Faculty of Electrical Technology and Engineering

DEVELOPMENT OF IOT BASED SMART COMPOST TEA BREWER FOR SUSTAINABLE AGRICULTURE USING ARDUINO MICROCONTROLLER

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Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours

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**A project report submitted
in partial fulfillment of the requirements for the degree of
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DEDICATION

I extend my heartfelt gratitude to my parents, Johan Bin Mohamad Radin and Lannora Binti Hamdan for their unwavering support and encouragement throughout the completion of my senior Final Year Project. Their celebration of my achievements, no matter how small, and the words of encouragement in moments of doubt have been my pillars of strength. The pleasant and motivating workspace they created allowed me to generate concepts and find the inspiration needed to fulfil my duties. This project is a testament to their love and guidance, and I am profoundly thankful for their unwavering belief in my abilities.

ABSTRACT

Synthetic fertilizers have played a role in enhancing agricultural productivity, yet concerns over their environmental and health impacts requires the exploration of an alternative, an organic fertilizer. This project focuses on compost tea, an organic nutritional additive derived from compost fermentation, as a sustainable option for plant nutrition. The project is referred to the traditional method of compost tea brewing. Automating the brewing process can be made by introducing Arduino microcontroller and sensors. Aiming to produce the perfect compost tea there are certain key parameter needed to be monitor such as pH and liquid temperature. This parameter provides the optimum environment for microbial activity and nutrient extraction. Combining the project with Internet of Things Capabilities allowed for a real-time remote monitoring. The project has been tested and are able to perform the task of providing aeration for compost tea brewing and monitoring the key parameter. Overall, the project has deemed to be success in its development and are able to helps people in making their own organic fertilizer in hopes of reducing the use of synthetic fertilizer.

ABSTRAK

Baja sintetik telah memainkan peranan dalam meningkatkan produktiviti pertanian, namun kebimbangan terhadap kesan alam sekitar dan kesihatannya memerlukan penerokaan alternatif, baja organik. Projek ini memberi tumpuan kepada teh kompos, bahan tambahan pemakanan organik yang diperoleh daripada penapaian kompos, sebagai pilihan yang berterusan untuk nutrisi tumbuhan. Projek ini dirujuk daripada kaedah tradisional membancuh teh kompos. Mengautomasikan proses pembuatan the kompos boleh dibuat dengan memperkenalkan mikropengawal dan sensor Arduino. Bertujuan untuk menghasilkan teh kompos yang sempurna, terdapat parameter utama tertentu yang perlu dipantau seperti pH dan suhu cecair. Parameter ini menyediakan persekitaran optimum untuk aktiviti mikrob dan pengekstrakan nutrien. Menggabungkan projek dengan "Internet of Things" membenarkan untuk pemantauan jarak jauh dalam masa yang nyata. Projek ini telah diuji dan dapat melaksanakan tugas menyediakan pengudaraan untuk membancuh teh kompos dan memantau parameter seperti tahap pH, suhu dan aktiviti mikro semasa pembuatan the kompos. Secara keseluruhannya, projek itu dianggap berjaya dalam pembangunannya dan mampu membantu orang ramai dalam membuat baja organik mereka sendiri dengan harapan dapat mengurangkan penggunaan baja sintetik.

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CHAPTER 1

INTRODUCTION

1.1 Background

Due to the growing of agriculture sector around the world the demand of fertilizer as a catalyst to hasten the production of crops increases throughout the year. This leads to the use of synthetic or chemical fertilizer to increase their production rate of crops. Figure 1.1 shows the previous and expected market trend of United States (US) nitrogenous market trend from the year 2020 to 2030 in which shows the use of synthetic fertilizer are increasing in demand. Although the use of these fertilizer is quite efficient but on certain extend, it could bring harm towards humans and the environment. Synthetic fertilizer is carcinogenic to human due to the chemical content, could cause water pollution through runoff, nutrient imbalance of soil and would increase dependencies to fossil fuel from its manufacturing process [1]. While the prolong use of organic fertilizer is safer and environmentally friendly as they do not contain harmful chemical or synthetic additives, improves soil quality and does not give impacts toward surrounding environment and ecosystem. Hence, it is recommended to use organic fertilizer in agriculture or farming practices.

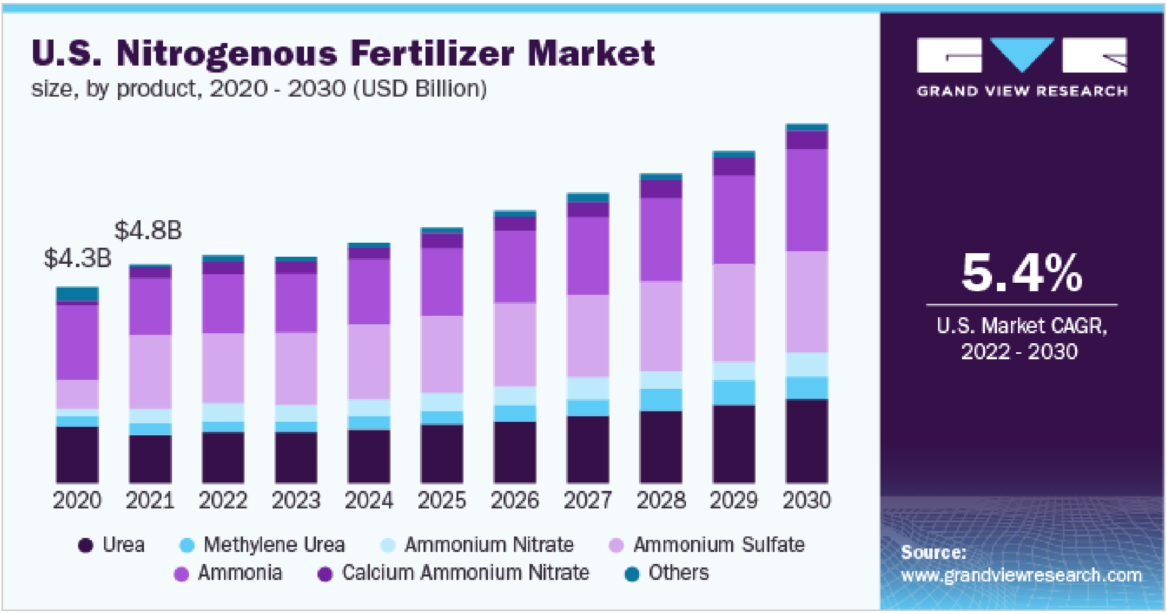


Figure 1.1 Current and Expected Synthetic Fertilizer Market Trends

1.2 Addressing Smart Compost Tea Brewer to Replace the Use of Synthetic Fertilizer to Organic Fertilizer.

There are several types of organic fertilizer and one of them is compost. Compost is a product of composting process by decomposing organic material such as plant, food waste and manure. It is used to improve the properties of soils. In [2], describe that composting is the act of reusing organic material into fertilizer for soil and plant, and anything that naturally grow can be decomposed into compost. In the context of waste management, composting is an effective way to reduce the amount of waste that ends up in landfills. It helps in reducing greenhouse gas emission and preventing harmful chemical from leaching into the soil and waterway. Proper management of waste is important due to its negative effect to environment such as air pollution, water pollution and thinning of ozone layer when burnt [3]. In the context of sustainable agriculture, composting is an essential practice to maintain soil's health that could prolong the use of soils for long term farming.

Compost can be turn into liquid fertilizer which are called compost tea. Compost tea is the product of fermenting organic compost into a liquid, which would give an organic solution that acts as a fertilizer. It is an alternative biological technique to combat soilborne illness in herbal plant which causes reduction in crop yield [4]. Thus, developing an Internet of Things (IoT) based smart compost tea brewer with Arduino microcontroller is relevant in the domain of sustainable agriculture. It could optimize the brewing process, reduces labour input and improve the quality of resulting compost tea. Integrating Arduino as the brain of the brewer is suitable for efficient control and monitoring. The system would be able control and monitor the process of brewing such as the time of brewing, the aeration in the liquid, the temperature and the pH level of the liquid. The system would then be able to be monitored and controlled through daily device as IoT will be integrated into the system. The finished product would then be used as an organic liquid fertilizer that promote the use of synthetic fertilizer.

1.3 Problem Statement

The use of synthetic fertilizer does not align with sustainable agriculture as it has more disadvantages than advantages when it is used for prolonged period and uncontrolled. Hence, the use of organic fertilizer such as compost tea is much more relevant as it is safe to use and friendly to the environment. Traditional compost tea brewing method is lack of consistency, efficiency and automation. To add on, manual monitoring and control of brewing parameter such as temperature, humidity and aeration can be time consuming and prone to human error. The absent of automation systems for compost tea brewing limits its widespread of adoption and hinder sustainable agriculture practices. Hence, there is a need of developing a smart compost tea brewer to optimize brewing process and producing consistent and high-quality compost tea production. Introducing Arduino microcontroller with variable sensor and actuator can enable real time-time monitoring, data collection and automated control of brewing parameter resulting in sustainable and efficient compost tea brewing system. Lastly, a smart compost tea brewer with IoT enabled will contribute to sustainable agriculture practices by providing farmers with a reliable and automated solution for producing nutrient-rich organic rich fertilizer.

1.4 Project Objectives

The main objective of the project is to develop and implement an IoT enabled smart compost tea brewer that promotes sustainable agriculture to extend the use of crop yield without bringing negative environmental impact of using fertilizer by farmers. Specifically, the objectives are as follow;

i) To design and develop a smart compost tea brewer system for sustainable agriculture by integrating Arduino Microcontroller.

ii) To incorporate the use of sensors and actuator to monitor crucial parameter such as temperature, pH and aeration levels during brewing process

iii) To implement a feedback mechanism that alert user of the brewing parameter based on real-time data.

1.5 Scope of Project

The scopes of project are as follow:

i) Design and development of an IoT-based smart compost tea brewing system which circle the designing and building a compost tea brewer that leverage Blynk IoT platform for data monitoring and remote-control capabilities

ii) Incorporating an Arduino microcontroller as central control unit with IoT enabling component such as ESP-01 Wi-Fi module to transmit data to Blynk IoT platform for Real-time data monitoring and remote controlling.

iii) Sensor integration such as temperature sensor, pH sensor and gas sensor to monitor key parameter of producing a compost tea.

iv) Automated control and optimization by developing algorithm and control mechanism within Arduino microcontroller to automatically or alert user to adjust brewing parameter based on real-time sensor data.

1.6 Limitation

Though the project can be developed but there are certain limitations of the project.

i) The scale and capacity of project may be limited to a small-scale compost tea brewing system which is suitable for experimenting or small agricultural use.

ii) The performance of the sensors used in the project may have its limitation such as the accuracy, precision and calibration requirement

iii) The limited budget for the project can affect the selection of component, sensor and actuator and affordability is prioritized.

iv) The project focused on the development and evaluation of smart compost tea brewer in a controlled environment. Hence, the challenges and complexity that may arise from real world implementation may not be fully addressed within the project scope.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review section is a comprehensive review of existing research and scholarly works on the chosen topic. To obtain a deeper understanding of the topic matter, it explores through the wealth of research available in academic papers, books, journals, and other credible sources. The review creates a solid foundation for the current study by critically analyzing and synthesizing the findings, theories, methodology, and important topics offered in the literature. It not only demonstrates the breadth and depth of previous knowledge, but it also shows any gaps or limits that the present research is attempting to address. Through this in-depth analysis, the literature review provides valuable insights, informs the research questions, and highlights the significance of the study in advancing the field. It serves as a critical component in situating the research within the broader scholarly context and showcasing the contribution it makes to the existing body of knowledge.

2.2 Sustainable Agriculture and its importance

Growing rate of human population calls for the long-term availability of food stocks produce by agriculture domain. Maximizing the production of live stocks and green crops is important to keep up the supply for future use. Though it is important, there are some factors needed to be overlooked before engaging in certain manner. Food and Agriculture Organization (FAO) define that sustainable agriculture refers to the management and conservation of natural resource, aimed at meeting the needs of present and future generation while ensuring profitability, environmental health, and social and economic equity. This is supported in [5], stating that sustainable agriculture accommodates three main goals which is environmental health, economic profitability and social equity. Thus, sustainable agriculture circles a wide approach in farming that balance the need of the present and future generation while considering the three goals. The practices of sustainable agriculture needed to be adopted by farmer to contribute in a more resilient, inclusive and environmentally-friendly economics. Figure 2.1 illustrate the three goals needed to be considered in sustainable agriculture that makes a perfect triangle showing balance.

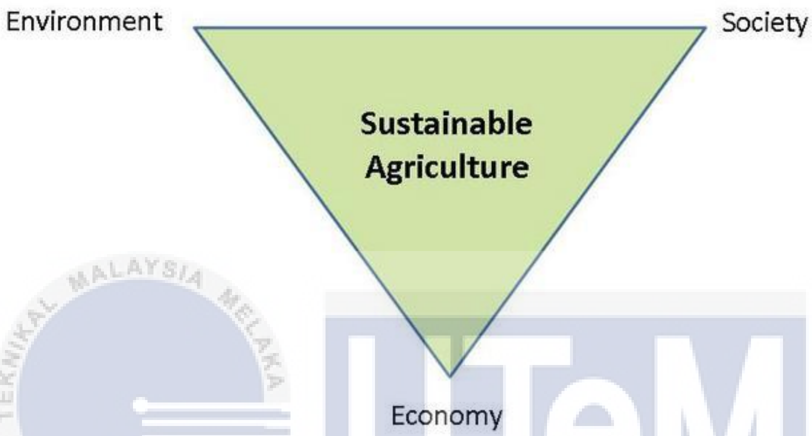


Figure 2. 1 Sustainable Agriculture Triangle

2.2.1 Resource Management

Sustainable agriculture emphasizes on the efficient and responsible use of natural resource such as land, water and energy. This promotes the practices of minimizing waste production, reduce resource depletion and conserving biodiversity. Where it aims to ensure a long-term environmental sustainability and support the needs of future generation.

In terms of efficient use of land, sustainable agriculture promotes the practices which optimize the use of land and minimize land degradation. Degradation and overuse of land in agriculture are often caused by inefficient farming strategy. Taken for example, land tillage. There are techniques of conserving long use of land in farming such as Conservation tillage technique. Conservation tillage techniques, such as no-till or reduced tillage, help to preserve soil structure, reduce erosion, and retain soil moisture [7]. Other than that, crop rotation technique which is the practices of planting different crop on the same plot sequentially. In [8], crop rotation and intercropping strategies enhance soil fertility, nutrient cycling and pest management.

Water conservation plays an important role in sustaining agriculture. Addressing the challenges of limited water resource, ensuring efficient irrigation method is important. Efficient irrigation systems, such as drip irrigation or precision sprinklers, have been recognized as effective methods to minimize water wastage in agricultural fields [8]. Compared to traditional irrigation method, this method optimized water usage efficiently and minimized loss of water. To add on, the technique of rainwater harvesting also plays a role in water conservation. Through the technique like roof rainwater harvesting or construction of reservoir allows farmer to store and utilize water resource during dry period . This practice reduces the reliance of freshwater source and contribute to overall water sustainability in agriculture.

Lastly, sustainable agriculture recognizes the adoption of energy efficient practices. The existing of agricultural technologies should be using less energy and also reduce the emission of greenhouse effect. For example, the use of renewable energy source for equipment or machinery. According to [9], The execution of various crop production techniques requires the direct consumption of fuel and energy. Energy efficient practices help both farmers and environment as can lower expenses in buying fuels and lowering the rate of emission from greenhouse effect. Reducing energy demand to go in line with sustainable agriculture can contribute in environmental and economic sustainability.

2.2.2 Environmental Health

Environmental health is one of the important aspects in sustainable agriculture. It emphasizes on the preserving and enhancing of soil quality, water resource and air quality through responsible farming practices. Organic farming, agroforestry and integrated pest management are the example of the practice where it goes in line with sustainable agriculture that will contribute to the environmental health and biodiversity conservation.

In [9], it is said that organic farming help to reduces soil, water and air pollution due to environmentally friendly farming practices. These practices cut the use of synthetic fertilizers and pesticides. Hence, minimizing the risk of chemical runoff and groundwater contamination. Additionally, organic farming encourages the preservation of soil health, promoting natural nutrient cycling and reducing soil erosion, which can further contribute to improved water quality. Furthermore, by avoiding the usage of chemical, organic farming helps reduce air pollution associated with the release of greenhouse gases and harmful volatile organic compounds commonly emitted during the production and application of synthetic fertilizers and pesticides. Figure 2.2 show the different between organic farming and intensive farming of how they work and its effects.

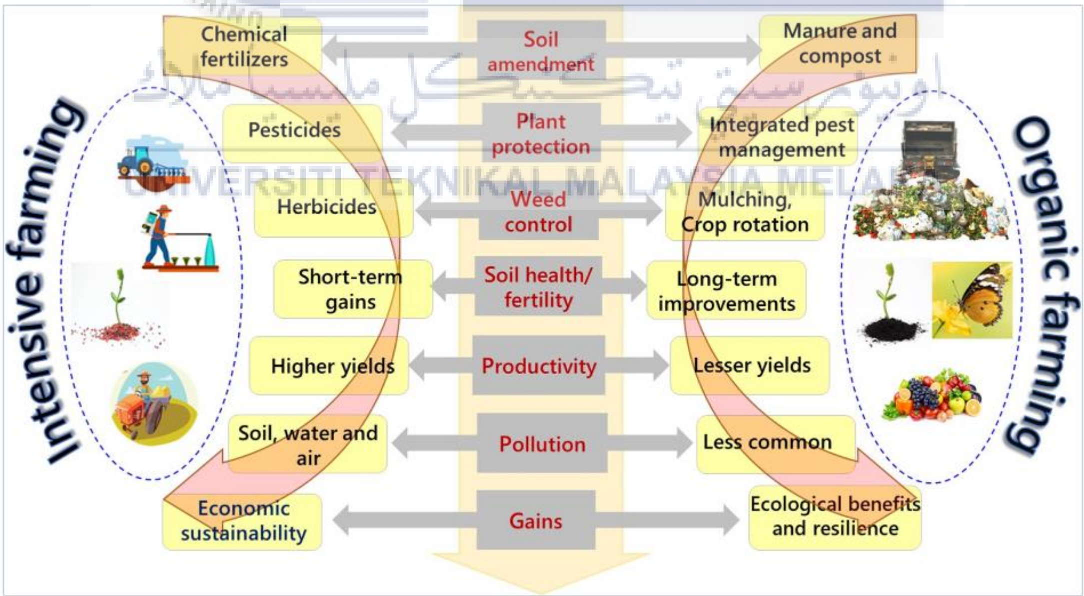


Figure 2. 2 Intensive Vs Organic Farming

While for agroforestry, it is a sustainable land use system that integrate trees, crops and livestock on same piece of land. It is traditional practice that has existed for centuries in many parts of the world. The practice also improves soil fertility, conserving water resource and raise biodiversity by providing an ecosystem for various species of animal and plant. According to research [10], Agroforestry can help to mitigate climate change by sequestering carbon in soil and vegetation. It can improve the living of farmer by providing additional sources of income and food. Agroforestry is a flexible system that can be adapted to different farming systems and environments. It can be used in both smallholder and commercial farming systems and can be applied in a wide range of agro-ecologies. Thus, it is a promising approach for sustainable agriculture and environment conservation. Figure 2.3, shows some of the goals that can be achieve through agroforestry.

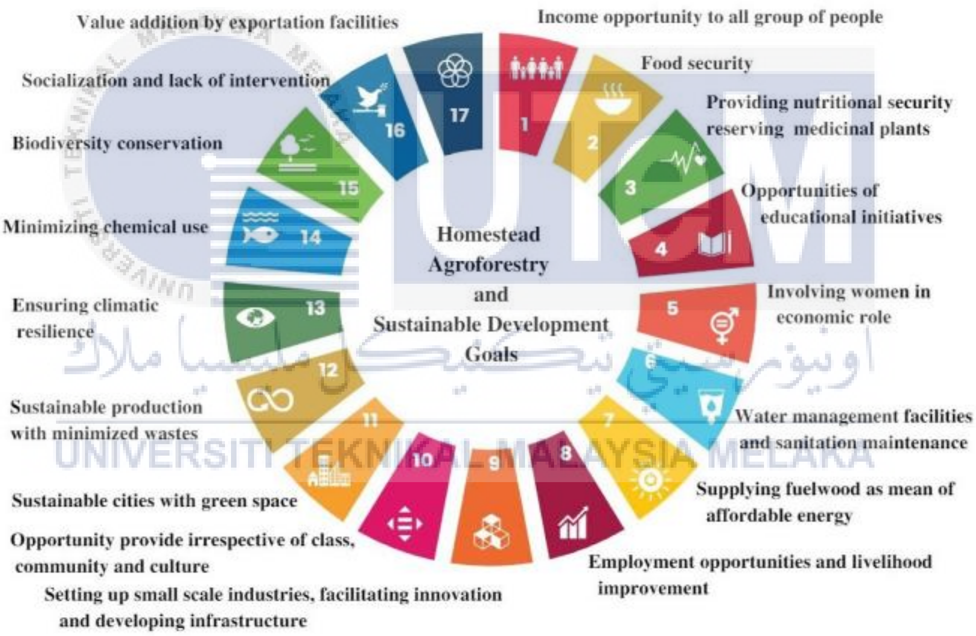


Figure 2. 3 Homestead Agroforestry and Development Goals

Integrated Pest Management (IPM) is a strategy that is environmentally friendly pest control strategy which combine various technique to manage pest effectively while reducing the use of synthetic or chemical pesticides. IPM highlight the use of biological control agent, crop rotation, habitat manipulation and cultural practices to control pest and diseases. In [13], stating that the development of IPM is a way to control pest without purely relying on chemical pesticide. Since most chemical or synthetic pesticide does not specify the organism to be attacked, IPM method can help reduce the negative impact on non-targeted organism and contribute to biodiversity conservation. In IPM, they promote the use of biological control agent such as predator and parasite. It helps to regulate pest population naturally, promoting the preservation of beneficial organism that contribute to overall balance of ecosystem.

2.2.3 Social and Economic Equity

Sustainable agriculture recognizes the importance of social equity and seeks to ensure fairness and equitable access to resources and opportunities in agricultural sector. The key aspect in ensuring social equity in sustainable agriculture is empowering small scale farmers and marginalized communities. Providing them with necessary support, knowledge and resource can improve their productivity in agriculture. Addressing the challenges and specific needs of this group can help in reducing inequalities and improved their social wellbeing through sustainable agriculture.

Sustainable agriculture encourages the initiation of partnership between and collaboration among different chain actor of agricultural sector. Fostering a good relationship between farmers, traders, wholesaler and the whole related value chain in agriculture can ensure transparency, inclusivity and fair-trade practice among them. Ensuring this behavior can create an equitable environment where all stakeholders can contribute and benefits from agricultural activities. In [15], highlights that local farming can be promoted from the increased ability of farmer to operates in a community through sustainable agriculture. Fair trades practices are also promoted through sustainable agriculture. This ensure that farmers receive fair prices for their product and have the access to transparent and equitable markets. A global movement, Fair Trade, aims to improve the lives of farmer and worker in developing country by ensuring that they have the access to export market and paid a fair price for their products [16]. Economic pressure on farmer in some rural communities can be reduced from the movement as it can help farmer proportionate their labour and the outcomes of their produce.

A stronger foundation for rural economies can be laid through economic development strategies and tax arrangements that support a wider range of agricultural production on family farms. Farmer can tap into new market and get a new income source by expanding agricultural activity. They can also foster a much better economic growth in a rural area.

2.3 Smart Agricultural Technologies

2.3.1 Introduction to Smart Agricultural Technologies

A variety of cutting-edge tools and systems are included in "smart agriculture technologies," which use cutting-edge technology to improve agricultural practices. These innovations optimize resource management, boost productivity, and boost sustainability in agricultural operations by integrating digital sensors, communication networks, data analytics, and automation. Aiming to address issues facing the agriculture sector, such as resource scarcity, climate change, and food security, smart agriculture, also known as precision agriculture or digital farming, also goes by the names of these other terms. Smart agriculture technologies enable real-time monitoring and data-driven decision-making in various farming processes. These technologies offer farmers useful information on crop development, soil characteristics, weather patterns, and insect control. Farmers can plan irrigation times, apply fertilizer, safeguard crops, and harvest crops by gathering and analyzing data from sensors placed in the field. This data-driven strategy helps to increase overall crop yield and quality while minimizing input waste and maximizing resource utilization. The utilization of smart agriculture offers several potential benefits. The use of smart agricultural technologies can offer various potential benefits.

In [17] points up precision farming based on smart technologies, reduced the input cost by precisely apply fertilizer, water and pesticides based on specific needs of crop. This minimize the environmental pollution, preserve natural resources and reduces dependencies on synthetic chemical. Furthermore, real-time monitoring and early detection of crop diseases, pests, and nutrient deficits are made possible by smart agricultural technologies, enabling farmers to take quick preventative measures. This pro-active method of crop management helps to boost production and reduce yield losses. The efficient crop monitoring over wide areas made possible by the use of remote sensing technologies, such as satellite imaging and drones, allows farmers to quickly identify and address problems.

Therefore, smart agriculture technologies smart agriculture technologies provide a revolutionary approach to modern farming. Farmers can make data-driven decisions, improve resource management, lessen their impact on the environment, and increases productivity by integrating modern technologies. These advancements have a lot of potential for solving the problems associated with sustainable agriculture.

2.3.2 Internet of Thing (IoT) and its Application in Agriculture

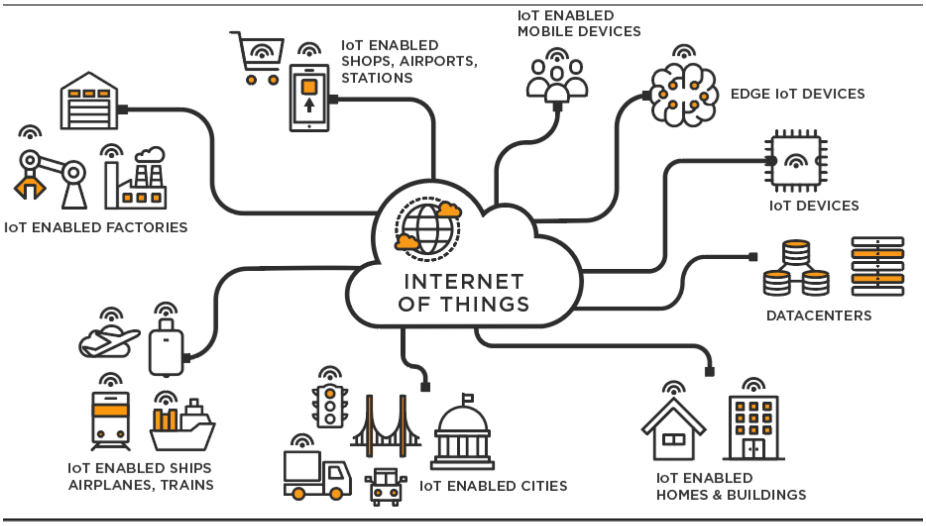


Figure 2. 4 IoT Application

Figure 2.4 shows how Internet of Thing (IoT) can be used in various places. IoT as a transformative technology has a wide range of application in various industries, this include agriculture industries. In agriculture, the terms IoT refers to the use of interconnected devices and sensors to collect and transmit data via a network for the purpose of improving management and farming practices [18]. The connectivity and data exchange facilitate real time monitoring, analysis and decision making which leads to increased efficiency, productivity and sustainability in agricultural operation. In agriculture, IoT are used in various application such as crop production, irrigation management, livestock farming and environmental monitoring. Device such as weather stations, crop management device and livestock farming which are based on IoT collect and send valuable key parameter. Which later are analyzed to provide valuable insights and support in decision making process.

One of the benefits of IoT in technologies is the ability to enhance precision and targeted resource management. In [19], points out that IoT technology helps in reducing the risk of resource overuse and the expenses in overusing the resource can be used to invest in IoT technologies. This is a more efficient and sustainable way of managing resource and improved in overall farming practices. The use of IoT can facilitate automation and remote monitoring of agricultural processes by interconnecting devices and sensor to collect and transmit data. The data can then provide farmer with real time information on various aspect of their farming operation. Allowing them to be well informed in making decision about their practices. For example, in [20] regarding irrigation system, stating that IoT sensors can be used to monitor soils moisture levels, temperature and other environmental condition, enabling farmers to remotely control irrigation systems and optimize water usage. This not only can save times but also labors for farmer to facilitate the condition of their crops.

However, the adoption of IoT in agriculture do come with a challenge. Connectivity and data management are one of the key challenges of adopting IoT in agriculture. A farm located at a rural area tends to have poor connection to the internet. Having a poor connectivity can hinder the fast transmission of data collected by IoT devices, reducing the effectiveness of real time monitoring and automation [21]. In addition, due to the vulnerability to a cyber threat; ensuring data privacy and security is crucial to prevent sensitive agricultural data to be exposed. Farmers can advance their digital literacy to keep themselves updated with technological advancements and effectively protect their data [21][22]. Farmer being notified of technological advancement is a protective measure in keeping out data breach.

Despite this, IoT has a great potential to revolutionize agriculture. More sustainable and effective farming techniques could come from the ability to monitor, regulate, and improve agricultural operations using real-time data. With improvements in IoT technology and a greater selection of affordably priced IoT devices, it is expected that the integration of IoT in agriculture will continue to expand, providing farmers with practical insights and revolutionizing how we think about modern agriculture.

2.3.3 Precision Farming and Automation

Precision farming or smart farming is an approach of using advance technologies to optimize agricultural practices and maximize resource efficiency. The concept of site-specific management as the core for precision farming which refer to the technology that improved management of a small production area in a single field. It involves the application of a specific management practice to a specific field location and in a single field operation [23]. Automation plays a crucial role in specific farming that can enable precise and controllable application of input, monitoring of crop condition and efficient farming operation. Precision farming or smart farming leverages automation technology and equipment to optimize almost every farming task.

2.3.3.1 Global Positioning System, Geographic Information System, Remote Sensing

Precision farming has been made possible by the use of Global Positioning System (GPS) and Geographic Information System (GIS). It enables the collection of real-time data with accurate positioning information, which leads to the efficient manipulation and analysis of a large amounts of geospatial data. Remote sensing technologies are one of the contributors in precision farming. The availability of having a high-resolution satellite image has promote the use of remote sensing in many precision farming applications. The application includes crop monitoring, irrigation management, nutrient application, disease and pest management, and yield prediction [23][24]. The use of this technologies brings about the optimization of resource, minimize waste and maximize crop yield and quality.

2.3.3.2 Benefits of Precision farming

Precision farming offers several benefits to farmer and the environment. Expenses on the farm can be reduced by precision farming. In precision farming, farmer is able to accurately decrease fertilizer, herbicide or seed rates in areas where it will not be economical to be utilized [25][26]. It increases profitability from reducing the extra expenses. Land value can be increased, this is due to precision farming maintain soils health from reducing the use of pesticide. Precision farming allow farmer to have higher resolution understanding of their farm. This is because in precision farming, farmers are able to harness real-time data to maximize yield [27]. Other than that, farmers are also be able to understand about their in-season harvesting and maximize their crop production. Overall, the precision farming is really beneficial compared to any traditional farming strategies.

2.3.3.3 Challenges of Precision Farming

Despites the potential benefits of precision farming, there are challenges that can hinder the adoption and implementation. One of the challenges include the interoperability of different standard. Due to the development of precision farming being fragmented across many industry bodies, it makes the adoption of new technologies slow on the ground [29]. Precision farming involve the implementation of cutting-edge technology that can be hard and complex to be in service [30]. Precision farming can be hard to be implement onto rural area as in rural area the connectivity to the internet can be challenging [28]. Certain precision farming technology can be high costing. For example, in precision farming it depends on the technologies such as GPS, GIS and Remote sensing. Which would need a lot of expenses to be invested in. Despite the challenges, precision farming can be implemented if small steps can be taken at a time reducing the burden of implementing the use of precision farming.

Automation and precision farming technologies are essential for optimizing processes in agriculture, improving resource efficiency, and promoting sustainable farming. Farmers can make sensible choices and set precise management practices into place by utilizing advanced sensors, analytics of data, and automated systems. Despite challenges, precision farming has tremendous potential to meet the increasing demand of crop production every year while sustaining the environment.

2.3.4 Smart Fertilizer Management

Sustainable agriculture requires effective fertilizer management because it encourages efficient nutrient utilization, minimizes negative environmental effects, and increases crop output. Utilizing cutting-edge technologies and data-driven strategies, smart fertilizer management involves using fertilizers precisely depending on crop nutrient requirements, soil characteristics, and environmental factors. Smart fertilizer management is an approach that utilizes information/data, sensors, and smart tools to allow for correct fertilization in precision agriculture, smart agriculture, and integrated nutrient management [30].

Fertilizer management is crucial in providing essential nutrient to crop that will promote a healthy plant growth. This helps in optimizing the nutrient uptake, minimize nutrient loss and prevent degradation of soils. Smart Fertilizing management ensures that fertilizer is applied at the right amount and at a right place. Thus, improving the effectiveness of fertilizer while reducing impact toward the environment [31].

There are various tools and technologies that are being used in smart fertilizer management. This includes the use of it in soil testing and analysis. Soil testing and analysis is important as it allow farmer to assess nutrient level and deficiency of the soil. Collecting and processing soil samples can enable farmer to analyze the extractable nutrient content of their soil and use the data collected to make alteration on their fertilizer application [32]. There are several soil testing methods that has been developed to estimate the capability of soil to provide nutrient for crops [33] This includes aggregate stability that measure the ability of soil aggregates to resist disintegration when exposed to water, counting earthworm which indicates the condition of soils health and using test kit for pH and nutrient [32][33][34]. Implementing an advance technology into those method can really ease the assessment of farmers in their farm.

To sum everything, Smart fertilizer management has a number of advantages, such as increased nutrient use effectiveness, decreased fertilizer prices, fewer environmental impact and higher crop produce and quality. However, there are also issues including the requirement for precise soil and crop data, accessibility of cutting-edge technologies, and farmer uptake. Investment in research, instruction, and farmer training programs are necessary to overcome these obstacles.

2.4 Arduino microcontroller in Agriculture

2.4.1 Introduction to Arduino Microcontroller

Figure 2.4 Arduino Board Line of Production

Arduino, an open-source electronic platform has release various type of microcontroller that is easy to integrated into any project by designer, engineers or anyone that is interested in creating. The microcontrollers able to read and processes input such as sensors and button. In agriculture, the microcontroller is used for automation of agricultural process. Arduino is used for different field in agriculture such as irrigation, livestock production and agriculture machine [35]. It is suitable to be integrated in agricultural use due to it being an open-source platform and is easy to implement. Arduino also has the capability of using IoT which offer a much wider ideas that can be design and offer the ability to monitor and collect real-time data. Other than that, Arduino are used in sensor network for environmental monitoring in agriculture such as temperature, humidity, light intensity and pH level. Arduino microcontroller is versatile and affordable making it a flexible option for farmer to do innovation and experiments. Therefore, Arduino microcontroller has the potential to increase productivity and efficiency in agriculture. It allows farmer having the access towards advance technologies to be integrated into their farming.

2.4.2 Sensor Network and Environmental Monitoring in Agriculture

Sensor networks play a crucial role in environmental monitoring in agriculture, enabling farmers to gather real-time data on various environmental parameters. By integrating sensors with Arduino boards, farmers can monitor key parameters such as temperature, humidity, light intensity, and soil conditions, allowing them to make informed decisions for optimal crop growth and resource management. [36] propose an IoT based irrigation system using Arduino, implement the use of soil moisture sensor that sense moisture content of soil, collect data and alert user of soil condition via Losant as IoT platform. This system allows real-time data monitoring for farmer to take further action on this system. Another example is from [37], focusing on the use of sensor system and control system for intelligence farming based on Arduino technology. In this system, sensor is used to sense temperature, humidity, moisture and light intensity. The data collected would then be filtered for automatic decision making via control system. Overall, the integration of sensors with Arduino boards for environmental monitoring in agriculture offers valuable insights into critical parameters for crop growth and resource management. These monitoring systems provide real-time data, enabling farmers to make data-driven decisions and optimize their farming practices.

2.4.3 Benefits of Using Arduino

Arduino can offer various benefits for farmer who want to tries to invest in revolutionize their system. In [38], points out that Arduino is cost effective, customizable, easy to use, open-source programming and scalable. Firstly, Arduino microcontrollers offer a cost-effective solution for agricultural applications. The affordability of Arduino boards makes them accessible to farmers with limited budgets, allowing them to implement smart agricultural technologies without significant financial barriers. Arduino microcontrollers provide a high level of customization for agricultural applications. The open-source nature of Arduino allows users to modify and adapt the hardware and software to suit their specific needs. Farmers can integrate various sensors, actuators, and modules to create creative solutions that address their unique requirements, enabling them to optimize their agricultural processes and achieve desired output. Arduino can be applied on a wide range of use, whether it be home project or for commercial operation. Hence, the use of Arduino in agriculture offer significant benefits. Arduino allow farmer to with the tools to improve their farming practice that lead to a more advance agricultural sector.

2.5 Study of Arduino Based Compost System

2.5.1 Towards Sustainable Society: Design of Food Waste Recycling Machine

The paper [40], focuses on the design and importance of a food waste recycling machine. The machine is intended to convert food waste into compost, which can be used to fertilize soil and promote the growth of healthy and organic food. It has addressed the factors that affect composting such as material factor, air factor, moisture factor and temperature factor. The factor mentioned is important to be taken for the process of making compost. The paper discusses the engineering design process, including identifying customer needs, translating them into design specifications, and considering external and internal constraints. The paper proposed a numerous alternative design of machine that meet the requirement of the machine which is to have an attractive design, quite working and a warning label to ensure using the machine safely. It has mentioned the used of Arduino microcontroller as a control mechanism to integrate with the use of sensors and actuators for the machine. The project aimed to show the importance of recycling food waste and helping environment by turning food waste into compost.

2.5.2 Design of Kitchen Waste Composting Machine: A Smart Approach

In the paper [41], the author proposed a design for a smart composting machine that could process 10 kg to 15 kg of organic waste. The machine design is automatic and compact in size where it uses Arduino Uno Microcontroller with humidity sensor, motor and heating element as an actuator. The machine aims to have a cost-friendly markup, promoting zero garbage, protect the environment and preserves landfill spaces. How the machine works is by grinding waste material into compost vessel then it would be grinded by a blade attached to a motor until it has reached the form of semi powder. Then, the product will be heated at

60 degree Celsius until the moisture level has met a certain level. In the paper, it has provided effectiveness of the machine compared to traditional composting where it has shown that the smart composting machine has a better efficiency in composting time. Thus, making the project has met the purpose of building.

2.5.3 Smart Chopper and Monitoring System for Composting Garbage

The paper [42] introduce a Smart Chopper and Monitoring System for Composting Garbage as a solution to the global issue of organic waste management. It offers an innovative and technologically advanced solution to this problem. The system is equipped with various components and technologies that work together to ensure efficient waste management. One of the key components is the Arduino mega 2560, which serves as the control unit for the system. It enables the automation and monitoring of various processes involved in waste management. Additionally, the system incorporates sensors such as ultrasound, temperature, soil moisture and LDR sensors, which provide real-time data on waste, temperature and moisture level, and also to act as feedback mechanism to initialize process. The system also features an LCD screen, which allows users to monitor important parameters such as temperature, humidity, waste crushing process, and chopper condition. This real-time monitoring capability empowers users to make informed decisions and take necessary actions to optimize waste management processes. The system aims to reduce garbage pollution by utilizing the chopper machine and monitoring its performance.

2.5.4 A Microcontroller-based Household Anaerobic Food Digester

The paper [43], describes the development and implementation of a microcontroller-based household anaerobic food digester. The purpose of this digester is to effectively manage food waste at a domestic level, addressing the growing concern of increasing food waste worldwide. The digester operates in a two-stage process. In the first stage, the food waste undergoes decomposition through the action of fermentative bacteria. To facilitate this process, a macerator pump is used to grind the food waste into fine pieces before transferring it to the first stage. Additionally, a layer of cow dung is placed at the bottom of the tank to introduce fermentative bacteria, which aids in catalyzing the decomposition process. Sensors are utilized in the digester to monitor the temperature and pH of these processes. Arduino Mega 2560 microcontroller processes the signals received from the sensors, allowing for optimal control of the anaerobic digestion. The results of the study indicate that the proposed model of the microcontroller-based household anaerobic food digester significantly improves processing time compared to conventional models. This suggests that this digester has the potential to be an efficient and effective solution for managing food waste at the household level.

2.5.5 Comparison of the Study

Table 2. 1 Comparison Table of Study Related to Arduino

Title of the Project	Author	Methodology	Benefits
Design of Kitchen Waste Composting Machine: A Smart Approach	Gaurav Chiplunkar and Avinash More	Microcontroller used: - Arduino Uno Sensors: - Moisture sensor to detect humidity of compost bin Actuator: - Does not specify the type of motor but mention a motor capable of producing 0.5 Horsepower - Heating element	Compared to traditional composting method, the project able to reduce the time taken for composting within 48 hours maximum
Smart Chopper and Monitoring System for Composting Garbage	V. A. Wardhany, A. Hidayat, and A. Afandi	Microcontroller Used: - Arduino Mega 2560 Sensors: - Ultrasonic Sensor used to detect level of garbage in container box - LDR sensor used to initiate the processing of household organic waste when it is put into chopper	The automation process of the system helps in reducing the labour needed to process a compost

		Actuator: - Motor that acts as a mechanism to crush waste	
Towards Sustainable Society: Design of Food Waste Recycling Machine	S. Bennbaia et. Al.	Microcontroller used: - Does not specify the Arduino microcontroller used Sensor: - No specific type of sensor is mention but key parameter of the design is to measure moisture and temperature Actuator: - No specific type of actuator is mention but incorporate the use of mixing mechanism into the system	The design of the system is towards customer needs whereby it is more appealing and could promote the use of the system
A microcontroller-based household anaerobic food digester	V. Oree and Maudhoo	Microcontroller used: - Arduino Mega 2560 Sensor: - Temperature sensor - pH sensor (both the sensor is used to monitor anaerobic process in the system) Actuator: - Macerator Pump which is used to transferring content for stages in the process of composting	The system produces and collect 2 output products. Instead of just producing compost the system also produce biogas.

2.6 Compost Tea and its benefits

2.6.1 Overview of a compost

Compost is an organic product that can be safely used in agriculture and other application obtain from the microbial decomposition of an organic material [43][44]. While in [45] define compost as a crumbly organic material made from decomposed plant matter and used in agriculture and gardening. Compost is a sustainable practice that converts organic waste, such as kitchen scraps, yards trimming and agricultural residue into a valuable resource. The figure 2.5 show homemade organic compost which was made from everyday waste product from household.

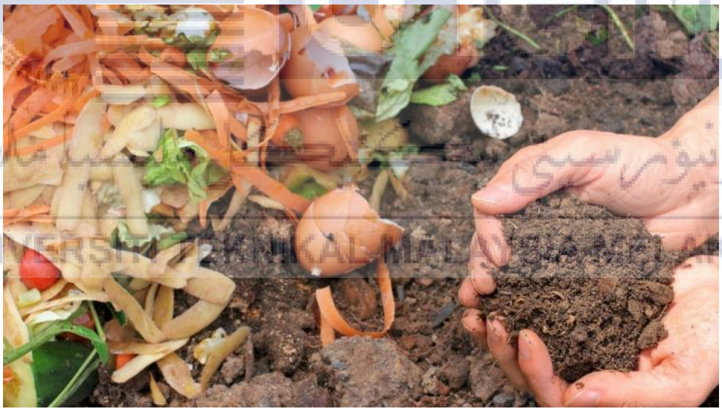


Figure 2. 5 Organic Homemade Compost

Compost can offer variable benefits in supporting sustainable agriculture and also in waste management. Composting helps in cutting down the amount of waste and the emission of greenhouse gas at a landfill. In landfills, organic waste such as food scraps, wood, and paper break down and releases methane, a greenhouse gas with a much higher global warming potential than carbon dioxide [46]. The reliance on synthetic fertilizer can be reduced from using compost. This is because compost act as a fertilizer to compliment the nutrients needs of plant. Compost can supply micronutrient and minerals that are usually unavailable in commercial fertilizer such as Sulphur, carbon, magnesium and calcium [47]. Due to compost is made up of organic matter, it can enrich soil with organic matter content which can improve soil structure and increasing nutrient availability. In [48], it stated that compost can increase soil matter content, increase water retention in sandy soil and increase cation exchange capacity. Other than that, Compost allows for nutrient recycling and reutilization of nutrient present in organic waste. When compost is applied onto soil, it slowly releases nutrient overtime. This provides a balanced and sustained supply of essential nutrient for plant growth at the same time maintaining soil fertility.

Overall, compost is a valuable tool that can benefits in supporting sustainable agriculture and waste management. It is an environmentally friendly way to manage organic waste by creating a nutrient-rich soils amendment that does not bring negative effect in industrial use or in small scale use.

2.6.2 Compost Tea

2.6.2.1 Introduction to Compost Tea

Figure 2. 6 Compost Tea

Figure 2.6 shows a compost tea, compost tea is a product produced by mixing compost with water and is fermented for a period of time, either by aerating or not aerating it, with or without additive that are used to increase microbial activity during production [49][50]. Compost tea contain a line of diverse beneficial microorganism such as nematodes, protozoa, certain bacteria and fungi. This microbe increases the biodiversity of soil and boost the defense mechanism of plants against erosion, pest and diseases. Compost tea act as a source of essential nutrient for plant. During composting process, organic material breaks down releasing relevant nutrient for plant. This nutrient is then ready to be absorb by plant in liquid form. Compost tea contains already dissolved organic matter from composted material. This organic matter enhances soil structure, moisture retention and promote the activity of microorganism. It also acts as a long-term source for nutrient to maintain soil fertility. Overall, compost tea is used for improving soil health, increase nutrient availability, support plant growth and contribute to sustainable agriculture practices.

2.6.2.2 Compost Tea Production Method

Compost tea production method depends on the scale of production. Whether it is in a small scale which to be use by home gardener or small farm or in a big scale which is for commercial use. It all depends on why was the compost tea are produced.

The method of producing compost tea comes in variable way such as continuous Non-Aerated Compost Tea (NCT) and Aerated Compost Tea (ACT) method, with or without additive to increase microbial activity in the production [49]. The most common method in production of compost tea is by ACT or bucket bubbler technique [51]. The process of aerated can be with a time interval. In fact, it is recommended to submerge your aeration device in the water, turn it on and let it run for at least 2 hours to aerate the water before adding compost and other ingredients [52]. All that is needed in this method is bucket for storing liquid, an air pump and air stone to supply continuous oxygen and agitation during the process. Compost in a teabag as the medium of processing compost tea is needed. It is important to choose high quality compost to be used as compost tea. Tips on brewing an aerated compost tea require a temperature ranging in between 13 degrees Celsius to 30 degrees Celsius with a pH ranging at 6.8 to 7.2 [52][53]. The table 2.2 describe the step by steps guide on how to produce compost tea by this method.

Table 2. 2 Steps of Making Aerated Compost Tea

Steps	Description
1	Start with a clean bucket or container. Use a food-grade bucket or container that is free from any residues or contaminants. This ensures a clean environment for brewing compost tea.
2	Fill the bucket with non-chlorinated water. It's important to use water that is free from chlorine, as chlorine can harm the beneficial microorganisms in the compost tea. Filtered or dechlorinated water is preferable.
3	Add compost (well-composted organic material) into a mesh bag or directly into the bucket. The compost serves as the source of beneficial microorganisms and nutrients for the compost tea. Ensure that the compost is well-composted and free from any harmful pathogens or contaminants.
4	Attach the air pump and air stone to the bucket using airline tubing. The air pump provides a continuous supply of air, while the air stone creates a steady stream of tiny bubbles. This aeration process promotes oxygenation of the water, facilitating the growth and reproduction of beneficial microorganisms.
5	Submerge the air stone in the water and start the aeration by turning on the air pump. Place the air stone in the water, ensuring it is fully submerged. Turn on the air pump to initiate aeration. The bubbling action agitates the water, providing oxygen to the microorganisms and creating a favourable environment for their growth.
6	Brew the compost tea for a specific duration (typically 24-48 hours). Allow the compost tea to brew for the recommended time period. During this time, the beneficial microorganisms in the compost will multiply and release nutrients into the water, creating a nutrient-rich solution.
7	Remove the compost or mesh bag from the bucket and strain the liquid to remove any remaining solids. Once the brewing period is complete, remove the compost or mesh bag from the bucket. Strain the liquid to remove any remaining solids, ensuring a clear and filtered compost tea.
8	The compost tea is now ready for application. The resulting compost tea is a nutrient-rich liquid that can be applied to plants, soil, or as a foliar spray. It provides beneficial microorganisms and nutrients to support plant growth and enhance soil health. Apply the compost tea as recommended for the specific plants or gardening needs.

In general, variable method in producing compost tea has that same end product which is a nutrient rich liquid that can be used as an organic fertilizer to replace synthetic that could affect the environment and condition of plant. The table 2.3 shows the additional table of method of producing a compost tea and its process taken obtained from [51].

Table 2. 3 Common Aeration Compost Tea Method

Method of Compost Tea	Processing Details	Diagrams
1. Bucket-Bubbler	This is the most common technique used to make compost tea among home growers. Aeration is supplied to the compost bucket using 1 or 2 hoses; the nozzle size does not matter as long as air is able to disuse through the bucket. Diffusion mats and aquarium-style stones and/or an impeller can be used to produce compost tea very rapidly (Ingham, 2015; Martin, 2014). This method "brews" mixes the composts and water together, for 3 days to fully extract all the nutrients from the compost.	 (Garden Gate eNotes, 2010)
2.Trough	This method is used for commercial production of compost tea. Compost, in a container with holes in the bottom, is suspended in the air over a trough. Water is poured over the compost, letting the tea drip from the top container into the bottom trough. Aeration can be added to circulate the compost tea, similar to the bucket method. Brew time is longer than bucket bubbler, can be up to 3 weeks because of the large volume of compost tea being made (Ingham, 2000).	

2.6.3 Benefits of compost Tea

Compost tea is full of nutrients and trace minerals that can help plants grow and build their defenses. There are several benefits of using compost tea in agricultural sector. This includes its effect on soil, plant and environment.

One of the benefits of using a compost tea is that compost tea can help to improve soil fertility. Due to compost tea is an organic substance, it can prolong the use of soil creating a self-sustaining environment for soil. Unlike chemical fertilizer, the overuse of the fertilizer can kill life expectancy of soil, harming plant ecosystem and causing water pollution to nearby water source [53]. Other than that, compost tea improved water retention on soil. Comparing the use of regular state of compost, compost tea is in liquid state that can help in loosening the composition of soil such as clay, allowing for air and water to move easily in the ground.

Compost tea is rich in nutrient and mineral that can improve the growth of plant. During the process of making compost tea essential nutrient are released into the liquid making the nutrient needed for plant growth is readily available when applying the compost tea. Thus, this promotes the healthy growth of plant. Compost tea is also rich in beneficial microorganism that suppress harmful pathogen that could cause disease on plant [55]. The high quantity of beneficial bacteria in the tea competes with the growth of harmful pathogen reducing the pathogen amount. Minimal amount of the harmful pathogen does not cause disease to plant but instead making plant to be exposed to it and improve their immune system against the pathogen.

The use of compost tea can benefit in combating the overuse of synthetic fertilizer that would affect the environment. In this case, overuse of chemical or synthetic fertilizer would cause water pollution from run-off to nearby water source. Synthetic fertilizer is rich concentrated with nutrient that would cause eutrophication, a blooming of algae [56]. Algae could be harmful to living as it can releases toxin into water. Therefore, compost tea helps in combating overuse of this synthetic fertilizer.

All in all, compost tea offers numerous benefits for plant growth and soil health. Its nutrient-rich composition, ability to enrich the soil, introduction of beneficial microorganisms, disease suppression capabilities, increased nutrient uptake, and eco-friendly nature make it a valuable tool for gardeners and farmers. By harnessing the power of organic matter and beneficial organisms, compost tea provides a natural and sustainable approach to fertilization, leading to healthier plants, improved yields, and a more environmentally conscious gardening or farming system.

2.6.4 Limitation and Challenges of Compost Tea Use

Although compost tea offers numbers of benefits but there are also limitation and challenges arise. One of the limitations is that the quality and effectiveness of compost tea might be vary. This depends on the compost used to make the tea. Other than that, if compost tea is not properly brewed it may result in survival of pathogen that can causes disease in plant. To obtain optimal result, the usage of compost tea requires proper timing and adequate application. There might also be limitation in term of scalability and cost-effectiveness especially in big-scale agricultural use. Therefore, it is truly important to consider these limitation and challenges when implementing compost tea as a practice for sustainable agriculture. Future development and research needed to done to overcome this issue and optimize it application.

2.7 Summary

The integration of technology in agriculture has paved the way for innovative practices like compost tea, revolutionizing sustainable farming systems. Cutting-edge technologies, such as precision agriculture tools, automated brewing systems, and data analytics, have transformed the production and application of compost tea. Automated brewing systems ensure consistent and controlled brewing parameters, optimizing the extraction of beneficial microorganisms and nutrients. Precision agriculture tools and sensor-based monitoring allow farmers to assess soil conditions, plant health, and nutrient levels, enabling precise and targeted application of compost tea. Data analytics provide valuable insights into the effectiveness of compost tea and allow for adjustments and improvements in brewing techniques. By embracing technology, farmers can harness the full potential of compost tea, enhancing soil fertility, disease suppression, and nutrient cycling, while minimizing environmental impact and fostering sustainable agricultural practices.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the methodology used in the development of an IoT-based smart compost tea brewer for sustainable agriculture is presented. The project aims to automate the brewing process and enable real-time monitoring of pH level, Co2 gas and temperature, utilizing the Arduino microcontroller with ESP32 as a Wi-Fi module. The chapter provides an overview of the research design, hardware setup, software implementation, data collection, and analysis procedures. It explains step-by-step approach used in designing and constructing the system, including the configuration of the microcontroller, Wi-Fi module and sensor connections for pH level, Co2 gas and temperature monitoring. Furthermore, it discusses the development of the code, techniques for data collection, and the procedures involved in data transmission and storage. The chapter concludes by addressing the limitations and constraints encountered during the project.

3.2 Approach to System Design

3.2.1 Overview

The foundation of the project where it involves the overall layout and organization of various hardware and component that build the system is pointed out. The IoT based smart compost tea brewer takes into account the requirement, performance objectives and limitation of the project. In this section, the project will be deconstructed and explained to have a better understanding in achieving the final project design.

3.2.2 Component Selection

3.2.2.1 Arduino Mega 2560

Figure 3. 1 Arduino Mega 2560

Figure 3.1 is a picture of Arduino Mega 2560. The Arduino Mega 2560 board is chosen for this project due to its powerful processing capabilities, extensive input/output options, and compatibility with the Arduino development environment. With its ample memory capacity and a wide range of digital and analog pins, the Arduino Mega 2560 provides the flexibility to interface with various sensors, actuators, and external devices. Its compatibility with the Arduino IDE simplifies the programming and development process, making it accessible for both beginners and experienced users. Overall, the Arduino Mega 2560 is a reliable and versatile board that meets the project's requirements for efficient data processing, control, and integration with different hardware components.

Table 3. 1 Features of using Arduino Mega 2560

Feature	Explanation
Processing Power	Powered by an ATmega2560 microcontroller, operates at a clock speed of 16 MHz
I/O Pins	Total of 54 digital I/O pins, in 54 pins, 15 Pulse Width Modulation (PWM) pins for precise control of analog outputs.
Analog Inputs	16 analog input pins with a resolution of 10 bits, providing a range of 0 to 1023 for analog-to-digital conversion.
Memory Capacity	256 KB of flash memory for ample storage for program code and data. 8 KB of RAM for temporary data storage during program execution.
Compatibility	The board is fully compatible with the Arduino development environment, including the Arduino IDE (Integrated Development Environment).
Expansion Options	The board features multiple interfaces, including UART, SPI, and I2C, allowing communication with a wide range of external devices such as sensors, displays, and modules. It is also compatible with Arduino shields for additional functionality.

3.2.2.2 ESP-01 Wi-Fi Serial Transreceiver Module

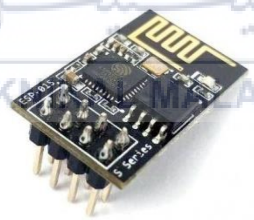


Figure 3. 2 ESP-01 Wi-Fi Serial Transreceiver Module

The ESP-01 module is a cheap and compact Wi-Fi serial transceiver module used in conjunction with the Arduino Mega 2560 board. It improves the system's capabilities by adding wireless connectivity which allow for seamless integration with Wi-Fi networks. The ESP-01 module offers reliable and efficient communication, enabling the system to connect to the internet, send and receive data wirelessly and interact with various IoT platforms. With its small form factor and compatibility with the Arduino Mega, the ESP-01 module provides a cost-effective solution for adding wireless connectivity to the project, expanding its functionality and enabling remote control and monitoring capabilities. Table 3.2 describe the feature of ESP-01 module.

Table 3. 2 Features of ESP-01 Wi-Fi Serial Transreceiver Module

Feature	Description
Microcontroller	ESP8266EX
Wireless Protocol	802.11 b/g/n
Voltage	3.3V
I/O Pins	2 digital I/O pins (GPIO0, GPIO2)
Communication	UART interface (TX, RX pins)
Flash Memory	1MB
Antenna	On-board ceramic antenna
Command Set	AT command set for control and configuration
Size	Compact form factor
Power Consumption	Low power consumption for energy efficiency

3.2.2.3 pH sensor Kit

Figure 3. 3 MD0415 – pH sensor with Probe

The MD0415 pH sensor with probe is used in the project to measure and monitor the pH levels of the compost tea solution being analyzed. The pH is a crucial parameter in the project. The MD0415 pH sensor offers high accuracy and reliability in pH measurements, ensuring precise and consistent readings. Its probe design allows for easy insertion into liquids or soil, providing direct pH measurements. By using the MD0415 pH sensor, the project can effectively monitor pH levels in real-time, enabling better control and adjustment of the tea. The sensor's compatibility with the Arduino platform ensures seamless integration and data acquisition, making it a suitable choice for pH monitoring in the project. Table 3.3 describe the feature of the pH sensor.

Table 3. 3 Features of MD0415 – pH sensor with Probe

Feature	Description
Measurement Range	0 to 14 pH
Accuracy	High accuracy in pH measurement at a displacement of ±0.05 pH
Probe Design	Durable and robust probe design for long-lasting performance
Calibration	Easy calibration process to ensure accurate pH measurements
Compatibility	Compatible with various devices and microcontrollers, including Arduino
Analog Output	Provides analog output (at 0-5V) for interfacing with other systems
Temperature Compensation	Built-in temperature compensation for accurate pH readings
Probe Material	Suitable probe material for compatibility with different solutions
Low Maintenance	Requires minimal maintenance and cleaning for continuous operation
Applications	Ideal for applications such as water quality monitoring and hydroponics

3.2.2.4 Temperature Sensor Kit

Figure 3. 4 DS18B20 Temperature Sensor

The DS18B20 temperature sensor is used in the project for monitoring and controlling the temperature of the compost tea. Temperature plays a crucial role in the compost tea production process, as it influences microbial activity and nutrient availability. By integrating the DS18B20 sensor, the project ensures accurate and reliable temperature measurements within the compost tea. This enables the system to maintain optimal temperature conditions for the growth and activity of beneficial microorganisms, ensuring the production of high-quality compost tea. The sensor's digital output and compatibility with the Arduino platform allow for seamless integration into the system. Table 3.4 describe the feature of the temperature sensor

Table 3. 4 Features of DS18B20 temperature sensor

Feature	Description
Temperature Range	Wide temperature range for accurate measurement (from -55°C to 125°C)
Accuracy	High accuracy in temperature measurement (at a displacement of ±0.5°C)
Digital Output	Provides digital output (One-Wire interface) for easy integration
Resolution	Adjustable resolution for fine temperature measurements

Power Supply	Can be powered from a wide range of voltages (ranging 3.0V to 5.5V)
Programmable Alarm	Allows setting programmable temperature alarm thresholds
Waterproof Option	Available in waterproof version for liquid or outdoor applications
Multiple Sensors	Supports multiple sensors on a single bus for simultaneous readings
Low Power Consumption	Designed for low power consumption, suitable for battery-powered systems
Compatibility	Compatible with various microcontrollers, including Arduino

3.2.2.5 Gas Sensor

Figure 3. 5 MQ135 Gas Sensor

The selection of the MQ135 gas sensor for detecting CO2 gases in compost tea is driven by its ability to provide valuable insights into the microbial activity and fermentation process. By monitoring CO2 levels, this sensor enables the assessment of active microorganism presence and their efficient decomposition of organic matter, leading to the release of beneficial compounds and nutrients. With its reliable performance, sensitivity, and compatibility with Arduino Mega, the MQ135 sensor proves to be a cost-effective and practical solution for real-time monitoring, allowing for optimal brewing conditions and the maintenance of desired nutrient balance and microbial diversity in compost tea production.

3.2.2.6 Air Pump with Motor Driver

Figure 3. 6 12V DC Motor Air Pump

Figure 3.6 shows a 12V DC motor Air Pump. The 12V DC motor air pump plays a critical role in the compost tea system by facilitating air circulation to ensure proper oxygenation of the tea. The air pump can continuously run for several hours. Specifically designed for this purpose, the motor-driven air pump delivers a continuous flow of air into the brewing vessel. This constant airflow promotes aerobic conditions within the tea, creating an ideal environment for the growth and activity of beneficial microorganisms. By maintaining adequate oxygen levels, the motor air pump enhances the quality of the compost tea, optimizing the fermentation process and maximizing the production of valuable compounds.

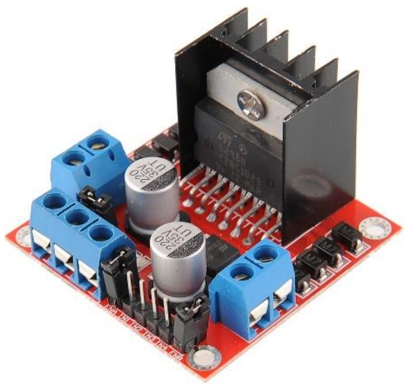


Figure 3. 7 L298N Motor Driver

Figure 3.7 shows L298N Motor Driver to integrate the use of Air Pump which is based on 12V DC motor, the use of L298N motor driver is needed. The motor driver has a build-in protection feature which provide overcurrent and overheating protection. The driver will be used to control the speed and direction of motor to allow the right aeration process during brewing.

Table 3. 5 Features of L298N Motor Driver

Feature	Description
Motor Control	Dual H-bridge motor driver capable of controlling two DC motors
Voltage Range	Supports a wide input voltage range (up to 46V)
Current Capacity	Provides a high current capacity, typically up to 2A per channel
Control Interface	Compatible with digital control signals (e.g., Arduino)
Built-in Protections	Includes built-in protections such as thermal shutdown and overcurrent protection

3.2.2.7 LCD Display

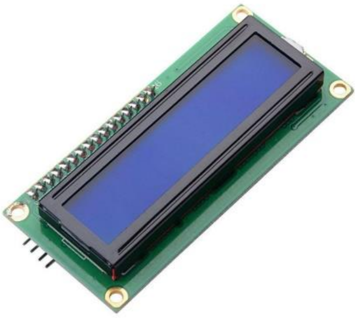


Figure 3. 8 16x2 LCD Display

The display is designed to communicate in I2C protocol which is simplifies the integration and reduce the use of required pin on the Arduino board. The display can provide an ample space to show various data in the system. Figure 3.8 is the I2C 16x2 LCD display where the pinout is already connected with I2C module.

Table 3. 6 Table 3.8 Features of 16x2 I2C LCD Display

Feature	Description
Display Size	16 characters per line and 2 lines
Communication	I2C interface for easy and efficient communication
Backlight Control	Built-in backlight with adjustable brightness
Contrast Control	Allows adjustment of the contrast level for optimal readability
Wide Viewing Angle	Provides a wide viewing angle for clear visibility from different angles
Low Power Consumption	Operates with low power consumption, suitable for battery-powered applications
Easy Integration	Compatible with various microcontrollers and Arduino boards

3.2.3 Software Integration

3.2.3.1 Arduino IDE

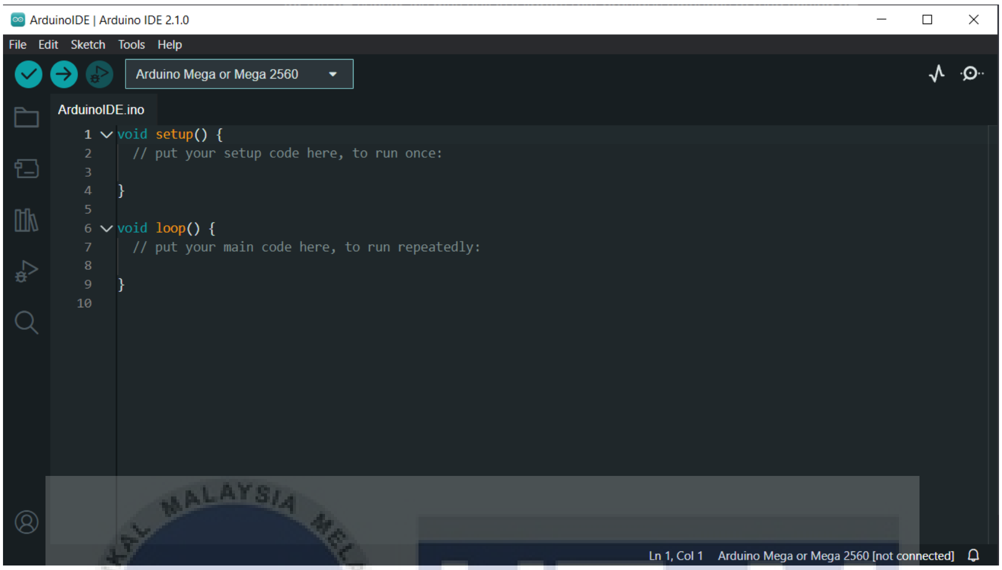


Figure 3. 9 Interface of Arduino IDE

Figure 3.9 is how interface of Arduino IDE looks. Arduino IDE acts as a programming platform to write, compile and upload code into Arduino board. It has a user-friendly interface for creating and modifying code and also provide libraries needed to widen the functionality of hardware component. To meet the project requirement the software, allow customization and fine-tuning of Arduino board behavior. It also can monitor data through serial monitor helping in debugging and troubleshooting task. The Arduino IDE plays an important role in developing the software and enable an efficient programming for the project. From the software, programming code can be obtained through Hex file where it will be then transferred into Proteus software to be simulate.

3.2.3.2 Proteus 8 Professional

Figure 3. 10 Proteus 8 Professional

Proteus 8 software helps in designing and testing the circuitry of the project. It provides a virtual platform to construct circuit, establish connection and simulate electronic circuit it realizing the project. This enables the capability to do testing and debugging process before constructing the real project. It offers various analysis tool for evaluating circuit performance such as voltage and current measurement. Arduino library can be downloaded online and can be utilized inside the software. Although, it capable of simulating Figure below show an example of the usage. Figure 3.11 show how proteus can be used to design a circuit and do simulation.

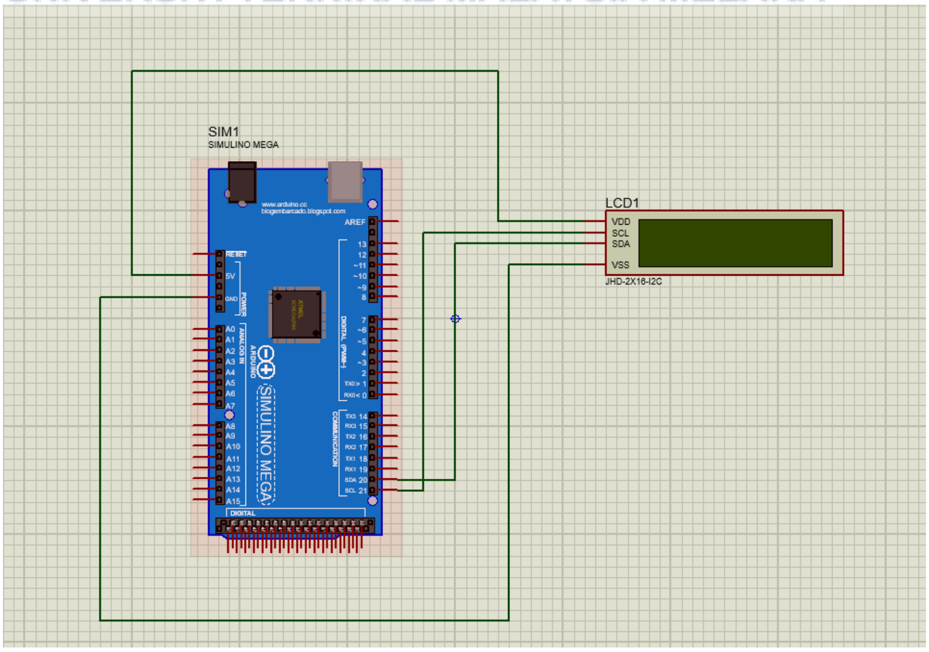


Figure 3. 11 Example of Proteus usage

3.2.3.3 Autodesk AutoCad

Figure 3. 12 AutoCAD Logo

AutoCAD is a computer-aided design (CAD) software which is widely used in various industries for creating, editing and viewing of 2D and 3D design. It has become one of the industry standards for professionals in fields such as architecture, engineering and construction. It also has become one of the software used by students in designing projects, in this case used for designing the compost tea system. The software offers precise and efficient capabilities which can allow user to design unique shape and expand their creativity. First time user can learn the use of the software easily due to there is many tutorials available online for them to start designing their own project.

3.2.3.4 Blynk IoT Platform

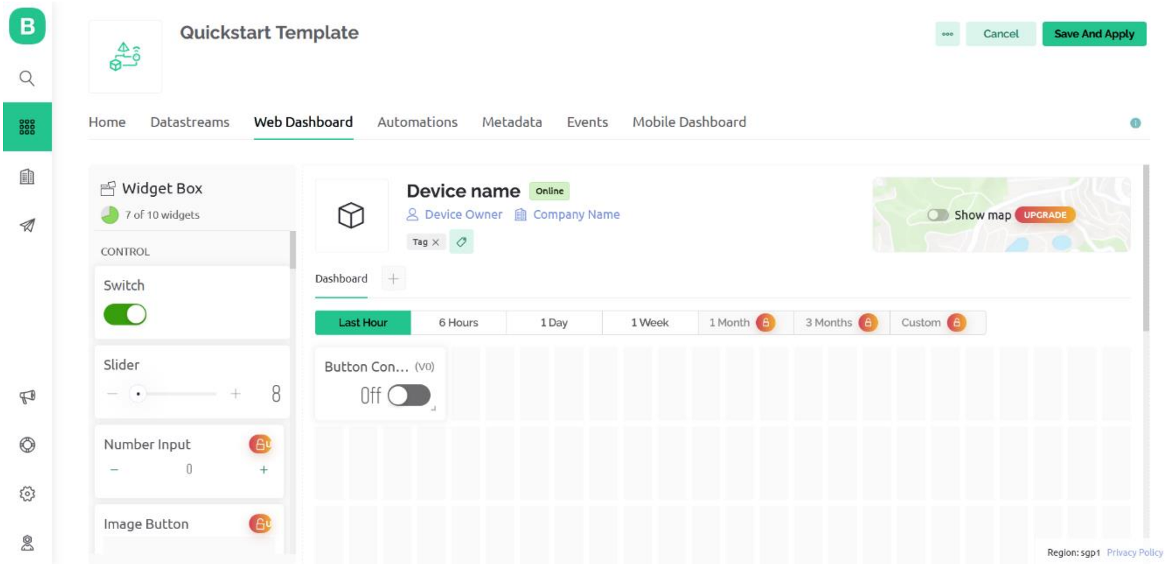


Figure 3. 13 Dashboard of Blynk IoT Platform

Blynk IoT platform provides a user-friendly interface for connecting and controlling various devices and sensor. It offers a simple and interactive ways in building custom application and dashboard for remote monitoring and controlling IoT project, in this case the smart compost tea brewer. Blynk support various hardware platform, this includes Arduino microcontroller making it more versatile and compatible with different device. One of the easy features of Blynk is the drag and drop interface. This allows for easily create and customize IoT platform dashboard according to user preferences. Blynk provide a cloud-based infrastructure where data from IoT can be securely stored and accessed from anywhere. Additionally, Blynk have a built-in support for notifications and alert to allow user to receive instant notification when on certain condition or event occur in accordance to the project objectives. The community of Blynk is big making resource and inspiration for the project can be expandable.

3.3 System Architecture

3.3.1 Compost Tea Brewer System

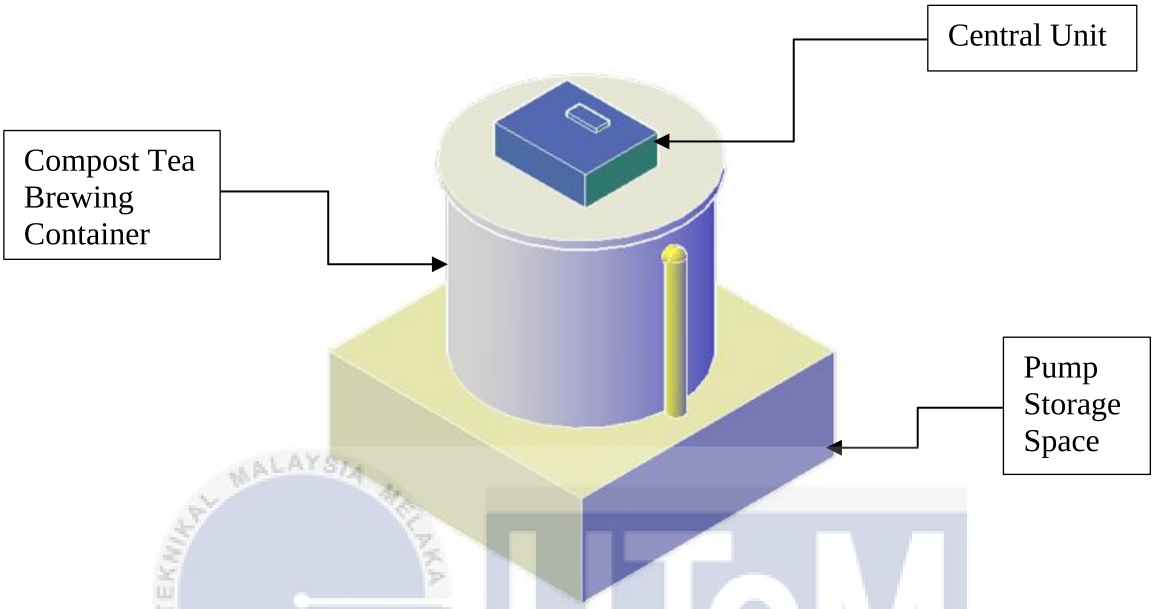


Figure 3. 14 Design of Compost Tea Brewer System

Figure 3.14 show the general design of the system which is inspired from a traditional aerated compost system. The designing of the system is aided by using AutoCAD software. The central unit is where the main component of the system will be kept and to display value of measured parameter. The main reason is to protect Arduino boards and its wiring from disconnection for the system to work. It is also to prevent the component from getting exposed to dirt or liquid that could damage the board. The compost tea brewing container is where the compost tea brewing process will take place. In this project, a bucket with a capacity of 18 liters will be used. It is suitable for a small-scale production of compost tea. Lastly the pump storage space, in this space the pump will be stored and where liquid detection unit will be placed to detect any leakage from the container so that the user will be alerted and make some adjustment. The design will be further improved in the future once the design has been implemented realistically.

3.3.2 Circuitry of System

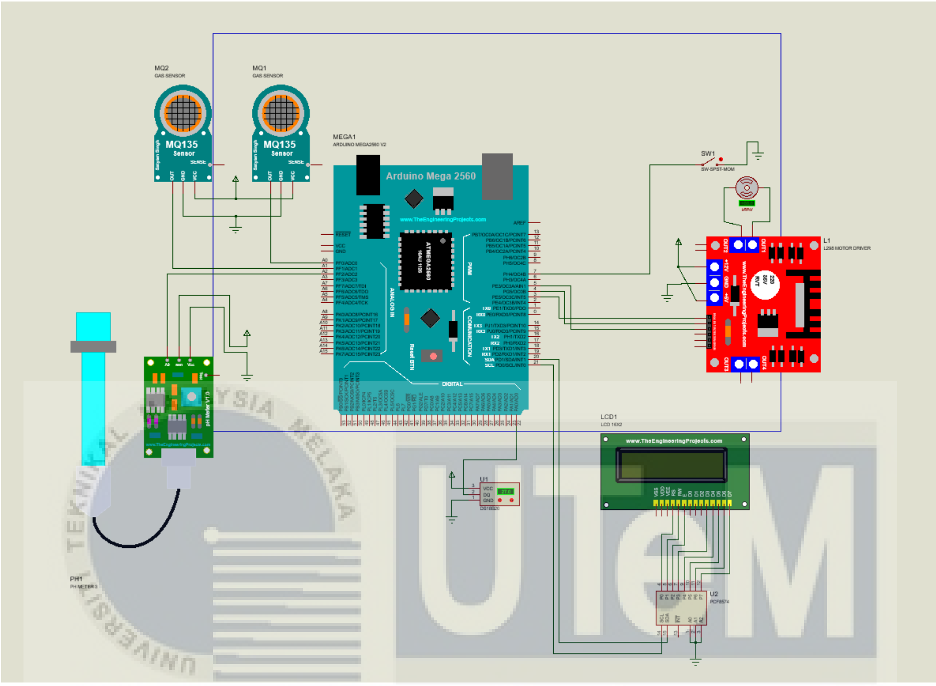


Figure 3. 15 Schematic Diagram

The figure 3.15 shows the design of the component circuitry. It was design by using the software, Proteus 8. The availability of abundance I/O port from Arduino Mega 2560 give variable connection for the circuit design. Hence, this design offer for a much easier wiring troubleshooting capability for future wiring problems. This is due to the connection for each sensor and module pin are not to close to each other. Thus, making it easier to locate each pins connection.

3.3.2.1 Input Output Pin

Table 3. 7 I/O pin connect of component

Arduino Mega 2560 Pins	Component	Connection
TX0 (D0)	**ESP01**	RX
RX0 (D1)	**ESP01**	TX
A0	**MQ135(1)**	Out
A1	**MQ135(2)**	Out
3	**L298N Enable 1**	Enable 1
4	**L298N Input 1**	Input 1
5	**L298N Input 2**	Input 2
22	**DS18B20**	DOUT
A3	**pH Sensor**	A0
SDA (20)	**I2C 16x2 LCD**	SDA
SCL (21)	**I2C 16x2 LCD**	SCL
3.3V	**ESP01**	VCC, CH_PD
5V	**MQ135, L298N, pH Sensor, I2C 16x2 LCD, L298N MOTOR DRIVER**	VCC
GND	**ESP01, MQ135, L298N, pH Sensor, I2C 16x2 LCD**	GND

3.3.3 Blynk IoT Platform User Interface

Figure 3. 16 Manual Tabs on Blynk Application

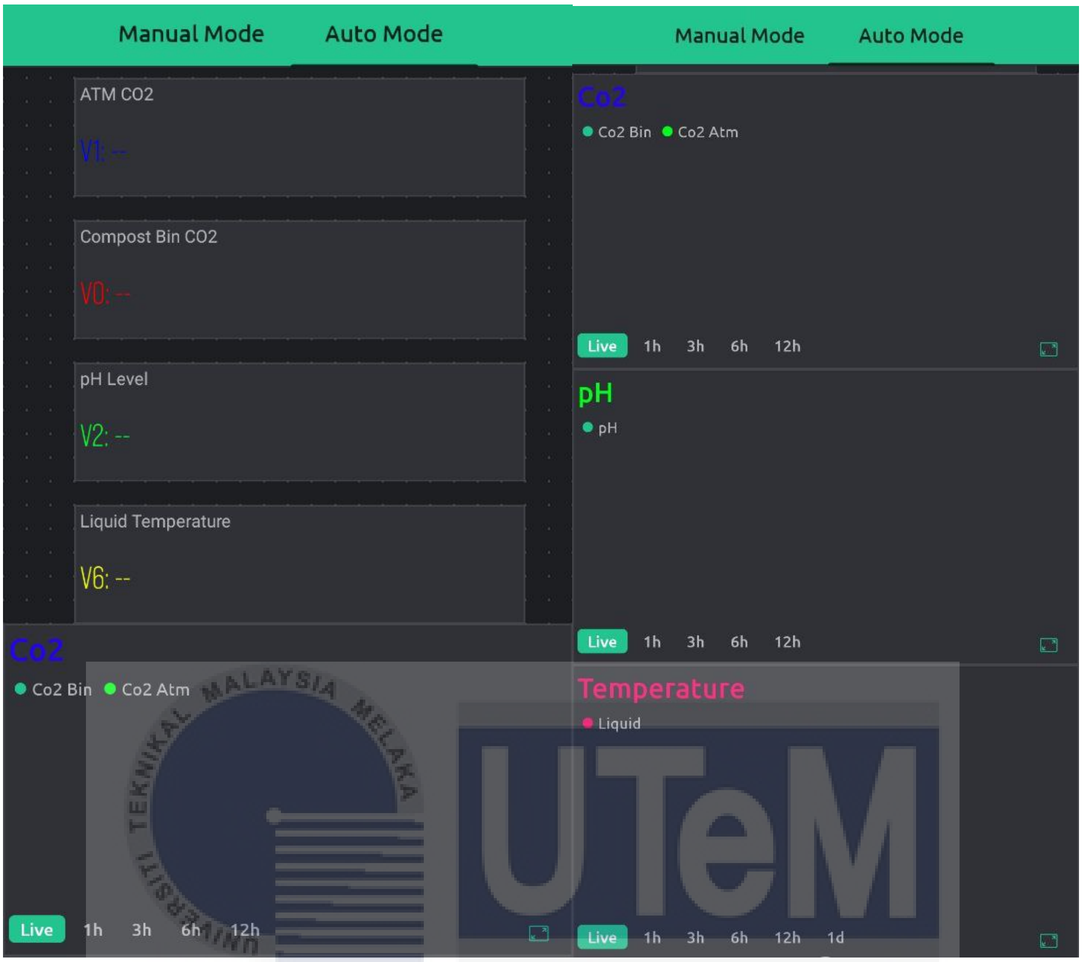
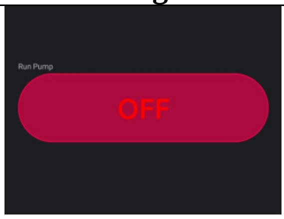


Figure 3. 17 Auto Mode Tabs on Blynk Application

Figure 3.16 and Figure 3.17 shows the display on Blynk application for the brewing system. Where in the application there are 2 tabs, one for manual Mode and automatic mode. In manual Mode tabs is where user can control the On and Off of the air pump. Each sensor reading is displayed real-time and the sensor reading can be monitored each hour from the chart. Thus, data for sensor reading can be collected through the sensor chart. As for in Auto Mode, it will only display sensor value for every 3-hour passed. The sensor will read data for one hour and the data can be read from the chart for each sensor.

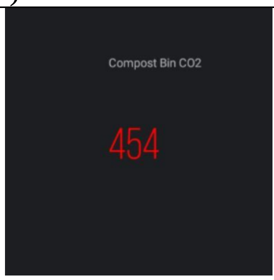
Table 3. 8 Table of Widget Function

<table>
<tr><th>Widget</th><th>Function</th></tr>
<tr><td>

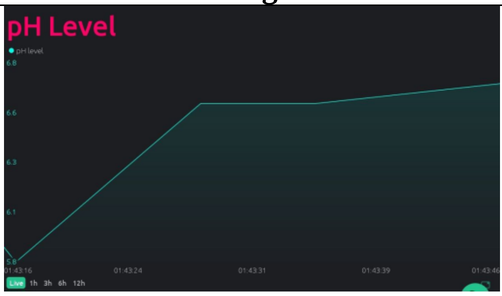
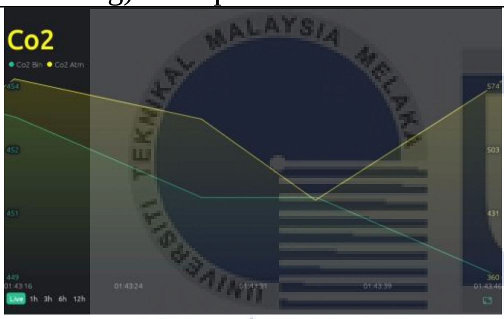
a) Air Pump Button</td><td>User can turn the Air Pump condition manually by switching the button ON and OFF.</td></tr>
<tr><td>

b) pH Level</td><td>Displaying pH sensor Value for user to monitor</td></tr>
<tr><td>

c) Temperature</td><td>Displaying compost tea value for user to monitor. The Unit of the reading is in degrees Celsius (°C).</td></tr>
<tr><td>

d) Atm Co2</td><td>Displaying Atmosphere Co2 concentration for user to monitor. The Unit of the reading is in Parts per million (ppm).</td></tr>
<tr><td>

e) Bin Co2</td><td>Displaying brewer bin Co2 concentration for user to monitor. The Unit of the reading is in Parts per million (ppm).</td></tr>
</table>

Widget	Function
 f) pH Level Chart	Displaying pH level in Chart form for user to monitor. The duration can be read from the range of per 1 second to range per 12 hours
 g) Temperature Chart	Displaying liquid temperature in Chart form for user to monitor. The duration can be read from the range of per 1 second to range per 12 hours
 h) Co2 Chart	Displaying Co2 Concentration in Chart form for user to monitor. The duration can be read from the range of per 1 second to range per 12 hours

3.4 Smart Brewing Process

3.4.1 Compost Tea Fundamental and Principle

When making an Aerated compost tea it is important to properly apply the ideal condition for the brewing to take place. Choosing the right and high-quality compost also plays a role in brewing a compost tea. The brewing of compost tea takes 24 to 48 hours to complete. The aerated compost tea brewing process can be aerated for at least 2 hours with a time interval to inject enough oxygen for the occurrence of microbial activity. Hence, it is important to keep track of the brewing time of the tea. Furthermore, the key parameter in making compost tea also needed to be taken into account. The temperature and pH are the main key parameter in making compost tea. To know about the microbial activity of the compost tea, one of the ways is that by measuring the Co2 content of surrounding atmosphere in the compost tea container. It should be higher than the average concentration of Co2 in the surrounding atmosphere. Hence, the project focuses on sensing these 3 parameters from the use of the sensor in the project.

3.4.2 Block Diagram

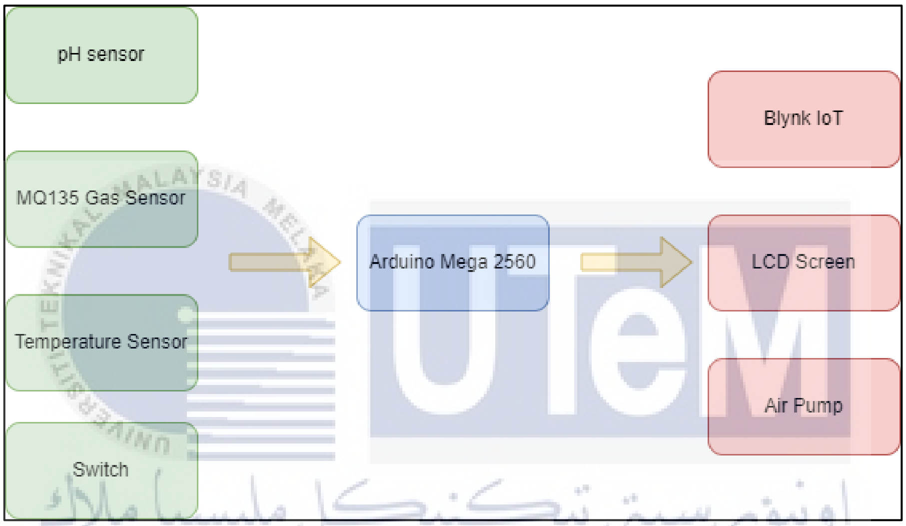


Figure 3. 18 Block Diagram of System

The diagram 3.18 shows the general view of how Arduino mega 2560 acts as the main component that control the whole process of the system. It serves as the brain of the system which is responsible of executing the programmed instruction and coordinating the operation of another component. It would receive input from the sensor and execute the necessary action based on the collected data. Once the input is determined, it would send the out data through the cloud or to display component. The Arduino board is also responsible in controlling the actuator which is the air pump. It controls the operation of air pump based on the instruction written in the program code.

3.4.3 System Flowchart

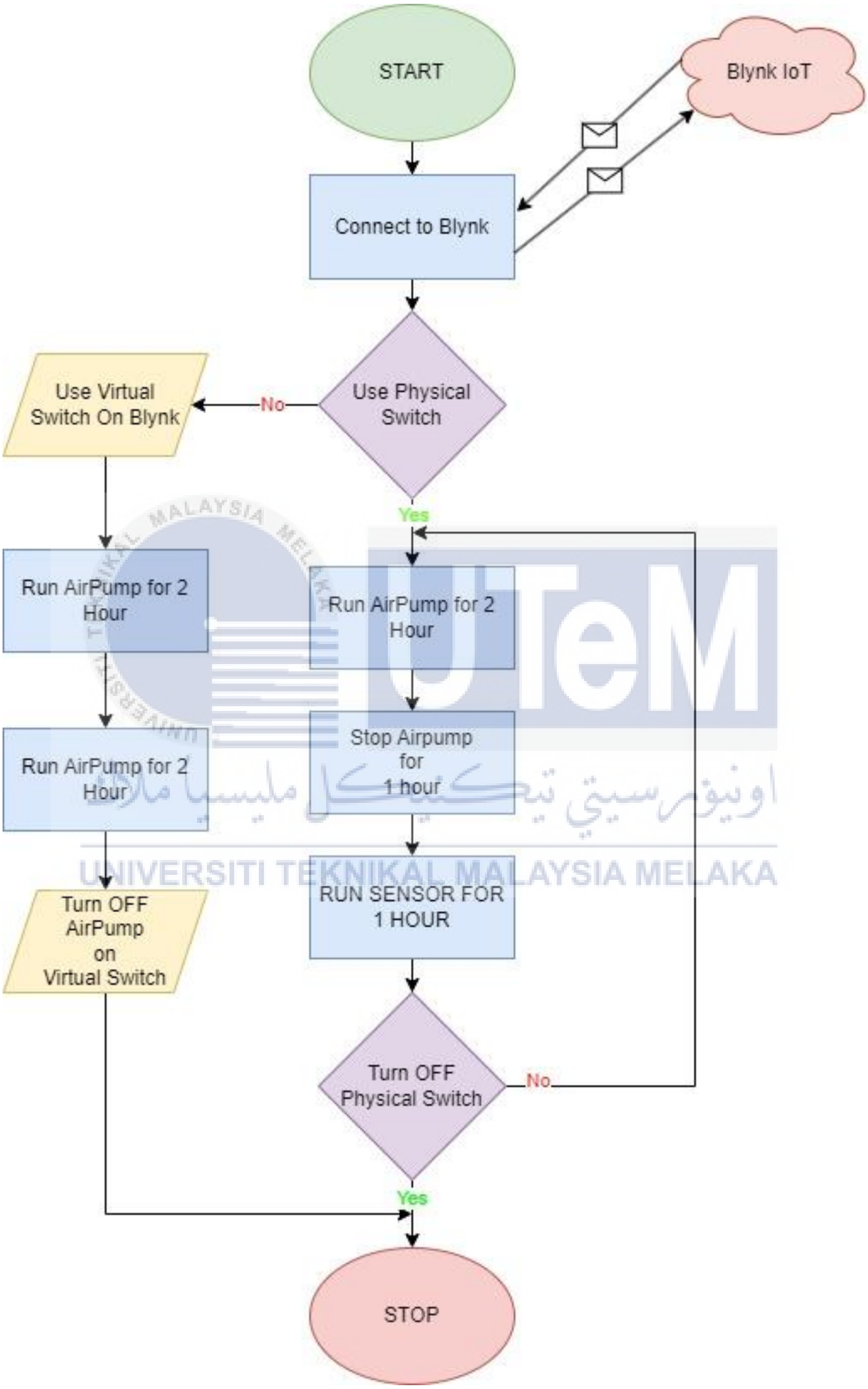


Figure 3. 19 Flowchart of System

Figure 3.19 shows the flowchart of system operation. The brewing system is set to have 2 run style which is automatic process and manual control process. The first run style is when the switch for operation is turned ON. The brewing system will start air pump for 2 hours, this is to supply enough oxygen into the brewed liquid for any microbial activity to occur. After 2 hours mark has passed, it will stop the air pump and let the liquid to sit for 1 hour. After the 1 hour, it will start sensor reading from all sensors. The data from the sensor will be send to Blynk for remote monitoring. After 1 hour of sensor reading, it will run the air pump again for 2 hours. The sequences of the brewing system will always run until the switch is turned off again. The manual control process is where the user can control the ON and OFF of the air pump remotely. At the same time the sensor reading will be displayed into the Blynk application. The system will notify user from Blynk application every 2 hours if there is any sensor reading showing an undesired value.

Table 3. 9 Ideal Parameter

Parameter	Value
pH	6.8 - 7.2
Temperature	13 – 30 degrees Celsius
Carbon Dioxide	more than surrounding measured during implementation (Where, Atmosphere Co2 ≈ 420 ppm)

Table 3.9 shows the ideal parameter of the process to brew a compost tea, where pH and temperature are one of the most crucial factors for brewing a compost tea. The carbon dioxide parameter will indicate the microbial activity for the compost tea.

3.5 Summary

Overall, the compost tea brewer methodology includes a systematic approach to system design and implementation. The system architecture was thoughtfully planned and executed, incorporating the necessary hardware components, such as sensors and actuators, along with the Arduino microcontroller and other supporting devices. The smart brewing process involved efficient monitoring of parameters, such as temperature, pH, and Co2 concentration, to optimize the growth of beneficial microorganisms in the compost tea. The choice of plant for product analysis plays one of the roles in proving the effectiveness of the compost tea. This project's methodology took an overall and organized approach, ensuring the effective design and implementation of the compost tea brewer. The methodology supported reliable data collection and analysis by taking into account numerous elements ranging that lead to significant results and insights for sustainable agriculture.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

The projects aim to evaluate the efficiency and effectiveness of the implemented automated system. It involves in the collection of data from sensors analysis, growth of plant, performance system analysis and overall system stability. The result obtains from sensors such as temperature, pH level and Co2 gas will affect the quality of compost tea produced. Then later on will be tested onto a growing plant on its effectiveness for evaluation. The analysis of system performance will enable a better understanding towards the capabilities and limitation of the system, which will highlight for potential improvement and future development toward the system. The overall system stability can be analyzed through data visualization. The trend, pattern and correlation chart could offer the understanding of the system stability.

4.2 Project Integration

4.2.1 Hardware Setup

a) Overall View

b) Top View

c) Side View

d) Side View

Figure 4.1 Hardware Setup

Figure 4.1 shows the hardware setup of the project. The setup are builds based on previously designed system where certain alteration are made onto the system. Main units are stored in a wooden box where it can be easily accessed for future troubleshooting. As the box is finished with "lid" style opening. The display unit is placed onto the lid of the bucket for ease of data monitoring and brewing phase of the system.

4.2.2 System Stability

4.2.2.1 Supply to Arduino

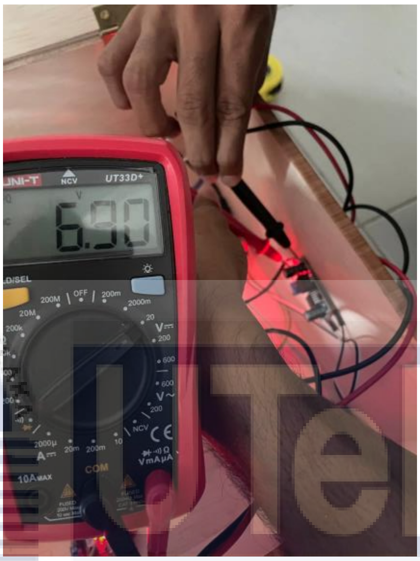


Figure 4.2 Power Supply to Arduino

Figure 4.2 shows the voltage supplied onto Arduino Mega 2560. The Arduino is supplied with 6.9 V in which it is enough to for the microcontroller to operate. The recommended input voltage ranges from 6V to 12V.

4.2.2.2 Motor Driver Supply

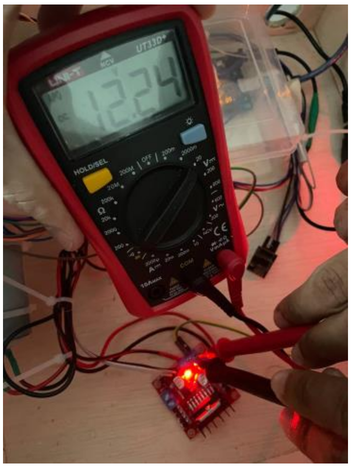


Figure 4.3 Motor Driver Supply

Figure 4.3 shows the supplied voltage onto the motor driver that supplied 12.24 V. Due to the rated voltage for motor used as an Air pump is 12 V, it meets the requirement for the motor to work at full load.

4.2.2.3 Arduino to Sensor Supply

i) **pH Sensor**

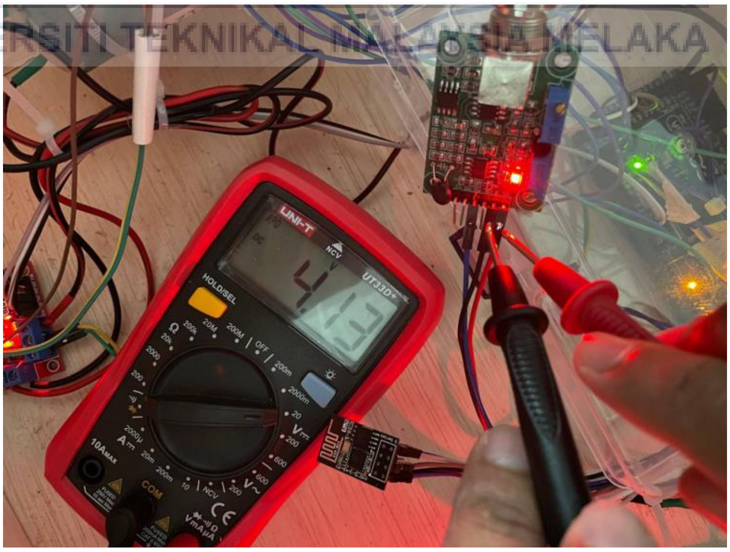


Figure 4.4 Supply to pH Sensor Module

Figure 4.4 shows the voltage supplied onto pH sensor module which is 4.13V. The recommended voltage supply to the module is 5V. This condition might affect the output reading for pH sensor.

ii) **Mq135 Gas Sensor 1**

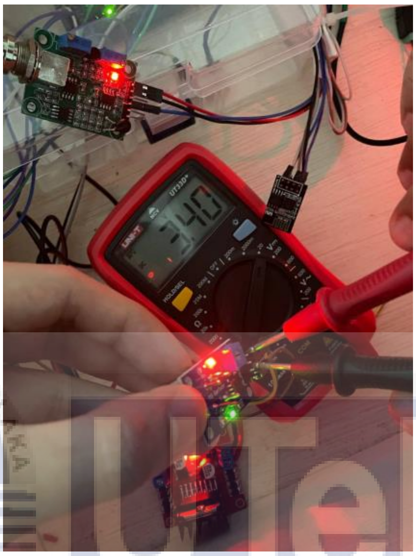


Figure 4.5 Supply to MQ135 Gas Sensor 1

Figure 4.6 Supply to MQ135 Gas Sensor 2

Figure 4.5 and figure 4.6 reads the voltage supplied to both gas sensor used. Gas sensor 1 and gas sensor 2 are supplied with 3.4V and 3.58V respectively. The recommended voltage for both sensors to work properly is 5V.

iii) **Liquid Temperature Sensor**

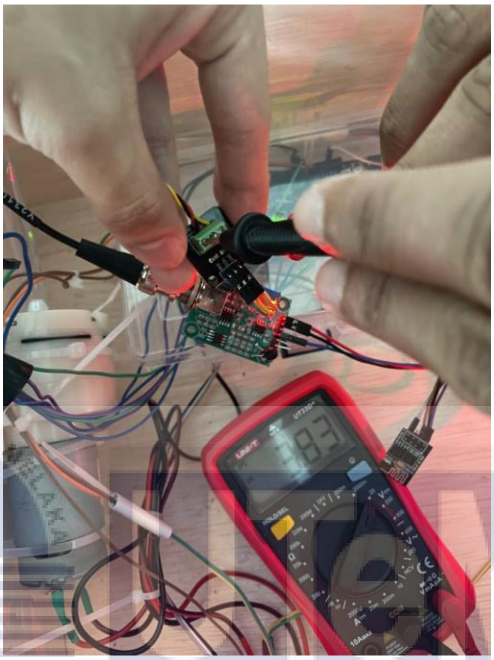


Figure 4.7 Supply to Temperature Sensor

It is shown in figure 4.7 the voltage supplied onto the temperature sensor is 3.83V. The rated voltage for the sensor to operate is at the range of 3V to 5V. The supplied Voltage is enough for the sensor to work properly.

4.2.2.4 System Operability

The brewing system is capable of functioning although there are some potential limitations in sensor performances that may impact the accuracy of the reading. It is important to be aware of supply parameter that could affect the whole system reliability and accuracy. The 5V pin in Arduino should give out the output voltage of 5V to each component. Wire resistance can contribute to the drop in voltage that is supplied onto each component. The longer the wire used, the higher the resistance and, thus, making the drop in voltage.

4.2.3 Compost Tea Brewing

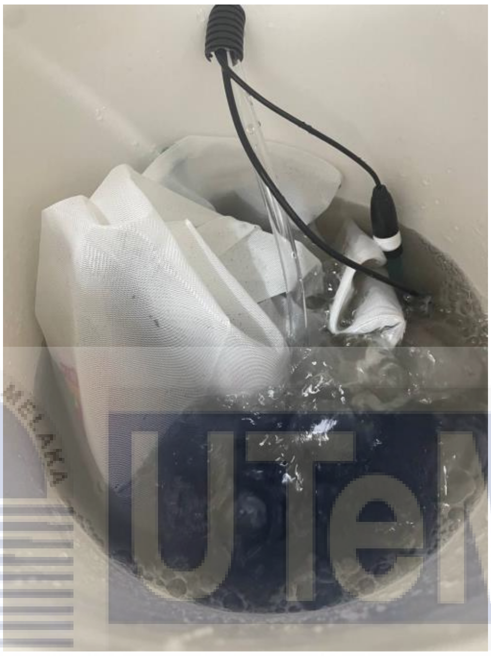


Figure 4.8 Making of Compost Tea

Figure 4.2 shows the brewing of compost tea by using the brewing system. The ratio from compost to water used for this brewing process is 1:5, where 1 kilogram of compost and 5 Liter of water is used. The process of brewing the compost tea will take several days, where 2 days are for brewing compost tea where operation are controlled by the system. 1 days taken for brewing compost tea controlled by the brewer user.

4.3 Data Analysis

4.3.1 Automatic Sequence

Automatic Sequence is when the system is run using the physical switch available for brewing compost tea. The sequence will be as follow:

i) Once the Switch is turn ON, it will run the Air Pump for 2 Hour.

ii) After 2 hours duration has passed, it will let liquid to sit for 1 hour.

iii) After 1 hour duration has passed, it will start sensor reading for 1 hour. Sensor reading will be sent to Blynk Application for remote monitoring.

iv) After 1 hour duration has passed, it will start air pump again. The sequence will keep running until the system is turned OFF.

The collection of data, it is the average of every 10 minutes in each cycle the sensor started reading.

4.3.1.1 Automatic Sequence Data Collection Day 1

Referring from the data collected in table 4.1, during this brewing process each sensor parameter are taken every 4 hours for a day. As seen on the table, the most important parameter for brewing the compost tea is the pH level and the liquid temperature. Both the sensor reading is on track for ideal parameter when brewing a compost tea. Until the final cycle at 24 hours mark, the pH level rise causing the Blynk notification to trigger. Indicating that the user should adjust check on the compost tea and adjust this parameter. The Co2 concentration differences between atmospheric (Atm) Co2 concentration and compost tea bin Co2 concentration will indicate the whether any microbial activity is occurring during the process. At the first 8-hour cycle of the brewing, it can be seen that the Bin Co2 concentration is lower than Atm co2. Blynk application will notify user indicating that there are no microbial activity occurring yet. But the reading can be seen to be fluctuated.

Table 4.1 Result Taken for Automatic Sequence Data Collection Day 1

Cycle	pH level	Blynk Notification	Temperature (°C)	Blynk Notification	Atm Co2 (ppm)	Bin Co2 (ppm)	Blynk Notification
4 hours	6.9	NO	28.7	NO	456	440	YES
8 hours	7	NO	28.6	NO	454	436	YES
12 hours	7.2	NO	28.6	NO	451	463	NO
16 hours	7.4	NO	28.8	NO	454	467	NO
20 Hour	7.3	NO	28.7	NO	467	484	NO
24 Hour	7.6	YES	28.6	NO	450	464	NO

4.3.1.2 Automatic Sequence Data Collection Day 2

The table 4.2 are the data obtained in day 2 for the automatic sequence of brewing system, the pH level started to fluctuate and increasing in value at its peak of 8.1, which might be due to the brewing system has been running nonstop for more than 24 hours. In this condition, the Blynk application sent a notification alerting user to adjust the pH parameter for the compost tea. The Co2 gas sensor shows a higher concentration in compost tea bin. This indicates that there currently microbial activity occurring during the process. Only at 12 hours mark, the Co2 concentration in the compost tea bin are lower than atm Co2. Blynk application sent the notification for this condition.

Table 4.2 Result Taken for Automatic Sequence Data Collection Day 2

Cycle	pH Sensor	Blynk Notification	Temperature (°C)	Blynk Notification	Atm Co2 (ppm)	Bin Co2 (ppm)	Blynk Notification
4 hours	7.4	NO	28.5	NO	440	445	NO
8 hours	7.8	YES	28.9	NO	469	483	NO
12 hours	7.8	YES	28.6	NO	463	444	YES
16 hours	7.5	YES	28.6	NO	457	478	NO
20 hours	7.9	YES	28.5	NO	464	472	NO
24 hours	8.1	YES	28.6	NO	467	468	NO

4.3.2 Manual Pump Control

Manual Pump Control refers to the ability of user to turn Air pump ON and OFF remotely by using Blynk Application. The sensor reading is taken from the average per 30 minutes every 2 hours duration.

4.3.2.1 First Trial

Table 4.3 refers to the first trial of manual air pump control, the air pump is turned on twice at the first 2-hour cycle and the last 2-hour cycle. The pH level and temperature of liquid during this brewing trial are all in ideal level. Thus, no notification is sent from Blynk application. As for the Co2 concentration difference from Atmosphere and compost tea bin, the co2 concentration in compost tea bin are higher than atmosphere co2 concentration occurs at the 6 hours to 8 hours cycle only. All the other cycle causes Blynk application to send notification to notify the user. The Co2 concentration value for both are also seen fluctuated.

Table 4.3 Result Taken from Manual Pump Control for First 12 Hours

Cycle	Air Pump	pH Sensor	Blynk Notification	Temperature (°C)	Blynk Notification	Atm Co2 (ppm)	Bin Co2 (ppm)	Blynk Notification
2 hours	ON	6.9	NO	27.6	NO	473	434	YES
4 hours	OFF	7	NO	28.3	NO	468	453	YES
6 hours	OFF	6.8	NO	28.5	NO	447	451	NO
8 hours	OFF	7	NO	28.1	NO	441	454	NO
10 hours	OFF	7.1	NO	28.3	NO	456	451	YES

Cycle	Air Pump	pH Sensor	Blynk Notification	Temperature (°C)	Blynk Notification	Atm Co2 (ppm)	Bin Co2 (ppm)	Blynk Notification
12 hours	ON	7.3	NO	28.1	NO	453	448	YES

4.3.2.2 Second Trial

Table 4.4 is the second trial of the manual pump control method and the same compost tea brewed from first trial are used. The air pump is only turned on once at the 4-hour cycle to supply oxygen in brewed liquid. The pH level and the liquid temperature in this trial is in the ideal parameter of brewing compost tea. The Blynk notification are sent only once during this trial which is on the 4-hour cycle where the Atm Co2 concentration is higher than in the bin Co2. The Co2 reading seem to be acceptable as the compost tea might have already started to manifest microbial activity.

Table 4.4 Result Taken from Manual Pump Control for First 12 Hours

Cycle	Air Pump	pH Sensor	Blynk Notification	Temperature (°C)	Blynk Notification	Atm Co2 (ppm)	Bin Co2 (ppm)	Blynk Notification
2 hours	OFF	7	NO	28.1	NO	454	473	NO
4 hours	ON	7.2	NO	28.3	NO	450	432	YES
6 hours	OFF	7.1	NO	28.3	NO	447	453	NO
8 hours	OFF	7	NO	28.5	NO	455	460	NO
10 hours	OFF	7.1	NO	28.4	NO	457	465	NO
12 hours	OFF	7.1	NO	28.3	NO	450	463	NO

4.3.3 Data Graph

When brewing a compost tea, there are certain important parameter that is ideal to make a perfect compost tea. As for the important parameter is the liquid temperature and pH level. The ideal parameter for temperature and pH level set for this system ranges from 13 °C to 30 °C and pH 6.8 to 7.4 respectively.

4.3.3.1 Automatic Sequence (Day 1)

The figure 4.9 shows the temperature graph for automatic sequences brewing process in day 1. From the graph above it is seen that the temperature is in the range of ideal temperature for brewing a compost tea. Hence, the temperature for brewing a compost tea is on track.

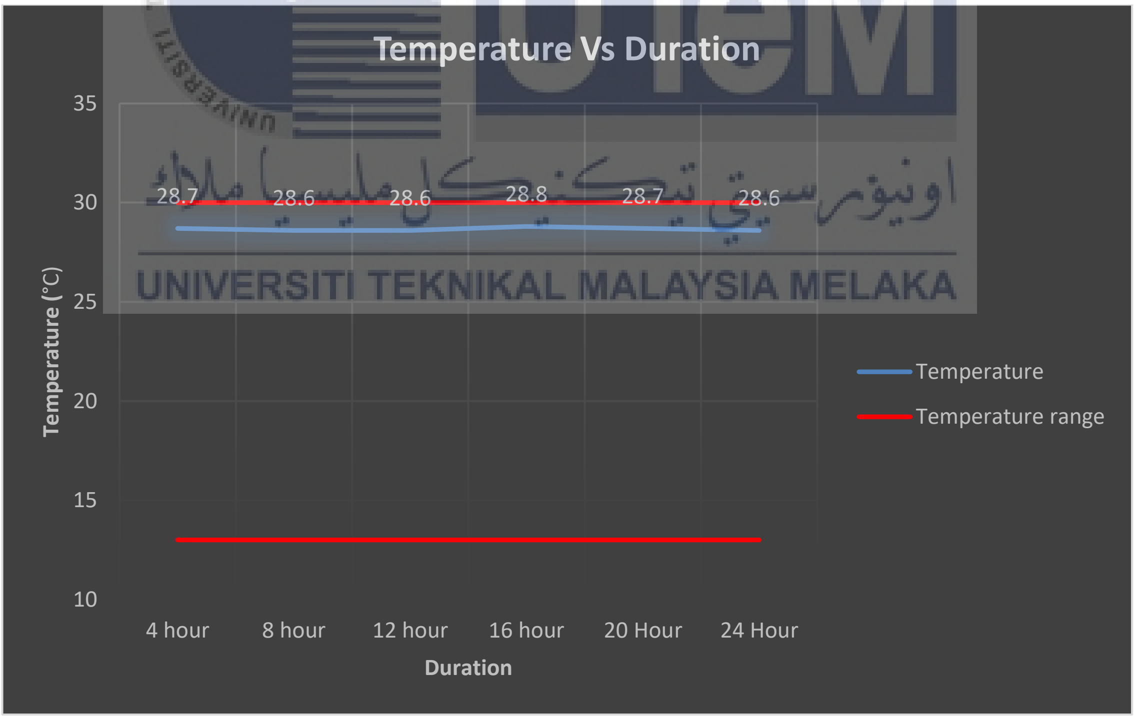


Figure 4.9 Automatic Sequence (Day 1), Temperature Graph

Figure 4.10 is the graph for pH level reading in automatic sequences of brewing compost tea using the system. In the first 20 hours, the pH level is in the range of ideal pH level when brewing compost tea. Reaching the 24-hour marks, the pH level is out of range for ideal pH level.

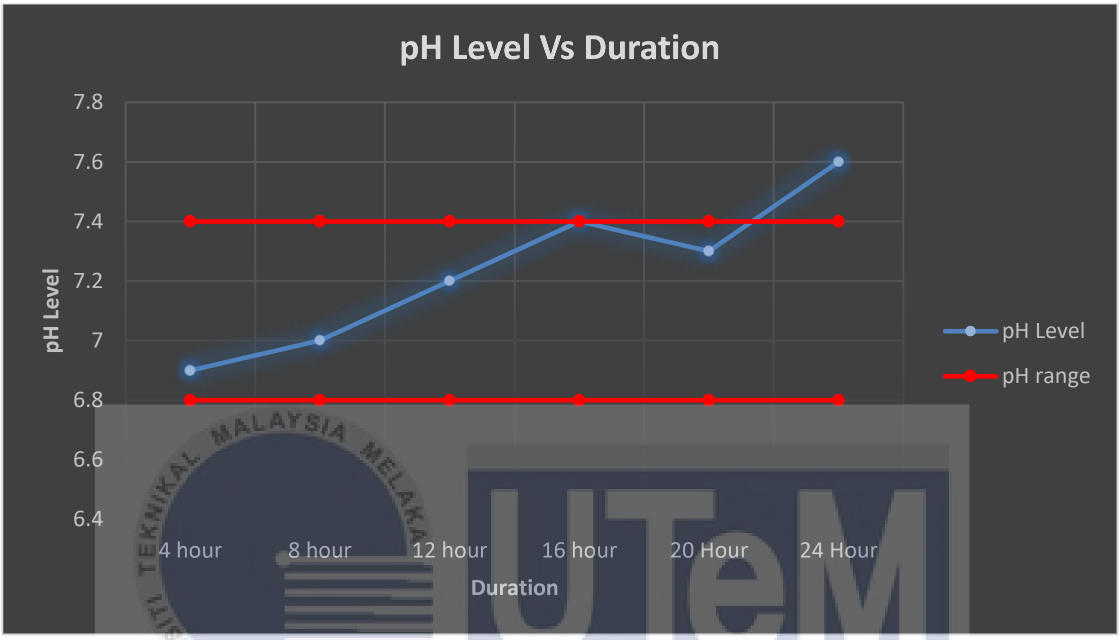


Figure 4.10 Automatic Sequence (Day 1), pH Level Graph

4.3.3.2 Automatic Sequences (Day 2)

Figure 4.11 is the chart for temperature graph for brewing process in automatic sequence in day 2. The temperature is seen to be in the ideal range for brewing a compost tea.

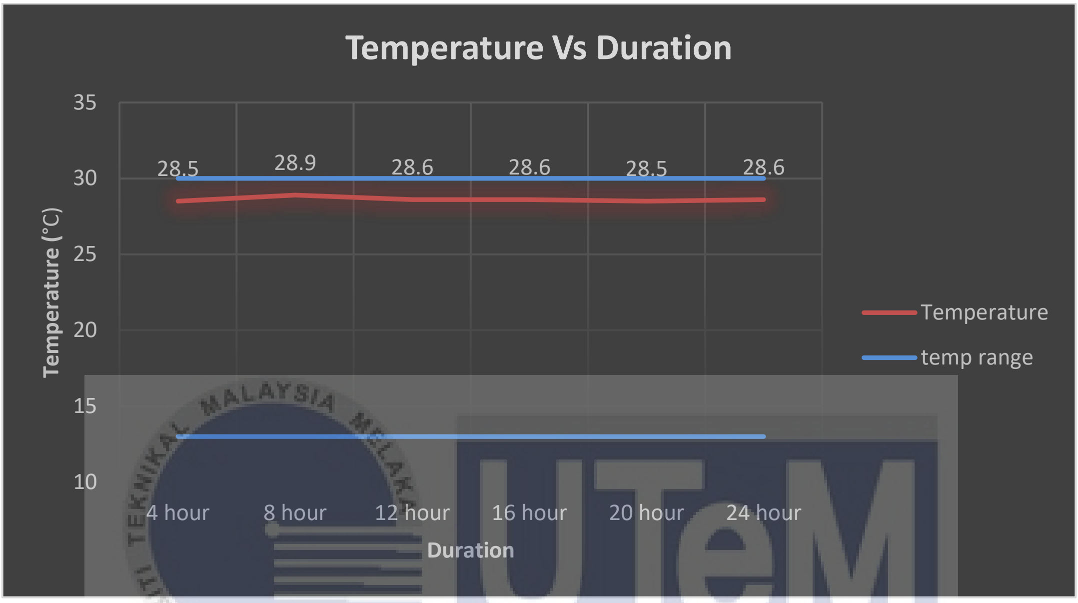


Figure 4.11 Automatic Sequence (Day 2), Temperature Graph

Figure 4.12 is the pH level graph for brewing process using the automatic sequence method when producing a compost tea. The line graph for pH level is outside of ideal pH parameter of brewing a compost tea. There are several considerations of why the value is outside of the pH range.

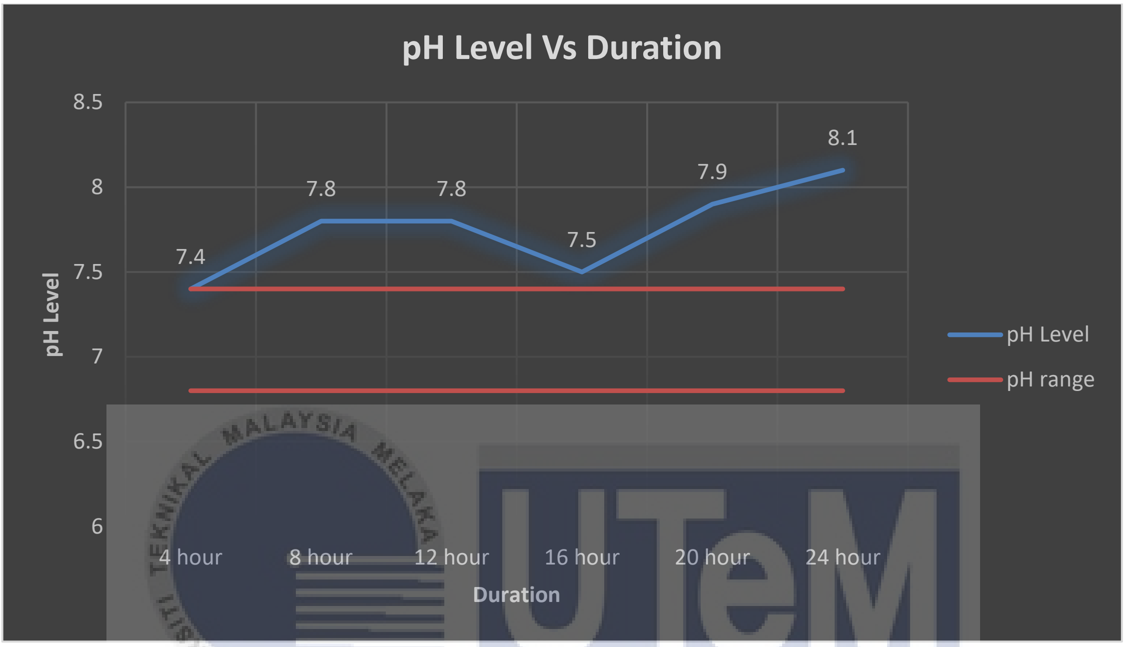


Figure 4.12 Automatic Sequences (Day 2), pH Level Graph

4.3.3.3 Manual Control (First Trial)

Figure 4.13 is the temperature graph, manual control method of brewing the compost tea for the first 12 hour. The temperature reading is on tracks where it is still in the range of brewing the tea.

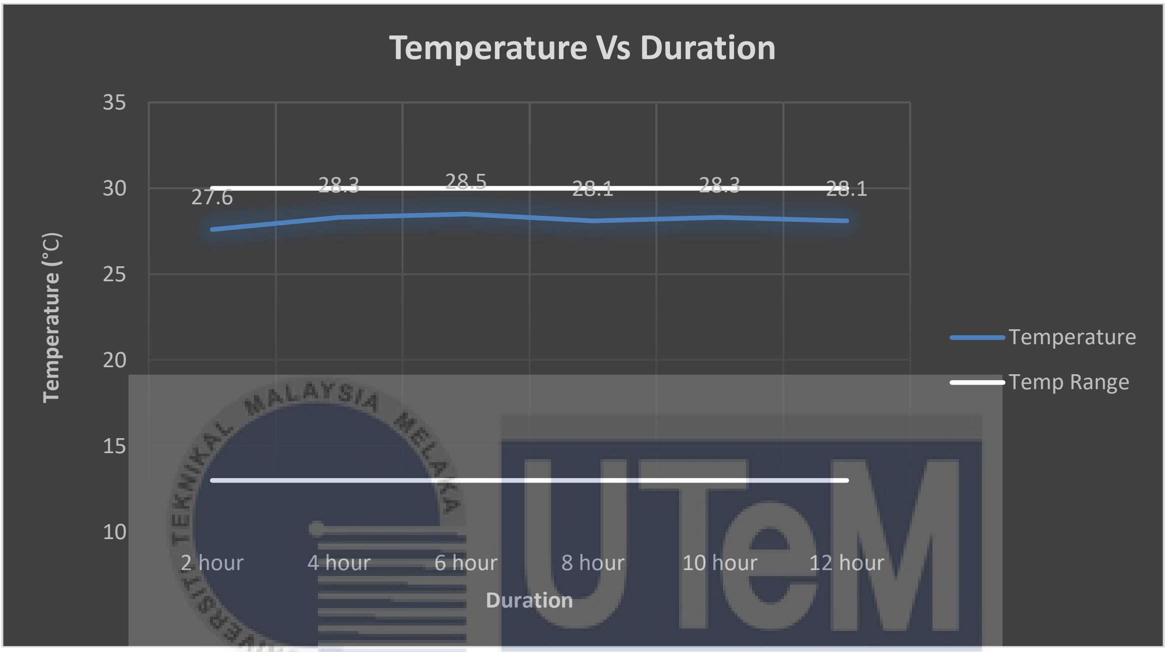


Figure 4.13 Manual Control (First 12 trial), Temperature Graph

Figure 4.14 refers to the pH Level graph of the manual control method for first trial of brewing compost tea in this method. It is shown in the graph the pH level is in the range of ideal pH level for the whole brewing process.

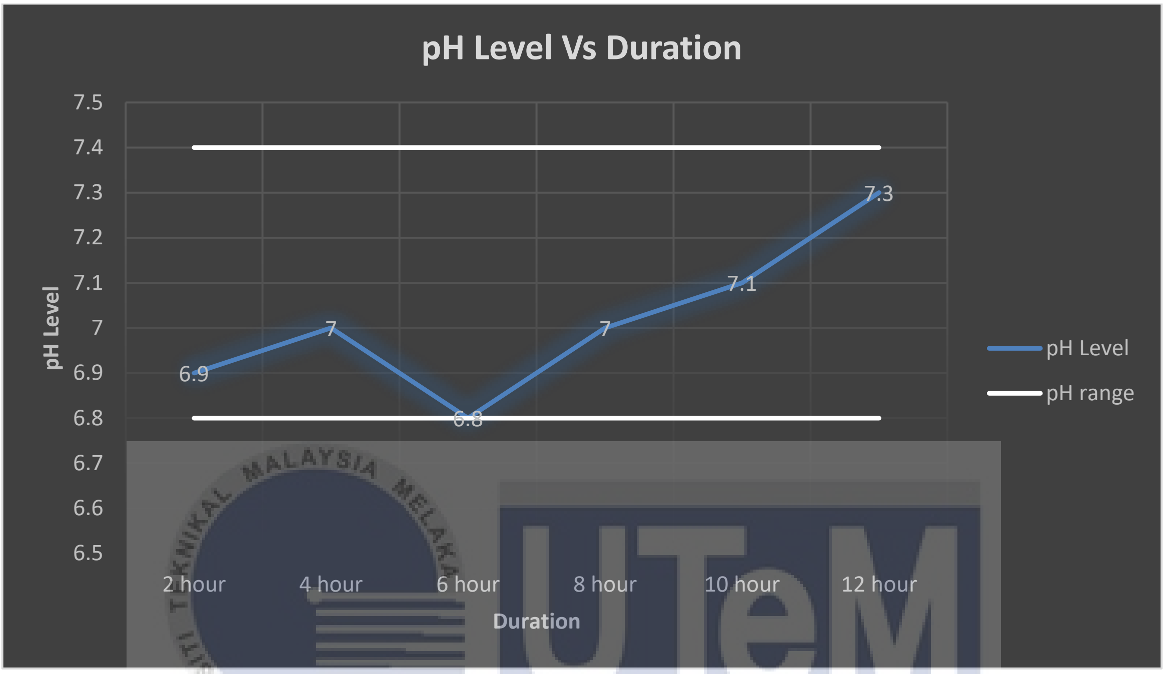


Figure 4.14 Manual Control (First Trial), pH Level Graph

4.3.3.4 Manual Control (Second Trial)

Figure 4.15 is the temperature graph for manual control of brewing process for the second trial which take a duration of 12 hour. As shown in the graph the temperature value is inside of the ideal temperature range for brewing compost tea.

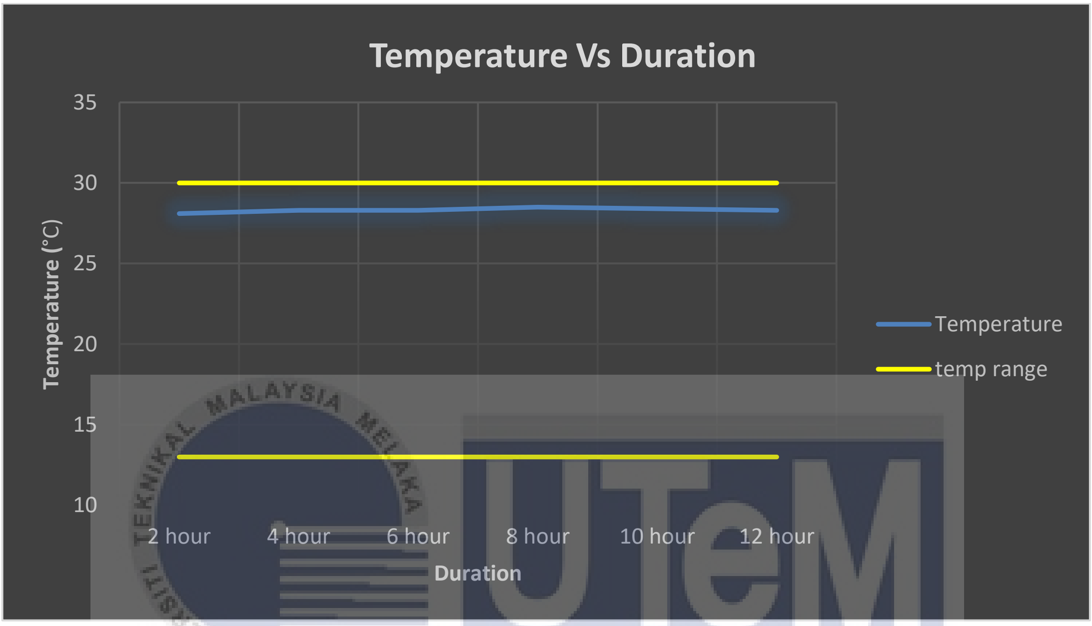


Figure 4.15 Manual Control (Second Trial), Temperature Graph

Figure 4.16 is the second trial pH level graph for manual control method of brewing compost tea. In the graph the pH level is seen to be in the range of perfect condition to brew a compost tea. This proves that the compost tea brewing is on the right condition.

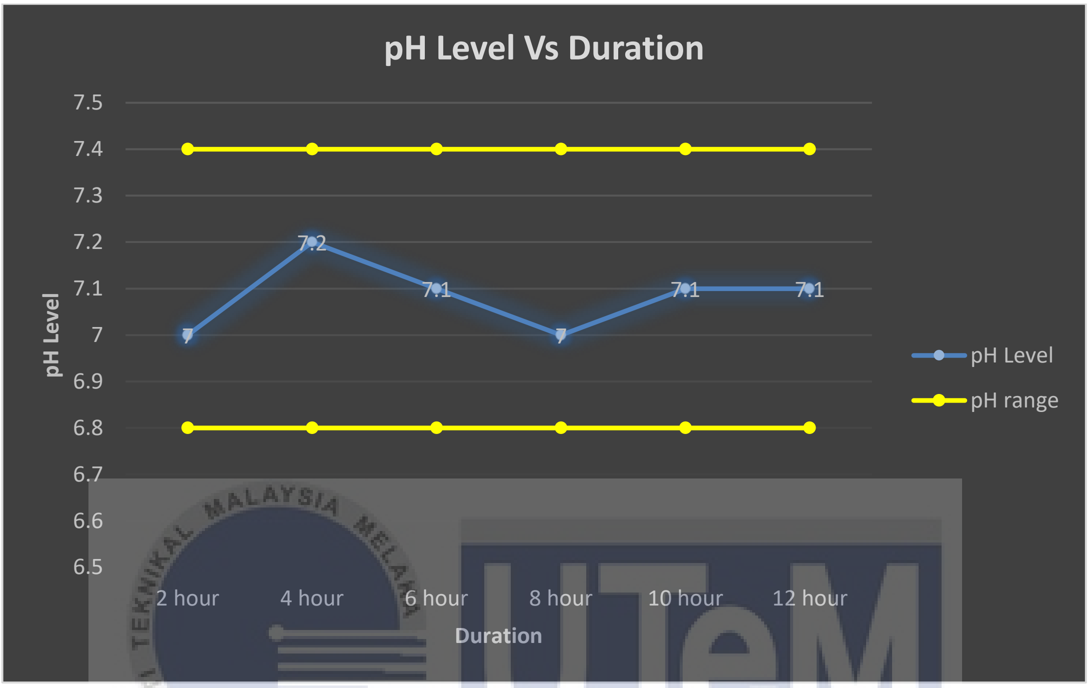


Figure 4.16 Manual Control (Second Trial), pH Level Graph

4.4 Discussion

Based on the result collected for this project, there are a few considerations need to be taken into place of why certain reading is not in its ideal ranges. Systematically thinking the pH reading from sensor can fluctuated due to faulty in sensor used, such as the sensor need constant calibration. Another logical reason is due to the pH sensor used are not working at its rated voltage. Hence, giving a reading that can affect the system reliability. In the condition of pH sensor are in perfect condition, user can try to adjust the pH level by adding any alkaline or acidic solvent into the compost tea. As for the fluctuated reading in Co2 concentration, this might be due to the sensor needs a more complex calibration method to detect co2 concentration properly.

4.5 Summary

Reviewing a thorough assessment of the system, it is proven that each sensor is performing its designated role effectively. The MQ135 gas sensor which is responsible for monitoring CO2 levels, occasionally displays readings with a slight variation. Similarly, the pH sensor, important for maintaining brewing compost tea pH level, needs periodic adjustments to maintain its accuracy in reading pH value of the brewing process.

An important feature of the system is its ability to issue alerts through the Blynk application which offers a real-time help during brewing process, especially the needs of user to start adjusting certain parameter such as temperature or pH level during brewing process.

In response to these observations, potential system enhancements are taken into consideration. This includes exploring the use of a more robust pH sensor that requires less frequent adjustment and using an alternative CO2 sensor known for reading a reliable and consistent readings. These adjustments aim to improve the system reliability without constant calibration of sensor used which can ensure a consistent and dependable performance over a long operational period. Finally, supplying enough rated voltage and current toward every component should be taken notes of, as it could also affect the sensor reading of the system

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the development of the IoT-based Smart Compost Tea Brewer has demonstrated the successful integration of Arduino microcontroller, sensors, and the Blynk IoT platform. The project has showcased its effectiveness and potential as a solution for sustainable agriculture. By leveraging technology, such as Arduino and IoT, the system automates and enhances the compost tea brewing process. Compost tea, as an organic alternative to synthetic fertilizers, offers numerous benefits for sustainable agriculture. It harnesses the power of beneficial microorganisms and organic matter to improve soil fertility, enhance plant health, and reduce the reliance on chemical inputs.

The Smart Compost Tea Brewer, with its controlled brewing process and sensor monitoring, ensures the production of high-quality compost tea with optimal nutrient content. The utilization of the Blynk IoT platform adds convenience and flexibility to the system. Through the Blynk mobile or web-based interface, users can remotely monitor and control the compost tea brewing process, making it more efficient and user-friendly. Despite the successful implementation, it is important to acknowledge the limitations and challenges faced during the development. These may include power supply management, scalability for larger-scale applications, and the complexity of programming and system integration.

Future research and development efforts should focus on addressing these challenges to further improve the system's efficiency and scalability. In summary, the IoT-based Smart Compost Tea Brewer, powered by Arduino and integrated with the Blynk IoT platform, presents an innovative solution for sustainable agriculture. It showcases the potential of technology in optimizing compost tea production, promoting eco-friendly farming practices, and contributing to the goal of achieving a more sustainable and environmentally conscious agricultural industry.

5.2 Future Works

In future works, it is recommended to use a much robust component such as the sensor. This includes the pH sensor and gas sensor for detecting Carbon Dioxide (Co2) concentration. Which require repetitive calibration from time to time. The pH sensor used in this project tends to broke and the sensor reading will be off as it intended to. Though MQ135 gas sensor is a cheaper alternative to works as a Co2 concentration sensor. The sensor does not read the exact Co2 concentration in surrounding area. The design of the project is only to be demonstrate in a controlled condition. Hence, it is recommended to improve this project overall so that it can be implemented to real life usage.

REFERENCES

[1] A. Sharma and R. Chetani, "A Review on the Effect of Organic and Chemical Fertilizers on Plants," International Journal of Applied Science and Engineering, vol. 5, pp. 677–680, Jul. 2020.

[2] I. Zhang, "Composting: The Path to Sustainable Agriculture and Waste Management," Global Research and Consulting Group Insights, Apr. 26, 2021. https://insights.grcglobalgroup.com/composting-the-path-to-sustainable-agriculture-and-waste-management/ (accessed Jun. 05, 2023).

[3] Ayilara, Modupe Stella, Olanrewaju, Oluwaseyi Samuel, O. O. Babalola, and O. Odeyemi, "Waste management through composting: Challenges and potentials," Sustainability, vol. 12, Art. no. 11, 2020, doi: https://doi.org/10.3390/su12114456.

[4] A. Nofal, M. ElRahman, A. Alharbi, and T. Abdelghany, "Compost tea for agriculture," pp. 6378–6391, Jan. 2021.

[5] B. Sonja, S. Johan, F. Gail, I. Chuck, and C. David, "Sustainable Agriculture," Knowledge Project, 2011, Accessed: May 26, 2023. [Online]. Available: https://www.nature.com/scitable/knowledge/library/sustainable-agriculture-23562787/#

[6] A. Trigo, A. Marta-Costa, and R. Fragoso, "Principles of sustainable agriculture: Defining standardized reference points," Sustainability, vol. 13, Art. no. 8, 2021.

[7] R. Lal, "Soil erosion and the global carbon budget," Environment international, vol. 29, Art. no. 4, 2003.

[8] M. Altieri and C. Nicholls, Biodiversity and pest management in agroecosystems. CRC press, 2004.

[9] A. Makki, S. Thiruvengadachari, Ibrahim, and Taib, Mohd Nasir, “Rainwater harvesting techniques and sustainable agriculture: A comprehensive review,” Journal of Cleaner Production, vol. 196, pp. 742–762, 2018.

[10] F. Baptista, E. Lorencowicz, L.L Silva and J.R.M Da Silva, “Energy efficiency in agriculture,” in Complete Communications of the 5th International Congress on Energy and Environment Engineering and Management, 2013.

[11] Seid Hussen Muhie, “Novel approaches and practices to sustainable agriculture,” Journal of Agriculture and Food Research, vol. 10, p. 100446, 2022, doi: https://doi.org/10.1016/j.jafr.2022.100446.

[12] S. Jose, “Agroforestry for ecosystem services and environmental benefits: An overview,” Agroforestry Systems, vol. 76, pp. 1–10, May 2009, doi: https://doi.org/10.1007/s10457-009-9229-7.

[13] A. Arora, L. K. Saha, S. Marwaha, R. Jain, and A. K. Jha, “Online system for integrated pest management on tomato in AGRIdaksh,” 2015, pp. 1125–1129.

[14] B. Ramakrishnan, Naga Raju Maddela, Kadiyala Venkateswarlu, and Mallavarapu Megharaj, “Organic farming: Does it contribute to contaminant-free produce and ensure food safety?” Science of The Total Environment, vol. 769, p. 145079, 2021, doi: https://doi.org/10.1016/j.scitotenv.2021.145079.

[15] Umama Begum Ruba and M. Samiul, “Potentiality of homestead agroforestry for achieving sustainable development goals: Bangladesh perspectives,” Heliyon, vol. 9, Art. no. 3, 2023, doi: https://doi.org/10.1016/j.heliyon.2023.e14541.

[16] A. Smith and I. Serna, “The Importance of Sustainable Agriculture,” Plug and Play Tech Center, Apr. 25, 2023. https://www.plugandplaytechcenter.com/resources/importance-sustainable-agriculture/ (accessed May 29, 2023).

[17] P. Bondarenko, “Fair trade | history, criticism, & facts,” Britannica, Jan. 2018. https://www.britannica.com/topic/fair-trade

[18] K. G. Liakos, P. Busato, D. Moshou, S. Pearson, and D. Bochtis, “Machine learning in agriculture: A review,” Sensors, vol. 18, Art. no. 8, 2018, doi: https://doi.org/10.3390/s18082674.

[19] I. Sarkar, “Internet of Things in Agriculture - IoTEDU,” IoTEDU, Apr. 18, 2020. https://iot4beginners.com/internet-of-things-in-agriculture/ (accessed May 29, 2023).

[20] L. Sokolova, “Council Post: What To Know About Smart Farming Using IoT,” Forbes, Sep. 22, 2021. Accessed: Jun. 09, 2023. [Online]. Available: https://www.forbes.com/sites/forbestechcouncil/2021/09/22/what-to-know-about-smart-farming-using-iot/?sh=5bf372056afb

[21] A. Subeesh and C. R. Mehta, “Automation and digitization of agriculture using artificial intelligence and internet of things,” Artificial Intelligence in Agriculture, vol. 5, pp. 278–291, 2021, doi: https://doi.org/10.1016/j.aiia.2021.11.004.

[22] A. Owade, “Three major obstacles for IoTs in agriculture - CGIAR Platform for Big Data in Agriculture,” CGIAR Platform for Big Data in Agriculture, Oct. 11, 2018. https://bigdata.cgiar.org/three-major-obstacles-for-iots-in-agriculture/ (accessed May 29, 2023).

[23] J. Kaur, Fard, M. Amiri-Zarandi, and R. Dara, “Protecting farmers’ data privacy and confidentiality: Recommendations and considerations,” Frontiers Media SA, 2022.

[24] R. Finger, S. M. Swinton, El Benni, Nadja, and A. Walter, “Precision farming at the nexus of agricultural production and the environment,” Annual Review of Resource Economics, vol. 11, pp. 313–335, 2019.

[25] Sishodia, Rajendra P, R. L. Ray, and S. K. Singh, "Applications of remote sensing in precision agriculture: A review," Remote Sensing, vol. 12, Art. no. 19, 2020, doi: https://doi.org/10.3390/rs12193136.

[26] S. Thomas, "Precision Farming: 7 Ways It Benefits Your Farm - Farmers Edge," Farmers Edge, Aug. 25, 2020. https://farmersedge.ca/precision-farming-7-ways-it-benefits-your-farm/ (accessed May 29, 2023).

[27] P. Kogut, "Precision Agriculture: Technology To Boost Crop Farming," EOS Data Analytics, Apr. 20, 2022. https://eos.com/blog/precision-agriculture/ (accessed Jun. 10, 2023).

[28] S. Fowler, "Precision agriculture technology helps farmers - but they need help," NPR, Apr. 27, 2023. https://www.npr.org/2023/04/27/1172434673/precision-agriculture-technology-helps-farmers-but-they-need-help (accessed May 29, 2023).

[29] K. Rundell, "5 Challenges For Precision Agriculture To Face | AgriTechTomorrow," Agritechtomorrow.com, Sep. 28, 2020. https://www.agritechtomorrow.com/story/2020/09/5-challenges-for-precision-agriculture-to-face-/12399/ (accessed May 29, 2023).

[30] D. Cleary, "Precision Agriculture: Potential and Limits," The Nature Conservancy, Mar. 29, 2017. https://www.nature.org/en-us/what-we-do/our-insights/perspectives/precision-agriculture-potential-and-limits/ (accessed Jun. 10, 2023).

[31] Raj Kishan Agrahari, Y. Kobayashi, T. Tanaka, Sanjib Kumar Panda, and H. Koyama, "Smart fertilizer management: the progress of imaging technologies and possible implementation of plant biomarkers in agriculture," Soil Science and Plant Nutrition, vol. 67, Art. no. 3, 2021, doi: https://doi.org/10.1080/00380768.2021.1897479.

[32] I. R. R, M. Hasanuzzaman, A. Pervin, R. M. H, and H. A. A, “Smart fertilizer management for sustainable crop production,” in IEEE, 2019, pp. 517–522. doi: https://doi.org/10.1109/ICREST.2019.8677227.

[33] G. Hochmuth, R. Mylavarapu, and E. Hanlon, “Soil testing for plant-available Nutrients—What is it and why do we use it?,” 2015.

[34] T. J. Mattila and J. Rajala, “Do different agronomic soil tests identify similar nutrient deficiencies?” Soil Use and Management, vol. 38, Art. no. 1, 2022.

[35] T. Chang, G. Feng, V. Paul, Ardeshir Adeli, and J. P. Brooks, “Chapter Three - Soil health assessment methods: Progress, applications and comparison,” in Advances in Agronomy, vol. 172, A. M. Jackman and N. E. Mendoza, Eds. Academic Press, 2022, pp. 129–210. doi: https://doi.org/10.1016/bs.agron.2021.10.002.

[36] J. C. Negrete, E. R. Kriuskova, G. De, C. Israel, and G. L. Hernandez, “Arduino board in the automation of agriculture in Mexico, a review,” International Journal of Horticulture, vol. 8, 2018.

[37] R. K. Kodali and A. Sahu, “An IoT based soil moisture monitoring on Losant platform,” in IEEE, 2016, pp. 764–768.

[38] N. Putjaika, S. Phusae, A. Chen-Im, P. Phunchongharn, and K. Akkarajitsakul, “A control system in an intelligent farming by using arduino technology,” in IEEE, 2016, pp. 53–56.

[39] Abdelshafy, Sohila Ahmed, “REVIEW ON ARDUINO AND ITS APPLICATION IN AGRICULTURE,” May 2023.

[40] S. Bennbaia, A. Wazwaz, A. Abujarbou, G. M. Abdella, and F. Musharavati, “Towards sustainable society: Design of food waste recycling machine,” 2018, pp. 6–8.

[41] G. Chiplunkar and A. More, “Design of kitchen waste composting machine: A smart approach,” *Internasional Journal of Trend in Research and Development*, vol. 5, Art. no. 3, 2018.

[42] V. A. Wardhany, A. Hidayat, and A. Afandi, “Smart chopper and monitoring system for composting garbage,” in *IEEE*, 2019, pp. 74–78.

[43] V. Oree and Maudhoo, Veeneet Anand, “A microcontroller-based household anaerobic food digester,” in *IEEE*, 2015, pp. 1–6.

[44] R. Barrena and A. Sánchez, “Home composting: A review of scientific advances,” Engineering Proceedings, vol. 19, Art. no. 1, 2022.

[45] M. Khan et al., “Way of Compost Application for Organic Farming,” SAARC Journal of Agriculture, vol. 17, Art. no. 1, 2019.

[46] M. Petruzzello, “Compost | description, composition, & process,” May 2023. https://www.britannica.com/topic/compost

[47] J. Bruggers, “Your Trash Is Emitting Methane In The Landfill. Here’s Why It Matters For The Climate,” NPR, Jul. 13, 2021. https://www.npr.org/2021/07/13/1012218119/epa-struggles-to-track-methane-from-landfills-heres-why-it-matters-for-the-clima (accessed Jun. 10, 2023).

[48] D. Lipford, “What Nutrients Can Be Found in Compost? - Today’s Homeowner,” Today’s Homeowner, Mar. 08, 2011. https://todayshomeowner.com/lawn-garden/guides/what-nutrients-can-be-found-in-compost/ (accessed May 30, 2023).

[49] L. R. Cooperband, “Composting: art and science of organic waste conversion to a valuable soil resource,” Laboratory medicine, vol. 31, Art. no. 5, 2000.

[50] J. Winger, “How to Make Compost Tea • The Prairie Homestead,” The Prairie Homestead, Jul. 28, 2016. https://www.theprairiehomestead.com/2016/07/compost-tea-recipe.html (accessed May 29, 2023).

[51] S. J. Scheuerell, "Compost tea production practices, microbial properties, and plant disease suppression," in Citeseer, 2004, vol. 10, pp. 313–338.

[52] Manasa Reddigari, "All You Need to Know About Compost Tea," Bob Vila, Nov. 15, 2017. https://www.bobvila.com/articles/compost-tea/ (accessed Jun. 10, 2023).

[53] V. Joe, C. Rock, and J. McLain, "Compost tea 101: what every organic gardener should know," College of Agriculture, University of Arizona (Tucson, AZ), 2017.

[54] T. Greer, "How to Make and Use Aerated Compost Tea (ACT) in Your Garden," Morning Chores, Apr. 08, 2019. https://morningchores.com/aerated-compost-tea/ (accessed Jun. 13, 2023).

[55] T. O'Neill, "Top Benefits of Compost Tea," Simplifygardening.com, May 28, 2023. https://simplifygardening.com/top-benefits-of-compost-tea/ (accessed Jun. 10, 2023).

[56] H. Shaban, B. Fazeli-Nasab, H. Alahyari, G. Alizadeh, and S. Shahpesandi, "An overview of the benefits of compost tea on plant and soil structure.," Advances in Bioresearch, vol. 6, Art. no. 1, 2015.

[57] L. Khalil and Edson Luiz Furtado, "Chapter 4 - The effect of incompatible plant pathogens on the host plant," in Molecular Aspects of Plant Beneficial Microbes in Agriculture, V. Sharma, Richa Salwan, and L. Khalil, Eds. Academic Press, 2020, pp. 47–57. doi: https://doi.org/10.1016/B978-0-12-818469-1.00004-3.

[58] L. Reddington, "How Fertilizers Harm Earth More Than Help Your Lawn," Scientific American, Jul. 20, 2009. https://www.scientificamerican.com/article/how-fertilizers-harm-earth/# (accessed May 29, 2023).

[59] Silvia, "Everthing You Need To Know About Compost Tea pH | A Special Tea For Your Garden," Enviromom.com, Dec. 2021. https://enviromom.com/compost-tea-ph/ (accessed May. 29, 2023).

APPENDICES

Appendix 1 Full System Code

```
//Blynk
#define BLYNK_TEMPLATE_ID "TMPL60TF0fSXa"
#define BLYNK_TEMPLATE_NAME "Arduino Mega 2560"
#define BLYNK_AUTH_TOKEN "iluKNZph2RKioFcXnobRyP1vZ9AaZTL_"

#define BLYNK_PRINT Serial

#include <ESP8266_Lib.h>
#include <BlynkSimpleShieldEsp8266.h>

char ssid[] = "wifi name";
char pass[] = "password ";

#define EspSerial Serial1

#define ESP8266_BAUD 115200

ESP8266 wifi(&EspSerial);

BlynkTimer timer;

//I2c lcd screen
#include <LiquidCrystal_I2C.h>
#include <Wire.h>
LiquidCrystal_I2C lcd(0x27, 16, 2);

//motor
#define enA 3
#define in1 4
#define in2 5

//ds18b20 temp
#include <OneWire.h>
#include <DallasTemperature.h>
#define ONE_WIRE_BUS 22
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);

//phsensor
float calibration_value = 21.54;
int phval = 0;
unsigned long int avgval;
int buffer_arr[10], temp;
```

```
//mq135sensor
#define S1 A0
#define S2 A1
const int co2Zero1 = 180;
const int co2Zero2 = 160;

unsigned long startTime;
unsigned long duration;

const int Auto = 7;

bool brew = false;
bool brewDisplayed = false;
bool go = false;

float manco2ppmout;
float manco2ppmin;
float ph_actman;
float temperatureCelsiusman;

BLYNK_WRITE(V3) {
  int state = param.asInt();
  bool go = false;
  if (state == 1) {

    lcd.init();
    lcd.print(" Motor Running");
    delay(1000);

    digitalWrite(in1, HIGH);
    digitalWrite(in2, LOW);
    analogWrite(enA, 255);

  }

  else {

    lcd.init();
    lcd.print(" Motor Stopped");

    digitalWrite(in1, LOW);
    digitalWrite(in2, LOW);
    analogWrite(enA, 0);
  }
}

void setup() {
```

```
  //Blynk
  Serial.begin(115200);
  EspSerial.begin(ESP8266_BAUD);

  lcd.init();
  lcd.backlight();
  lcd.begin(16, 2);
  lcd.print("Connecting to");
  lcd.setCursor(0, 1);
  lcd.print("Blynk...");

  Blynk.begin(BLYNK_AUTH_TOKEN, wifi, ssid, pass);

  while (Blynk.connect() == false) {
    delay(500);
  }

  timer.setInterval(10000L,sensorread);
  timer.setInterval(1000*2*60L,warning);

  lcd.init();
  lcd.setCursor(5, 0);
  lcd.print("Blynk");
  lcd.setCursor(2, 1);
  lcd.print("Connected!");

  delay(500);

  pinMode(enA, OUTPUT);
  pinMode(in1, OUTPUT);
  pinMode(in2, OUTPUT);
  digitalWrite(in1, LOW);
  digitalWrite(in2, HIGH);

  sensors.begin();

  pinMode(S1, INPUT);
  pinMode(S2, INPUT);

  pinMode(Auto, INPUT_PULLUP);

  Serial.begin(9600);

  lcd.init();
  lcd.print("Brewer Ready");
  delay(1000);
}
```

```
void loop() {

  Blynk.run();
  timer.run();

  if (brew == false) {
    lcd.init();
    lcd.print("   Auto Mode  ");
    lcd.setCursor(0, 1);
    lcd.print("    Switch     ");
    delay(500);
    lcd.init();
    lcd.print("  Manual Mode  ");
    lcd.setCursor(0, 1);
    lcd.print("     Blynk     ");
  } else {
  }
  int state = digitalRead(Auto);
  if (state == HIGH) {

    if (!brewDisplayed) {
      lcd.init();
      lcd.print(" BREWER RUNNING");
      delay(1000);
      brewDisplayed = true;
    }
    brew = true;
    go = true;
    delay(500);
    duration = millis() - startTime;
    Serial.println("ON SUDAAA - ");
    Serial.print(duration);
    delay(1000);


    unsigned long elapsedTime = duration % 14400000UL;  // Cycle every 4
hour

    if (elapsedTime < 7200000UL && state == HIGH) {

      digitalWrite(in1, HIGH);
      digitalWrite(in2, LOW);
      analogWrite(enA, 255);

      lcd.init();
      lcd.print("Pump Running...");
```

```
  } else if (elapsedTime < 10800000UL && state == HIGH) {
    digitalWrite(in1, LOW);
    digitalWrite(in2, LOW);
    analogWrite(enA, 0);

    lcd.init();
    lcd.setCursor(0, 0);
    lcd.print("Brewing...");
  }

  else {

    liqtemp();

    ph();

    co2();
  }

}

else {
  brew = false;
  startTime = millis();

  if (go == true) {
    digitalWrite(in1, LOW);
    digitalWrite(in2, LOW);
    analogWrite(enA, 0);
    go = false;
  }
  lcd.init();
  lcd.print("   System OFF");

  brewDisplayed = false;

  float temperatureCelsius = 0;
  float ph_act = 0;
  float co2ppmout = 0;
  float co2ppmin = 0;

  Blynk.virtualWrite(V6, temperatureCelsius);
  Blynk.virtualWrite(V2, ph_act);
  Blynk.virtualWrite(V1, co2ppmout);
  Blynk.virtualWrite(V0, co2ppmin);
```

```
  }
}



void liqtemp() {

  sensors.requestTemperatures();

  float temperatureCelsius = sensors.getTempCByIndex(0);

  Blynk.virtualWrite(V6, temperatureCelsius);
  if (temperatureCelsius < 24 || temperatureCelsius > 34) {
    Blynk.logEvent("temperature_is_undersired");
  }

  lcd.init();
  lcd.setCursor(0, 0);
  lcd.print("Temp: ");
  lcd.setCursor(6, 0);
  lcd.print(temperatureCelsius);
  lcd.setCursor(14, 0);
  lcd.print(" C");
}

void ph() {
  for (int i = 0; i < 10; i++) {
    buffer_arr[i] = analogRead(A2);
    delay(30);
  }
  for (int i = 0; i < 9; i++) {

    for (int j = i + 1; j < 10; j++) {

      if (buffer_arr[i] > buffer_arr[j]) {

        temp = buffer_arr[i];
        buffer_arr[i] = buffer_arr[j];
        buffer_arr[j] = temp;
      }
    }
  }
  avgval = 0;
  for (int i = 2; i < 8; i++)
    avgval += buffer_arr[i];
  float volt = (float)avgval * 4.2 / 1024 / 6;
  float ph_act = -5.70 * volt + calibration_value;
```

```
  lcd.init();
  lcd.setCursor(0, 0);
  lcd.print("pH Val:");
  lcd.setCursor(9, 0);
  lcd.print(ph_act);

  Blynk.virtualWrite(V2, ph_act);
  if (ph_act < 6.8 || ph_act > 7.4) {
    Blynk.logEvent("undesired_ph_detected");
  }
}

void co2() {

  int co2nowout[10];
  int co2nowin[10];
  int co2rawout = 0;
  int co2rawin = 0;
  int co2ppmout = 0;
  int co2ppmin = 0;
  int aveout = 0;
  int avein = 0;

  for (int x = 0; x < 10; x++) {
    co2nowout[x] = analogRead(A0);
    co2nowin[x] = analogRead(A1);
    delay(200);
  }

  for (int x = 0; x < 10; x++) {
    aveout = aveout + co2nowout[x];
    avein = avein + co2nowin[x];
  }

  co2rawout = aveout / 10;
  co2rawin = avein / 10;

  co2ppmout = co2rawout + co2Zero1;
  co2ppmin = co2rawin + co2Zero2;

  lcd.init();
  lcd.setCursor(0, 0);
  lcd.print("In CO2 : ");
  lcd.setCursor(8, 0);
  lcd.print(co2ppmin);
  lcd.setCursor(0, 1);
  lcd.print("Out CO2: ");
  lcd.setCursor(8, 1);
```

```
  lcd.print(co2ppmout);

  Blynk.virtualWrite(V1, co2ppmout);
  Blynk.virtualWrite(V0, co2ppmin);

  if(co2ppmin<co2ppmout){
  Blynk.logEvent("undesired_ph_detected");
  }
}

//////////////////////////////////////////////////////////
void sensorread(){
  //
  sensors.requestTemperatures();
  float temperatureCelsiusman = sensors.getTempCByIndex(0);
  //
    for (int i = 0; i < 10; i++) {
    buffer_arr[i] = analogRead(A2);
    delay(30);
  }
  for (int i = 0; i < 9; i++) {

    for (int j = i + 1; j < 10; j++) {

      if (buffer_arr[i] > buffer_arr[j]) {

        temp = buffer_arr[i];
        buffer_arr[i] = buffer_arr[j];
        buffer_arr[j] = temp;
      }
    }
  }
  avgval = 0;
  for (int i = 2; i < 8; i++)
    avgval += buffer_arr[i];
  float volt = (float)avgval * 4.2 / 1024 / 6;
  float ph_actman = -5.70 * volt + calibration_value;
  //
  int co2nowout[10];
  int co2nowin[10];
  int co2rawout = 0;
  int co2rawin = 0;
  int manco2ppmout = 0;
  int manco2ppmin = 0;
  int aveout = 0;
  int avein = 0;

  for (int x = 0; x < 10; x++) {
```

```
    co2nowout[x] = analogRead(A0);
    co2nowin[x] = analogRead(A1);
    delay(200);
  }

  for (int x = 0; x < 10; x++) {
    aveout = aveout + co2nowout[x];
    avein = avein + co2nowin[x];
  }

  co2rawout = aveout / 10;
  co2rawin = avein / 10;

  manco2ppmout = co2rawout + co2Zero1;
  manco2ppmin = co2rawin + co2Zero2;

  Blynk.virtualWrite(V7, manco2ppmout);
  Blynk.virtualWrite(V8, manco2ppmin);
  Blynk.virtualWrite(V5, ph_actman);
  Blynk.virtualWrite(V4, temperatureCelsiusman);
}

void warning(){
  //
  sensors.requestTemperatures();
  float temperatureCelsiusman = sensors.getTempCByIndex(0);
  //
    for (int i = 0; i < 10; i++) {
    buffer_arr[i] = analogRead(A2);
    delay(30);
  }
  for (int i = 0; i < 9; i++) {

    for (int j = i + 1; j < 10; j++) {

      if (buffer_arr[i] > buffer_arr[j]) {

        temp = buffer_arr[i];
        buffer_arr[i] = buffer_arr[j];
        buffer_arr[j] = temp;
      }
    }
  }
  avgval = 0;
  for (int i = 2; i < 8; i++)
    avgval += buffer_arr[i];
  float volt = (float)avgval * 4.2 / 1024 / 6;
  float ph_actman = -5.70 * volt + calibration_value;
```

```
  //
  int co2nowout[10];
  int co2nowin[10];
  int co2rawout = 0;
  int co2rawin = 0;
  int manco2ppmout = 0;
  int manco2ppmin = 0;
  int aveout = 0;
  int avein = 0;

  for (int x = 0; x < 10; x++) {
    co2nowout[x] = analogRead(A0);
    co2nowin[x] = analogRead(A1);
    delay(200);
  }

  for (int x = 0; x < 10; x++) {
    aveout = aveout + co2nowout[x];
    avein = avein + co2nowin[x];
  }

  co2rawout = aveout / 10;
  co2rawin = avein / 10;

  manco2ppmout = co2rawout + co2Zero1;
  manco2ppmin = co2rawin + co2Zero2;

  if (temperatureCelsiusman < 24 || temperatureCelsiusman > 34) {
    Blynk.logEvent("man_temp");
  }

  if (ph_actman < 6.8 || ph_actman > 7.4) {
    Blynk.logEvent("manph");
  }

  if(manco2ppmin<manco2ppmout){
    Blynk.logEvent("man_co2");
  }
}
```

Appendix 2 Gantt Chart for BDP 1

No.	Task Description	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	BDP 1 Briefing														
2	Title Selection & Submission														
3	Component Review														
4	Software Review														
5	Purchasing of Component														
6	Literature Research														
7	Report Writing														
8	Report Draft Submission to Supervisor														
9	Report Adjustment														
10	Final Report Submission														
11	BDP 1 Presentation														

Planning -
Actual -

Appendix 3 Gantt Chart for BDP2

No.	Task Description	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	BDP 2 Briefing														
2	Hardware Purchasing														
3	Report Writing														
3	Design and Assembling component														
4	Project Optimization														
5	Data Collection														
7	Report Draft Submission to Supervisor														
8	Report Submission to Panel														
9	BDP 2 Presentation														

Planning -
Actual -