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Automated IoT Device to Manipulate Environmental Condition of Black Soldier Fly

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Abstract— **Trash has been one of the main problems in human life. It can bring global warming and spreads toxic pollutants when burnt. Since unfiltered trash is harder to utilise, it is better to filter trash in order to help the action of recycling and reusing. Related to organic trash, black soldier fly is one of the decomposers that also brings value in the form of high protein and lipid on their larva stage. This research represents the goal to create optimization tools to increase the breed product of the Black Soldier Fly around 10 to 30 percent of the egg produce by using IoT concept and utilising Arduino board, DHT22 sensor to read temperature and humidity and BH1750 sensor to read light intensity with common output devices such as warm bulb and mini fan to control temperature, water pump to control the humidity, and spotlights to control light intensity. Validations and constraints were put in the Arduino to control both the sensor and the output devices to work together and stabilize the environment. Each day eggs will be taken and weighted from controlled cage and non-controlled cage. The more stable environment make the Black Soldier Fly produces more eggs.**

Keywords—**Black Soldier Fly, Internet of Things, Arduino Uno, Organic trash, alternative fish food**

I. INTRODUCTION

Global warming has been an issue for several decades. It must be taken care of seriously since it can lead to natural disasters and climate changes that affect human life. Trash is one from many factors that lead to this issue. Low level of knowledge on how to treat trash makes trash a slow but surely dangerous threat to human life. In Jakarta, research [1] shows that with low level of awareness and knowledge on how to treat trash and bad behaviors of litter bring flood almost every time rain come. Low level of knowledge of how to separate trash could also lead to a not optimum way to treat trash, recycle-able trash and organic trash cannot be use if they are not filtered correctly. People then will try to remove this unusable trash from land to air by burning it.

According to [2] Trash burned bring a toxic pollutant that can disrupt and damage human respiratory system leading to respiratory illness and damage neurons.

Research [3] also shows that estimated 40 to 50 percent of trash are made of carbon, when trash is burned then it will majorly emitted carbon dioxide that is also leads to global warming. Improvement in trash filter where organic and inorganic waste can be separated might be the cheapest and fastest solution for this problem.

Black soldier fly larva can help to solve this organic waste problem. This larva is a rich source of protein and can be use as food for chicken, poultry and fish. According to [4], Usage of larva can help to reduce household organic waste from 65% to 75%.

Figure 1.1 Black Soldier Fly

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PT Solusi Kreatif Kompis is one from many who uses black soldier fly larva shown in figure 1.1 to dissolve organic waste. The larva itself then will be sold in dried form. Analysis done by [5], showed that black soldier fly larva could give a positive output in case of entrepreneur in a developing country that has lot of organic waste.

Several conditions like cloudy and rainy weather reduce the process of black soldier fly mating, causing a decreasing of eggs produced as shown in figure 1.2.

Figure 1.2 Black Soldier Fly Egg

This research is conducted in order to control the unstable temperature, light intensity, and humidity in the breeding site. Arduino as the microcontroller to read the temperature, light intensity and humidity through sensors and activate output accordingly.

Black soldier fly larva is commonly used as an alternative food for fish as it contains lot of proteins. This larva could replace effectively up to more than 50% fish meal [6]. Although in the meantime the usage of black soldier fly larva to feed chicken and poultry nor even for direct human consumption is still hard to find, Black soldier fly contains high amount of protein and lipid [7] that might be useful in the future as alternative food or even as the primary protein source. Black soldier fly larva color usually starts with white color shown in figure 1.3, similar to other maggot and will turn into black color like in figure 1.4 before it becomes a Black Soldier Fly.

Figure 1.3 Black Soldier Fly White Larva

Figure 1.4 Black Soldier Fly Black Larva

II. Related Work

A. Internet of things

IoT has recently gained widespread acceptance as a viable paradigm with the potential to alter our society and industries. It is capable of integrating numerous devices with sensing, identification, processing, communication, actuation, and networking capabilities [8]. IoT input sensor is a device that works as a media to collect all data required as the base indicator for the IoT to work.

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The Internet of Things (IoT) is a new technology that uses the Internet to link physical devices or "things" [9] IoT has a wide range of applications, including manufacturing, logistics and construction, environmental monitoring, healthcare systems and services, and so on [10-12]. The selection of IoT components such as sensor devices, communication protocols, data storage, and computation must be appropriate for the intended application when creating an IoT application, which is the first step in developing IoT systems. Sensors are the primary contributors to the IoT. They are used to gather and transmit data in real time. The usage of sensors improves effectiveness and functionality, and it is important to the success of the IoT [13]. Theebak et al.,[14] established the Internet of Things; further possibilities may be assessed with linked engineering organization approaches and ideas. For example, cloud computing, the future Internet, massive data sets, and mechanical technologies. Lukas et al. [15] developed a device that uses sensors to receive information from its surroundings and, based on that data, follows up on its surroundings using actuators. Environmental sensors have been integrated into the generation of information related to environmental factors, as well as allowing for easy integration with any other types of sensors linked to smart city measurement [16]. Future Internet Technologies is regarded as the top environmental informatics provider, offering geospatial solutions as well as scalable IoT-based technologies that support the "Environmental Observation Web" [17].

B. Data Reading Sensor

Hermetia illucens (L.) (Diptera: Stratiomyidae) has been discovered as a potential species for organic waste treatment [18]. BSF larvae can convert a broad variety of organic wastes into larval biomass, which may then be utilized as an element in animal feed. Organic waste leftovers can be utilized as organic fertilizers after being digested by BSF larvae [19]. When sunlight is limited due to unfavourable weather conditions or in temperate countries due to lengthy winters or low sunshine levels throughout the year, BSF mating slows, resulting in an irregular generation of fertile eggs. In addition to light, BSF has ideal temperature requirements, which are often achieved by heating [20]. An alternate method is to build a well-insulated indoor BSF breeding system with efficient temperature control and an artificial light source to enable the constant generation of fertile eggs.

Sensor device research and future trends aim at the development of sensor applications to improve load shaping and customer awareness, as well as the creation of particular facilities to boost renewable energy generation [21]. The usage of sensor devices in the energy sector as part of the IoT vastly enhanced diagnostics, decision-making, analytics, optimization processes, and integrated performance metrics. Remote monitoring and control are made possible by the use of Internet-connected sensors. Liu et al. [22] proposed a colony effect on BSF mating success, which needs further research and evaluation utilizing the presence of sperm in the spermathecae as a valid metric of mating success. They discovered a highly successful artificial light source for BSF reproduction, allowing detailed reproductive research of this species to be undertaken in readily managed indoor conditions. Temperature, relative humidity, light source, and other waste-related variables (such as moisture level and pH) all have a significant impact on larvae ovulation and growth. The presence of ideal circumstances improves the treatment efficacy of BSF larvae as well as the species growth and development. BSFs are eurythermal species that can tolerate a wide temperature range (15–47 °C) while remaining extremely sensitive [23]. Various studies conducted by various groups of authors revealed that 99.6% of oviposition occurred at temperatures ranging from 27.5–37.5 °C and relative humidity levels of 60%. Another group of writers stated in the same area that 50–90% relative humidity is optimal for the growth of BSF in laboratory circumstances. In this study, the BH1750 light intensity sensor and DHT-22 sensor will be used to monitor light intensity, humidity, and temperature levels and then send them to the Arduino.

III. PROPOSED METHOD

This research will be applied into the Black Soldier Fly cage prototype first to see if it works perfectly with the result of more egg productions. Once the system works with the prototype, it will be applied directly into the PT Solusi Kreatif Kompis Black Soldier Fly Farm to get the better result of the Black Soldier Fly breeding.

This system will not change the how Black Soldier Fly farmer activity instead it will only help to manipulate the Black Soldier Fly environment to breed and produce more egg.

PT Solusi Kreatif Kompis Black Soldier Fly farmer will still have to farm the Black Soldier Fly egg manually as the system will only help increasing the value of the egg.

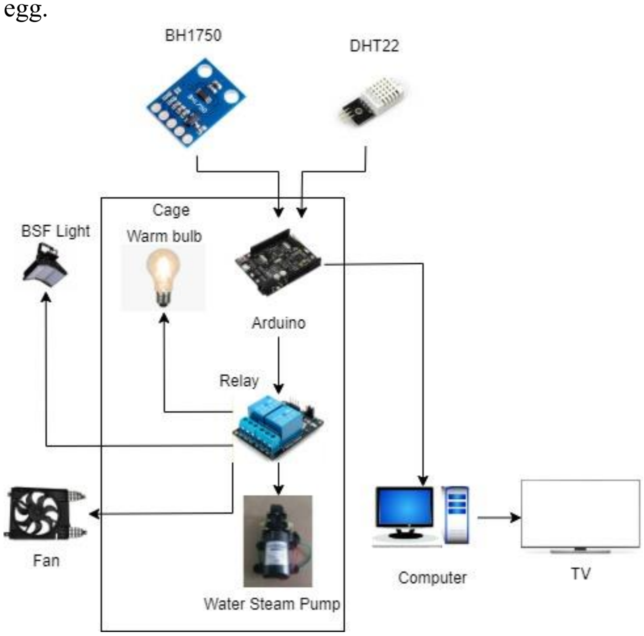

Figure 1.0

The system development is using Arduino Uno R3 WiFi ESP8266 CH340G with the C++ programming language provided by the Arduino IDE. The board works to achieve and validate the data collected by the sensors. BH1750 will be used to read light intensity, this sensor is able to read from 1 lux to 65535 lux and works in the temperature range of -40°C to 85°C [26]. Meanwhile, DHT-22 will be used to read humidity and temperature level. It works in the temperature range of -40°C to 80°C and humidity level of 0 to 100% [24] with an accuracy range between 2-5%. These sensors then will send signals to the output device while still maintaining the sensor data collection to control the output device work. The system also will show the data collection continuously into the display monitor and phone application with wifi connection.

The base architecture design idea was shown in figure 1 which will be implemented in the prototype cage. Sensor BH1750 and DHT22 collects data from the outside into the Arduino. The Arduino will decide which output to be activated through the relay channels.

The decision will follow current environment condition by real time and will be followed by the outputs to optimize the environment.

Two prototype cages used in this research are to determine the effectiveness of the system by putting it into one of the prototypes. The other prototype cages will not be using the system as it will be the comparison between the cage with system and without the system to see if the system works correctly and affects the Black Soldier Fly breeding effectivity. The data comparison between the prototype cages are:

A. Black Soldier Fly's movement activity
B. Black Soldier Fly's breeding effectivity
C. Black Soldier Fly's egg weight

By comparing the cages, we can calculate the effectivity of the system towards the Black Soldier Fly breeding activity. If the system on the prototype did not work as expected, a different input or output device will be implemented until the expected result is achieved.

Figure 2.0 Microcontroller and sensor

Figure 2.1 Water pump

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Figure 2.2 Water output from water pump

Figure 2.3 Warm bulb

Figure 2.4 Fan

Figure 1 shows the implementation of the project that has been applied in the real cage. Compared to the prototype cage, the project was too small for the real cage and requires more extension like jumper cables, longer water hose and bigger scale output.

The microcontroller shown in the figure 2.0 will be attached in the wall with safer and easier to access and configure the microcontroller and the sensors. The warm bulb was put in upper middle inside the cage to distribute better warm and lighting shown in figure 2.3. The fan shown in the figure 2.4 was put outside of the cage to prevent the black soldier fly getting crushed inside the working fan.

IV. System Design And Activity Result

To detect the Black Soldier Fly's environment condition such as humidity, temperature and light intensity we will turn on the system to collect the environment condition data with the sensors. The system as shown in figure 2.0 run from 9am until 1pm according to Black Soldier Fly's breeding time. For every five minutes the system will collect data from the sensor and if the data reaches the peak of the sensor validation that requires an action, the system will send signal to run the output device to manipulate the environment condition into the perfect state for the Black Soldier Fly to breed. The humidity and temperate sensor DHT22 will be paired with water pump device shown in figure 2.1 and figure 2.2 as an output to manipulate the condition. DHT22 Sensor work is explained in [24]. According to [25] the perfect temperature and humidity to trigger the Black Soldier Fly breeding activity are 27℃ for temperature and 60% humidity level. Each time the humidity is getting lower than 60%, system will send a signal to the water pump to run for five minutes. The same concept also goes for the temperature, each time the sensor reads the temperature below or over 27℃, it will send the signal for the fan as shown in figure 1.4 or warm light bulb output shown in figure 2.3 to turn it on depends on if the temperature is lower or higher until it stabilizes to 27 ℃ every five minutes. For the light output, the BH1750 sensor to collect light intensity will be paired with BSF Light to manipulate light intensity required. BH1750 sensor work is described in detail in [26]. The sensor will work as the light intensity is getting lower caused by cloudy or rainy weather. The light intensity required to trigger the breeding activity for the Black Soldier Fly mostly in daylight intensity [25] which is around 6000 lux to 10000 lux. If the light intensity data collected by the BH1750 sensor is getting lower than 6000 lux, the system will send a signal to the output device BSF Light to turn on until the light intensity from the outside more than 6000 lux for the Black Soldier Fly to continue or start breeding until the next five minutes or next data collection.

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The light purpose is only to accommodate when the weather is cloudy or even raining to substitute the daylight for the Black Soldier Fly.

TABLE 1.0
CAGE WITHOUT OUTPUT

Time & Day	Average Humidity	Average Temperature	Average Light Intensity
Day 1 (9 AM to 13 PM)	76%	29°C	4571 Lux
Day 2 (9 AM to 13 PM)	65%	30°C	5233 Lux
Day 3 (9 AM to 13 PM)	53%	32°C	6245 Lux
Day 4 (9 AM to 13 PM)	45%	33.5°C	6367 Lux
Day 5 (9 AM to 13 PM)	67%	26°C	4598 Lux
Day 6 (9 AM to 13 PM)	78%	27°C	4278Lux
Day 7 (9 AM to 13 PM)	85%	26°C	4067 Lux
Day 8 (9 AM to 13 PM)	80%	28°C	4257 Lux
Day 9 (9 AM to 13 PM)	69%	29°C	3278 Lux
Day 10 (9 AM to 13 PM)	72%	28°C	2987 Lux
Day 11 (9 AM to 13 PM)	90%	26°C	1956 Lux
Day 12 (9 AM to 13 PM)	86%	26°C	1256 Lux
Day 13 (9 AM to 13 PM)	45%	29°C	6234 Lux
Day 14 (9 AM to 13 PM)	40%	30.5°C	6187 Lux

TABLE 2.0
CAGE WITH OUTPUT

Time & Day	Average Humidity	Average Temperature	Average Light Intensity
Day 1 (9 AM to 13 PM)	72%	28°C	6785 Lux
Day 2 (9 AM to 13 PM)	65%	28.5°C	6988Lux
Day 3 (9 AM to 13 PM)	62%	27°C	6245 Lux
Day 4 (9 AM to 13 PM)	60%	28°C	6367 Lux
Day 5 (9 AM to 13 PM)	67%	26.5°C	6344 Lux
Day 6 (9 AM to 13 PM)	78%	27°C	6542Lux
Day 7 (9 AM to 13 PM)	85%	26.5°C	6775 Lux
Day 8 (9 AM to 13 PM)	80%	27.5°C	6532 Lux
Day 9 (9 AM to 13 PM)	69%	28°C	6296 Lux
Day 10 (9 AM to 13 PM)	72%	28°C	6387 Lux
Day 11 (9 AM to 13 PM)	90%	26.5°C	6556 Lux
Day 12 (9 AM to 13 PM)	86%	27°C	6756 Lux
Day 13 (9 AM to 13 PM)	61%	27.5°C	6234 Lux
Day 14 (9 AM to 13 PM)	63%	29°C	6187 Lux

According to table 1.0 and table 2.0, the cage with output treatment shows more stable environment for the Black Soldier Fly. The treatment affects the breeding process a lot. In the treatment cage, the Black Soldier Fly seems more active and breed more egg than the non-treatment cage. The egg difference compared in its weight, shown in the table 3.0 in total of every day in total of five days

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TABLE 3.0
EGG RESULT COMPARISON

Day	Non-treatment cage	Treatment cage
Day 1	6 grams	7 grams
Day 2	3 grams	4 grams
Day 3	2 grams	4 grams
Day 4	5 grams	7 grams
Day 5	4 grams	5 grams
Day 6	3 grams	4 grams
Day 7	5 grams	6 grams
Day 8	7 grams	7 grams
Day 9	2 grams	3 grams
Day 10	4 grams	4 grams
Day 11	4 grams	5 grams
Day 12	5 grams	6 grams
Day 13	6 grams	7 grams
Day 14	2 grams	4 grams

The result shows that cage with treatment produce around 20 to 30 percent more eggs than the non-treatment cage. It is because the treatment cage provides more stable environment that makes the Black Soldier Fly more comfortable to mate and breed.

V. CONCLUSION

As a result, usage of Arduino uno with BH1750 as light intensity and DHT22 as temperature and humidity sensors could increase the number of black soldier fly eggs. By using the fan, LED light, warm bulb and water pump as the output, conditions around the breeding site can be manipulated in real time to the optimum environmental conditions for black soldier fly to lay eggs. Based on the result, this method could be useful in the time of changing weather and unsuitable conditions around the black soldier fly breeding site. As this larva could digest organic waste and create something more useful for human life, it might help humans to reduce waste that damages the environment while also producing something valuable. With increasing earth temperature every year and more natural disasters occur, any action to help reduce global warming will be a great help for human civilization. This research uses a basic method of IoT to monitor and manipulate the environment condition of Black Soldier Fly in tropical country.

There are some methods and conditions that can be applied and adjusted to improve the effectiveness of this device. Adjustments in a more suited way for 4 seasonal countries and implementation of machine learning can be applied for the future research.

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