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POSSIBILITY TO DEGRADE WATER HYACINTH BY BLACK SOLDIER LARVAE

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Abstract

The study aims at assessing possibility to degrade water hyacinth by Black soldier fly larvae (BSFL). experiments were carried out with fresh hyacinth that were pre-treated to have different sizes; quantities and separated parts of water hyacinth (as stems, leaves and roots) using a homemade lab-scale model. It is found that highest degradation and biomass conversion could be achieved if feeding 2 kg water hyacinth of less than 2 cm size with 2 g black soldier larvae (BSF). Amount of the larvae increased from 2 g at the beginning to 12 g at the end of the process, while water hyacinth decreased from 2 kg to 0.4 kg. Leaves of water hyacinth showed highest degradation rate. If feeding BSF with a mixture of leaves, stems and roots of water hyacinth, bio-conversion rate of BSF and biomass degradation rate of water hyacinth will be lower.

Key words: *Black soldier fly larvae, BSFL, water hyacinth.*

1. Introduction

Vietnam has a diversified and plentiful river system with about 2360 rivers and canals, creating a water transportation, trade and service system in different areas of the country. However, recently, several areas in Vietnam where river system passing through are facing great difficulties, especially in agriculture due to rapid growth of water hyacinth. Thick layers of water hyacinth seems blocking water flow of rivers and leading to other problems. Removal of water hyacinth from rivers consumes high labor, waste time and money and is difficult to complete. It is easy to recognize how serious problems caused by water hyacinth in several locations via electronic newspapers such as "mosquito outbreaks because of water hyacinth growth in the West region of Vietnam[1]", "Ho Chi Minh city has to remove water hyacinth from rivers and canals to prevent mosquito[2]", "Thua Thien-Hue is miserable because of water hyacinth spreading on over the rivers[3]", "water hyacinth clogging waterways in Hau Giang[4]," etc. Not only in Vietnam, it seems that all over the world is also facing serious problems caused by water hyacinth growth.

The water hyacinth causes significant negative effects to both economic and ecological system. Without well controlled, they will grow very fast and coalesce into large piece floating and covering the surface of rivers, lakes, canals, etc. This hinders waterway, slows down water flow, reduces power generation and irrigation, and increase costs for maintenance the reservoir. Rapid growth of water hyacinth invades living space of other species in water, leads to moving of other aquatic species to other areas, changes the food chain in aquatic ecosystems, and reduces biodiversity in the aquatic environment (Villamagna and Murphy, 2010). In addition, the large layers of water hyacinth covered surface rivers causes prevention of photosynthesis of aquatic plants, while their degradation consume dissolved oxygen, hence reduces water quality. Besides, floating layer of water hyacinth is a living space of mosquitoes (a vector) and a parasitic snails carrying schistosomiasis (fever)[5].

According to Villamagna (2009: 25-30), there are many ways to treat and control water hyacinth, almost methods have negative impacts to economic or ecology. The mechanical methods used cranes, conveyors, cutter, etc. are considered as the best short-term solution, but this method requires large area for installation and operation. It is also high transportation cost as water hyacinth contains about 90% of water. Chemical methods will be more effective if applied on a large scale. However, the use of chemicals may kill also other aquatic life. The chemicals in herbicides may affect the lives of other animals and humans. In addition, this method requires special means spray chemicals that need high investment cost. Biological method is an alternative to replace mechanical and chemical methods. It has advantages of none toxic chemical requirement, reduction in labor and equipment investment and lower operational cost. However, one of the weak points of this method is time consuming for doing research and selecting suitable biological agents under different controlled environmental conditions.

The application of organisms that are capable of decomposing organic matter to transform them into useful products is developing nowadays. In particular, BSFL are widely applied in many areas in the world. In Texas - the United States, BSFL have been used to process yard waste, domestic waste, animal manure and human excrement to produce compost and harvest the larvae as feed for cattle and poultry (Newby, 1997; Newton et al., 2004). Several studies have been carried out by FAO using BSFL instead of fish meal in feed for aquaculture in many countries.

[1]http://phapluattp.vn/20130502114027592p0c1085/bung-phat-muoi-vi-luc-binh-o-nhiem.htm, July 26, 2013.
[2]http://nongnghiep.vn/nongnghiepvn/vi-vn/72/1/24/79406/Cuoc-chien-luc-binh.aspx, July 26, 2013
[3]http://www.thuysanvietnam.com.vn/thua-thien-hue-kho-so-vi-luc-binh-dan-kin-song-article-5408.tsvn, July 26, 2013
[4]http://canthotv.vn/tin-tuc/khan-truong-dep-nan-luc-binh-gay-tac-nghen-duong-song-o-hau-giang/, July 26,2013

[5]http://en.wikipedia.org/wiki/Water_hyacinth

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Application of BSFL has also been conducted in Vietnam Dr. Paul Olivier to process food waste from vegetable markets and domestic solid waste in Dalat[6]. In addition, several researches using BSFL to treat animal manures, to produce livestock feed and compost have been carried out by different universities in Vietnam such as Ho Chi Minh City University of Agriculture and Forestry, Can Tho University, etc. However, so far, the use of BSFL to increase degradation rate of water hyacinth has not been done yet. If succeed, this study would contributes a solution for handling water hyacinth and convert it into a valuable livestock feed.

This study aims at assessing and determining suitable conditions to degrade water hyacinth and recover biomass by BSFL in Vietnam's natural conditions. To achieve the core objective of the study, the following sub-objectives have been carried out:

- Ascertain effect of wet weight ratio of water hyacinth and initial BSFL to conversion efficiency;
- Ascertain effect of sizes of water hyacinth to conversion efficiency;
- Ascertain effect of stems, roots and leaves of water hyacinth to conversion efficiency.

2. Materials and methods

The study was implemented in two steps: (1) generating eggs and larvae and (2) studying the factors affecting to degradation rate of water hyacinth by BSFL.

Black soldier larvae breeding

To ensure sufficient and available BSFL for doing experiments continuously, it is important to maintain the larvae breeding. At the beginning, BSF eggs and larvae were taken from existing open dumpsites. However, due to fluctuation of amount of dumped waste and frequently use of insecticides at the sites, BSFL from this source was unstable. Therefore a BSFL breeding model was applied to ensure continuous egg collection and multiplication. A BSLF cage model was built based on its reproductive characteristics to create favorable conditions for them to lay eggs and help to determine the life cycle of BSFL in Ho Chi Minh city's climate.

The model of BSFL cage was designed in rectangular shape with sizes of 1.0 m x 1.0 m x 1.5 m = 1.5 m^3. It was made of plastic pipe ϕ16 mm including 8 pipes 1.0 m and 4 pipes 1.5 m. This frame was covered by a net (200:1) to ensure that adult flies do not fly out. One side of the cage has a door to get in the cage if needed.

The model was placed at the 2nd floor hallway in Van Lang University, where sunlight shines on directly. This location ensures the conditions of space, temperature, lighting for adult flies' copulation and reproduction. Adult flies needed sunlight directly and the temperature in the range of 27°C - 40°C to copulate and lay eggs. Trees with large leaf canopy were put into the cage to create living space for adult flies. Regular watering helps the plant grew and creates stable humidity and ambient temperature in the cage. Bucket trap to collect eggs are placed under the tree with available food for larvae and trap to collect eggs. The bucket trap was made of 20 L-paint container and drilled drainage holes. Sawdust was placed at the bottom of bucket to have a layer of 15 cm to keep stable temperature and humidity for the fly pupae reproduction.

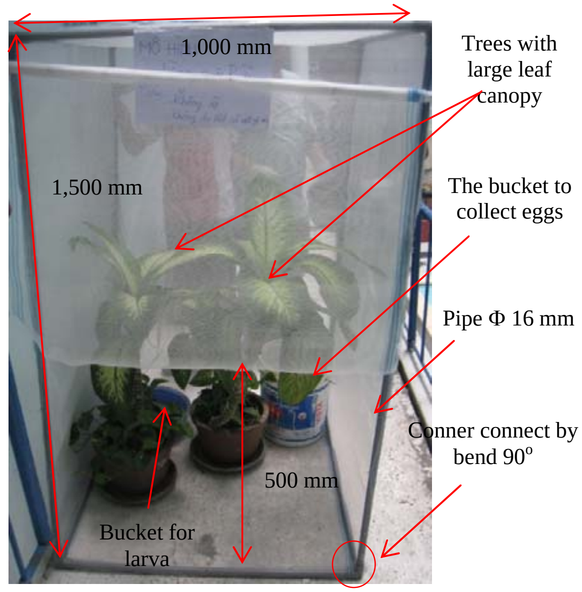

Fig. 1 BSFL breeding model.

Lab-scale model to determine suitable conditions for water hyacinth degradation by BSFL

Model was prepared based on characteristics of BSFL. Structure of the model helps to maintain humidity, temperature (29-40°C), drain out leachate and has places for larvae to crawl out when pupating. The models are often designed to have plastic trenches with slope in the rage of 35 - 40° (such as BioPod), or slope at 1 or 2 ends as a boat (for instance Bug Barrack). The simplest way is to put bucket sloping (Bug Blaster). However, each of these models have their own limits (Table 1) and unsuited to apply in this study.

In order to overcome disadvantages of the existing models, a new model was prepared for this study. The lab-scale model used in this study can be characterized as follows:

- Made of PVC pipe with a diameter of ø114 mm, length of 1 m, both ends sealed by lids;
- On the surface of the pipe at the upper side, there are 6-8 trenches with 0.1 cm in width and 10-12 cm long. Distance between two trenches is 2 cm. These trenches were covered by a net which has 200 holes/cm^2 to ventilate the model and prevent the larvae moving out;
- On the below side of the pipe, the top of the pipe was drilled a hole of ø21 mm and attached a pipe of ø21 mm with 7 cm long to connect to larva collection bottle;

[6] Empowering the Poor through waste transformation, 2011.

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- The bottom end of the model was also drilled 4-5 hole lines of ø0.3-0.5 cm. Distance between two holes is 0.5 cm. Similar trenches were also made for draining leachate.

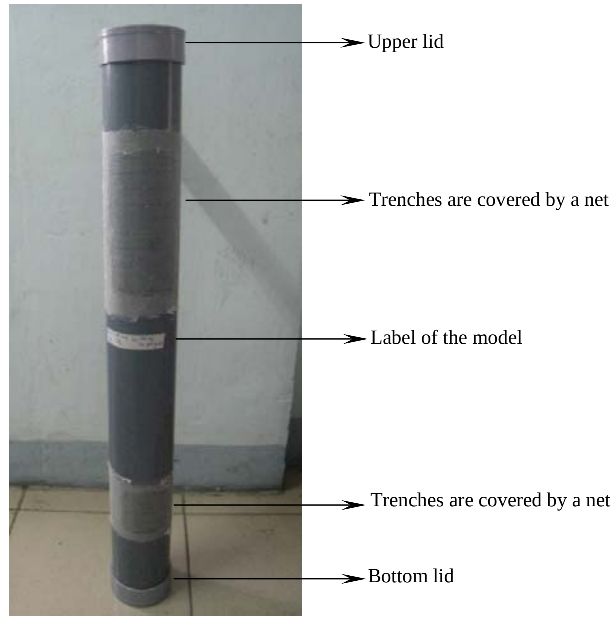
Table 1 Advantages and disadvantages of available BSFL models

Biopod	Bug Barrack	Bug Blaster
Advantages		
- High biomass degradation rate; - Less land requirement; - Simple operation; - High pupae generation rate.	- High biomass degradation rate - Suitable for high capacity; - Simple operation; - High pupae generation rate.	- High biomass degradation rate - Less land requirement - Simple operation; - Low investment cost; - High pupae generation rate.
Disadvantages		
- High price; - Facing problem of leachate during operation; - Limited amount of waste per treatment unit	- Large area requirement; - High construction cost; - Accumulation of non-biodegradable waste in in the model.	- Limited amount of waste to be treated per unit; - It is important to control suitable slope of the model for pupae crawling out.
		

This model was tested with larvae in the pre-pupae stage and found to be suitable for carrying out experiments of this study. Larvae crawled out of the pipe and fall into the bottle. Declination of the model was kept stable at 35^{o} by putting the model on an iron shelf. Advantages of new model compared to the available models include:

- Maintaining moisture of the model and creating suitable environment for BSFL;
- To be able to control number of BSFL in the model;
- Minimizing influences from outside;
- To be able to collect all pupae moving out;
- Less space requirement.

Fig. 2 Experimental model.



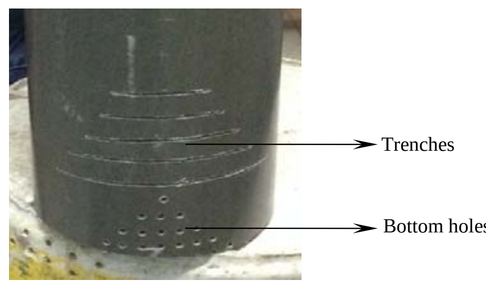


Fig. 3 Detail of the experimental model.

Materials

Water hyacinth was taken from Saigon River passing through Thanh Da area, Binh Thanh District, Ho Chi Minh City.

Initial BSFL was collected from the traps placed at Da Phuoc landfill. Initial fly eggs source was taken from Ho Ngoc Phuong farm in Hoc Mon District, Ho Chi Minh City. BSFL was breed using the model described above.

Ascertain effect of wet weight ratio of water hyacinth and initial BSFL to conversion efficiency

In the same period of time, a certain amount of BSFL can degrade only a certain amount of raw material. This experiment was carried out to evaluate proper ratio of water hyacinth and BSFL to achieve the highest degradation rate of water hyacinth, highest biomass conversion of BSFL, in the shortest period of time with lowest amount of the remaining. Experimental conditions are summarized in Table 2.

The experiment was conducted as follows:

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1st day

- Balancing the models;
- Balancing water hyacinth which have a size of 2 cm and feeding into the models with indicated amount (Table 2);
- Balancing amount and counting number of BSFL added into each model;
- Balancing total amount of the models after feeding;
- Measuring temperature inside of the models as well as ambient temperature;
- Sampling and analyzing moisture content, pH of water hyacinth in the models.

Table 2 Experimental set up to ascertain effect of wet weight ratio of water hyacinth and initial BSFL to conversion efficiency

Condition	Model 1	Model 2	Model 3	Model 4
Initial amount of BSFL (g)	2	2	2	2
Initial amount of water hyacinth (kg)	0,5	1,0	1,5	2,0
Moisture content (%)	Fresh water hyacinth			
Size of water hyacinth (cm)	2			

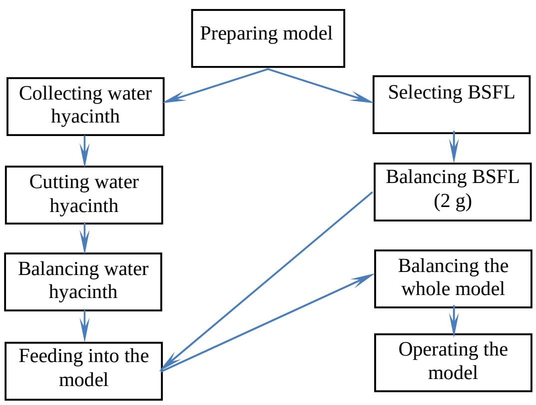

Fig. 4 Experimental set up procedure.

2nd day

- Measuring temperature inside the models and ambient temperature;
- Balancing the whole models. If the weight of the models decreased about 30% - 50%, adding new water hyacinth to reach the same weight of the 1st day.
- Balancing amount of leachate drained out.

3rd day

- Measuring temperature inside the models and ambient temperature;
- Balancing amount and counting number of BSFL of each models;
- Sampling and analyzing moisture content, pH of water hyacinth remained in the models;
- Balancing the whole models. If the weight of the models decreased about 30% - 50%, adding new water hyacinth to reach the same weight of the 1st day.
- Balancing amount of leachate drained out.

The next days, the models were operated similar to those first 3 days mentioned above. Besides, amount and number of pupa moved to the collection bottles were also measured. Observation and comparison sizes, color, activities of BSFL among these models were also done. The models were operated until their weights reached stable and number of pupa in the collection bottles pupa bin collector equaled to 80% total number of initial BSFL added into the models.

Ascertain effect of sizes of water hyacinth to conversion efficiency

The experiment was carried out following the procedure described above with the conditions summarized in Table 3.

Table 3 Experimental conditions to assess effect of size of water hyacinth to conversion efficiency

Condition	Model 1	Model 2	Model 3	Model 4
Initial amount of BSFL (g)	2			
Initial amount of water hyacinth (kg)	2			
Moisture content (%)	Fresh water hyacinth			
Size of water hyacinth (cm)	2 – 4	5 - 7	8 -10	Uncut

Ascertain effect of stems, roots and leaves of water hyacinth to conversion efficiency

The experiment was carried out following the procedure described above with the conditions summarized in Table 4.

Table 4 Experimental conditions to assess effect of stems, roots and leaves of water hyacinth to conversion efficiency

Condition	Model 1	Model 2	Model 3
Initial amount of BSFL (g)	2		
Initial amount of water hyacinth (kg)	2		
Moisture content (%)	Fresh water hyacinth		
Portion of water hyacinth	Roots	Stems	Leaves

3. Results and discussions

3.1 Effect of wet weight ratio of water hyacinth and initial BSFL to conversion efficiency

The temperature in the models was in the range of 30 - 34^{o}C, higher than ambient temperature about 1-2^{o}C. The higher the amount of water hyacinth is, the higher the temperature inside of the models. Figure 5 shows clearly difference between temperature in the models feed with 1.5 kg and 2.0 kg of water hyacinth compared to that of the model with 0.5 kg. This is attributed to the heat releasing from biodegradation of water hyacinth.

In general, pH values of the mixtures in the models were similar and ranged from 7.9 to 8.7. Moisture contents of these models ranged from 81.0% to 93.5% that matches to the optimal range for BSFL growth. Moisture contents of the models feed with 1.0 kg; 1.5 kg and 2.0 kg of water hyacinth seemed stable in the range of 90-92%. However, moisture content of the model feed with 0.5 kg of water hyacinth was unstable and reduced significantly during operation. Its moisture content was dropped to 81% at day 15. This is attributed to smaller amount of water hyacinth in this model leading to water evaporation and rapid reduction of the moisture content (Fig. 6).

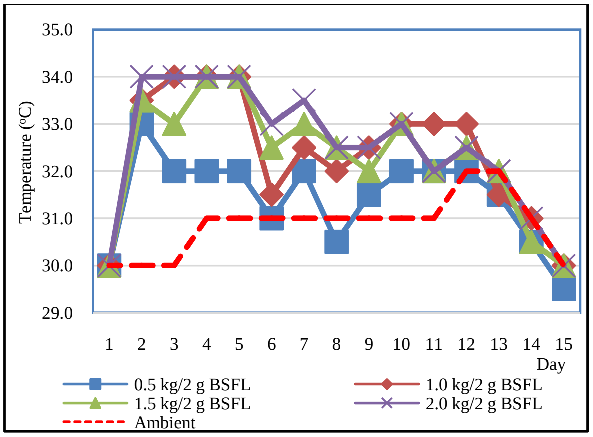

Fig. 5 Variation of temperature in the models.

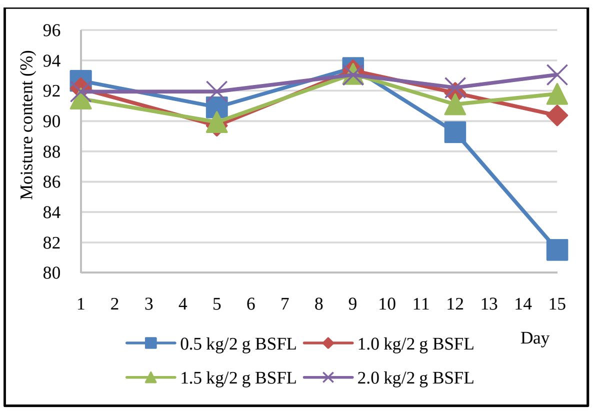

Fig. 6 Variation of moisture content in the models.

After 15 days of operation, it was found that amount of water hyacinth in the models have decreased steadily over time. However, there were differences in reduced amount and reduction rate. Amount of water hyacinth in model 1, 2, 3, 4 reduced from 0.5 kg at the beginning to 0.1 kg; 1.0 kg to 0.2 kg; 1.5 kg to 0.4 kg and 2.0 kg to 0.6 kg, respectively (Fig. 7). Thus, in average, reduction rates of these models were 27 g/d; 53 g/d; 73 g/d and 93 g/d, respectively. Organic matter content of water hyacinth in the models decreased from 75-80% (dry weight) at the beginning to 41-53% (dry weight) after 15 days of operation.

As amount of water hyacinth decreased, amount of BSFL increased during operation period. Figure 8 shows that the model fed with 2.0 kg of water hyacinth has highest amount of BSFL after 15 days grown. 2.0 g BSFL added into the model at the beginning increased to 6.0 g in the first week and then reached about 7.0 g at the day 15. In the models fed with 1.0 and 1.5 kg of water hyacinth, amount of BSFL increased from 2.0 g at the beginning to 5.8 g after 15 days, while for the model fed with 0.5 kg of water hyacinth, these values were 2.0 g and 4.2 g. Weight of BSFL increased rapidly within the first week and gradually slowed down as they changed to the pre-pupa stage In the 2 kg water hyacinth model, BSFL grew faster and pupae-stage started earlier compared to other models. Within 3 days, from day 15 to day 17, the amount of pupae biomass became stable and BSFL crawled out of the model.

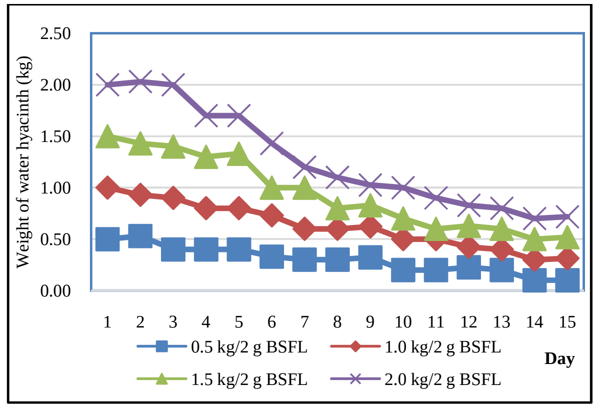

Fig. 7 Variation of organic matter content in the models.

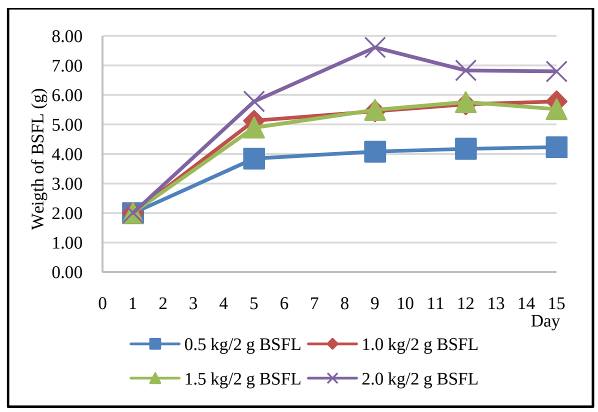

Fig. 8 Variation of BSFL weight in the models.

3.2 Effect of sizes of water hyacinth to conversion efficiency

The experiment was carried out with different sizes of water hyacinth (2-4 cm, 5-7 cm, 8-10 cm and uncut raw materials). During operation, the temperature in the models were similar and remained in the range of 28-34^{o}C. The temperature inside of the models varied with the variation of ambient temperature.

During the first week, pH of the models ranged from 7.0 to 8.5. The week later, pH of 4 models were greater than 8 and continued to increase. By the day 31, the end of operation stage, pH of the models maintained at about 8.8.

Moisture contents of 4 models were relatively similar and in the range of 86-95%. After 31 days of operation, amount of water hyacinth in the model 1 (the size of 2-4 cm) and the model 2 (the size of 5-7 cm) decreased significantly from 2.0 kg at the beginning to 0.4 kg.

However, if compared to the previous experiment, the time required to reach steady state longer (31 days compared to 17 days) while the amount of consumed water hyacinth increased only 0.2 kg. This is attributed to the decrease in enzyme secretion when BSFL started transforming into pupa. This caused reduction in substrate degradation rate. In addition, almost biodegradable materials were consumed in the initial stage, the remaining were more difficult for biodegradation and needed longer time. Organic matter contents in the models were reduced approximately from 80% to 42% (by dry weight) after 31 days of operation. Amount of BSFL in the models increased steadily over time. Especially, the model 1 where the size of water hyacinth was controlled at 2-4 cm, gained highest amount of BSFL after 27 days of operation, 7.0 g compared to 2.0 g at the beginning. . If extending operational time, amount of BSFL decreased as pupa did not use substrates and started consuming themselves nutrient and to be ready to transform into flies.

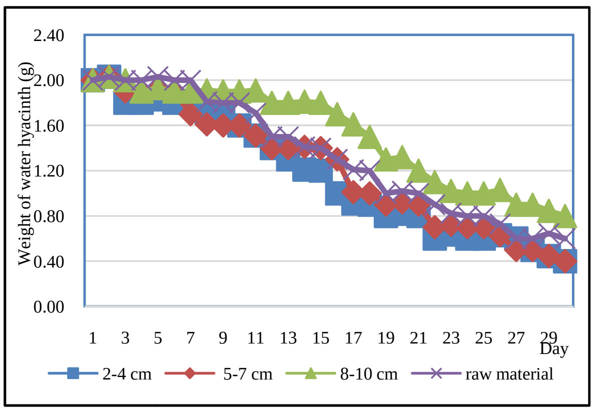

Fig. 9 Variation of water hyacinth weight in the models controlled different sizes.

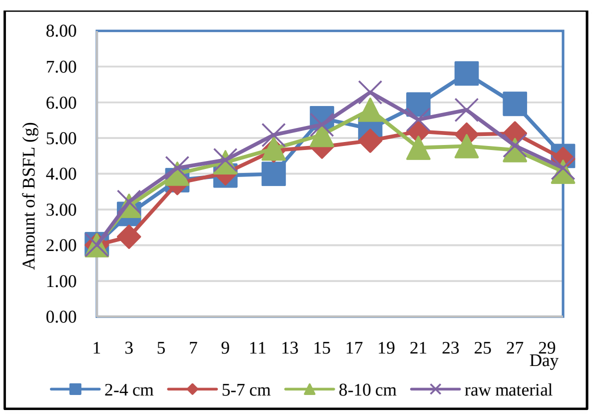

Fig. 10 Variation of BSFL weight in the models controlled different sizes of water hyacinth.

3.3 Effect of stems, roots and leaves of water hyacinth to conversion efficiency

There were significantly different in reduction of water hyacinth of the 3 models. Amount of water hyacinth stems and leaves decreased greatly from 2.0 kg at the beginning to 0.4 kg after 25 days of operation, while water hyacinth roots only decreased from 2.0 kg to 1.4 kg in the same operational period (Fig. 11). This is attributed to the difference in cellulose, hemicelluse and lignin contents in roots compared to those in the stems and leaves. In addition, it may also due to higher heavy metal contents in the roots compared to the stems and the leaves leading to inhibition of BSFL activity. Organic matter content in the stems- and the leaves-model decreased from 80% at the beginning to about 24% (by dry weight) after 25 days of operation. While in the model using the roots as feed, organic matter content decreased only from 80% to 44% in the same operational period.

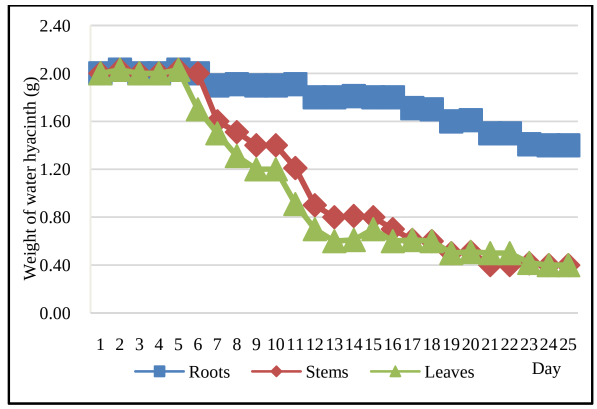

Fig. 11 Variation of water hyacinth weight in the models using only roots, stems or leaves.

There were also significantly differences in quantity of BSFL in these models. The model used roots of water hyacinth as feed, weight of BSFL did not increase, while in the models fed with stems and leaves, total weight of BSFL increased from 2.0 g at the beginning to 12.0 g at day 15 (Fig. 12). It was also possible to observe that BSFL from the model fed with roots was very small and weak.

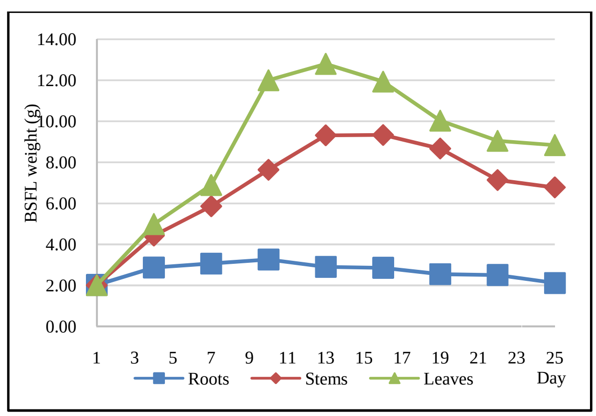

Fig. 12 Variation of BSFL weight in the models using only roots, stems or leaves.

4. Conclusions and recommendations

4.1 Conclusions

The experimental results allow to draw the following conclusions:

- By cutting water hyacinth to < 2 cm and feeding at the ratio of 2 kg water hyacinth/2 g BSFL , it is possible to get both highest biodegradation rate of water hyacinth and biomass conversion rate of BSFL;
- Water hyacinth leaves are the best component for feeding BSFL compared to its stems and roots;
- 80% of water hyacinth was degraded, corresponding to its quantity decreased from 2.0 kg at the beginning to 0.4 kg while BSFL increased from 2.0 g initially to 12.0 g within 15 days of operation
- If feeding BSFL with a mixture of roots, stems and leaves of water hyacinth, biomass conversion of BSFL will be lower compared to the case of feeding them with only leaves.

4.2 Recommendations

- It would be better to operate larger scale models to evaluate possibility for practical application;
- It is also important to increate biomass conversion rate and shorten the retention time;
- Further study on alternatives to reuse water hyacinth left from the model is also necessary.

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