Energy efficient smart indoor fogponics farming system

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Abstract. Fogponics is a modern modified version of an Aeroponics farming system which may also be known as “Aeroponics 2.0”. This kind of farming method has been practised and introduced by NASA through a lot of research and experiments. To explain further, Fogponics operates similarly like the Aeroponics which uses soilless cultivation and the process of growing plants is by suspending it in the air or a fog without relying on soil to give the nutrients that plants required to grow. In addition to that, the fog is produced by placing an ultrasonic fog generator inside the mixture of water and nutrients within an enclosed base chamber. The ultrasonic fog generator capable to vibrates at supersonic frequencies and produced micro droplets of water nutrient make it easier and faster for the plant to absorb via the roots with enough amount of mixture and oxygenation. In general, one of the main factors to grow plants is the existence of sunlight energy where it will later be converted into chemical energy through the process of photosynthesis. During this process, water is broken down through a chemical reaction to separate oxygen and hydrogen with the released of carbon dioxide into the atmosphere. Thus, by the practice of indoor Fogponics farming system, the sunlight energy will be replaced with the use of suitable LED light wavelengths. LED lights are capable to emits a full photosynthetically active radiation. Another factor that contributes to the system is by monitoring the temperature, humidity, pH of the water nutrients as well as the light intensity projection. Therefore, these parameters will be monitored and controlled with the use of sensors and through the implementation of the Real-Time Clock (RTC) functionality which is benefited to operate the system with enough amount of time throughout the day, suitable for plant’s growing condition.

1. Introduction
Fogponics is a new revolution and technological leap forward on Aeroponics gardens which may also be called as “Aeroponics 2.0” [1]. Fogponics by means operates similarly like Aeroponics. However, in Fogponics system, it uses water vapour to hydrate and transport the essential minerals and nutrients to plant roots suspended in the air with enough oxygenation and moisture constantly supplied to the plants [2]. Whilst, in Aeroponics system, it uses mist sprayer fine mist water particles to delivers the nutrients. In order to produce the fog, an ultrasonic fog generator will be implemented and placed into a bucket of nutrient solution. For the plants however, it should be placed to their separate pots and filled with a growing medium such as rock wool, expanded clay or even coco chips/fibre that lie on the lid/pot. Once the plant’s roots are developed, the plants can be effortlessly removed without experiencing transplant shock to normal growth [3].

Expanded clay or may also be known as ‘Leca clay’ is a popular growing medium where the structure is in the form of porous pebbles. The advantage of using this medium is, it absorbs moisture as well as any nutrient solution that is added to the Fogponics system. Apart from that, this medium has pores in
the pebbles and the function is to keep the air circulating around the roots to get enough amount of oxygen.

The vapour that functions like smoke produced by the ultrasonic fogger machine will keep the air inside the containers moist and full of nutrients. This method is a very efficient way to grow crops and plants since there is no need for water flowing yet consume maximum amount of nutrients allowing to produce crops much faster compared to Hydroponics and Aquaponics [2]. The development and installation of this system requires less maintenance since it may only need one ultrasonic fog generator placed inside a bucket or any other suitable enclosed area/chamber such as containers and pipes suitable for the plants and water nutrients to be placed. The ultrasonic fogger vibrates at supersonic frequency like a typical humidifier and the vapor produced micro droplets of water nutrient make it easier and faster for plant to absorb [4].

Researchers and scientists have designed the Fogponics systems to reduce the maintenance and increase yield as well as to maximize crop production. Fogponics system provides multiple advantages such as: the enriched nutrients transferred by the fogs penetrate into root tissues making them moist and well-nourished. Moreover, it minimizes the use of water and nutrients by up to 50% due to limited use of water consumption [5]. The system is also adequate even in a small space of area since the crops production is independent on land and soil quality i.e. less fertilizer.

Over the years, technological advancement has revolutionized the world made it possible for the exploration of many multi-functional devices like the optimization of sensors and actuators. By the development of this kind of technology, it may help in playing an important role in terms of an agricultural perspective and farming tactics. (S.Snigdha, 2017) mentioned by the implementation of sensors in agriculture, it will give a big impact to capture all important data such as the soil moisture, temperature and humidity [6]. In addition to that, light intensity sensor, pH and electrical conductivity sensor are also a proper sensor that can be implemented to interact with the environment [7]. Moreover, collecting information by using sensors and communication technology played a significant act for farmer that can bring benefit into agricultural value chain to increase productivity and quality improvement in terms of agricultural inputs and outputs demand. For instant, the sensors will be connected to the Arduino platform with suitable codes written inside the Arduino programming language. The code will then be debugged, compiled and burnt within the utilization of the Arduino [8].

In the development of vegetable plants and flowers growth, photosynthesis is the major process used by plants in order to convert the sunlight energy into chemical energy where this process can only be driven via solar light. As for the implementation of indoor Fogponics condition however, it is necessary to provide a suitable light quantity of up to 8 hours to 10 hours a day to produce a healthy plant production. With the employment of substitute lighting such as the fluorescent light bulb and LED can also be the replacement to support the plants growth in indoor condition [9]. In the operation of LED lights, the white light is being excited by the combination of blue wavelengths emission and yellow wavelengths coated on the phosphor at the glass of LED bulbs [9]. Moreover, most LED will emit a full photosynthetically active radiation ranging between 400nm to 700 nm [10] to triggered a big response in plants and good response for seed and root development.

The working principle of an Fogponics system can be summarized into three most important factors required for the plants to grow. The factors consist of the sunlight energy, water and air. In Indoor Fogponics systems, the sunlight will be replaced by the LED lighting system. The water will come from the mixture of nutrients and water placed inside the Fogponics system’s enclosed base and the air will be duplicated by the transfer of water nutrient in fog or water vapour.

2. Design and simulation

Control Objectives in Fogponics System

The factors that required to be controlled and monitored within the system are as mentioned in Table 1.

| Table 1. Factors that required to be controlled and monitored |
### Initial System Design

The schematic design of Smart Indoor Fogponics System is as shown in Figure 1.

**Figure 1.** (a) 3D model of the initial system design (b) Inside view within the enclosed base.

The model consists of some important equipment to be included into the system such as the enclosed base, plant’s pots, growing medium, LCD display, LED lighting and plants/crops/vegetables. As for the growing medium, the type of medium to be used is by using ‘Leca clay’ where the structure is in the form of porous pebbles and capable to absorb moisture and nutrient solution that is added to the Fogponics system. The Leca clay also has pores within their structure, the purpose of the pores is to keep the air circulating around the roots so it will produce a sufficient amount of oxygenation. The plants will be placed on each pot embedded together with the growing medium as a replacement of using soil. This will be beneficial as well as it is able to support and hold the plants when the roots are suspended in the air inside of the enclosed base.

This project is meant to be an indoor system; therefore, 12V LED lighting is added on the design to transmit the light spectrum with suitable wavelength projection. The application of adding this LED system will eventually help to grow plants with the replacement of sunlight energy for the...
photosynthesis process. Apart from that, with the replacement of the sunlight energy with the LED lighting system, it will help the plant’s leaf to trap and capture the light energy within their chlorophyll.

The system also include a LCD display which will present the temperature, humidity, pH and light intensity measurement that is retrieve from the sensor connected to the Arduino microcontroller placed within the system. If the temperature is exceeding 30°C or below 4°C, abnormalities affect might be occurred on plants which in the worst case, plants might be dead and develop diseases. As for the humidity value should be higher than 80% available moisture of fog production delivering water nutrient to the roots of the plants. The light intensity sensor is placed outside of the enclosed base to monitor the light intensity on the surrounding. With different plant’s type will eventually need a different value of light wavelength spectrum and specification, therefore the monitoring of light intensity is quite important to be included on the system. On the other hand, the pH sensor will be used to monitor the pH level of the nutrient solutions.

The most important equipment to deliver the nutrient solution is by the Ultrasonic Fog generator. This equipment vibrates at supersonic frequency and produced 100% fog or water vapor. The nutrient solution is aerosolized into tiny droplets typically around 5 – 10 μm in diameter which is able to nourish the plant’s roots in a nutrient-rich cloud of fog without a limited amount of oxygenation.

Simulation System Design
The fundamental electronic components designed on the simulation system included:

- Arduino Uno
- DHT11 Temperature and Humidity sensor
- pH sensor
- Light Intensity sensor
- LCD display with I2C interface
- Virtual terminal serial port

![Figure 2. Microcontroller Simulation design simulated via the Proteus software.](image)

The microcontroller used in this design is using an Arduino Uno. This microcontroller has its own speciality and capabilities since it provides a simplified and user-friendly programming language. Apart from that, this microcontroller is equipped with sets of digitals and analogs input/output pins which can be used to interface with other device such as different sensors and memories. The Arduino platform does not require a separate piece of hardware to be able to upload new code onto the board. One way of communicating, giving actions and commands into the Arduino is by using a special software called the “Arduino IDE (Integrated Development Environment)” which uses a simplified version of C++ programmable language and transferred via a USB Type-B cable. The board has 20 pins in total where 6 of the pins consists of the Analog and the other 14 of the pins consists of the Digital. The range of the
The voltage value that can be accepted by an Arduino is between 7 V to 20 V thus, an external battery that is within the suitable value can be used to power up the Arduino.

The purpose of performing the simulation was to verify the real-life situation for smart indoor fogponics system hardware implementation. However, when the simulation was conducted, there were several limitations had been faced. The limitations were due to the lack of some other equipment that has not been tested for the actuators such as the ultrasonic fog generator, LED grow lighting system and RTC module.

**Hardware System Design**

The fundamental hardware components of the system included:
- Arduino Uno R3
- DHT22 Temperature and Humidity sensor
- pH sensor
- BH 1750 Light Intensity sensor (GY-30)
- 20x4 LCD Screen with I2C interface
- IRF 520 MOSFET module (for 12V LED lighting)
- 5V Relay module (for ultrasonic fog generator)
- DS 1302 Real-Time-Clock (RTC) module

The schematic block diagram of the prototype system is shown in Figure 3. The temperature & humidity sensor, pH sensor, Real-Time clock RTC module and light intensity sensor module is designed to be the input of the system. Besides that, the output of the system consists of the 20 x 4 LCD display, 12V LED grow lighting system and Ultrasonic fog generator with added electronic modules for each of these two actuators.

![Microcontroller Block diagram of the Prototype System.](image)

The flowchart of the prototype system is as shown in Figure 4. At the beginning of the process, the initialization of the system is started by initializing the variable and protocol upon the activation of the Real Time Clock (RTC). Once the system read and retrieve the RTC data, the Arduino microcontroller will then continue to obtain and retrieve the data via the temperature & humidity sensor from the DHT22 module, light intensity sensor from the GY-30 module and pH sensor from the pH meter. After the data are all collected, the Arduino microcontroller in correlation with the RTC data will send a signal timer to the IRF 520 MOSFET and Relay module to indicate that they required to turn on the 12V LED grow lighting as well as the Ultrasonic Fog generator for 8 hours a day. Followed by the next process, the Arduino microcontroller will analyze whether the temperature inside the enclosed base of the prototype system is within a sufficient range which should not be higher than 30°C. If it does exceed above 30°C, the Arduino will send a message to the LCD display to notify that the temperature is high.

In addition to the next process, the utilization of the pH sensor will then monitor the pH balance of the water nutrients solution depending on the requirements of the plants' needs. The pH sensor will indicate the acidity and alkalinity of the water nutrients solution suitable for the plants. If the pH value obtained is greater than 7, the LCD display will notify that the pH is alkene whilst if it is smaller than 7,
the LCD will represent that the pH is acidic. At the end of the day, once the timer set by the RTC module reached for 8 hours of operational time for both the grow lighting and the ultrasonic fog generator, the Arduino microcontroller will eventually send signal LOW to the IRF 520 MOSFET and Relay module to imply that they required to turn off.

**Figure 4.** Flowchart of the Prototype System.

**Main Electronic modules used in the System**

The Main Electronic modules of the system included in the system:

(i) GY 30 Light Intensity Sensor Module

The GY 30 Light Intensity Sensor module is a small board for light sensor BH1750FVI type. This module is capable to measure the lux value ranging from 0 to 65535 lux. The board is essentially having a built-in analog to digital converter and has a digital output. The reason why this type of board is chosen in the project was due to the specialty of the module communicates via an I2C interface. The operating voltage of the sensor is 3.3V to 5V thus, it can be connected directly to the Arduino microcontroller.
The initial temperature and humidity sensor simulated by the Proteus software was by using the DHT 11 model. However, as for the real hardware implementation, the DHT 11 is replaced with the DHT 22 model because it provides more precise reading and slightly larger range on both temperature and humidity elements. The DHT 22 is capable to measure the humidity readings from 0 to 100% with 2-5% accuracy compared to the DHT 11 which only able to measure the humidity range from 20 to 80% with 5% accuracy only. Moreover, the temperature readings that can be taken by the DHT 11 are only ranging from 0 to 50°C whereas the DHT 22 can measure from -40 to 80°C.

The general applications of pH sensor are basically to measure the quality of water, aquaculture related and laboratory experiment purposes. However, as for the project implementation, the pH sensor was used to measure the pH concentration by using acid-based measurement device and indicates the acidity as well as alkalinity of nutrients solution. The pH meter v1.1 has an operating voltage of 5V and can be connected directly to the analog pins of Arduino microcontroller. This sensor can be operated with the surrounding temperature from 0 to 60°C. In order to connect this sensor to the analog input of the Arduino pin, a BNC connector attached to its pH probe is required. The cable length from the sensor to BNC connector is 66 cm long. Before the sensor can be use completely, an adjustment need to be done with regards to the accuracy of the pH probe and the calibration also required to perform regularly to maintain the optimal pH scale for plant growth between 5.8 to 7.5.
(iv) 12V LED Grow Lighting and IRF 520 module

As mentioned before, one of the highlighted factors required for the plants to grow is due to the existence of sunlight energy since the tiny green cells called the chlorophyll within the leaves enables photosynthesis to take place and make their own food. It also can support the plant's growth in indoor condition since they provide suitable wavelength and ultraviolet light illumination. Therefore, a 12V LED Grow lighting strips are chosen in this project which in each sequencing of the LEDs, there is 3 red LED and 1 blue LED (3:1) which produces a spectrum of ‘violetish’ color.

However, as this LED strips are going to be connected to the Arduino microcontroller which the microcontroller is only capable to supply an operating voltage of up to 5V, the IRF 520 MOSFET transistor module is subsequently used. This module is basically designed to switch and convert the operating heavy DC loads from a single digital pin of the microcontroller and can generally be used to control most high current and voltage DC loads. The module has an operating input voltage of 3.3V and 5V which can be supplied from the microcontroller and capable of delivering the output load voltage up to 24V. In order to operate the LED Grow light in correlation to IRF 520 MOSFET module, a 12V battery is used whereas in this project specifically, 8 pieces of 1.5V AA alkaline battery are tested and placed at the 12V battery holder.
Figure 8. 12V LED Grow Lighting.

At the left side of the module beside the IRF 520 MOSFET, 3 pins required to be connected to the Arduino microcontroller. The pins at the Arduino that specified with regards to the LED grow light strip is the Digital pin 9 (D9).

(v) Ultrasonic Fog Generator and 5V Relay module

This device is generally built-in AC/DC adapter and consist of a metallic ultrasonic transducer plate embedded within the device. Apart from that, it also has a built-in sensor that detects the presence of water and activates the ultrasonic transducer plate to produce fog. In order to operate the device, it requires a switching AC/DC adapter that has an input AC of 110 – 230V with the frequency of 50 – 60 Hz and an output DC of 24V and 1200 mA current. Assuming that the adapter is having an output DC of less than 24V, the device will not be working as it requires enough amount of voltage to vibrate the ultrasonic transducer plate rapidly. The schematic diagram of Relay module connection to electrical plug and 1-gang switched plug is as shown in Figure 9.

Figure 9. Relay module connection to electrical plug and 1-gang switched plug schematic.

As seen in Figure 9 is the schematic of how the Relay module is connected to the 1-Gang switched plug socket and the electrical plug with correct configuration of color coded wires. The Ultrasonic Fog Generator with attached to its switching AC/DC adapter will be connected to the 1-Gang Switched plug socket while the electrical plug will be connected to the home AC power sockets.
Figure 10. (a) Hardware connection of Ultrasonic Fog Generator AC/DC switching adapter (b) Ultrasonic Fog Generator placed inside the enclosed base of Fogponics system.

**Full System Assembled**

The complete prototype design of the Smart Indoor Fogponics Farming System after the assembling process for both the electrical and hardware component is represent in Figure 11.

Figure 11. Smart Indoor Fogponics Farming System Prototype during day time.
Figure 12. Smart Indoor Fogponics Farming System Prototype during night time with vegetables seedling placed.

3. System experiment results and analysis

Voltage measurement of 12V alkaline battery

The voltage measurements of the 12V alkaline battery which specifically used to turn on the LED grow lighting were taken for a day within 11 hours at an interval of every 1 hour. The LED grow lighting of the prototype system is required to turn on for 8 hours a day. Thus, since the system is using alkaline batteries, it is essential to measure how long can the batteries last within the operational period of time. The operational hours were tested for 11 hours, which started at 9 am and finished at 8 pm. The output graph for the Vmeasured against time is also plotted as shown in Figure 13. The graph demonstrates the plotted graph of the voltage measurements against time for the 12V alkaline battery which was used to light up the LED grow lighting during the operational time of the system prototype.

Figure 13. Measured voltage against time graph of 12V alkaline battery.
As shown in Figure 7.1, it is observed that the voltage measurements are continuously decreasing from the first hours until the 11th hours in which the measurement of the voltage started at 11.6V at 09:00 and decreased to 5.43V at 20:00. Additionally, once the voltage measurements of the alkaline batteries were decreases to 5V and below, the LED grow lighting performance is getting lower by which the brightness of the LEDs are becoming dimer from time to time.

**Temperature readings within the enclosed base of the system**

The temperature readings within the enclosed base of the prototype system was retrieved by the temperature sensor placed in the inside of the main Fogponics system. The range of temperature environment value suitable for healthy plant’s growth should be between 4°C to 30°C. Therefore, it is essential to monitor and aware of the temperature values obtained. As for the results attained for 11 hours of operational time starting from 9 am to 8 pm, the results demonstrate in a graph representation shown in 14.

![Temperature readings against time.](image)

**Figure 14.** Temperature readings against time.

As seen in Figure 14, During the first hour of operational time, the temperature value within the enclosed base was 25.7°C and slightly increased to 25.9°C after 3 hours of operation. After 4 hours, the temperature value was then increased continuously to 27.8°C before it gets decreasing back to 26.1°C. However, as the Ultrasonic fog generator within the enclosed base of the Fogponics system continuously vibrating the water nutrients particles and turns it into fog scattered into the air, the electronic transduce plate of the fogger device started to produce heat. Therefore, the temperature values were then increasing drastically to 29.3°C after 7 hours of operation. In the next hours, the temperature values were then slightly decreased to 27.2°C and continuously decreasing from time to time back to the initial temperature value around 25°C to 26°C. Since the water particles are vibrated by the device, the water may get hotter when it does not turn off approximately for more than 11 hours.

**Humidity readings within the enclosed base of the system**

The fog produced in the inside of the enclosed base of the Fogponics system should provide 100% available moisture and water vapour in order to nourish the plant’s roots without a limited amount of oxygenation. As part of the experiment results, the humidity readings of the fog inside the enclosed chamber were also measured for 11 hours of time and demonstrated in a graph representation shown in 15.
Figure 15. Humidity readings against time.

The humidity readings were constantly obtained value of 99.90%. Therefore, the humidity surrounding within the enclosed base chamber was within the suitable and acceptable values outstanding for the plant’s roots condition.

Light Intensity measurements

The projection of the light onto the vegetable’s leaves should be ranging between 2500 lux to 7500 lux for the purpose of photosynthesis process. However, after several experiments done, it can be noticed that the GY-30 module has a less sensitivity to ultraviolet light radiation by which the readings obtained for the projection of LED grow lighting were not absolute and decreased overtime. Even that the case, the light intensity value can be increased by lowering the stand to support the upper base of the prototype Fogponics system very near to the vegetable’s leaves. This are proven by data recorded during the experiments as the light intensity values were measured for 11 hours.

Figure 16. Light Intensity against time.

The graph represents in Figure 7.4 is the light intensity measurements obtained within 11 hours of operation. During the first hour of operational time, the highest light intensity value obtained was 575 lux. However, after the time goes by to the next hours, the light intensity values were noticeably to be
decreasing continuously with the reduction of approximately 100 lux. By observation, the light intensity was dependent on the brightness as well as the dimness of the LED grow lighting. The performance of the light projection was dependent on the voltage value of the alkaline battery which will give impact to the performance of the LED grow lighting. Since the LEDs were became dimmer due to the decreased in voltage value, the light intensity measurement will hence, reduces as well.

4. Vegetable plant’s development results

Vegetable Plant’s development experiment results. (First phase)

The results of the plant’s development were observed after being experimented onto the Fogponics farming system with two different growing medium: Leca Clay and Rockwool. The vegetable grown in the first phase is Chinese mustard and Pak choy. After 23 days of being experimented, both of the vegetable seedlings type shows sign of overwatering and wrong amount of light since the seedling looks stretched and tends fall over. The seedling leaves were also drooped and damped off. It shows a sign of malnutrition as the leaves turned yellow and some of their leaves have rotted. Moreover, the leaves started to discoloured and crispy showing that the seedling was also unhealthy.

![Figure 17. Pak Choi seedling growth (Age: 23 days)](image1)

![Figure 18. Chinese Mustard seedling growth (Age: 23 days)](image2)

Vegetable Plant’s development experiment results. (Second phase)

As it can be seen that the plant was not growing well in the first phase. A second phase of experiment was done which replicate the first phase experiment but the vegetable seedlings were replaced and experimented by using Butterhead lettuce seedlings aged 3 weeks which were placed on the pots of the Fogponics system, embedded with Leca clay and sponge growing medium. During the first two days of implantation, the leaves were started to grow well with serrated leaves sprouted along with the seedlings.
This shows that the seedlings were well developed without any symptoms of malnutrition, overwatering and drooped off. However, after two days of experiment, the Butterhead Lettuce seedling shows sign of unhealthy conditions. From the experiment, it can observe that by using Leca clay type growing medium, the seedling was dying a lot quicker compare to the sponge type growing medium.

**Figure 19.** Butterhead Lettuce seedling growth (Age 21 days).

**Figure 20.** Butterhead lettuce seedling experimented by sponge type growing medium (Age 24 days)

**Figure 21.** Butterhead lettuce seedling died after 24 days of experiment in Leca clay growing medium type.

*Discussion of The Whole System Results*

With the use of DS 1302 Real-time-clock (RTC) module, it can control the system by giving command towards different hours, minutes, seconds or even day and date of the year. The system can be operated
depending on specified schedule of time. For the project specifically, the RTC module managed to be operated for 8 hours daily and automatically turned off once the timer was over before it can be continued for the next day.

As for the actuators of the system which consisted of the ultrasonic fog generator and 12V LED grow light, both were working perfectly. The only limitation was the 12V alkaline battery used to turn on the LED grow light, it drained really fast which results in reducing the performance of the light projection as well as the light intensity readings.

On the other hand, after quite sometime of operating the ultrasonic fog generator, the device started to produce heat and affecting the temperature within the enclosed base of the Fogponics system. When the ultrasonic fog generator was operated for several hours, it was observed that the device started to produce warmth surrounding and increased the temperature value within the enclosed base of the Fogponics system.

The pH sensor of the Fogponics system works well, with the percentage uncertainty of 5% to the pH calibration tests. The pH sensor was not required to monitor the nutrients solution all the time. It was only used at the beginning of the process of adding nutrients into the clean water within the enclosed base. During the experiment, the pH readings obtained a pH value of around 7 which was still acceptable for plant’s growth. After several hours of operating the Fogponics system, the pH sensor will again be used to check the pH value of nutrients solution. For any significant increase or decrease of pH value, the more reasonable alternative was either to add more clean water or to add more nutrients solution.

The full setup in assembling all the electrical component and mechanical hardware were done and prepared to be used. With regards to the hardware construction design, the system needed to be improved in the future especially for the wiring connection of the actuators and sensors. The wiring connection of the system have minor problems mostly on dealing with replacing the water nutrient solution with a new one. When the top layer of the enclosed base is opened, the wiring connections of the sensors may be affected and required to be adjusted afterwards.

In the early stage of smart indoor fogponics system testing phase (First phase), some of the vegetable seedlings shows signs of unhealthy conditions and symptoms. After few days later, the testing phase was continued for the Second phase by replacing with fresh Butterhead lettuce seedlings aged 3 weeks, placed on all of the pots of the system. With suitable amount of nutrients solution measured by both pH meter and TDS meter of value 7.4 and 1200 ppm, the Butterhead lettuce able to grow well for the first 2 days of implantation and shows no sign of malnutrition, damped off or dying. However, the next following day, the seedling leaves were observed to turn yellow and have rotted again. It also observed that the finest type of growing media suitable to be used in the Fogponics system was by using Rockwool compare to Leca clay since the plants were observed to standalone more than dying with the Leca clay type.

5. Conclusion

The budget to build full setup of the hardware prototype system exceeds around B$ 237.85. The results of the system implementation and hardware construction may not have followed the initial system designed on the simulation as the type of sensors as well as program codes were changes accordingly. As for the hardware implementation, the design was well structured, which requiring simple adjustment and some assembling processes to construct the whole system. On the prototype system, the readings of all sensors were monitored by the LCD display in accordance to check the temperature, humidity, pH and light intensity readings suitable for the plant growth. The RTC will eventually kept the system to be operated for 8 hours daily. The experiments have shown that during the implementation of the system, the voltage measurement to operate the LED grow lighting decreased from 11.6 V to 5.43 V in 11 hours of experiment meanwhile, the temperature environment within the enclosed base of the Fogponics system varies from 25.7°C to 29°C. Whilst, the humidity remain constant at 99.99% and finally, the light intensity projection varies significantly from 575 lux to 113 lux.

Some vegetable plants had been experimented on the smart indoor fogponics farming system for 3 – 4 weeks of duration. However, by the experiment results obtained, none of the plants managed to grow well.
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