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BLACK SOLDIER FLY - ECOLOGICAL WASTE RECYCLING TOWARDS HEALTHIER TOMORROW

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Abstract

Organic waste management is becoming a serious problem especially to developing countries like the Philippines. There are laws and guidelines for reusing, recycling certain materials, reducing food waste, etc., but due to growing population and urbanization, there is a challenge in implementation and even little attention is given to organic waste segregation and management. The focus of this study is to explore a low-cost, efficient, and eco-friendly approach for waste decomposition by utilizing what nature has already provided for us – Black Soldier Fly or BSF (Hermetia illucens) – through maximizing each stage of its life cycle, as means for upcycling almost all organic waste into compost that will enrich the soil and become fertilizers. By using the byproducts of the black soldier fly farming, we will also explore the possibility of creating a viable business model in producing a sustainable source of high-protein feeds for livestock and fish that will certainly help the farmers and fishermen with a more affordable and renewable source of feeds (protein) while managing the organic waste management to create a full cycle of an economic and environment-friendly business structure.

Index Terms

Black Soldier Fly, ecological recycling, healthier tomorrow

I. INTRODUCTION

As one of the developing countries, the Philippines, is faced with a problem with waste management. A law - "Republic Act (RA) 9003" - Ecological Solid Waste Management Act of 2000, which basically mandates the local government units in the country to establish solid waste management plans and achieve waste reduction with a target of at least 25%. The National Solid Waste Management Commission through the DENR created a 10-year plan *(DENR, 2019)* that aims in assisting the local government units (LGUs) in their campaign to implement the Ecological Solid Waste Management Act of 2000 for the main purpose of environmental protection. The assistance will include the materials recovery facilities establishments wherever suited, as well as the rehabilitation and/or closure of dumpsites (based on proximity with residents) and to make an ecologically efficient disposal system. *("Philippine Solid Wastes" 2017, November)* noted that based on World bank calculation, it estimates that solid waste being produced by Philippine cities will go up by 165% or total of 77,776 tons per day from 29,315 tons as a consequence of a projected 47.3 percent hike in urban population. In one of the fast developing regions like CALABARZON Region 4A, data shows that the average volume of wastes generated is five thousand six hundred ninety four tons per day (5,694 tpd), or 0.320 kg per head per capita in terms of waste generation. This number is projected to go up to as high as six thousand five hundred fifteen tons per day (6,515 tpd) by year 2023. In the same report, it

shows that 41-53% comprises biodegradable waste that just end up in landfills. (*DENR CALABARZON SWM report 2020.* With its landfill limits, DENR calls on the LGUs to implement segregation at source – food scraps to turn into agricultural excess, plastics recycling, repair and reuse and upcycling of waste into something useful *(Jonathan L. Mayuga 2020)*. The call to address this is important since there are health hazards for those who are living near landfills. *(Oxford University Press, 2016).*
(Prince O. Njoku, Joshua N. Edokpayi, and John O. Odiyo2. 2019 June) also concluded in a related study that landfill management is very essential due to the health risk associated for near-landfill residents as compared to those living far away from landfill sites due to all types of pollution.

II. RESULTS

Black Soldier Fly as treatment for organic waste problem
The black soldier fly, in terms of nutrient-recycling through bioconversion of organic waste into biomass, would seem to be the most promising candidate in the insect world. *(Kaya, C., Generalovic, T. N., Ståhls, G., Hauser, M., Samayoa, A. C., Nunes-Silva, C. G., ... & Sandrock, C. 2021).* Black soldier fly life cycle can be divided into 4 stages; egg, larvae, pupa, and adult. Once it goes from larvae to pre-pupae stage, it will look for a dry place as a pupation site and turn into pupa. This pupa will only survive on the fat stored during the larval stage and will no longer eat anything. It will then emerge and become an adult fly, at that point, it will feed only on water. That is why the adult flies are neither considered a pest or disease vector. *(Liu, X., Chen, X., Wang, H., Yang, Q., ur Rehman, K., Li, W., ... & Zheng, L. 2017).* The optimal stage to feed them are during the larval stage of five days after hatching from eggs as this is is the cycle when they are heavy-eaters and would consume any organic material given to them *(Singh, A., & Kumari, K. 2019)*, the larvae would devour the food by forming a mountain around the food to access it. *(Shishkov, O., Hu, M., Johnson, C., & Hu, D. L. 2019).* As noted by *(Cheng, J. Y., Chiu, S. L., & Lo, I. M. 2017)* , when you use the food waste with 80% moisture, that is when the larval growth is observed to be optimal and the moisture content of the substrate does not significantly affect the survival rate of the larvae. *(Lalander, C., Diener, S., Zurbrügg, C., & Vinnerås, B. 2019)* noted the effects on the development of larvae and their process efficiency in terms of organic waste consumption based on different (with moisture of about 40% water) substrates such as poultry feed, dog food, and food waste that was collected from a restaurant, fruits and vegetable (combination of lettuce, apples and potatoes), abattoir waste, abattoir-fruit and vegetable waste, poultry manure (from laying hens in a poultry farm), human faeces, primary sludge and undigested sludge, and concluded that abattoir waste, food waste, human faeces and a mixture of abattoir waste – fruits & vegetables are highly suitable substrates for fly larvae treatment using black soldier fly larvae. While pure fruit & vegetable waste and different sewage sludges are less suitable. A study to compare black soldier fly versus composting in terms of eco-friendliness was also conducted, *(Mertenat, A., Diener, S., & Zurbrügg, C. 2019)* and that in terms of GHG emissions, the BSF showed a lower emission compared to the microbial emissions in the open composting process. However, the study for the overall global warming potential impact of BSF treatment facility mainly will depend on the type of post-processing for the residue and taking into account the electricity consumption used and may need to be further studied or observed. In Indonesia, there is a successful bio-waste facility, a project between the Swiss and Indonesian government to address the waste management problem in the urban area where unsegregated wastes are collected and transported outside the city that is costing the government a lot of money, not to mention the risk of pollutants getting scattered all over the places before it reach the dumpsite. Through the black soldier fly technology, they are now able to upcycle the organic waste and they found out from their market study that from other options such as compost, biogas, biochar, or insect protein – it is the insect protein that is more suitable for public demand. *(Prof. Enri Damanhuri, Dr. Cindy Rianti Priadi, Dr. Chris Zurbrugg, Ir. Dodi Krispratmadi, Bart Verstappen, Bram Dortmans 2017).* The food

waste to bsf larvae ratio is only about 30% - where you will have to feed 0.3 ton of larvae to a ton of food waste to get the optimum development of the larvae, and feed them from 5-dol (days old) to 12 days before harvesting them as feeds and use only 1% of the population for the next cycle or generation of the black soldier fly colony, *(Dortmans B.M.A., Diener S., Verstappen B.M.,Zurbrügg C. 2017)*. Locally, in the Philippines, (*Department of Agriculture, 2020 January)*, The Agricultural Training Institute through the Department of Agriculture partnered with a farm to conduct a seminar to introduce the technology to producing chemical-free animal feeds – through the black soldier fly farming as well as help on waste management.

Black Soldier Fly as a sustainable animal feed source

(Shumo, M., Osuga, I. M., Khamis, F. M., Tanga, C. M., Fiaboe, K. K., Subramanian, S., ... & Borgemeister, C. 2019) Black soldier fly on its larval stage can contain up to 50% of crude protein (CP), up to 35% lipids, and it was also discovered that it has amino acid profile that is close to that of the qualities of a fishmeal. These are the main characteristics of the black soldier fly that can be considered as possible substitute sources for feeds of chicken, pigs, and even shrimp and several species of fish. *(Bruno, D., Bonelli, M., De Filippis, F., Di Lelio, I., Tettamanti, G., Casartelli, M., ... & Caccia, S. 2019)* Observed the black soldier fly larvae on three different diets of substrates namely – fish, vegetable and standard diet for optimal rearing purposes and what was found is that the bsf larvae reached the maximum weight on the standard diet substrate, and for those larvae placed on the fish meal, it even doubled the developmental time for the larvae and almost only contained half of the maximum weight as compared with the standard diet. *(De Smet, J., Wynants, E., Cos, P., & Van Campenhout, L. 2018)* noted that on a fiber rich or protein rich diet, the larvae showed a much slower development, as compared with the larvae that fed on a balanced diet of cereal processing leftovers. On a study conducted by *(Mariod, A. A. (Ed.). 2020)*, it was concluded that bsf larvae that fed on food waste and vegetable matter, were able to reduce the volatiles and the nitrites and were effective in converting the nutrients into their own biomass which can be then fed on directly to fish, and other livestocks as protein substitute. It was observed that even if you feed the bsf with the substrate from livestock manures, they will convert it effectively into nutritional value and can be fed back to the livestock which is almost creating an important nutrient loop, without having to genetically alter the black soldier fly. (*Shelomi, M. 2020),* further confirms the conclusion that bsf converts even the manures and lignocellulosic wastes to protein and fat for livestock consumption as a renewable food supply. The crude fat found in bsf are further studied and found traces of omega-6 to omega-3 fat ratios. Even some traces of vitamin E and certain minerals were found though a more rigid study and observation will have to be carried out for these. One important thing to note with bsf is that they do not bioaccumulate pesticides, drugs, or mycotoxins. However, they found some traces of cadmium. Further study can be conducted as to what contributes to the cadmium accumulation and if it will pose a health hazard for animal or human consumption.

Black Soldier Fly as Livestock feed

(Cutrignelli, M. I., Messina, M., Tulli, F., Randazzo, B., Olivotto, I., Gasco, L., ... & Bovera, F. 2018) conducted bsf as a total meal replacement of soybean for laying hens diet from 24 to 45 weeks. It was observed that this diet had a negative effect on the feed intake and reduced the live weight of the chickens. It was recommended that further study needs to be conducted on the optimal inclusion of the bsf for the chicken in their diet in order to balance the nutrient digestibility and reduce or eliminate the negative effects on the health of the chickens. *(Kawasaki, K., Hashimoto, Y., Hori, A., Kawasaki, T., Hirayasu, H., Iwase, S. I., ... & Fujitani, Y. 2019)* noted that in the study performed to observe what kind of effect does the bsf have in terms of the eggs produced by laying hens. A separate set of hens were fed with bsf – these larvae and pupa fed to the hens were only cultivated using food waste with no special diet and only in a backyard setting. They completely replaced the soybean ingredient in the chickens' diet and it resulted that the eggshells got actually thickened as compared to the different set of hens that were placed under a controlled diet.

Black Soldier Fly on fish diet

A need to search on other sustainable sources for fish diet for both long term and short term solution is called upon to replace the conventional protein sources such as fish meal, fish oil, soybean meal, etc. due to the growing aquaculture area and pressure on the natural ecosystem and as immediate effect in the environment, several studies are conducted (and more dedicated research are needed) towards finding a more renewable source that will require much less natural resource to cultivate and yet be able to cope with the market demand, especially when it is forecasted that the world population will peak at 9-10 billion by 2050. *(Tschirner, M., & Kloas, W. 2017).* In a study conducted in for seebass in Europe *(Magalhães, R., Sánchez-López, A., Leal, R. S., Martínez-Llorens, S., Oliva-Teles, A., & Peres, H. 2017),* it was found that the black soldier fly, on its pre-pupa stage that was fed to the European seabass can actually be considered as a form of replacement for abou 19.5% of fish meal in their diets as this showed that it did not have an adverse effect (digestibility coefficients and enzyme activities) on the growth performance of the fish even after the inclusion of the bsf meal in its diet. *(Rana, K. S., Salam, M. A., Hashem, S., & Islam, M. A. 2015),* study conducted in a rural place in Bangladesh to check if bsf that is reared in a natural environment as well as from a laboratory can be used as a supplement feed for tilapia fish. Even with only using household waste as substrate, it was proven that bsf that is cultivated under natural condition can be used as an effective meal supplement for tilapia fish feed and reduce the environmental wastes such as kitchen waste and poultry manure. *(Dietz, C., & Liebert, F. 2018),* conducted a similar study with tilapia, by replacing the soy protein concentrate on tilapia feeds (partly defatted bsf meal), or 18.5% inclusion in the total diet of the fish, and concluded that this approach improve the dietary protein quality of the tilapia feeds and did not affect the growth performance of the tilapia which is a significant finding. In the same study, it was further taken to a 100% replacement but resulted in a negative impact on the dietary nutrients for the tilapia. A more recent study, *(Yildirim-Aksoy, M., Eljack, R., Schrimsher, C., & Beck, B. H. 2020),* the larval frass as a replacement meal is a suitable ingredient for use in tilapia diets on up to 30% as it was found to improve the growth as well as protein utilization of the juvenile hybrid tilapia fish.

Adding the larval frass also appears to have a positive effect on the increased immunization of the tilapia to certain infections. *(Tippayadara, N., Dawood, M. A., Krutmuang, P., Hoseinifar, S. H., Doan, H. V., & Paolucci, M. 2021),* on a more recent research noted that there is no significant difference in terms of replacing the fish meal by bsf meal (partially or fully) in terms of the tilapia feed utilization, survival rate and growth performance. If any, it even improved the mucosal immune response of the fish that was fed by bsf compared to the fishmeal. It is highly recommended that bsf can be used as a substitute for the Nile tilapia diet and be adapted in developing aquafeed for sustainable aquaculture.

Black Soldier Fly on small pigs diet

(Barragan-Fonseca, K. B., Dicke, M., & van Loon, J. J. 2017), noted that black soldier fly larvae as meal could be a suitable ingredient in pig diets due to the calcium and amino acid content (though some deficiency were noted in methionine and cystine) and the pigs seemed to like it.

An observation for the weaned pig, however, is that it did not perform well when fed on bsf and further study may be needed to improve the performance on early weaned pigs for that matter.

On another study, *(Spranghers, T., Michiels, J., Vrancx, J., Ovyn, A., Eeckhout, M., De Clercq, P., & De Smet, S. 2018),* piglets can be fed with either full-fat or defatted bsf prepupae and will not have adverse effect in terms of performance and growth. This is even when replacing the soybean factor in their feeds by 100%. *(Nekrasov, R., Zelenchenkova, A., Chabaev, M., Ivanov, G., Antonov, A., & Pastukhova, N. 2018),* conducted a study on dried black soldier fly larvae and showed promising results in terms of pig growth on the average daily gain aspect with high total protein concentration. As of larvae's fat examination, they also found that it is rich in lauric and other medium-chain fatty acids. Moreover, some traces of melanin, chitin, antimicrobial peptides are also found in the post-processed, dried black soldier fly larvae. *(DiGiacomo, K., & Leury, B. J. 2019),* another study was conducted in Australia and concluded that it poses a big

opportunity to develop a sustainable feed source for pig producers in the area. This will also help in addressing the manure management for the pig farms and would be a great replacement from other protein sources because it will reduce the GHG production as well as water and land requirements to cultivate.

Black Soldier Fly Farming as a viable business

Every stage of the black soldier fly life cycle adds value in the ecosystem chain. From hatching as 5-day-old larvae upto pre-pupa stage this is when they will consume the food waste. By "saving" some cost to dispose the food waste alone, you are actually one step in creating an income, that is why other countries are already utilizing this fantastic creature to complete the value chain as you can integrate and even make it an income generating as well as long-term approach to resolve the problem in solid waste, particularly organic waste management. *(Weidner, T., Yang, A., & Hamm, M. W. 2019),* insect farming (using different species) are now being explored for protein production, and black soldier fly based on studies conducted is the most promising medium. Rearing insects, compared to other sources of protein, need less requirements in terms of natural resources to cultivate, and with the simple technology needed, they generate less GHG compared to most animal farming. Although there is still a room of acceptance still to talk about human consumption, when referring to animal feeds such as chicken, fish, pigs, these black soldier flies are already gaining attention. *(Madau, F. A., Arru, B., Furesi, R., & Pulina, P. 2020),* insects for feed and food - creating a business model of value for them, to solve their problems, where a new add-value product can be created just based on utilizing the remaining economic value in the products after use in the production – as new products at a cost lower than the value of the problem you are trying to provide resolution to. Given that, in terms of market study between different statuses of farmers – based on level of their awareness and capacity of purchasing insects as feeds; some are less likely to accept than others; those who are somewhat aware and wealthy as well as those who have other income aside from farming, are more likely to accept the idea of insects as a consumer product, while those who are not so much aware, and those who are less wealthy are also less likely to have favorable response in the market. Given this result, further study of the market in different regions and their livelihood can be conducted to be able to reach the point where at least those who will benefit from this insect industry – farmers and fishermen, will be willing to accept the insect-based product that will emerge from a new industry of farmers for different protein-rich source of feeds and possibly food *(Okello, A. O., Nzuma, J. M., Otieno, D. J., Kidoido, M., & Tanga, C. M. 2021).* Apart from using the larvae as direct feed for animals, you can also use them as feed ingredient and include in the production for livestock feed as substitute to soybean and fishmeal (which costs about 70% of the feed), *(Chia, S. Y., Tanga, C. M., van Loon, J. J., & Dicke, M. 2019)* – where most studies show that using black soldier fly larvae/pupa costs less in most regions than others. Most likely, the production of the larvae will be based on waste streams which will cost you zero – or even create another stream of income, that is, because some industries need to pay people to handle their trash. Government municipalities in most, if not all, are also allocating a certain percentage of their budget on waste management. In which case, it will involve an additional investment in the technical infrastructure with space and containers as well as machineries in order to produce them, not to mention, the utility costs to operate them, such as water, electricity and other possible raw materials that a producer would need to create a value-add product – you can supply the raw materials to be more cost-effective or complete the production, either way, this will also incur cost of some manual labor and will require employment - which is also good for the economy. In Germany, *(Rumpold, B. A., Speckmann, H., Schlüter, O., Kloas, W., & Prochnow, A. 2018),* where similar study was conducted to see the potential of bsf larvae that is reared in different substrate available in the country, would be best suited as fishmeal replacement for aquafeed (rainbow trout). The larvae were set on different residues such as agricultural by-products, forestry residue, municipal waste, industrial residues, residues from other areas. And what was found is that the highly suitable substrates with high nutrient content were from the municipal waste as well as from industrial residues, while all other substrate contain only low nutrient value and are not deemed

to be feasible – even if deemed ecologically and economically attractive, the technical potential still needs to be further investigated as well as the complete nutritional effect on the bsf meal. Government policy also prohibits using manure to cultivate due to toxicological and ethical concerns that could be raised in the country. However, I know that in some countries that are already farming BSF, utilizes even the livestock manure to grow the larvae, and then later on post-process the feeds and feed them to the same livestock – only that now, the larvae already converted these from manure to their biomass and contains fat and protein content. Black soldier fly as fertilizer, its residue can be further converted to fertilizer, making it a completely zero-waste processing all through the bsf life cycle. BSF nutrition is proven to be dependent on the different substrates used, as well as the environmental conditions where they are raised. *(Boaru, A., Vig, A., Ladoşi, D., Struţi, D., Păpuc, T., & Georgescu, B. 2018),* conducted a study that covered the period of approximately 37 days for laying hen manure bioconversion – which was precedented by other studies such as – (1) 14-day period for swine manure processing, by (2) 30-day period for cattle manure, while some studies also indicated (3) 24-day period for converting poultry manure to organic fertilizer. The bsf larvae was observed from the moment it hatched – it started to feed on the substrate and through digestion, the bioconversion process began. Same type of substrate were used to monitor the impact, and this is from larvae to prepupal stage upto the time when it ceased to feed and migrates, to be ready for adulthood. The experiment of larvae development in laying hen manure concluded that the substrate that can be used as an organic fertilizer can be obtained by larval composting of poultry manure, the insect biomass which can be used as a protein source can be obtained depending on the harvest stage. Accelerated bioconversion of manure from poultry farms can be obtained by using both the composting period and the environment; negative impacts are notably reduced. Following larval digestion, the resulting bio compost can be used as a horticultural and agricultural fertilizer. *(Mariod, A. A. (Ed.). 2020),* bsf larvae as a raw material for other commercial products – it can also be ground into pellets or mashed them for better transportation or later processing, some studies proved that bsf oil when extracted are comparable to soy or fishmeal and soy or fish oil. Apart from that, in the future, it may even surpass the silkworm or cricket in terms of valuable, commercially farmed insects. *(Altieri, M. A., & Nicholls, C. I. 2020),* is it a viable business even during pandemic COVID caused an imbalance in the animal/protein supply all over the world. It has caused malnutrition, ironically, obesity in some areas, loss of biodiversity, food waste and appalling working conditions for migrant laborers, and most impact felt by small farmers and their livelihood. If there's one thing we have learned, it is that there is an urgent call for food production to be in the hands of small producers and farmers. With this, we can ensure the supply of fresh food, at affordable prices in nearest local markets, away from the chains of the capitalist market *(Holden, P. 2020).* At which point, when the customers do support small farmers instead of those in the corporate food chain, who are certainly more at risk, they create socio-ecological sustainability and resilience. We can try create a new world that is led by allied social, urban, and rural movements that are aware that a return to the way of agriculture was before the pandemic is not an option; and that will actively turn local farms into integral asset for producing food and encourage independence for each municipality, region, while consolidating sustainable and healthy agroecological territories. As for the considerable solid waste management, there are many options or approaches that are in practice to achieve the desired high waste-to-biomass conversion ratio and creating value added chains by incorporating biomass-based products. BSF larvae composting outshines the present conventional ways in terms of waste-to-biomass conversion by a substantial margin *(Choudhury, A. R., Ashok, K. N., Arutchelvan, V., Thota, K. R., Ravi, S. N., Sandeep, K. D., & Goutham, R. M. 2018).*

III. SYNTHESIS

In conclusion, the black soldier fly as a tool to convert waste to biomass is already proven that is why more and more countries are putting it into practice and is continuously gaining more attention from people all around the world as they find it useful to address the problem of organic waste management. Governments are even making partnerships to seek help from the

pioneers who already have the working system in their countries - to teach and train staff and create a similar facility in their respective area. Byproducts of black soldier farming is also continuously being studied as to what substrate is the most optimal medium to be used for the development stages for consumption, although in terms of waste management, they can survive in almost any organic substrate and are highly effective in converting these waste materials to be an add-value raw material that can even be commercialized. This medium alone, can help address at least 9 out of the 17 sustainable development goals designed by United Nations namely, promote zero poverty, zero hunger, gender inequality, clean and water sanitation, decent work and economic growth, industry innovation and infrastructure, responsible consumption and production, life below water , and life on land which proves to be a very effective and eco-friendly medium. In terms of economic scalability, even small farmers and fishermen, where most of the important costs in raising livestock/fish is the feed which amounts to upto 70% of the process, especially on the protein components – soybean, fishmeal which prices are only increasing in costs. This proves to be a great alternative for protein needs and creating a sustainable and low cost protein source. In terms of operational costs, rearing black soldier fly does not need too much of natural resources to produce such electricity, water resource, land resources to produce as compared to other conventional protein sources. Apart from that, in terms of composting, studies show that if we compare bsf to vermicomposting – bsf is emitting way less GHG as compared to traditional vermicomposting ways of creating fertilizers. Also, more research is still needed for optimizing and upscaling this bsf rearing farming opportunity. Imagine the circular production opportunity that can be done with the use of bsf – from household consumption to food residue – then to bsf farming, to creating an insect meal and/of feed component – that will generate an income. From crops, to soil enrichment, to manure processing then as feed for fish and animals, to producing the fish, meat and eggs – it will clearly generate an income. We are seeing an improved food security since it can even be done in a backyard setting and very little space is required. It will reduce poverty because even humans also require protein (although a lot of research has to go for human consumption and health-related findings), an innovation and economic improvement indeed, as well as improved environment sustainability as it helps create a full cycle of ecology. When a solid waste management facility is created, it will create employment opportunities within the location, and it can be easily operated even by those with non-degree holders within the community since the system, process and life cycle of the bsf is very easy to follow and is not complicated and hard to monitor. In terms of support, it will heavily be dependent on the cultural and social factors of the implementing municipality or country for that matter – in Philippines, especially in CALABARZON Region4A, I think we would likely be more open to accept these bsf larvae as animal feeds, but we are still far from accepting it as human food -even if it is already being consumed by people in other countries (post-processed as dried bsf or powdered). Political factors are also a great player for the waste management segregation campaign, in terms of policy making and more support is needed for implementation and awareness for the community. That said, further effectiveness of the facility will require technical know-how and the ability to evaluate the performance of different animal breeds that are reared on the bsf as feed but it certainly can be done.

Abbreviations:

BSF	Black Soldier Fly
CALABARZON	Cavite, Laguna, Batangas, Rizal and Quezon.
DENR	Department of Environment and Natural Resources
FCR	Feed Conversion Ratio
GHG	GreenHouse Gas
GWP	Global Warming Potential
LCA	Life Cycle Assessment
LGU	Local Government Unit
NSWMC	National Solid Waste Management Commission
SPC	Soy Protein Concentrate

SWM Solid Waste Management

References:

Altieri, M. A., & Nicholls, C. I. (2020). Agroecology and the reconstruction of a post-COVID-19 agriculture. *The Journal of Peasant Studies*, *47*(5), 881-898.

Barragan-Fonseca, K. B., Dicke, M., & van Loon, J. J. (2017). Nutritional value of the black soldier fly (Hermetia illucens L.) and its suitability as animal feed–a review. *Journal of Insects as Food and Feed*, *3*(2), 105-120.

Boaru, A., Vig, A., Ladoşi, D., Struţi, D., Păpuc, T., & Georgescu, B. (2018). Studies regarding the fertilizing capacity of poultry manure biocomposted by fly larvae (Diptera: Stratiomyidae). *Advances in Agriculture & Botanics*, *10*(3), 114-121.

Bruno, D., Bonelli, M., De Filippis, F., Di Lelio, I., Tettamanti, G., Casartelli, M., ... & Caccia, S. (2019). The Intestinal Microbiota of Hermetia i llucens Larvae Is Affected by Diet and Shows a Diverse Composition in the Different Midgut Regions. *Applied and environmental microbiology*, *85*(2), e01864-18.

Cheng, J. Y., Chiu, S. L., & Lo, I. M. (2017). Effects of moisture content of food waste on residue separation, larval growth and larval survival in black soldier fly bioconversion. *Waste management*, *67*, 315-323.

Chia, S. Y., Tanga, C. M., van Loon, J. J., & Dicke, M. (2019). Insects for sustainable animal feed: inclusive business models involving smallholder farmers. *Current Opinion in Environmental Sustainability*, *41*, 23-30.

Choudhury, A. R., Ashok, K. N., Arutchelvan, V., Thota, K. R., Ravi, S. N., Sandeep, K. D., & Goutham, R. M. (2018). Black soldier fly larvae, a viable opportunity for entrepreneurship. *Acta Scientific Agriculture*, *2*(9), 11-20.

Cutrignelli, M. I., Messina, M., Tulli, F., Randazzo, B., Olivotto, I., Gasco, L., ... & Bovera, F. (2018). Evaluation of an insect meal of the Black Soldier Fly (Hermetia illucens) as soybean substitute: Intestinal morphometry, enzymatic and microbial activity in laying hens. *Research in veterinary science*, *117*, 209-215.

De Smet, J., Wynants, E., Cos, P., & Van Campenhout, L. (2018). Microbial community dynamics during rearing of black soldier fly larvae (Hermetia illucens) and impact on exploitation potential. *Applied and Environmental Microbiology*, *84*(9), e02722-17.

Department of Agriculture (2020 January). *Kahariam Farms Introduces Black Soldier Fly Technology Department of Agriculture - Agricultural Training Institute* https://ati.da.gov.ph/ati-main/news/01282020-1127/kahariam-farms-introduces-black-soldier-fly-technology

Department of Environment and Natural Resources (2019, January 11). *Intensified Environmental Protection: Solid Waste Management*. DENR. https://www.denr.gov.ph/index.php/priority-programs/solid-waste-management

Dietz, C., & Liebert, F. (2018). Does graded substitution of soy protein concentrate by an insect meal respond on growth and N-utilization in Nile tilapia (Oreochromis niloticus)?. *Aquaculture Reports*, *12*, 43-48.

DiGiacomo, K., & Leury, B. J. (2019). Insect meal: a future source of protein feed for pigs?. *animal*, *13*(12), 3022-3030.

Dortmans, B., Diener, S., Bart, V., & Zurbrügg, C. (2017). *Black soldier fly biowaste processing: a step-by-step guide*. eawag.

Environmental Management Bureau Calabarzon Region. (2020). *List of Waste Classification in CALABARZON Region (2018). DENR EMB.* http://calabarzon.emb.gov.ph/wp-content/uploads/2019/02/2018-swm-consolidated-report.pdf

Holden, P. 2020. *The Coronavirus Pandemic and Future Food Security*. https://www.ehn.org/coronavirus-food-security-2645620103.html?rebelltitem=1#rebelltitem1

Jonathan L. Mayuga (2020, August 21). *DENR flags Calabarzon landfill limits. Business Mirror*. https://businessmirror.com.ph/2020/08/21/denr-flags-calabarzon-landfill-limits/

Kawasaki, K., Hashimoto, Y., Hori, A., Kawasaki, T., Hirayasu, H., Iwase, S. I., ... & Fujitani, Y. (2019). Evaluation of black soldier fly (Hermetia illucens) larvae and pre-pupae raised on household organic waste, as potential ingredients for poultry feed. *Animals, 9*(3), 98.

Kaya, C., Generalovic, T. N., Ståhls, G., Hauser, M., Samayoa, A. C., Nunes-Silva, C. G., ... & Sandrock, C. (2021). Global population genetic structure and demographic trajectories of the black soldier fly, Hermetia illucens. *BMC biology*, 19(1), 1-22.

Lalander, C., Diener, S., Zurbrügg, C., & Vinnerås, B. (2019). Effects of feedstock on larval development and process efficiency in waste treatment with black soldier fly (Hermetia illucens). *Journal of Cleaner Production, 208*, 211-219.

Liu, X., Chen, X., Wang, H., Yang, Q., ur Rehman, K., Li, W., ... & Zheng, L. (2017). Dynamic changes of nutrient composition throughout the entire life cycle of black soldier fly. *PLoS One*, 12(8), e0182601.

Madau, F. A., Arru, B., Furesi, R., & Pulina, P. (2020). Insect farming for feed and food production from a circular business model perspective. *Sustainability, 12*(13), 5418.

Magalhães, R., Sánchez-López, A., Leal, R. S., Martínez-Llorens, S., Oliva-Teles, A., & Peres, H. (2017). Black soldier fly (Hermetia illucens) pre-pupae meal as a fish meal replacement in diets for European seabass (Dicentrarchus labrax). *Aquaculture, 476*, 79-85.

Mariod, A. A. (Ed.). (2020). *African edible insects as alternative source of food, oil, protein and bioactive components*. Springer Nature.

Mertenat, A., Diener, S., & Zurbrügg, C. (2019). Black Soldier Fly biowaste treatment–Assessment of global warming potential. *Waste management, 84*, 173-181.

Nekrasov, R., Zelenchenkova, A., Chabaev, M., Ivanov, G., Antonov, A., & Pastukhova, N. (2018). PSIII-37 Dried Black Soldier Fly larvae as a dietary supplement to the diet of growing pigs. *Journal of Animal Science, 96*(suppl_3), 314-314.

Okello, A. O., Nzuma, J. M., Otieno, D. J., Kidoido, M., & Tanga, C. M. (2021). Farmers' Perceptions of Commercial Insect-Based Feed for Sustainable Livestock Production in Kenya. *Sustainability, 13*(10), 5359.

Oxford University Press. (2016, May 24). *Living near a landfill could damage your health.* ScienceDaily. www.sciencedaily.com/releases/2016/05/160524211817.htm

Philippine Solid Wastes - Senate of the Philippines. (2017, November) *Philippine Solid Wastes at a glance. Senate of the Philippines.* http://legacy.senate.gov.ph/publications/SEPO/AAG_Philippine%20Solid%20Wastes_Nov2017.pdf

Prince O. Njoku, Joshua N. Edokpayi, and John O. Odiyo2. (2019 June). *Health and Environmental Risks of Residents Living Close to a Landfill: A Case Study of Thohoyandou Landfill, Limpopo Province, South Africa.* Int J Environ Res Public Health. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6617357/

Prof. Enri Damanhuri, Dr. Cindy Rianti Priadi, Dr. Chris Zurbrugg, Ir. Dodi Krispratmadi, Bart Verstappen, Bram Dortmans (2017). *Biowaste - Moving FORWARD. Sandec Eawag*. https://www.youtube.com/watch?v=Rn0Er_GzCpU

Rana, K. S., Salam, M. A., Hashem, S., & Islam, M. A. (2015). Development of black soldier fly larvae production technique as an alternate fish feed. *International Journal of Research in Fisheries and Aquaculture, 5*(1), 41-47.

Rumpold, B. A., Speckmann, H., Schlüter, O., Kloas, W., & Prochnow, A. (2018). Potentials of a biogenic residue-based production of Hermetia illucens as fish meal replacement in aquafeed for Oncorhynchus mykiss in Germany. *Journal of Insects as Food and Feed, 4*(1), 5-18.

Singh, A., & Kumari, K. (2019). An inclusive approach for organic waste treatment and valorisation using Black Soldier Fly larvae: A review. *Journal of environmental management, 251*, 109569.

Shelomi, M. (2020). Nutrient Composition of Black Soldier Fly (Hermetia illucens). *In African Edible Insects As Alternative Source of Food, Oil, Protein and Bioactive Components* (pp. 195-212). Springer, Cham.

Shishkov, O., Hu, M., Johnson, C., & Hu, D. L. (2019). Black soldier fly larvae feed by forming a fountain around food. *Journal of the Royal Society Interface*, *16*(151), 20180735.

Shumo, M., Osuga, I. M., Khamis, F. M., Tanga, C. M., Fiaboe, K. K., Subramanian, S., ... & Borgemeister, C. (2019). The nutritive value of black soldier fly larvae reared on common organic waste streams in Kenya. *Scientific reports*, *9*(1), 1-13.

Spranghers, T., Michiels, J., Vrancx, J., Ovyn, A., Eeckhout, M., De Clercq, P., & De Smet, S. (2018). Gut antimicrobial effects and nutritional value of black soldier fly (Hermetia illucens L.) prepupae for weaned piglets. *Animal Feed Science and Technology*, *235*, 33-42.

Tippayadara, N., Dawood, M. A., Krutmuang, P., Hoseinifar, S. H., Doan, H. V., & Paolucci, M. (2021). Replacement of fish meal by Black soldier fly (Hermetia illucens) larvae meal: effects on growth, haematology, and skin mucus immunity of Nile Tilapia, Oreochromis niloticus. *Animals*, *11*(1), 193.

Tschirner, M., & Kloas, W. (2017). Increasing the sustainability of aquaculture systems: Insects as alternative protein source for fish diets. *GAIA-Ecological Perspectives for Science and Society*, *26*(4), 332-340.

Weidner, T., Yang, A., & Hamm, M. W. (2019). Consolidating the current knowledge on urban agriculture in productive urban food systems: Learnings, gaps and outlook. *Journal of cleaner production*, *209*, 1637-1655.

Yildirim-Aksoy, M., Eljack, R., Schrimsher, C., & Beck, B. H. (2020). Use of dietary frass from black soldier fly larvae, Hermetia illucens, in hybrid tilapia (Nile x Mozambique, Oreocromis niloticus x O. mozambique) diets improves growth and resistance to bacterial diseases. *Aquaculture Reports*, *17*, 100373.