REPUBLIC OF TÜRKİYE
HARRAN UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

MASTER OF SCIENCE (MSc) THESIS

THE POTENTIAL USE OF GRASS CLIPPINGS, VEGETABLES AND PISTACHIO WASTE AS COMPOST AND BIOCHAR

Ahmet AYDOĞDU

DEPARTMENT OF SOIL SCIENCE AND PLANT NUTRITION

SANLIURFA
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The study on **"The Potential Use of Grass Clippings, Vegetables and Pistachio Waste as Compost and Biochar"** prepared by Ahmet AYDOGDU under the consultancy of Prof. Dr. Ali Volkan BILGILI has been accepted as a MASTER of SCIENCE THESIS in Harran University, Graduate School of Natural and Applied Sciences, by unanimous vote of the following jury on 29/07/2022.

☐ Unanimously / ☐ By majority of votes

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ÖZET

Yüksek Lisans Tezi

ÇİM, SEBZE VE ANTEP FISTIĞI ATIĞININ KOMPOST VE BİYOKÖMÜR OLARAK POTANSİYEL KULLANIMI

Ahmet AYDOĞDU

Harran Üniversitesi
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Kompostlama ve biyokömür üretimi, prosedürün yüksek maliyeti, işlem süresinin uzunluğu ve nihai ürünlerin geleneksel uygulamadaki kararsız yapısı nedeniyle Türkiye' de özellikle Güneydoğu Anadolu Bölgesi'nde organik katı atıklar için fazla kullanılmamaktadır. GAP Bölgesi'ne özgü antepfıstığı atıkları, yeşil ot ve sebze ve meyve atıkları kompost ve biyokömür gibi değerli organik bir gübreye dönüştürülebilir. Bu çalışmada, sebze atıkları, çim atıkları ve iki farklı fıstık atığı gibi GAP bölgesi için ekonomik değeri yüksek materyaller kullanılarak Berkeley hızlı kompostlama metodu ile üç farklı kompost üretilmiştir. Ayrıca çimden ve diğer tüm olgun kompostlardan toplamda dört farklı biyokömür üretilmiştir. Bu araştırma arazi denemesi olarak toprak yüzeyinde yarı açık alanda yürütülmüştür. Araştırma konuları; Fıstık kompostu (PC), sebze ve meyve kompostu (VC), çim kompostu (GC), çim biyokömürü (GB) olarak belirlenmiş ve taze çim atıklarından üretilen biyokömür taze çim biyokömürü (FGB), elde edilen kompostlardan üretilen biyokömürler ise sırasıyla fıstık kompostu biyokömürü (PCB), sebze atığı biyokömürü (VCB) ve çim kompostu biyokömürü (GCB) olarak adlandırılmıştır. Hızlı kompostlaştırma işlemi PC, VC ve GC için sırasıyla 26 gün, 30 gün ve 20 gün sürmüştür. Sonuçlar, kompostlama işleminin çim kompostlaştırmasında atık kütlesini %41 oranında azaltabileceğini göstermiştir. PC, VC ve GC için azot içeriği ve C/N oranı sırasıyla %2,48 ve %15,72, %2,14 ve %14,66, %3,08 ve %10,11 olarak elde edilmiş olması, elde edilen komposların standartlara göre stabil ve olgun olduğunu göstermektedir. Ağır metallerin sonuçları tüm kompostlar için standart limitlerin altındadır. Farklı kompost türlerinin özellikleri arasındaki ilişkiler PCA analizi kullanılarak araştırılmıştır. PCA analiz sonuçları, VC, GC ve PC'nin sırasıyla besinler, azot ve karbon ile ilişkili olduğunu göstermiştir. Sonuç olarak, çalışmamızın sonuçları, elde edilen kompostların bölgemizde toprak organik maddesini ve mikro besin maddelerini arttırmak için değerli bir toprak düzenleyicisi ve organik gübre olarak kullanılabileceğini göstermiştir.

ANAHTAR KELIMELER: Organik atık, Fıstık kompostu, Hızlı kompostlama, Biyokömür, Sürdürülebilir tarım

ABSTRACT

MSc Thesis

THE POTENTIAL USE OF GRASS CLIPPINGS, VEGETABLES AND PISTACHIO WASTE AS COMPOST AND BIOCHAR

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Composting and producing biochar are not common technique to treat organic solid wastes in Turkey locally in South-eastearn Anatolian Region (GAP) due to the high cost of the procedure, the length processing time and the unstable structure of the final products in a conventional treatment. Pistachio nut, green grass and vegetable and fruit wastes which are crucial and have economical value to the GAP region, could be transformed to an organic soil amendment such as valuable organic fertilizer as a compost and biochar. In this study, from these raw materials, in total three composts were produced from the two different type solid fraction of pistachio waste, grass clippings and vegetables by using Berkeley rapid composting (BRC) method. On the other hand, in total four different biochars were produced from the lawn wastes and all mature composts. This research was carried out as a field experiment in a semi-open area on the soil surface. Sixteen elements including heavy metals were detected using ICP Spectrometer. Research topics; Pistachio compost (PC), vegetable and fruit compost (VC), grass compost (GC), grass biochar (GB) were determined and the biochars produced from fresh grass waste and the obtained composts were named fresh grass biochar (FGB), Pistachio compost-biochar (PCB), Vegetable compost-biochar (VCB) and grass compost-biochar (GCB), respectively. Rapid composting process was lasted for 26 days, 30 days and 20 days for PC, VC and GC, respectively. The results demonstrated that the composting process could reduce waste mass by 41% in grass composting. Nitrogen content and C/N were found to be 2.48% and, 15.72, 2.14% and 14.66, 3.08% and 10.11 for PC, VC and GC composts, respectively proving that the obtained composts are stable and mature in accordance with the standards. Results of heavy metals were under standard limits for all composts. Relations among characteristics of different types of composts were investigated using PCA analyse. PCA analysis results showed that VC, GC, and PC were respectively associated with nutrients, carbon and nitrogen. Consequently, the results of our study indicated that obtained composts could be valuable soil conditioner and organic fertilizer for enhancing soil organic matter and micronutrients in GAP region in Türkiye.

KEYWORDS: Organic waste, Pistachio compost, Rapid composting, Biochar, Sustainable agriculture

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LIST OF SYMBOLS and ABBREVIATIONS

°C	Degrees Celsius
C/N	Carbon and nitrogen ratio
Cd	Cadmium
Co	Cobalt
Cr	Chromium
Cu	Copper
DGW	Dry Grass
EC	Electrical Conductivity
EU	European Union
Fe	Iron
FGW	Fresh Grass Waste
GAP	South-Eastern Anatolian Project
GC	Grass Compost
ICP OES	Inductively Coupled Plasma Optical Emission Spectroscopy
K	Potassium
MC	Moisture Content
Mg	Magnesium
MGM	The Ministry of Agriculture and Forestry General Directorate of Meteorology
Mn	Manganese
N	Nitrogen
Na	Sodium
Ni	Nickel
NPK	Nitrogen-Phosphorus-Potassium
PC	Pistachio Compost
PCA	Principal Component Analyse
PCB	Pistachio Compost's Biochar
PGHSE	Pistachio Green Hull Solid Extract
pH	Hydrogen Ion Concentration
PSW	Pistachio Solid Waste
PW	Pistachio Waste
TOC	Total Organic Carbon
TUIK	Turkish Statistical Institute
VC	Vegetable Compost
WHO	World Health Organization
Zn	Zinc

1. INTRODUCTION

In the last decades, it has been observed that the rate of waste generation per capita has significantly increased on a global scale, accompanying an increase in the level of consumption specifically with the implementation of the South-Eastern Anatolian project (GAP) in the South-East Anatolia in Turkey (Bilgen, 2018). The GAP is a regional development initiative aimed at the full socioeconomic development of Upper Mesopotamia, often known as the Fertile Crescent, which historically hosted one of the world's first civilizations. The GAP's concept is one of sustainability, with a focus on human health and well-being (Yesilnacar and Cetin, 2005). However, organic wastes have become a critical issue and the amount of organic waste in the region has started to increase abundantly in agricultural activities and outputs such as residues after harvesting in a wide agricultural area (Bhuvaneshwari et al., 2019). Some organic solid wastes gathered in our region are disposed in conventional ways, like animal feed, in most cases, these wastes are burned or transported to landfills (Erses, 2015). Inappropriate dealing with solid organic wastes can have negative social, economic, and environmental consequences, so scholars and policymakers-makers should pay more attention to this issue (Diener et al., 2011).

Reusing organic industrial and agricultural wastes is a simple, cost-effective, and ecologically beneficial method of waste management and soil fertility improvement. Organic wastes from the processing stages of agricultural outputs abound in the food and agriculture industries (Kutu et al., 2019). The use of these wastes, either directly or after decomposition, is determined by material qualities such as carbon to nitrogen ratio, soluble salt content, and so on. Depending on their properties, these materials could be used as soil conditioners and plant nutrition sources for soils (Karagöktaş et al., 2014). So, it is crucial to evaluate and distinguish the organic wastes such as plant and animal wastes with the increase in urbanization, industrialization, agricultural inputs, and production (Yang et al., 2015).

Soil provides nutrients for plant development and successful agriculture. Healthy soils provide healthy food for human beings. Agronomic yield is strongly influenced by soil quality. Despite the fact that food and nutritional insecurity are worldwide concerns, they are especially crucial in developing countries due to population increase and diminishing land, water, and other agricultural resources (Lal, 2015). In agricultural practices are vital to prevent soil degradation by increasing soil quality and to ensure proper soil fertility (Noor et al., 2020). Instead of plant nutrients removed from the soil with the products harvested in agricultural production, synthetic fertilizers have been using to maintain essential plant nutrients for plant growth. However, healthier agricultural products can be produced by integrating soil additives such as compost and biochar.

Composting will contribute to the creation of sustainable agricultural systems that make efficient use of nutrient resources. Using organic compost and biochar for plant cultivation reduces chemical inputs to the soil. Additionally, carbon sequestration in soils increases soil carbon, promotes soil health, and minimizes climate change.

Compost is created when organic material is broken down by microorganisms in a regulated oxygen atmosphere. The procedures involved in creating compost have both benefits and consequences. The open compost pile method requires very little labor, has a flexible capacity, and takes up very little area. It also has no initial investment requirements. Visual blight, odour, and pest issues when not run properly, as well as a lack of protection from rain and sunlight during the composting process, are consequences. Aerobic composting in thermophilic circumstances may be a regularly utilized method for the breakdown of organic wastes. Although 60 °C is considered the ideal temperature for composting, the temperature can occasionally exceed 60 °C during the composting process.. This temperature change may depend on the kind, amount of the material used, and local weather conditions, as well as the size of the pile used (Geethamani et al., 2021). In Turkey, composting procedures are only used sparingly and at a low level. Composting methods are used to dispose of only 6% of the total waste, compared to options including sanitary landfills, recycling, and composting (Koçak and

İkizoğlu, 2020). The need for compost production for sustainable agriculture to protect soil resources has been increasing day by day (Noor et al., 2020). Technological developments in the field of organic waste management provide new opportunities for improving soil quality. It is important to have more knowledge about organic fertilizer production and soil for future generations and sustainability. Composting provides important techniques and benefits for both farmers and researchers.

When biomass is heated in a confined container with little available air, a carbon-rich substance called biochar is produced. The pyrolysis process is the thermochemical conversion of biomass at temperatures exceeding 300 °C in an oxygen-depleted atmosphere (Otte and Vik, 2017).

Pistachio is a common fruit crop in the arid area of South-east East Anatolia. Harvesting and processing pistachio nuts produces a huge quantity of organic waste (Karagöktaş et al., 2014). According to Turkish Statistical Institute (TUIK, 2021) data total pistachio production in Turkiye was 119,355 tons, in Sanliurfa city was 38,576 tons, as the largest in terms of production amounts when compared with other provinces (TUIK, 2021). In Türkiye around 40,000 tons compostable pistachio wastes are available. In Sanliurfa city around 13,000 tons compostable pistachio wastes are available. Considering that one-third of total produced pistachio are compostable (approximately 120,000 tons per year) (TUIK, 2021)

Significant amounts of green grass clippings are obtained from the grass fields harvested at least twice a month in the Harran University campus. Important outputs were obtained by using this material to produce compost and biochar. The highlighted topics in this thesis are compost and biochar which can be used in soil amendment that increases soil fertility and are important alternative to chemical fertilizers in agricultural production. In this respect, it supports sustainable agriculture and productivity.

The goal of the current study was to investigate the use of plant and animal wastes locally available in the region with composting and pyrolyzing as an alternative waste management strategy. It was also aimed to determine the properties of the composts and

biochars within the scope of this thesis. Berkeley rapid composting method used for producing composts in this research is active composting method for small scale farms without mechanization and any additional equipment (Raabe, 2001). This technique fixes some of the issues with the previous methods of composting.

In summary, the overall objectives of the thesis are:

General objectives;

- To examine the importance of preparing and using compost and biochar produced from organic wastes in the GAP region.
- Investigation of the potential of using organic wastes and to propose an integrated approach such as an alternative soil amendment inputs which are biochar and compost.

Specific objectives;

- Conversion of organic solid wastes into compost in the osmanbey campus in Harran University by Berkeley rapid composting method and to show how compost can be produced with the active composting method which is also suitable for small scale farms (Raabe, 2001).
- Examination of the characteristics of the composts and biochars produced from organic wastes.
- To perform the characterization of organic amendments to comprehend the procedure of the compost and biochar treatment more accurately.
- To monitor the evolution of temperature profile and evaluate the effect of temperature increases in the composting process.

2. LITERATURE REVIEW

Based on a comprehensive assessment of the literature, investigation into how effectively the composting process works for various forms of organic waste has revealed varying results. Composting has been shown to drastically reduce the amount of waste in the nation when used as a treatment for organic waste. Additionally, composting can offer nutrients that are appropriate for farming and can be utilized as fertilizer instead of chemical fertilizer. Additionally, compost is non-toxic, inexpensive, hygienic, and can be utilized as a soil amendment. In conclusion, adding animal manure to agricultural waste during the composting process can speed up the decomposition process. However, because heavy metals are harmful, it's critical to assess their concentration in municipal solid waste and food trash when composting is occurring. To ensure the reliability of the compost and the given compost must correspond to the specified limit (Kadir et al., 2016).

The contents of the resulting chapters are briefly summarized for a quick overview. Organic Waste Potential and Use, Legal Framework, Waste Collection Systems, a summary of the earlier chapters with suggestions. The case studies highlight many appropriate methods under framework conditions. As a result, it may be concluded that information must be provided about biochar and compost products, input materials, sources, and the composition of the substrate instructions could help consumers make more informed decisions (Meyer-Kohlstock et al., 2015).

Researchers investigated some non-technical issues of biochar system implementation in Norway approach using a socio-technical system. Non-technical factors research primarily addresses the viability of using biochar economically. However, they demonstrated in this study perspective is very constrained because the adoption of new technology is influenced by a variety of factors, not just their potential for financial gain. This viewpoint overlooks the social aspects of adopting technology. Numerous non-technical factors must be taken into account. In the framework of the socio-technical

system approach, which served as the basis for our investigation, they identified six pertinent components. Three alternative biochar system scales' values for these six elements were examined (i.e., centralized, medium centralized, and decentralized). The project design for biochar systems must consider the major variances in the non-technical aspects, despite the fact that some values are the same among systems. Decentralized biochar projects may face difficulties due to a lack of knowledge as well as a variety of cultural factors, including the degree of diversification and the social identity of the farmer, whereas centralized systems place higher demands on infrastructure by necessitating a centralized mechanism for storage and delivery that collects feedstock from various areas and delivers it to the desired location (Otte and Vik, 2017).

The conducted research goal was to evaluate whether the agronomic characteristics of vermicompost, which was created from partially stabilized sewage sludge digestate following thermophilic composting, were preferable to those of ordinary compost. The impacts of several additives (green waste, wasted mushroom compost, wheat straw, and biochar) were also evaluated. In their results they indicated that vermicomposting did not produce noticeably more intensive mineralization than composting. Thus, the average concentrations of all macronutrients and available macronutrients were the same in both treatments. The organic matter quality was unaffected by the processing technique, either (Rékási et al., 2019).

In this conducted study the organic wastes are transformed into a compostable form in 14 to 21 days. In comparison to the typical range of 23 to 30:1, the C: N ratio is low. Even if the pH of the compost ranges between 6 and 8, indicating maturity. This might be as a result of the increased amount of greenery and grass clippings. Manure, a source of nutrients, nursery media, and soil supplements are all uses for compost. For campus plants, the compost is obtained. It eliminates the waste issue and lessens the demand for chemical fertilizers. Rapid composting destroys any organism that causes plant illnesses. During the composting process, insects perish. Some may be enticed to the pile, but the compost their eggs are laid in will kill them. In order to increase the profitability of mushroom

farming, their work also contributed to the creation of a trustworthy, low-cost, quick-duration, natural pasteurization, and outdoor composting technology (Geethamani et al., 2021).

Yang et al. (2015) found that increasing the proportions of incineration and composting in municipal solid waste management over the next 10-15 years is more feasible than landfilling. In the case of municipal solid waste management, composting is more practical than landfilling.

The mineralization of PC was facilitated by its low carbon to nitrogen ratio, which finally released plant nutrients and organic compounds. This substance decreased soil pH and dissolved Ca-phosphates, increasing the availability of phosphorus in soils as well as extractable cationic micronutrients, particularly zinc (Karagöktaş et al., 2014).

The C/N ratio, which is the most important component in compost, can be maintained by some bulking agents, including sawdust, cow manure, and rice husk. Rice husk and bran, cotton waste, sawdust, and cow dung are the most efficient and extensively utilized bulking agents in composting, and they have all been employed in numerous studies. The use of these bulking agents by compost producers may be effective and beneficial. Although the information on currently used bulking agents is interesting, more investigation is required to identify bulking agents that are more accessible and less priced (Manish et al., 2013).

Pistachios have a high nutritional value and are packed with phytochemical components. They are rich in nutrients and trace minerals, as well as fat, protein, and dietary fibers. Their antioxidant action is mostly caused by the existence of phenolic compounds (Zarei et al., 2014).

Conducted study, pistachio waste (PW) treatment in various ratios with cow dung. PW used for a combined composting-vermicomposting process using a worm on an

experimental scale. In the pilot scale, the procedure was carried out in two sections: pre-composting and vermicomposting, each of which takes 45 days to complete. Physical, chemical, and worm growth ratios in various treatments were assessed and contrasted. The outcomes demonstrated that the combined procedure considerably improved the end product's quality, and the fertilizer that was created was uniform, granular, odorless, and nutrient-rich (Esmaeili et al., 2020).

In this investigation, 59.2 kg of simulated ordinary municipal solid food waste were placed in a 0.166 m^3 bioreactor tank. The bioreactor ran anaerobically for 70 days after 30 days of aerobic operation, until the composting was complete. Results indicated that employing the composting technique, the mass of the wastes could be decreased by 69%. The findings demonstrated that the created compost meets the criteria for stability and maturity in terms of nitrogen concentration, C/N, nitrification index, NPK, and germination index. Zinc (Zn), Copper (Cu), Molybdenum (Mo), Zirconium (Zr), Strontium (Sr), Rubidium (Rb), Manganese (Mn), Scandium (Sc), Iron (Fe), Titanium (Ti), Calcium (Ca), and Potassium were the 12 heavy metals that were found. Results for Cu and Zn were acceptable, but not for the others (Zamil et al., 2019).

An effective co-composting procedure was accomplished over a 60-day period by combining two distinct materials. In one of the composting procedures, the temperature increase was greater, which led to more efficient pathogen elimination. Both final reactors and product’s pH fell within the acceptable range, while both co-composting reactor’s EC rose. Though C/N ratios fell in both reactors, the first reactor had a quicker rate of organic compound breakdown. Na and K concentrations rose, but other metal concentrations including those of Mn, Fe, Zn, and Cu declined. The finished item’s metal content fell within the WHO guideline range. Although parasite egg counts increased, pathogen and indicator bacteria levels fell in both co-composting systems and were at normal levels in the first one (Jalili et al., 2019).

The woody fraction of biowaste, or green trash, would be sufficient to produce enough biochar to make biochar-compost mixes based on the total potential biowaste in the EU. The possibilities of forestry waste for making biochar as well as agricultural inputs for making compost were briefly covered even though they weren't the main topic of this research. It is feasible to draw the conclusion that various EU legislation stimulate the legal framework for biochar and compost as a basic principle for the recycling of organic waste. However, based on an analysis of the untapped waste potential, suggestions were made to enhance the existing legislation. The case studies on bio-waste collecting and pre-treatment systems highlighted a variety of solutions to various problems. While there cannot be a single best collection system for the entire EU, some effective tactics can be applied to other areas with comparable conditions. This might increase the usage of the available bio-waste and raise the effectiveness of the current systems. For sewage sludge and some organic wastes from the food sector, a similar approach to providing information about effective solutions can be suggested. In order to enable novel practices and promote regional trade, it should also be advantageous for organic leftovers in agriculture and forestry that are currently underused (Waqas et al., 2018).

Multiple nutrient shortages connected to a serious loss of soil fertility is now represented as the principal barrier to the sustainability of agriculture on a worldwide scale. It has been claimed that one method for enhancing soil fertility, rehabilitate damaged land, and lower agricultural greenhouse gas emissions is to employ biochar and biochar-compost blends from diverse alternative organic sources. They analyzed the results of 634 papers over the last 10 years in order to find any gaps in our understanding of the usage of biochar and biochar-compost combinations as soil amendments. The review concludes that the lack of extensive, well-planned field studies on the efficiency of biochar and biochar-compost blends on various soil types and agroclimatic zones has generally limited our understanding of compost and biochar's capacity to increase crop yield and reduce climate change. To progress the research and global use of this crucial technology, they also urge policymakers, biochar producers, and researchers to collaborate more (Agegnehu et al., 2017).

Two different feasibility studies have been conducted as part of the project. Sanliurfa Compost Facility Feasibility Study which was first feasibility study investigated two alternative waste combinations made up of easily accessible wastes from open markets, grass clippings from parks, and animal manure. Compost and biogas facilities were planned separately or together, and whether heat, electrical energy, and fermented manure were all sold at once or only electrical energy and fermented manure were sold, there were five different scenarios in the second feasibility study, "Sanliurfa Biogas and Compost Facilities Feasibility Study," where manure from 1500 cows and 180 tons of municipal organic wastes were used. The quantities of wastes in various combinations were calculated using the relevant appropriate C/N rate. The return period was short in composting facilities, but internal production rates and profitability ratios were high. The profitability rate of biogas facilities where no heat energy is sold slightly fell, but they were still commercially viable. Results showed that the solutions that include compost and biogas facilities would be the most advantageous (Bilgili et al., 2011).

The purpose of their study was to identify some of the physical and chemical characteristics of compost made from grape pruning waste. In the study, a 1:1 mixture of goat dung compost (7.5 kg goat manure and 7.5 kg of pruning waste) and pruning residues from eight distinct grape types were sampled from the Dardanos Campus Vine Yard Cultivation Grape Varieties Application and Research Area in Canakkale in Turkiye during the winter pruning season in 2016. Both the ambient temperature and the internal temperature of the compost were continuously monitored and recorded during the process of the composting process. From June to October, the composting process took around 4 months to complete. Only the latest samples were used to determine the composition of the compost as well as its pH, EC, C%, and N% values. While the temperature of the outside air progressively increased over a 51-day period, compost temperature fell and produced four temperature peaks. The compost's pH value, which started out at 8.57, increased to its greatest point 9.13 in late July and then progressively declined throughout the following weeks. Late in July and August, the EC values of the compost samples rose, and the mature compost's EC was 5.76 dS/m. From the start of the composting period until

the finish, the C/N ratio declined steadily and reached 10.4 in October. As a result, compost made from vineyard pruning can be applied to farming (Şahin et al., 2018).

Each compost that was used in this experiment provided a balanced amount of minerals that provided the plant with the nutrients it needed to grow well. Compared to the soil with inorganic fertilizer, the altered soils had higher concentrations of N, P, K, and organic matter. Compost-amended soils increased soil fertility, but the control's olive oil's composition and quality remained the same. Composting two-phase olive mill waste with agricultural wastes can be a cost-effective and suitable low-cost method for recycling olive oil by-products and a sustainable solution to the dilemma of how to dispose of these wastes (Fernández-Hernández et al., 2014).

The purpose of their project was to create biochar by pyrolysis and use it in a compost bioreactor for food waste. It was shown that composting of food waste was improved by biochar produced from yard waste. There was a significant increase in temperature, high OM breakdown, and an accumulation of ash content when biochar was added to the composting mixture. The addition of biochar raised the pH of the compost and encouraged nitrification and ammonification, which raised the concentrations of NH^{+4} and NO^{-3} in the composting mixture. For the majority of compost parameters, biochar produced at different temperatures, however, yielded results that were comparable. High mineral nitrogen content, rapid thermophilic temperature, and excessive moisture absorption from the composting mixture were all noted. Compost characteristics showed that after 50–60 days of experimentation, compost stability was obtained with biochar amendments. This is in line with the compost quality requirements established by the US, California, Germany, and Austria. Because the organics may still contain between 70 and 80 percent water, municipal and industrial biosolids might pose special issues. If moisture is not regulated, the high-water content of the sludge might lead to lower composting temperatures and less effective operation. Designing functional sludge composting systems requires an understanding of the thermodynamics of composting (Waqas et al.,

2018). And also, according to Haug free air space should be more than 30% in the end of composting process (Haug, 2018).

The application of compostable pistachio residues and commercial poultry manure had a favorable impact on saffron corm development and nutrient uptake, according to the findings of study conducted in the University of Torbat Heyderiah, Iran between August 2017 and May 2018. These outcomes were in line with an improvement in the fertility-related soil chemical characteristics. Given the large quantities of pistachio waste generated in the Torbat Heidarieh region as well as the high nutritional value of this product, the proper application of pistachio residue composting and its use as a clean and sustainable solution in saffron farms can play a critical role in improving soil biological function, maximizing saffron yield by feeding more assimilates to the daughter corms. The quality features of composted pistachio residues, particularly in farm settings, require additional in-depth study, though (Daneshmandi and Seyyedi, 2019).

3. MATERIALS and METHODS

3.1. Study Site

The present study was carried out in the 2020-2021 period in the experimental area located in the Construction and Technical Directorate of Harran University Osmanbey Campus in Turkiye. The research area is in the city of Sanliurfa which is province of southeastern Anatolia region, between the coordinates (39º10´20.42´´D - 39º00´38.92´´D, 37º09´40.12´´K - 37º10´02.33´´K). The image of study area and city of Sanliurfa where study is conducted highlighted in red is shown in Figure 3.1.

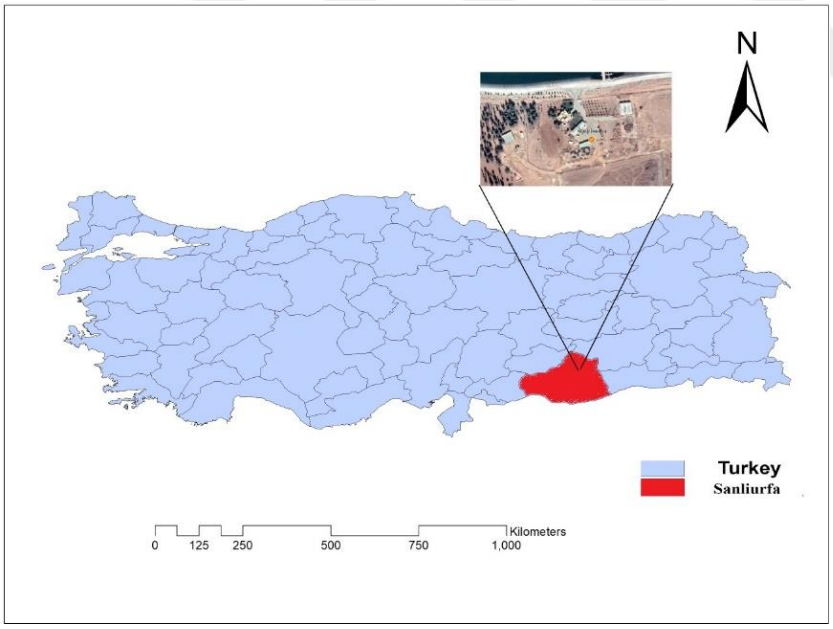


Figure 3.1. Study location

3.2. Climate

The study area was held in Sanliurfa province of southeastern Anatolia region. Sanliurfa province has terrestrial (continental) climate characteristics. Summers are hot

and dry, while winters are temperate and mild. Sanliurfa, as in many provinces in Turkiye, is under the influence of different air masses in different seasons. There is a warm period in summer and a cold period in winter. Sanliurfa province, located in the Southeastern Anatolia Region, encounters warm air masses due to the impact of the Basra Low Pressure (BAS) area. Therefore, the summer months are quite dry and cause the amount of precipitation to decrease. While the winds from the desert region of Syria, Turkiye's southern neighbor, affect daily life in a negative area, it positively affects agricultural areas and ensures the transport of abundant minerals to the soils.

Table 3.1. Sanliurfa Province weather station long terms climate data (1929-2019, MGM)

Months	Average Temperature (°C)	Average Maximum Temperature (°C)	Average Number of Rainy Days	Average Monthly Total Precipitation (mm)
January	5.5	9.8	11.9	87.6
February	7.0	11.9	10.5	69.5
March	10.8	16.4	10.4	62.8
April	16.1	22.2	8.9	49.8
May	22.1	28.6	6.1	26.7
June	28.0	34.6	1.4	4.4
July	31.9	38.7	0.3	2.0
August	31.5	38.3	0.2	3.4
September	27.1	33.9	0.8	4.6
October	20.5	26.9	4.8	26.5
November	13.0	18.7	7.4	44.6
December	7.5	12.0	10.8	81.7
Annual	18.4	24.3	73.5	463.6

According to the average climate data of the Ministry of Agriculture and Forestry General Directorate of Meteorology (MGM) Sanliurfa province between 1929 and 2019, Table 3.1 shows the July has the highest average temperature of the year, at 38.7 (°C). January is the coldest month of the year, with an average temperature of 5.5 (°C). While the summers were quite dry, the average annual rainfall was 463.6 mm.

Table 3.2. Sanliurfa Province weather station temperature data 1929-2019 years (MGM)

ŞANLIURFA	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Highest Temperature (°C)	22	26	30	36	40	44	**47**	46	42	38	31	26
Lowest Temperature (°C)	-11	**-12**	-3	3	3	8	15	16	10	2	-6	-6

Table 3.2 shows the warmest highest temperature of the 1929-2019 years is July, with an highest temperature of 47 (°C). The coldest month of the 1929-2019 years is February, with the lowest temperature of -12 (°C).

3.3. Materials

The raw materials for composting (vegetable wastes, animal manure, chickpea straw, grass clippings and pistachio wastes) in this study were collected from Urfa province in south-eastern Turkey. Vegetable wastes were collected from bazaars and markets. Solid wastes which are Turkey manure and horse manure were collected from horse and turkey farms in Urfa, transported to study area. The chickpea straw with a size ranging between 2 and 5 cm was collected from Harran University Osmanbey Campus fields are shown in Appendix. Grass clippings were obtained from lawns in university are shown in Appendix. Two different types of pistachio wastes were collected from local pistachio peeling facilities in Bozova district of Sanliurfa province are shown in Appendix 11 and Appendix 12.

Figure 3.2. Two different types of pistachio wastes from left side to right side Pistachio solid waste (PSW), Pistachio green hull solid extract (PGHSE)

3.3.1. Chemical properties of feedstocks

Table 3.3 shows some chemical properties of the four waste feedstocks, namely Dry grass (DGW), fresh grass (FGW), pistachio green hull solid extract (PGHSE) and Pistachio solid waste (PSW). Macro and micro element values in feedstocks indicated a variety of origin and character.

The micro elements including heavy metals were observed. On the other hand, fresh grass waste was used as a feedstock as it comes from campus lawns and was dried out under the sun for around eight weeks, which caused the moisture that had been adsorbed to evaporate. Fresh grass has a significant amount of TC since the leaves had dried and converted into highly carbonaceous substance. Dry grass waste would therefore primarily act for microbes to use as a source of energy. Each of the four feedstock's C/N ratios Dry grass waste (DGW), fresh grass waste (FGW), pistachio green hull solid extract (PGHSE) and pistachio solid waste (PSW) was measured and found to be 16.43, 11.83, 30.33 and 33.62, respectively. Therefore, the effect of feedstocks on the cumulative C/N of the feedstock consortium was adequate. The C/N of the four feedstocks were determined to be close to optimum at C/N ratio for initial composting process, respectively. It was observed that the two types of pistachio wastes have the mean of 1.41% Total N content,

with a mean of C/N 31.97, respectively. Dry and fresh grass have the mean of Total N content 3.01%, with a mean of C/N 14.13, respectively.

Table 3.3. Some parameters of raw materials (pistachio and grass wastes) used for the preparation of the composts.

		Raw Materials				Limits (mg kg^{-1})
		Dry Grass	Fresh Grass	Pistachio Green Hull Solid Extract	Pistachio Solid Waste	
Characteristics	Total C (%)	41.72	41.29	45.81	43.95	-
	Total H (%)	5.57	5.18	5.94	5.43	-
	Total N (%)	2.54	3.49	1.51	1.31	-
	C / N ratio	16.43	11.83	30.33	33.62	-
	Total Al (mg kg^{-1})	5472	7877	2854	4961	-
	Total B (mg kg^{-1})	0.6	0.0	1.3	2.0	-
	Total Ca (mg kg^{-1})	526.9	123.4	313.2	661.2	-
	Total Cd (mg kg^{-1})	0.0	0.0	0.0	0.0	1.5*
	Total Co (mg kg^{-1})	0.0	0.0	0.0	0.0	-
	Total Cr (mg kg^{-1})	0.2	0.1	0.1	0.2	100*
	Total Cu (mg kg^{-1})	0.4	0.2	0.2	0.3	200*
	Total Fe (mg kg^{-1})	45.5	6.1	27.8	47.3	-
	Total K (mg kg^{-1})	580.3	330.6	660.6	639.2	-
	Total Mg (mg kg^{-1})	105.0	43.7	43.5	125.2	-
	Total Mn (mg kg^{-1})	2.8	1.0	0.8	1.8	-
	Total Na (mg kg^{-1})	18.0	17.3	1.8	2.0	-
	Total Ni (mg kg^{-1})	0.5	0.3	0.3	0.4	50*
	Total Pb (mg kg^{-1})	0.0	0.0	0.0	0.0	120*
	Total Si (mg kg^{-1})	5.4	3.0	5.7	0.4	-
	Total Zn (mg kg^{-1})	1.7	1.1	0.4	0.6	600*

Source:* PTE limits proposed in EoW criteria for biodegradable waste report (Garbarino and Saveyn, 2015).

Heavy metals in all feedstocks among all the targeted heavy metals were seen under certain restrictions according to the biodegradable waste report (Garbarino and Saveyn, 2015). Al (Aluminium) was present in the highest concentrations in all feedstocks DGW at 5472 ppm, FGW at 7877 ppm, PGHSE at 2854 ppm and PSW at 4961 ppm.

3.4. Composting Method and Experimental Setup

The Berkeley rapid composting method was used to compost the feedstocks. Some of the issues with older composting techniques are resolved by this procedure. The composting study was conducted on the ground that was operated with this aerobic and

active composting process, compost can be produced in 2–3 weeks (Raabe, 2001). Procedures of method were implemented as described. The study was conducted in a well-ventilated covered shed. Three types of piles (Pistachio Compost, vegetable compost, grass compost) were created using the available wastes: Pistachio solid waste (PSW), pistachio green hull solid extract (PGHSE), dry grass waste (DGW), fresh grass waste (FGW) and vegetable waste. A total of 3 actively aerated compost piles were monitored are shown in Appendixes. The piles were on average 0.8 to 1.2 meter high, 0.8 to 1.2 meter wide and 0.8 to 1.2 metres long. The production rate of vegetable waste products in the area, rather than chemical characteristics, determined the mixing ratios. However, vegetable composting process is started by using some bulking agents such as chickpea straw, DGW, horse and turkey manure. The bulking agents helped to initial C/N ratio for initial stage of vegetable composting process (Chen et al., 2020). Grass composting process at the initial stage was consisting of DGW and FGW in a ratio of 1:1. Pistachio composting process at the initial stage was consisting of PSW and PGHSE in a ratio of 1:1.

3.5. Analyses

Figure 3.3. Prepared and grounded (1 mm) samples, GC: grass compost, VC: vegetable compost, PC: pistachio compost, PGHSE: pistachio green hull solid extract, DGW: dry grass, PSW: pistachio solid waste

Final oven-dried (65 °C) composts, biochars and raw materials were first ground (1 mm) using a laboratory mill and samples have been packaged with transparent plastic bag for Organic elemental analyzer and ICP spectrometer are shown in Fig 3.3. In order to determine pH and EC value of the composts and biochars, the samples was mixed with

distilled water as follows; 2 g sample/10 mL distilled water, at a ratio of 1/5, the pH and EC was then measured with the pH meter after 30 minutes of shaking with shaker (Trautmann et al., 1996). The pH measurements were done using HI-2002 Edge pH meter and AZ 86505 Multiparameter Benchtop water quality meter. Moisture contents (MC) of final composts in this study's measurements were made by drying the samples for around 24 hours at 105 °C.

3.5.1. Organic elemental analysis

Total values of C, H, and N of raw materials, compost and biochar samples were identified using Thermo Scientific Flash 2000 CHN-S elemental analyser. Device that is used for this analyse is shown in Appendixes. Containers made of aluminium foil was used for weighing 2-3 g of samples. It operates with dynamic combustion of the sample (modified Dumas method) for 12 minutes up to 950 °C degrees for Nitrogen, Carbon, Hydrogen and Sulphur determination, and Oxygen determination by pyrolysis. Finally, Samples were detected by a Thermal Conductivity Detector (TCD).

3.5.2. ICP OES Optical emission spectrometer

Nitric acid (65 %) is used in the preparation of the samples. The samples are disintegrated in the microwave oven. Argon and nitrogen gases are used for this analysing. Extraction is required for solid samples. Macro and micro elements, heavy metal concentration in raw materials, compost and biochar samples were determined. ICP OES Spectrometer is shown in Appendixes.

3.5.3. Statistical analysis

Principal Components Analysis (PCA) was utilized to interpret relations between different characteristics of different composts using JMP Statistical Discovery software.

3.6. Production and Characterization of Biochars

FGW obtained from Harran University lawn residues, PC, VC and GC were pyrolyzed (500ºC) under limited oxygen conditions for 5 hours by using NÜVE MF 106 pyrolizer. The photo of pyrolizer that is used for producing biochar is given in Appendixes.

4. RESULTS and DISCUSSION

4.1. Mass Loss

Mass change in transferring waste materials into compost was calculated in grass composting. The starting weight of 57 kg raw materials (fresh green grass and air-dried grass) of grass compost had turned to be 33.7 kg after the 20th days of rapid composting indicating a successful reduction in mass quantities.

4.2. Properties of Final Composts

At the end of composting process, required characteristics for a mature compost such as temperature constancy, fine texture, significantly dark brown or black colours, and material homogeneity were observed in all composts.

Figure 4.1. Grounded final compost samples, pistachio compost (PC), vegetable compost (VC) and grass compost (GC)

As a result, the composting process was stopped, and samples were taken for analysis. In respect to the physical and chemical features of the various varieties, the qualities of compost varied greatly in Table 4.1.

Table 4.1. Some parameters of final composts produced from pistachio, grass and vegetable wastes.

		Final Composts			Limits (mg kg^{-1})
		PC	VC	GC	
Characteristics	pH	7.8	7.9	8.6	-
	EC (dS/m)	8.6	8.2	4.6	-
	Moisture (%)	47	9	34.0	-
	Total C (%)	39.05	31.41	31.12	-
	Total H (%)	4.57	3.78	3.85	-
	Total N (%)	2.48	2.14	3.08	-
	C / N ratio	15.72	14.66	10.11	-
	Total Al (mg kg^{-1})	82.0	2726.0	7361.0	-
	Total B (mg kg^{-1})	1.9	1.4	0.2	-
	Total Ca (mg kg^{-1})	1005	1960	906.1	-
	Total Cd (mg kg^{-1})	0.0	0.0	0.0	0.7*
	Total Co (mg kg^{-1})	0.1	0.2	0.0	-
	Total Cr (mg kg^{-1})	0.3	0.8	0.2	70*
	Total Cu (mg kg^{-1})	0.4	0.7	0.2	70*
	Total Fe (mg kg^{-1})	840.7	246.4	50.8	-
	Total K (mg kg^{-1})	777.5	837.3	370.6	-
	Total Mg (mg kg^{-1})	126.7	220.8	93.4	-
	Total Mn (mg kg^{-1})	2.8	6.5	2.5	-
	Total Na (mg kg^{-1})	8.4	30.8	11.7	-
	Total Ni (mg kg^{-1})	0.8	3.6	0.5	25*
	Total Pb (mg kg^{-1})	0.0	0.1	0.0	45*
	Total Si (mg kg^{-1})	2.8	2.4	3.3	-
	Total Zn (mg kg^{-1})	1.5	2.6	1.1	200*

PC: Pistachio compost; VC: Vegetable compost; GC: Grass compost
Source: *Compost Ordinance Austria (Class A+ [organic farming]) (Garbarino and Saveyn, 2015)

For different compost types, the moisture content values ranged from 9 to 47 %. Compost made from vegetable and fruit wastes had the lowest moisture content value (9%), whereas compost made from pistachio solid waste and pistachio green hull solid extract (50:50) had the highest moisture content (47%).

PC and VC composts produced by this study reached a pH range of 6 to 8.5, which is advised (Thompson et al., 2001), with the values being close to neutrality (7.8–7.9). However, GC was slightly higher (pH = 8.6) than suggested levels. pH readings in the neutral or relatively alkaline range show that the finished compost products have stabilized (Pérez-Godínez et al., 2017).

The C:N ratio, indicating the maturity stage of composts, varied amongst compost types, ranging from 10.11/1 to 15.72/1. Grass clippings compost had the lowest C/N ratio (10.11/1), whereas pistachio compost had the highest C/N ratio (15.72/1). C/N is the carbon-to-nitrogen ratio in compost. It is the most essential composting characteristic since it indicates the compost quality (Manish et al., 2013). The high degree of mineralization and stability of the organic waste throughout the composting process was reflected by a decrease in C/N. The resultant low C:N ratio might be attributed due to carbon loss as CO_2 emission from microbial respiration. Adding N content by the earthworms in the structure of mucus, growth hormones and enzymes, along with their population, the final product's C:N ratio was reduced (Esmaeili et al., 2020). The maturity and stability of the organic materials are indicated by a C/N ratio that is less than 20 (Pérez-Godínez et al., 2017). All three composts in this study had C/N ratios that were less than 20; this indicates that the stabilization of organic matter was satisfactory.

The EC values ranged from 4.6 ds/m to 8.6 dS/m for three compost types. The lowest value of EC (4.6 dS/m) was found for grass compost (GC) and the highest value of EC (8.6 dS/m) was obtained for pistachio compost (PC). The EC indicates the salinity of different substrates, and it also an important indicator for compost maturity. The release of many mineral ions, including potassium, ammonium, and phosphate, may have caused the difference in EC values (Geethamani et al., 2021).

Total C content ranged from 31.12% to 39.05%. The lowest value of total C (31.12%) was found for GC and the highest value of total C (39.05%) was obtained for PC. Indicators of stabilized compost towards the end of the composting process include a higher rate of carbon content breakdown and the decline in TOC indicates mineralization of organic materials and compost maturity (Sharma et al., 2017). In table 4, the TOC value of PC was observed higher than VC and GC. The literature reported a similar outcome in the values of total organic carbon in organic waste (Rékási et al., 2019).

Total N values ranged from 2.14% to 3.08%. The lowest value of total N (2.14%) was observed for Vegetable compost (VC) and the highest value of total N (3.08%) was

obtained for GC. The decomposition of organic matter, carbon loss in the form of CO2, as well as the contribution of nitrogen-fixing bacteria, were all considerations that may cause to rise the total nitrogen value in final product (Sharma et al., 2017).

Total Si ranged from 2.4 mg kg^{-1} to 3.3 mg kg^{-1}. Total B value ranged from 0.2 mg kg^{-1} to 1.9 mg kg^{-1}. Total Na values ranged from 8.4 to 30.8 mg kg^{-1}.

Total AI values ranged from 82 mg kg^{-1} to 7361 mg kg^{-1}. The lowest value of total AI (82 mg kg^{-1}) was found for PC and the highest value of total AI (7361 mg kg^{-1}) was found for GC. Total Fe ranged from 50.8 to 840.7 mg kg^{-1}. The lowest value of total Fe (50.8 mg kg^{-1}) was found for GC and the highest value of total Fe (840.7 mg kg^{-1}) was found for PC.

Total Cr ranged from 0.2 to 0.8 mg kg^{-1}. Total Cu ranged from 0.2 to 0.7 mg kg^{-1}. Total Ni values ranged from 0.5 to 3.6 mg kg^{-1}. Total Pb was not found in three composts. Total Zn ranged from 1.1 mg kg^{-1} to 2.6 mg kg^{-1}. Total Mn values ranged from 2.5 mg kg^{-1} to 6.5 mg kg^{-1}. According to the heavy metal limitations for European compost standards that are created by (Hogg et al., 2002) and (Meyer-Kohlstock et al., 2013) Pb, Zn, Ni, Cu, Cd, Cr so far below standard limits. Additionally, comparing limits in European countries showed that All composts are also in class A+ and suitable for organic farming as stated in Austria standard limits (Garbarino and Saveyn, 2015).

Total Ca values ranged from 906.1 mg kg^{-1} to 1960 mg kg^{-1}. Total Cd was not found in all three composts. Total Co ranged from 0 to 0.2 mg kg^{-1}. Total Mg ranged from 93.4 to 220.8 mg kg^{-1}. The lowest value of total Mg (93.4 mg kg^{-1}) was found for GC and the highest value of total Mg (220.8 mg kg^{-1}) was found for VC.

Total K ranged from 370.6 to 837.3 mg kg^{-1}. The lowest value of total K (370.6 mg kg^{-1}) was found for GC, and the highest value of total K (837.3 mg kg^{-1}) was found for VC.

4.3. Properties of Produced Biochars

Pyrolyzing processes were done by using NÜVE MF 106 pyrolyzer. Some chemical characteristics of all four biochars pistachio compost-biochar (PCB), vegetable compost-biochar (VCB), grass compost-biochar (GCB) and fresh grass biochar (FGB) are given in Table 4.2.

Table 4.2. Some chemical properties of biochars produced from PC, VC, GC and FGW

	Biochars			
	PCB	**VCB**	**GCB**	**FGB**
pH	10	10	10	10
EC (dS/m)	10	7.3	10.5	13.7
Total C (%)	39.73	34.75	28.03	46.03
Total H (%)	1.32	1.14	1.04	1.64
Total N (%)	1.90	1.50	2.15	3.26
C / N ratio (%)	20.95	23.15	13.04	14.13
Total Al (mg kg^{-1})	1133.0	283.0	260.6	2807.0
Total B (mg kg^{-1})	3.7	2.1	2.2	2.3
Total Ca (mg kg^{-1})	4947.0	4551.0	1641	1255.0
Total Cd (mg kg^{-1})	0.0	0.0	0.0	0.0
Total Co (mg kg^{-1})	0.1	0.2	0.1	0.0
Total Cr (mg kg^{-1})	0.5	1.0	0.7	0.2
Total Cu (mg kg^{-1})	0.6	1.5	1.3	1.0
Total Fe (mg kg^{-1})	114.8	270,6	247,3	29.9
Total K (mg kg^{-1})	1750.0	1737.0	2348	2501.0
Total Mg (mg kg^{-1})	216.9	380.4	401.4	336.9
Total Mn (mg kg^{-1})	4.3	11.5	12.1	5.4
Total Na (mg kg^{-1})	18.4	62.7	73.8	73.3
Total Ni (mg kg^{-1})	0.5	1.0	0.8	0.4
Total Pb (mg kg^{-1})	0.0	0.0	0.0	0.0
Total Si (mg kg^{-1})	1.4	2.4	2.9	2.7
Total Zn (mg kg^{-1})	1.8	8.3	4.9	4.7

PCB: Pistachio compost's biochar, VCB: Vegetable compost's biochar, GCB: Grass compost's biochar, FGB: Fresh grass biochar

Weber and Quicker (2017) demonstrated the pH values of several types of carbonized straw and carbonized wood as a function of carbonization temperature. For temperatures exceeding 500 °C, biochars can achieve maximum pH values in the range of 10 to 12 and the temperature, like other parameters, has the biggest impact on the pH level of biochar. Regarding on that we observed the same pH values at 10 for all four biochars.

High-pH biochars may work best when applied to acidic soils, and may work better when C sequestration is the primary objective (Agegnehu et al., 2017).

EC values ranged from 7.3 dS/m to 13.7 dS/m for different biochar types. The lowest value of EC (7.3 dS/m) was found for pistachio compost's biochar (PCB) and the highest value of EC (13.7 dS/m) was obtained for fresh grass biochar (FGB).

Total C content ranged from 28.03% to 46.03%. The lowest value of total C (28.03%) was found for grass compost's biochar (GCB) and the highest value of total C (46.03%) was obtained for fresh grass biochar (FGB).

Depending on the biochar feedstock and pyrolysis conditions, the characteristics of biochar materials might change (Bird, 2015).

Total N values ranged from 1.5% to 3.26%. The lowest value of total N (1.5%) was observed for vegetable compost's biochar (VCB) and the highest value of total N (3.26%) was obtained for fresh grass biochar (FGB).

C/N ratios ranged from 13.04 to 23.15 for all four biochars. The lowest value of C/N ratio was found for grass compost's biochar (GCB) and the highest values of C/N ratio was observed for vegetable compost's biochar (VCB).

Total AI values ranged from 283 mg kg^{-1} to 2807 mg kg^{-1}. Total Fe ranged from 29.9 to 270.6 mg kg^{-1}. The lowest value of total Fe (29.9 mg kg^{-1}) was found for FGB and the highest value of total Fe (270.6 mg kg^{-1}) was found for VCB.

Total Ca values ranged from 1255 mg kg^{-1} to 4947 mg kg^{-1}. No Cd was detected in all biochars. Total Co ranged from 0 to 0.2 mg kg^{-1}. Total Cr ranged from 0.2 to 1 mg kg^{-1}. Total Cu ranged from 0.6 to 1.5 mg kg^{-1}.

Total Mg ranged from 216.3 to 401.4 mg kg^{-1}. The lowest value of total Mg (216.3 mg kg^{-1}) was found for PCB and the highest value of total Mg (401.4 mg kg^{-1}) was found for GCB.

Total K ranged from 1737 to 2501 mg kg^{-1}. The lowest value of total K (1737 mg kg^{-1}) was found for VCB, and the lowest values of total K (2501 mg kg^{-1}) was found for FGB.

Total Ni values ranged from 0.3 to 1 mg kg^{-1}. Total Pb was not found in all biochars. Total Total Zn ranged from 1.8 mg kg^{-1} to 8.3 mg kg^{-1}. Total Mn values ranged from 4.3 to 11.5 mg kg^{-1}.

Total Na values ranged from 18.4 to 73.8 mg kg^{-1}. Total B value ranged from 2.1 to 3.7. Si ranged from 1.4 mg kg^{-1} to 3.9 mg kg^{-1}.

4.4. Temperature

One of the main indicators of microbial activity during the composting process is temperature. It alters reaction times and aids in the elimination of dangerous germs. The primary stages of the composting process include the first mesophilic phase (25–40 °C), the second thermophilic phase (45–70 °C), the cooling phase (second mesophilic phase), and the maturation phase (Diaz et al., 2007). Final composts were considered as mature when recorded final temperatures of the process was similar to air temperature, and composting process was halted at average of 35°C. It can be concluded that evolution went according to the standard composting profile.

The temperature variation recorded in evaluation on current research is consistent with (Waqas et al., 2018) and (Luo et al., 2014). Pathogens, weed seeds, and fly larvae must all be killed by higher temperatures in the compost (Diener et al., 2011). On the other hand, turning compost pile is essential to regulate the temperature and volumetric rate of fermentation of raw materials, ultimately to boost fermentation rate and shorten fermentation cycle (Mengqi et al., 2021). Avoiding ultrahigh temperatures (≥75°C) is vital in terms of maintain thermophilic and mesophilic bacteria in the composting process. We can keep the temperature in the suggested range by frequently turning the pile. According to the procedure it will take two weeks or a little longer for the material in the pile to

decompose if It is daily turned. It will take around three weeks if it is turned every other day (Raabe, 2001). In our experiment compost piles turned every other day and thermophilic phase lasted for three weeks for PC and VC, and for two weeks for GC, and after that it entered the second mesophilic stage of cooling steadily.

Pistachio composting took place at a temperature between 22 and 62 °C, vegetable composting took place at a temperature between 30 and 65 °C, and grass composting took place at a temperature between 35 and 72 °C (Fig 4.2).

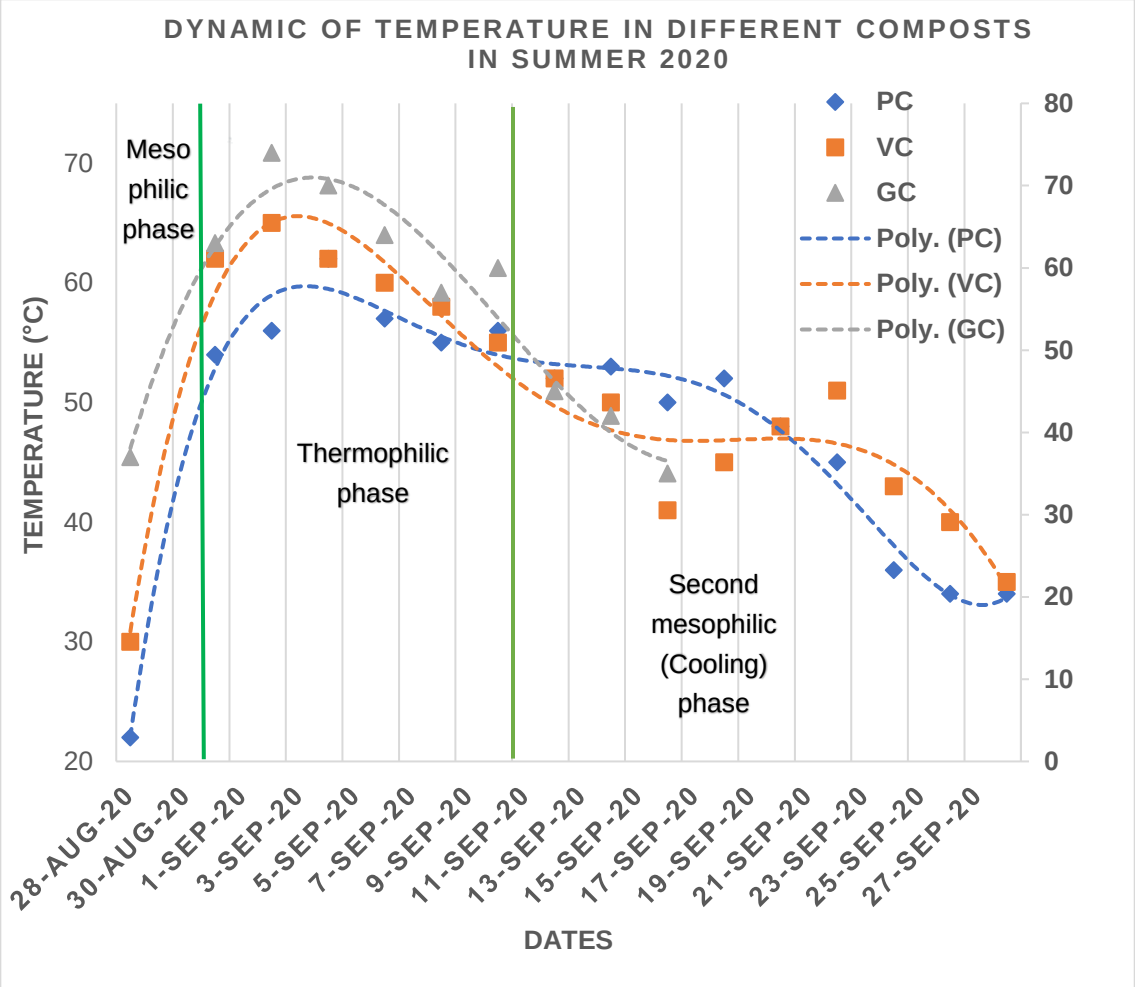
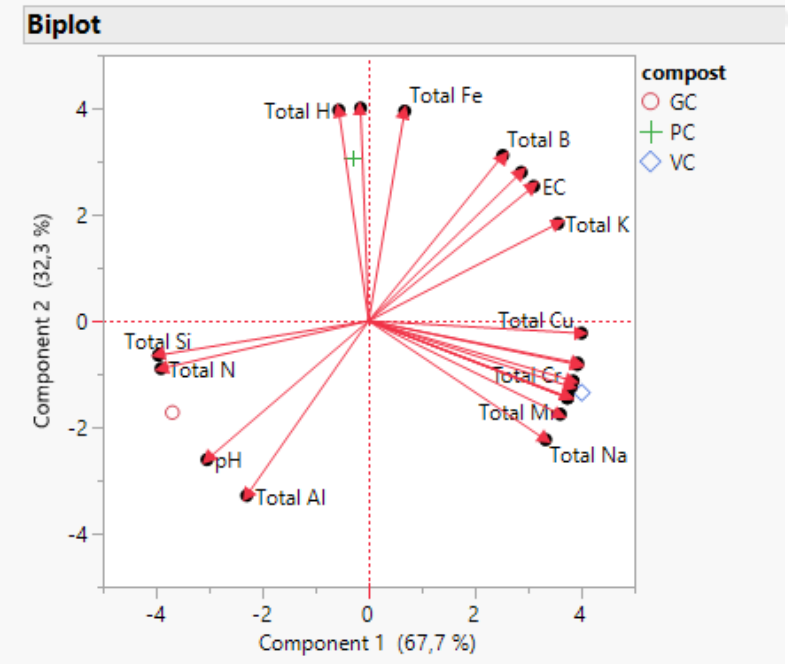


Figure 4.2. Changes in temperature during feedstocks composting. PC: pistachio composting, VC: Vegetable composting, GC: Grass composting

Fig 4.2 showed that all monitored piles exceeded the temperature of 55 ºC during at least 7 consecutive days. To produce a pathogen-free compost, the temperature should be between 55 and 60 °C for at least three days (Jain et al., 2019). All compost piles entered to the thermophilic stage at 4th day of composting process. 4th day was also first day of turning pile. Temperature at initial stage of composting processes rapidly increased and peaked at maximum levels 62 °C in PC, 65 °C in VC and 72 °C in GC after 6-8 days of experiment (Fig. 2). The temperature of the composts was steadily declined, and after 26 days, 30 days and 20 days no noticeable changes were observed for PC, VC and GC, respectively.

4.5. Principal Component Analyse (PCA)

PCA analysis was used in order to interpret comparatively characteristics of different compost types measured.



Loading Matrix

	Prin1	Prin2
pH	-0,75910	-0,65098
EC	0,77453	0,63254
Total C	-0,03815	0,99927
Total H	-0,14056	0,99007
Total N	-0,97474	-0,22332
C N ratio	0,71604	0,69806
Total Al	-0,57279	-0,81970
Total B	0,62929	0,77717
Total Ca	0,93297	-0,35996
Total Cd	0,89901	-0,43792
Total Co	0,95947	-0,28182
Total Cr	0,95061	-0,31038
Total Cu	0,99836	-0,05726
Total Fe	0,16894	0,98563
Total K	0,88888	0,45814
Total Mg	0,98030	-0,19749
Total Mn	0,93237	-0,36152
Total Na	0,83035	-0,55724
Total Ni	0,93263	-0,36083
Total Pb	0,93439	-0,35624
Total Si	-0,98700	-0,16071
Total Zn	0,97883	-0,20468

Figure 4.3. Biplot of Principal Component Analysis (PCA) of correlation coefficients by JMP statistical discovery and loading matrix of compost parameters. GC: Grass compost, PC: Pistachio compost, VC: Vegetable compost

Biplot belonging to PCA analysis applied on different composts is given in Figure 4.3. The first and second principal component explained 66 % and 34 % variation in the data set, respectively. Vegetable compost (VC) grouped mostly with micronutrients, pistachio compost (PC) is grouped mostly with Carbon and grass compost (GC) grouped with Nitrogen.

While component 1 separated the GC and PC from VC, component 2 separated GC and VC from PC. According to loading matrix shown in figure 4 that present loading weights of each compost characteristics in each principal component, component 1 had a substantial amount of Total Cu, Si, Mg, Zn and component 2 had substantial amount of Total C and Fe. This showed that pistachio compost (PC) has high C and C/N ratio and vegetable compost (VC) had more elements and grass compost (GC) is high in nitrogen.

5. CONCLUSION

With the regard to the findings in this thesis, Pistachio compost has higher total organic carbon regards on that composted pistachio wastes could be suggested to maintain soil organic matter in soils. To achieve this, institutions and individuals should collaborate with local farmers using land applications, support scientific research with legislation, and ensure it is applicable. By using composts, it is possible to reduce pistachio solid wastes, while also improving soil fertility and, consequently, plant productivity. Additionally, the disposal of all wastes obtained by pistachio nut facilities in an integrated management system should be created rather than treating them separately.

Almost 41% reduction in mass quantity was significantly observed in grass materials after conversion into compost. As parallel to waste mass reduction, C/N ratios had decreased to 15.72 for PC, 14.66 for VC and 10.11 for GC which was within the range to be qualified satisfactory level (Pérez-Godínez et al., 2017).. At the end of composting process temperature values lower than 35 °C showed all composts are in maturation phase and are considered as mature compost. Analyses of mature compost samples showed that the final composts have a viable C/N ratio, a concentration of organic matter, and concentrations of measured heavy metals were so far below compost standards within the EU, North America and Australia (Hogg et al., 2002), and is therefore valuable for use in agriculture in GAP region.

Current study was conducted in Osmanbey Campus of Harran University in Turkiye. The findings of the study showed that rapid composting method, passive aerated, is a viable option for treating biowaste that is collected separately at local pistachio farms, supermarkets, restaurants, and Harran University campus lawns. The given experience demonstrates that biowaste decomposes into mature compost in fewer than 30 days, guaranteeing a reasonable timeframe even without any specialized technology and depending simply on manual mixing and turning.

This research also contributed to the development of a dependable a quick, inexpensive, natural, and outdoor composting method based on rapid composting method to increase the financial viability of pistachio nut farming, vegetable, and lawn waste valorization.

All produced biochars had higher pH values and fresh grass biochar by its higher content of total organic carbon compared to composts. Fresh grass biochar could be used as a soil enhancer for asidic soils.

In particular, in developing countries where waste management is still not well-established as a technological process, this case study should promote more researches in this sector and contribute to the future research into the process of turning waste into useful compost and biochar. Composting and pyrolysis as a waste treatment method contributes to environmental goals such as protecting natural resources, turning biowaste into a product, and lowering the usage of imported chemical fertilizers in Türkiye, in addition Türkiye has a high potential in terms of compostable pistachio wastes (40,000 tons per year) to financial gains.

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APPENDIXES

Appendix 1. Chickpea straw used for composting

Appendix 2. Fresh grass clippings

Appendix 3. Air-dried grass clippings

Appendix 4. Grass composting process by using Berkeley Rapid Composting Method

Appendix 5. Vegetable composting process by Berkeley Rapid Composting Method

Appendix 6. Pistachio composting process by Berkeley Rapid Composting Method

Appendix 7. Grounding process (1 mm) by using laboratory mill

Appendix 8. NÜVE MF 106 pyrolyzer machine

Appendix 9. PerkinElmer Optima 5300 DV used for microelement analyses

Appendix 10. Thermo Scientific Flashsmart Organic Elemental Analyzer

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Appendix 11. Pistachio green hull solid extract

Appendix 12. Pistachio solid waste

Appendix 13. Pistachio nuts with green hull before de-hulling process