World population, n.d.), food become an important factor for living and functioning but with the growth of population food scarcity started to appear specifically in developing countries which means that people have low access to enough food for a safe and nutritious food this is because the food production is under pressure to meet the needs of people or people can't afford it this can lead to extreme and dangerous hunger, it estimated that almost 1 billion hungry people worldwide (UAE banking facts and figures, 2022) and almost 821 million people don't have access to food there are several reasons behind it such as the drought were developing countries are exposed to drought because of climate change and global warming as well as the high population in these countries lead to increase deforestation and natural resource degradation which automatically reduced the amount of food available (Why are so many people in the world hungry?, n.d.). According to the UN, global supplies decreased by 2.6% in 2012, including grains such as wheat by 5.2% (Vidal, 2012).

However, the situation is the opposite in developed countries where the discharge of food increased as it reached 222 million tons (Ishangulyyev, Kim and Lee ,2019) as well as its highly consumed and mainly turned into a habit where people buy more portions of food than they need this can result in food waste that put pressure on the natural resources and destroys the environment and harm land and water biodiversity as well, wasting the food is not only throwing the food but also wasting the effort, investment and precious resources and emitting more greenhouse gases while producing and transporting the food. Food waste is usually treated in an unfriendly way to get disposal of it such as in landfill which is the largest source of climate change or incinerated which generates landfill gasses and floating dust. Moreover, food waste considers a serious issue that faces the gulf region, especially in the UAE approximately 225kg of food is wasted per person in UAE (Chandran, 2022). According to Sanna Pirani (2018), each year in UAE nearly 3.7 million tons of food are wasted, this waste is worth more than USD3.54 billion. Food demand doubles in Ramadan when the food waste reached 60% which is double the percentage compared to the rest of the year when the percentage reached (38%) which makes UAE rank the top nation for per capita waste generation worldwide with 2.7kg per (Our food is damaging the environment, n.d.). Food waste consider one of the main challenges that face the global. As a result of this huge waste, we can reduce it in an effective, affordable, and eco-friendly way which is by converting food waste into organic fertilizer that increases the utilization of renewable resources. Converting food waste into fertilizer can be an excellent choice to create economic and environmental benefits, improve soil health and water quality, eliminate the need for chemical fertilizer and enhance agriculture yields as it is estimated that 85% of food waste is biodegradable and due to its high organic matter and water content, it has great recycling value and its rich in nutrients. In addition, food waste consists of a variety of elements in food waste, including organic matter, starch, cellulose, proteins, and inorganic sources as well as many other elements like Nitrogen, Potassium, Phosphors, Calcium, Magnesium, and Iron. One of the most popular ways to convert food waste to organic fertilizer, composting is an organic material that breaks down food scraps such as leaves into the soil which assist the plants in growth where currently more than 30% of the waste, we produce comes from food scraps and yard waste combined (Composting at home, 2022). Additionally, according to Environmental Protection Agency (2022), 2.6 million tons of food was composted which accounts for 4.1% of wasted food. My research will discuss, compare, and test the quality of compost both aerobic and anaerobic and the chemical fertilizer and how it affects plant growth as well as the soil content and how we could optimize the quality of it in the future.

Literature Review:

Different methods for preparing organic fertilizer:

Hazren et al. (2019) performed a study that aims to reduce the waste food at landfills on the UTHM Pagoh campus by creating a compost bin and utilizing aerobic composting. Two types of food waste were collected from the cafeteria: Greens and Browns. Greens contain high nitrogen contents, and browns; rich in carbon. A plastic container punctured with a few holes was used as a compost bin. First, they placed it layer by layer starting with browns that assist soak up extra moisture and enhance aeration then they placed the greens. When the compost becomes mature and has a soil-like smell and dark brown color they tested the content of nutrients. The findings show the initial temperature was 32˚C and increased to a maximum temperature of 42˚C, then decreased till reaches the maturation phase. Also, the pH varied from acid to nature, where the compost started with a pH of 2 then the value increased to 7.5 at the end which is the neutral stage. According to the results, the total N in the composting is 0.9%, the total P is 0.8% and the total K is 0.4%. They conclude that the number of nutrients is in an acceptable range for mature fertilizer where N is 0.9% and it's above the minimum percentage of mature compost (0.6%), the P content is 0.8% as P_2O_5 which is in an acceptable range (the suggested range is 0.22%) and K content is 0.4% as K_2O and its acceptance as the minimum range is 0.25% (Hamid et al., 2019). This indicates that food waste composting can be used as fertilizer.

Testing the quality of anaerobic fertilizer:

In India, a study was conducted to produce liquid fertilizer from food waste that is collected from marriage halls, hotels, and restaurants using an anaerobic process. First, 5kg of food waste was collected and processed in a closed container, then molasses was added to the food waste under anaerobic conditions, the food waste started converting to liquid organic fertilizer after 3 days and the chemical characteristics (NPK- Nitrogen, Phosphorous, and Potassium) of liquid fertilizer was analyzed were Nitrogen 1.15%, Phosphorous 0.308%, and Potassium 0.77% and in pulp N is 0.39%, P is 0.159% and K is 0.51% (Unnisa, 2015). After producing the final organic fertilizer and pulp a toxicity experiment is done on seed germination to test the toxicity of organic fertilizer with various concentrations (0.57ml, 1.14ml, 2.28ml, and 4.56ml), and 30ml of distilled water was added, the results display that adding organic fertilizer enhanced mustard seed germination and the length of it by 90%.

Owamah et al. (2014) performed a study to evaluate the fertilizer quality and sanitary quality of digestate using anaerobic digestion. 3kg of human excreta were mixed with 12kg of food waste collected from the university cafeteria. A decrease in BOD was found by 50.0%, COD by 10.63%, organic carbon by 74.30%, and ash content by 1.5%. However, other parameters show an increase such as the total solid by 12.39%, total suspended solid by 12.64%, and nitrogen content by 12.12% (Owamah et al., 2014). The pH of anaerobic digestion was unstable between 4.5 and 6.5. Moreover, the microbial count for the biofertilizer digestate was $2.0x10^3$ for coliforms, the total aerobic plate was $1.0x10^4$ and the fungal was $2.0x10^3$. This indicates that the value of coliform, total aerobic plate and fungal decreased in the digestate even though they were high in the feedstock. For the biogas production, the maximum production of biogas reached 6000 $cm^3$and the minimum production reached 200 cm^3. After obtaining the compost they tested the element of it they found that the percentage of carbon is 37.91%, nitrogen is 2.4% and phosphate is 3.49%. To conclude, they found that the digestate biofertilizer can be a good way to improve soil fertility.

Effect of compost on plant yield:

Okareh et al. (2014) manage food waste from institutions and communities and convert it to fertilizers through composting and use it in plantain production. This study focuses on comparing the yield and the performance of plantain sucker with organic and without fertilizer, they analyzed the soil before and after adding the compost. Then they analyzed the quality of the compost, and it contains 40.0 ± 5.5% of carbon, 3.56 ± 5.65% of total Kjeldahl Nitrogen, 1.12 ± 5.53% of phosphors, 2.03 ± 12.87% of Potassium, and the ratio of C/N is 11.23. Also, there was a presence of heavy metals such as lead at 1.40 ± 1.32 mg/kg, Chromium at 1.6 ± 7.12 mg/kg, Cadmium at 1.1 ± 4.52 mg/kg, Nickel at 1.41 ± 6.64 mg/kg as well as Copper with 0.29 ± 14.11 mg/kg. The results show an increase in pH with an increase of organic matter from 3.58% to 5.37% and total organic carbon from 2.04% to 3.07% as well as in phosphorus from 104.30 to 122.8 and potassium from 0.59 to 2.42 cmol/kg which mean that composting has improved the physical conditions of the soil (Okareh et al., 2014). As a result, the crop yield from soil treated with compost had a significant difference in bunch weight and finger numbers ($P>0.05$) compared with soil treated without compost. Moreover, compost produced by the developed technique contained three times nitrogen as much nitrogen as compost produced by other methods (1% to 2%).

Kochakinezhad et al. (2012) compare and tested different types of fertilizer on tomato plants. They implant different types of tomatoes; Chief, Flat, Redstone, and Peto Pride in a clay loam soil with a pH of 7.2 in the Guilan University and used various fertilizers; Municipal Solid Waste Compost with 100, 200 and 300t/ha, Spent Mushroom Compost (10, 20, and 30t/ha), Cow Manure (20, 30 and 40t/ha) and Chemical Fertilizer (150N-100P-300K kg/ha) and unfertilized “control”. To measure the impact of cultivar, type of fertilizer, and the combination of the two of them on the tomato an ANOVA test has been used. The results display that under optimized organic fertilization, Flat yields were 99.5% of those achieved with chemical fertilization and the recommended maximum yield is 30 t/ha of CM, Redstone yields were 98.4% and the optimum yield recommended of it is 20 t/ha of SMC, Peto Pride yields were 97.6%, and Chief yields were 95.7%, for both Peto Pride and Chief the recommended yield is 300 t/ha of MSWC (Kochakinezhad et al., 2012.). They conclude, for the four cultivars evaluated in the present study, selecting an appropriate organic fertilizer was shown to reduce yield decrement by 0.5% to 4.7%.

Effect of various temperatures on the organic fertilizer:

Jiang et al. (2015) compare the organic fertilizer that is produced within 96h by Dynamic High-temperature Aerobic Fermentation (DHAF) and Traditional Static Composting (TSC) which takes 24 days. To produce the organic fertilizer from food waste under high temperatures they used a designed bioreactor, where the material involves 18.2kg of boiled rice mixed with 14kg cabbage and 7kg of boiled pork. The proportions on a wet weight basis were 41.6% of matured compost and +58.4% of food waste (w/w). According to the results, the EC value of the DHAF reached a maximum of 3.96mS/cm within 16h then it decreased to 2.35mS/cm at 96 h, while the value of EC of TSC raised to a maximum value of 4.69mS/cm within 6 days then declined to 2.58mS/cm. The pH, in DHAF, started at 6.2 and increased to 8.2 within 96h, and for TSC the pH decreased at the beginning to 5.9 then increased to 7.7 on the 24 days. The TC/TN ratio of DHAF started at 27.3 and decreased to 18.0 at 96h and for TSC the ratio started at 27.4 and declined to

19.7 at 24 days (Jiang et al., 2015). Also, DC/DN ratio in DHAF started at 36.6 and decreased to 6.8 at 96h and the ratio of TSC decreased where it started at 32.3 and reached 7.8 at 24 days. The Germination

Index measured, for DHAF was 88% and TSC is 82%. Moreover, they tested particle size, for DHAF was < 0.1mm which contributed 64.28%, and for the TSC the majority of particle size was between 2.0mm and 3.0mm about 39.07%. They conclude that because of the continuous collision and friction in the DHAF process created a perfect environment for microorganisms to reproduce and that the anaerobic area in DHAF is limited to only particles that are larger than 2mm.

Cheong et al. (2020) investigated heat treatments to simulate different concentrations of digestate. To prove the growth of xiao bai cai using anaerobic digestate. They collected a 1000-L digester fed with food waste from the canteen located at the National University of Singapore Kent Ridge Campus. To test the 3 types of untreated FWAD, treated at 60˚C and 121˚C, and undiluted or diluted with tap water to a concentration of 20%, 40%, and 80%, they included a control treatment with 1.2g of dissolved NPK 15-15-15 fertilizer. The findings show the heat treatment of FWAD exhibits an increase in pH where the untreated has a pH of 7.81, 60˚C has a pH of 8.73, and the 121˚C has 9.76 (Cheong et al., 2020). They observed an increase in soluble COD with an increase in temperature treated while the total COD has the lowest value of 8080 for the 60˚C. In contrast, the concentration of NO_3^- was extremely low for all the types of FWAD about 0.58, 0.51, and 0.66. The effect of heat-treated on fresh weight was not significant, where the highest aerial fresh weight of xiao bai cai fertilizer with anaerobic digestate was 40% concentration, for 60˚C the highest mean was 20% concentration, and for 121˚C the maximum concentration was 80% thus, they noticed that with the increase in temperature the greatest mean fresh weight yield decreased. Also, the same results were acquired when analyzing dry weight yields. For the chlorophyll content index, the untreated FWAD was highest at 40% concentration, the 60˚C was highest at 20%, and the 121˚C treated at 80% (Cheong et al., 2020). They conclude that using FWAD even in the untreated form led to improve crop yield and they found growth utilizing commercial fertilizer does not significantly differ from growth utilizing aerial fresh weight, dry weight chlorophyll content, and increased chlorophyll content in the soil dissolving organic matter.

Gao et al (2021) used different Thermal Hydrolysis temperatures; 140˚C, 160˚C, 180˚C, 200˚C, and 220˚C. To convert food waste to liquid organic fertilizer (LOF). Food waste was collected from Nanyang Technology University and crushed using a blender to obtain particle size <2mm, then they used a pressure reactor to conduct Thermal Hydrolysis (TH). They filled the reactor with 500g of wet food waste and mixed it with 500g of MilliQ water then they settled the temperatures. They obtained hydrolyzed liquor (HL) as liquid fertilizer. According to the results when the HL temperature was 180˚C, the dissolved total N concentration was 1585mgN/L and the ammonium reached the highest at 1299mgN/L when the HL temperature was 200˚C. As observed the TN solubilized in HL was approximately 33%-48%, and the Phosphorus solubilization was

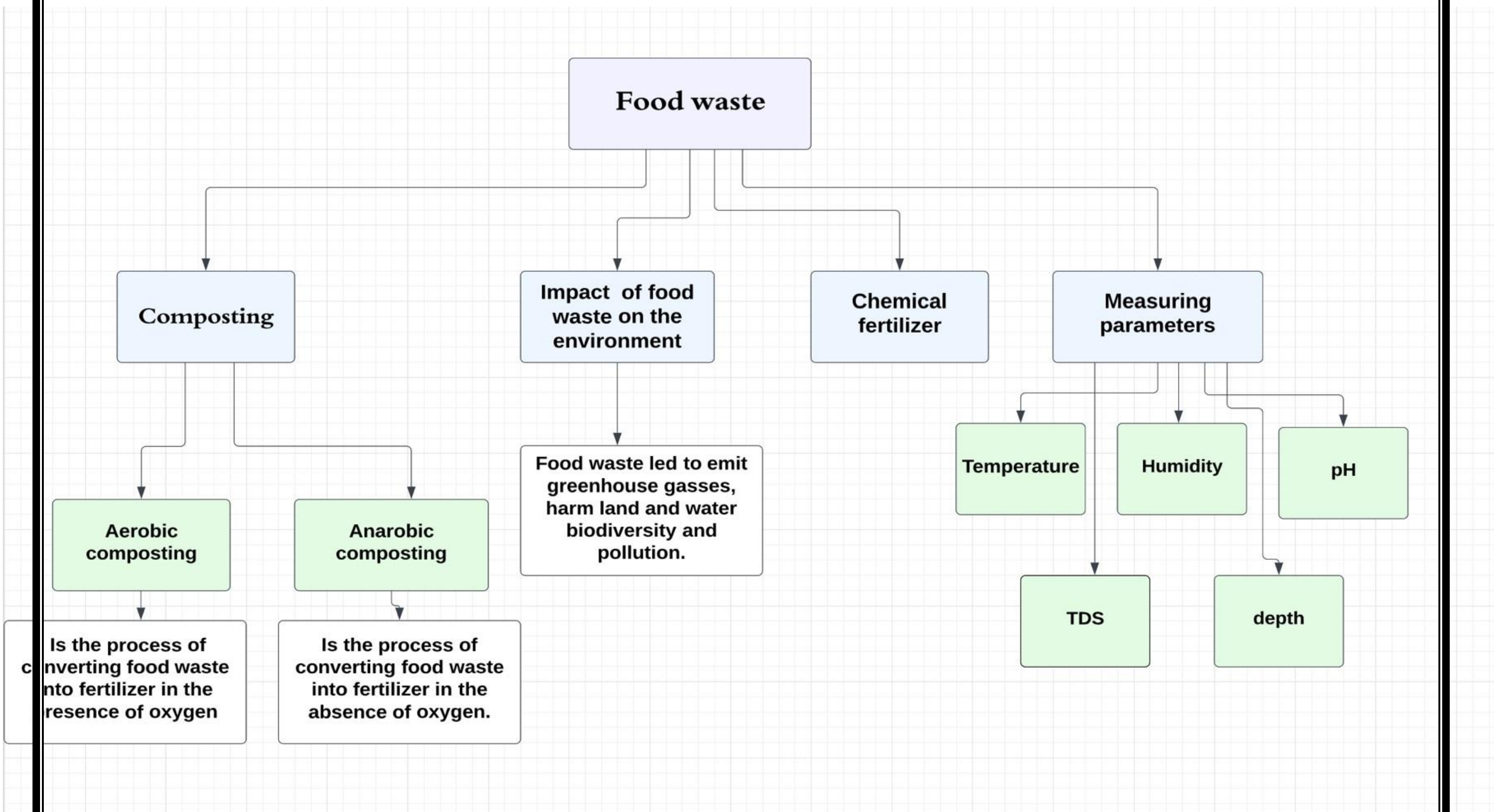
74%-96% where the highest concentration of P is 231 ± 16 mg/L at 180˚C. The solubilization of K^+ from food waste to HL was 82%-85% and the concentration ranged from 278.88 to 293.95mg/L (Gao et al., 2021). In addition, 20 types of Free Amino Acid (FAA) were detected from HL and HL180 liquor was found to have the highest concentration. Moreover, a phytotoxicity test was conducted to assess the toxicity of HL. HL180 appears to be best suitable product as liquid fertilizer. For the biotoxicity of HL, they found that its biotoxicity-free to Pseudomonas putida cells. Organic matter and nutrients were made abundant at 180˚C, which was the optimal TH temperature, and the diluted HL did not show any phytotoxicity and biotoxicity which make it a perfect choice as LOF.

Effect of biochar as fertilizer:

Song et al. (2021) investigated a study that utilize two methods; an untreated anaerobic digester (AD) and AD-biochar residue to improve the agronomic performance. Food waste feedstock was collected from the student residential hall canteen in Kent Ridge Campus of the National University of Singapore to obtain anaerobic digestate. The first experiment tested the impact of varying concentrations of untreated AD (undiluted 100%, or diluted to 20%, 40%, 60%, and 80% and commercial fertilizer) on 4 types of leafy vegetables, and the second experiment focus on utilizing of AD-biochar residue on different kinds of vegetable and they monitored the plant's growth for both experiments. Song et al, found that 20-40% Conc consider the best AD treatment for plant growth for all 4 types of vegetables according to aerial fresh weight compared to the other AD treatments while 80% and 100% Conc. have the least plant growth. The Chlorophyll Content Index was measured, and they found a concentration of 40%-60% AD treatment had the highest value where the plants grow compared to commercial fertilizer. Moreover, for the Shannon index, the soil treatment for Chine's spinach had the highest value of 5.98 and the pH was 7.21 also shows that the alpha-diversity of it was higher while the Chine's cabbage had the lowest value of 4.65 and the pH was 6.88 (Song et al., 2021). The second experiment was performed to recover the nutrients from untreated AD and decrease its volume, different type of biochar was used which are Black Soldiers Fly (BSF), Municipal Waste (MW), virgin biochar, and spent biochar. They noticed that the BSF and MW biochar has the lowest value of aboveground fresh weight for all the vegetables. They conclude that the best procedure to recover the nutrients from liquid and solid fractions is utilizing biochar to filter AD.

Environmental impact of organic fertilizer and chemical fertilizer:

To measure the environmental impact of organic fertilizer produced from food waste through anaerobic digestion compared to chemical fertilizer, a study was conducted by Chiew et al. (2015). They created two scenarios; Digestate fertilizer (DF) food waste was gathered from 155,273 houses to 5 reloading stations, then it continued the process to producing biogas and generate liquid and solid digestate and chemical fertilizer scenario; collecting and transporting food waste, then it was incinerated. Results show the net primary energy for DF is -283MJ per FU and CF produces more primary energy with -784 MJ per FU. Also, Global Warming Potential (GWP) was measured, and they discovered that for DF the GWP was 8.4kg CO_2 eq per FU and CF was -17.1kg CO_2 eq per FU. The emissions of CF were small compared to DF. For the potential acidification, they found that DF has 0.58kg SO_2 eq per FU while CF has a potential acidification -0.02kg SO_2 eq per FU. Thus, all processes of CF released small amounts of compounds that lead to acidification. Moreover, they measured the potential eutrophication for the DF scenario as 0.13kg PO_4^{3-} eq per FU while the CF was 0.01kg PO_4^{3-} eq per FU. For Cadmium, they discovered that DF contains 8.6mg, CF scenario contains 0.6mg, and flow of phosphate was 0.20kg in CF and for DF was 0.02kg. The carbon in the waste products in DF was 5.7kg per FU and food waste incinerated in CF was 31.8 kg per FU (Chiew et al., 2015). The use of chemical fertilizer is better in comparison with digestate as fertilizer in terms of lowering the GWP, and net contribution to primary energy and leading to less acidification and eutrophication.



Conceptual Framework

Objectives and Variables:

Main object:

To investigate the effect of different types of composting on plant growth.

Specific objective:

1. To test the effectiveness and the quality of the compost produced from food waste.
2. To evaluate the existence of compost and chemical fertilizer on the soil.
3. To find out how the compost is impacting the plant's growth and the nutrient of the soil.
4. To compare which type of compost (aerobic and anaerobic composting) is more efficient and eco-friendlier for plant growth.

Dependent Variable:

The growth of plant (height), quality of the soil (nutrient content in soil).

Independent Variable:

Type of food waste, different process of composting (aerobic and anaerobic composting), chemical fertilizer.

Control group:

Types of plants, location, amount of water, sunlight, soil type.

Research Questions:

Main research question:

Do different types of composting affect the growth of plants?

Specific research Questions:

1. What is the chemical characteristic of the compost produced from food waste?
2. How is the soil nutrient will be affected by compost and chemical fertilizer?
3. What is the effect of composting on the growth of plants? And on the soil quality?
4. Which type of compost (aerobic and anaerobic) is more efficient to plant growth?

Hypotheses:

Research Hypothesis:
Organic fertilizer has positive effect on the plant growth and soil quality than chemical fertilizer.

Null Hypothesis:
Organic fertilizer has no influence on the plant growth and soil quality.

Study Methodology:

Study design:

- In this study the study design will be quantitative as the quality of the compost on plant growth will be tested and several parameters will be measured during the composting such as the depth of the composted material, TDS, humidity, Temperature, and pH. Also, this study will be a cross-sectional study as the composting materials will be check-ins weekly for 5 to 6 weeks for checking the parameters.

Study setting:

- The study will be done outdoors on Zayed University campus grounds, in Abu Dhabi,

UAE.

Study population:

- Food waste will be gathered from Zayed University Canteen and home food waste as well.

Sample size:
• At least 5 kg of food waste will be collected from Zayed University canteen and about 3 kg from domestic food waste.

Sample Technique:

• The sample techniques used in this study is composting both aerobic composting (with the availability of oxygen) and anaerobic (in the absence of oxygen) as well as chemical fertilizer in order to test the effectiveness of the composting and chemical fertilizer on plant growth and soil quality.

Methods: (Hamid et al., 2019).

About 5 kg of food waste will be collected from the Zayed University canteen and 3 Kg from home food waste. First food waste will collect in one place and separating it into composting material and non-composting material also, in greens (wet, green) and browns (dry, nitrogen). After separating food waste, select an appropriate container pile or bin with a lid that has holes in the sides for airflow and select a dry place that is near a water source to put the composting bin. Then start with building the pile at least 3 feet deep by mixing three parts browns and one part of the greens, add more browns in case the pile smells or it was wet, and if it was dry add more greens. Place the compost in warm temperature so that microorganisms will work more effectively. Add water to the compost pile to keep it moist and a consistently damp sponge. Continuously add water to speed up the process of composting. As the decomposition microorganisms will begin to decompose the compost material. Exposed the compost to oxygen in order to speed up the compost process. Start monitoring the temperature using a thermometer, at the beginning as it is hot use a thermometer to read, (110˚F to 160˚F) consider the best time to convert to compost. Also, measure the other parameters. Rotate the compost pile which will assist the compost to cook faster as well as prevent materials in the compost to become matted down. When the compost is dark brown, dry, crumbly, and has earthy smells this means that the compost is ready to use. Repeat the same exact process of composting but with exposing the compost to oxygen (anaerobic composting), then use the compost in planting and compare it with chemical fertilizer.

Results:

• The results will be done after the study.

Discussion on results:

• The discussion on results will be done after the study.

Conclusion:

In conclusion, in order to solve the issue of food waste and make it an opportunity is by convert this waste into organic fertilizer that is rich with nutrients and uses it in planting and for better soil quality. My study will test the effectiveness and the applicableness of making an organic fertilizer in the Zayed university ground and monitor the parameters of the composting (aerobic and anaerobic) and finally test the compost quality by applying it to plants with chemical fertilizer. Also, to see how we could improve the quality of the compost in the future and make it applicable everywhere to all people.

Ethical Consideration:

• There is no ethical consideration.

Timetable:

Task	Weeks									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	10

Research proposal										
University approval										
Collection of food waste										
Data collection and Analysis										
Writing first Draft										
Final Draft										
Submission of Report										
Presentation Submission										

Budget:

• The budget is not needed for this study.

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