Semi-automated IoT based Cabinet for Rearing Black Soldier Fly Larvae (BSFL)

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***Abstract*— Black soldier fly larvae (BSFL), *Hermetia illucens* can compost organic materials. They are bioconversion agent that is promising for insect-based waste management. Thus, producing of BSFL in farms is needed. The farms require dedicated semi-automated cabinet of BSFL is a prototype for supporting the rearing processes of BSFL. This study aimed to establish BSFL rearing system which use IoTs platform (Raspberry Pi boards). A prototype of semi-automated cabinet of BSFL is created with Microsoft 3D Viewer application. An IoTs adopt by open-source automatic (Arduino Node MCU ESP8266). It plays an important role for operation of feeding system and monitoring temperature and moisture in rearing unit. The data will be shared and saved in a web user Interface. This study concludes that the semi-automated cabinet can increase productivity of BSFL by reduced time, and labour. Moreover, it can be efficiency alternative method for reducing organic materials.**

Keywords*— Black Soldier Fly Larvae (BSFL), IoT, Organic waste management

I. INTRODUCTION

Waste in the world is expected more 3.40 billion tons in 2050 which exponentially rising from 2.01 billion tons in nowadays [1]. Municipal solid waste problem has increase gradually in Thailand. Due to coronavirus pandemic, government has implemented lockdown and monitored the unvaccinated people for preventing coronavirus cases[2]. Due to covid-19 pandemic situation is the one of main impact on waste production. In agricultural sector, suppliers have been stopped production and kept livestock for longer period that need to use more feed [3]. Moreover, people's behavior has changed by increasing organic waste in the household. Therefore, organic fraction of municipal solid wastes was increasingly in household. Pollution Control Department, Ministry of Natural Resources and Environment revealed that solid waste in the community average of 64% as organic waste (25.37 million tons/year, and 69,322 tons/day). Although government attempt to recycle and get rid of them, organic wastes still have inappropriate management. Thus, the black soldier fly (*Hermetia illucens*) larvae can be a potential method for recycle organic materials which lead to sustainability of environment [2]. They have the specific competencies to convert organic materials into compost and reduce waste by a half of original amount. Furthermore, BSFL have rich sources of nutrients including 42% crude protein and 29% fat which are regarded as animal feed [4].

As the larvae capable feed a large quantity of organic materials, the results showed drastically reduced weight and volume of waste in a short period. The BSFL technology is economically the promising for low cost harvesting and environmentally technique [5]. Black solider fly market has economic potential which expected to growth in the future. In 2019, the market research found BSFL by product worth $128 million and expected reach to $ 3.4 billion in 2030. Asia Pacific revealed both of value (50%) and volume (57.1%). Moreover, Asia Pacific accounted for the largest share of the global market in 2019, both in terms of value (50%) and volume (57.1%) increased global population and demand for meat and seafood. These lead to aquaculture industry has increasingly cost of animal feed, so the sustainability of food is concerned. Therefore, insect-based food for future become growing [6].

BSFL can consume various of organic materials (Fig. 1). Moreover, they are non-transmitted pathogens, no biting, and environmentally friendly insect. Furthermore, BSF can reduce developmental growth of bacteria such as *Escherichia coli* and *Salmonella* sp. which cause the unpleasant odors of organic wastes [7]. BSF larvae is not only can reduce organic waste, but also contain high nutrition including protein value of 56.9%, followed by fat 26.0 %, calcium 7.56%, phosphorus 0.9%, amino acid [8], and lauric acid (inhibit developmental growth of pathogens). BSF larvae or pupae stage are suitable for feeding animal including chicken, bird, fish, pig, mouse, reptile, and amphibian etc. [9]. In addition, BSF larvae and pupae have been

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shown to be valuable for biodiesel production that increase combustion efficiency and reduce greenhouse gas emissions. Therefore, BSF production has a high demand and appropriate rearing method still required. Previously, farming BSF was used widely space about 150 m^2 that cannot rear them in limited area like urban area. Moreover, rearing method need special care to adjust suitable condition (temperature and humidity) and attention from labors and take times in each procedure. For this reason, these lead to aim of study to establish BSF rearing system via semi-automated cabinet which use IoTs platform (Raspberry Pi boards). Raspberry Pi is a series of small single-board computers which promising to increase the efficacy of BSF production. In addition, IoT can play an important role to monitor environmental conditions and order the feeding system through smartphone application. IoT is a connecting device which applied with wireless conditions, then the Remote Monitoring System (RMS) is proposed [10]. It has become very essential technology for monitoring and operating system in interest areas. The design of the semi-automated system provides monitoring of various threshold values, alerting the administration and cleaning with the help of IoT based sensors. Maintenance cost is reduced drastically, and the system works without human fatality [11]. These lead to approve BSFL production which efficiently reduce time and labor. Besides it can improve sustainability of organic waste management. Due to the budget, the study didn't depend on a farm, instead of that, a dedicated IoT based semi-automated cabinet for BSFL is used.

Fig. 1. Larvae of black solider fly

II. Materials and Methods

A. Cabinet Structure Development

The semi-automated cabinet is modified and contained appropriate system for feeding BSFL. Moreover, it can maintain light, humidity, temperature, and monitor both of air and under tray condition. In addition, the semi-automated cabinet also acquire better visual perception. The automation software setup used an open source electronic via Arduino which create for monitoring humidity and temperature. According to hardware setup only used for feeding system (Fig. 2).

B. Building and Deploying Monitoring System

1) Hardware setup; Feeding device for BSFL including 1) Silo- Each of rack has 3 silos in for storing dry food ~2-3 kg/silo. It has a lid cover on top for preventing moisture which connected the funnel (Ø=20 cm., height=10 cm.). Then, dry food was easily released through funnel by gravity force. 2) Screw pressure- each of three screw pressures were operated separately which connected with motors for pressing dry food to feeding pipes 3) Three feeding pipes were operated separately in each of tray. They made from polymer plastic PVC (Ø=20cm, length =44 cm.) that connected with screw pressures for transporting dry food to each of tray. 4) Tungsten lights were provided for operate light and keep warming in each of tray. 5) Motor 12 VDC is geared metal motor for feeding dry food. It operated by turn on and turn off via module relay circuitry. 6) Relay 5V module is used for controlling turn on and turn off switching electrical device (Fig. 3).

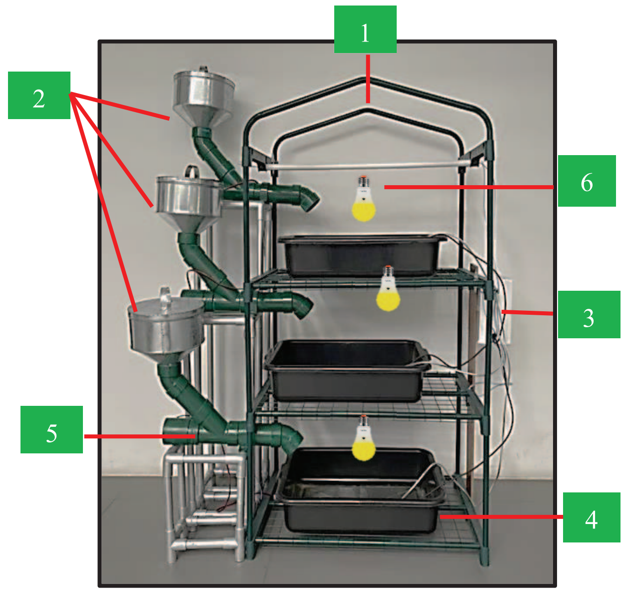

Fig. 2. The numbers are given for clarity, and they denote as given 1=The semi-automated cabinet, 2=Feeding tank, 3=Controller box, 4=Tray, 5=Feeding pipe and 6=Tungsten light bulb.

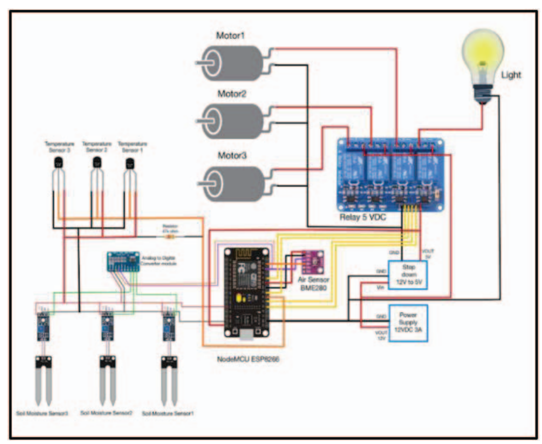

Fig. 3. Circuit diagram for hardware setup

2) Software Setup

a) Arduino Node MCU ESP8266

Node MCU ESP 8266 is the Internet of Things (IoTs) open source for micro-controller development board which connected via internet Wi-Fi networking. It cans collect and transfer data from other sensors, then analyze environment (temperature and humidity data) to cloud base server.

b) Operating data and sensor

Semi-automated cabinet augmented with different types of sensors to measure environmental conditions consist of 1) The BME280 is digital temperature and humidity sensors in environment that is developed specifically for mobile applications, 2) Soil moisture module determined moisture in larvae foods. A sensor has both of analogue and digital output which converted data transmission to Arduino platform, and 3) The BS18B20 is the temperature sensor for measuring temperature of BSF larvae food.

c) Power supply

The power supply converted alternating current electricity from 220VAC to 12VDC 3A which is the main source for providing voltage and electric current to all electronic devices.

d) Step down module

It is a converter for adjusting voltage level. In this experiment, the module can reduce voltage DC from 12V to 5V for supplying to Arduino Node MCU ESP8266 and Relay.

3) Application Programming Interface (API)

a) Node red

It is the programming paradigm tool for IoT platform which provided for connecting between machine to machine (M2M). Node red operated by passing message via a web browser-based flow editor.

b) Message Queuing Telemetry Transport (MQTT)

Protocol is used for machine to machine connecting IoTs connectivity protocol. It is designed to communicate between semi-automated feeding cabinet and all of sensors. In this study, MQTT used to control feeding machine and order to turn on and turn off Tungsten lights via mobile phone or Web.

c) Dashboard

This study used Grafana which is open-source Dashboard tool working with InfluxDB (The time series platform). It can help user for created and corrected on Dashboard.

d) Database

According to collect data on semi-automated cabinet system, these data were brought to InfluxDB which is time series database combined with TICK Stack. It is the accumulation of open-source components. This combines to deliver the platform for storing, capturing, monitoring and visualizing data (ex. Light, Temperature and Humidity)

4) Conditions to be maintained in proposal method

Wet food 200 grams/day/tray, such as fruits, vegetables, and waste foods were provided as food for BSFL. The food shall be given by bare hands. The proposed method encourages the dry food because the food pipe jammed in running method. Regular Tungsten light bulb is used for warmth. Temperature for larvae shall be maintained under room temperature from 25-32 ºC. If temperature exceeds, the larvae will move out of tray. The growth of the larvae is identified by the active movement of larvae inside the tray. The humidity will be acquired humidity sensor/moisture sensor BME280. In the Fig. 3a the sensor BME280 shall be implanted in surface areas of the tray. The BME280 shall also acquire temperature. In Fig 4 the over all flow of the method is shown as flow chat.

III. Results and Discussions

A. Cabinet Structure Development

The cabinet (49×69×120 cm.) compose of two functions including hardware and software systems. Firstly, hardware system was used to feed larvae and control light system. It constructed by three racks. Each of rack has plastic tray (39×50×11 cm.) and feeding funnel for rearing BSFL. Each of tray provide of 800-1,000 BSFL/tray containing of wet food which given by hand and dry food given by feeding pipe. Feeding pipe has developed pipe feeding system for supplying dry food to larvae. These feeding tank compose of motor 12 VDC which connected with feeding pipes (Fig. 3). In addition, lighting system has been divided separately in each of rack for maintaining temperature and visualization. Secondly, the software system, each of tray has monitored environmental condition through IoT sensors including air temperature, food temperature, soil moisture, environment humidity, light sensor. In term of temperature and humidity monitoring, these sensor data detected at the sensor node stage are received by an embedded server via Wi-Fi, transmitted through an IoT cloud service, and then visualized on the Web or mobile phone (Fig. 4).

B. Web User Interface

As shown in Fig 4, this study designed web user interface into three units including 1) Temperature and humidity in surrounding and tray of BSFL, 2) Time-series data on temperature, humidity of food in tray, 3) Status of illuminance and feeding system.

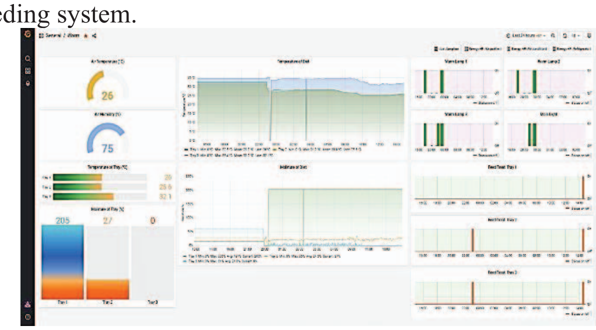

Fig. 4. Implemented over all of web user interface

The monitoring processes was designed to observe ambient temperature and humidity at the first unit. The detection result indicates that air temperature average 26%, air humidity value of 75%. Meanwhile, the other rows shown temperature and moisture of BSFL in tray1, tray2, and tray3, respectively. The advantage of monitoring system improves productivity of BSFL, better security, prevent incidents or faults, save time and labors on controlling infrastructures. In addition, the middle unit shown time-series data on temperature, moisture in diet in 1 day the collection and storage of time-series data on temperature, moisture in diet of tray, tray2 and tray3, respectively. Finally, the last unit shown status of illuminance and feeding system. These relative time range has been collected into every 5 minutes until last 7 days. Furthermore, these data were kept in cloud service for more than 5 years.

Fig. 5 illustrates the first unit of web user interface. The monitoring processes was designed to observe ambient temperature and humidity. The detection result indicates that air temperature average 26%, air humidity value of 75%. Meanwhile, the other rows shown temperature and moisture of BSFL in tray1, tray2, and tray3, respectively. The advantage of monitoring system improves productivity of BSFL, better security, prevent incidents or faults, save time and labors on controlling infrastructures. In addition, the middle unit shown time-series data on temperature, moisture in diet in 1 day the collection and storage of time-series data on temperature, moisture in diet of tray, tray2 and tray3, respectively (Fig. 6). Finally, the last unit shown status of illuminance and feeding system (Fig. 7). These relative time range has been collected into every 5 minutes until last 7 days. Furthermore, these data were kept in cloud service for more than 5 years.

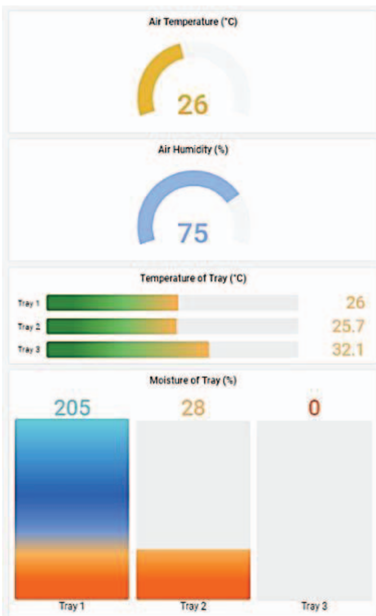

Fig. 5. System for monitoring of temperature and humidity

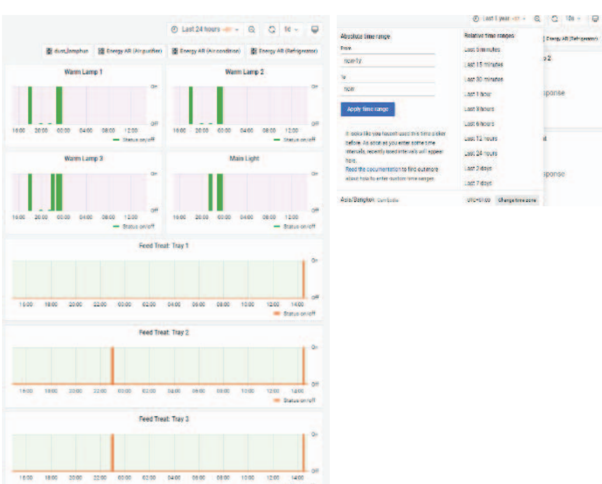

Fig. 6. The collection and storage of time-series data

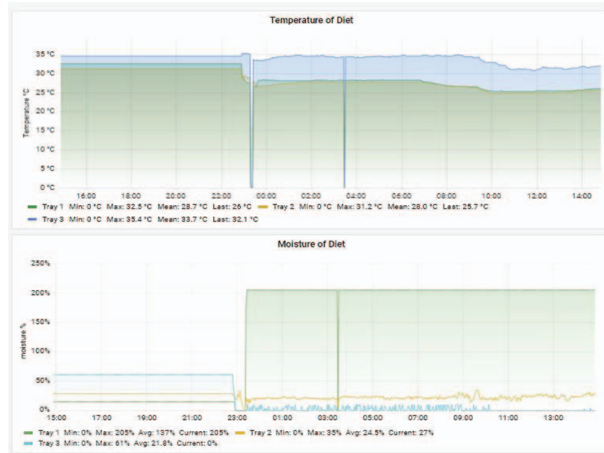

Fig. 7. Status of illuminance and feeding system

A flow chart is given in Fig 8 to understand the entire flow of the data and controls on the proposed method.

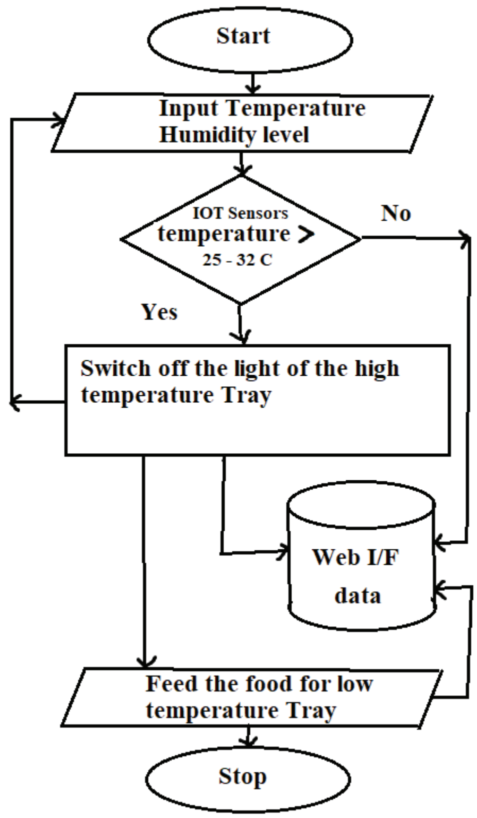

Fig. 8. Flow chart of the proposed method.

The Sensors will start to take the data as inputs from the tray environments. When the temperature is going more than 25 to 32 C, the lights will be switched off to reduce the temperature. Same time the date is being stored in web Interface. Then the temperature will reduce and the BSF Larve will start to eat the food or wastages again. When the temperature is being reduced than the temperature of 25, then the lights will be switched on and food is served again. The data is being stored again in Web Interface application. In future the food type, larve movements, weight of the tray, automation in data sharing, shall be taken into consideration for fully automation process. This will ensure the quality of more production and maintenance in BSF Larve.

IV. Conclusion

The proposed method confirms that the Semi automated cabinet shall be used in the black solider fly growth or feeding them. Semi-automated cabinet suit for rearing Black Solider Fly larvae. It approves BSFL production which efficiently reduce time and labor. Moreover, it has low-cost digital devices and easily accessible via application or website. This study also can provide the monitoring of air temperature, air humidity, food moisture and automation in feeding dry food by using IoT devices. The data will be shared and saved in a web user Interface to ensure the future enhancements as well. Therefore, this study proposed IoT system in order to enhance the feeding system and advance processing of the organic waste management.

Future study

Future plan is to compare the developmental growth of BSFL between control treatment and semi-automated cabinet treatment. Future study also consists of maintaining the temperature, feeding method, auto light controlling operations and alarming systems.

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