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The various vulnerable products and services from organic waste management using Black soldier fly, *Hermetia illucens*

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Abstract
Un-proper organic waste management leads to a deleterious action on our environment and can accelerate the negative actions of climate change and finally, it will be a big challenge to achieve sustainable development goals. So, the application of proper recycling technology of organic wastes, using three aspects of sustainability, economic, social and environmental is become an important issue, nowadays. Black solider fly (BSF), is considered as one of the promising recycling technologies that achieve the three sustainability aspects. The recycling of organic waste using BSF produces multiproduct and by-products of vulnerable molecules such as protein, chitin, antioxidants, sugars, amino acids, and lipids which has a direct impact on different industries such as animal food, pharmaceutical, biofuel, biohydrogen, and biogas industry.

Keywords: Black solider fly; circular economy; organic waste; recycling; eco-friendly technology; industrial application

Introduction
About 1.3 billion tons of consumed food annually are wastes, which represent one-third of produced food for humans. So, food waste which is considered organic waste as a global issue (Allegretti *et al.* 2018; Guo *et al.* 2021) [8, 43]. Also, un-proper organic waste management leads to a deleterious action on our environment and can accelerate the negative actions of climate change and finally, it will be a big challenge to achieve sustainable development goals. So, it's essential to reduce the negative impact of tremendous food waste at the environmental, social and economic levels by using various methods for sustainable recycling to deal effectively with them. One of the promising selections is to feed insect larvae with bio-waste (Liu *et al.* 2020) [60] and organic materials are converted into larvae biomass and compost (Čičková *et al.* 2015; Liu *et al.*, 2020) [26, 60], this method has been addressed as an eco-friendly method for recycling wastes and it also has the benefit of the low cost of installation. In this regard, black soldier fly larvae, *Hermetia illucens* (L., 1758) (Diptera: Stratiomyidae), showing a great interest in the last recent years. BSF live in tropical, subtropical, and temperature regions worldwide (da Silva & Hesselberg 2020) [29] and pupate as little as 2 weeks under ideal conditions of food supply, temperature, and humidity (Kim *et al.* 2021) [52]. By using feeding habitat way and digestive enzymes, it can decompose effectively different organic material (Pastor *et al.* 2015; Cho *et al.* 2020; Kim *et al.* 2021) [69, 25, 52]. Depending on Black soldier fly in the treatment of organic wastes has a variety of benefits are that treating organic materials in a rapid and easy way and reduce the growth of bacteria and offensive odor (Liu *et al.* 2016) [59]. In addition, adult BSFs can't transmit pathogens to humans unlike house flies (Banks *et al.* 2014; Kenis *et al.*, 2014; Dortmans, 2015) [16, 50, 34]. Larvae and prepupa also contain a large amount of fat and protein represent 40% and 30%, respectively (St-Hilaire *et al.* 2007; Cummins *et al.* 2017; Kim *et al.* 2021) [87, 28, 52] which can be a protein source for feeding animals while the composted insect Fras can be used as biofertilizer (Diener *et al.* 2011; Katongole *et al.* 2011; Kim *et al.*, 2021) [32, 49, 52] larvae reduce medicinal substances' half-life (Lalander *et al.* 2019; Kim *et al.* 2021) [56, 52] and nutrients such nitrogen and phosphor from waste (Myers *et al.* 2008; Kim *et al.* 2021) [64, 52]. Larvae also contain antibacterial peptide: defensin-like peptide 4 (DLP4), which is a neutral antibiotic secreted by fungi (Li *et al.* 2017) [58].

Larvae modify harmful microorganisms and reduce *Escherichia coli* abundance 0157:H7 and *Salmonella enterica* (Erickson *et al.* 2004; Kim *et al.* 2021) [39, 52]. In general, the BSF-based food waste treatment method is a promising one at environmental, economic, public health, and food security levels and provides various benefits for sustainable development.

Generation and composition of wastes in some African countries.

The waste formulation is considered essential data for waste management plans and performing eco-friendly technologies. The precise evaluations of these variables are important to apply the circular economy concept (Karak *et al.* 2012) [46]. The application of the 5Rs concept (Refuse, Reduce, Recycle, Repair, and Regulate) is very important today to decrease the deleterious effect of improper management of waste (Eltayeb *et al.* 2010) [38]. The quantity and structure of waste vary greatly from country to country, and heterogeneous waste composition can occur between neighboring localities and even between homes within the same town from time to time (Birhanu & Berisa 2015) [21].

The waste compositions which are generated in different African countries were showed in Fig. 1. The organic wastes show the major category of the waste, except in Johannesburg (South Africa). The highest percentage of organic waste was showed in Jinja (Uganda) with a percentage value of 78.9% followed by Kampala (Uganda) with a percentage value of 77.2. However, the lowest percentage value of organic wastes occurred in Johannesburg with percentage levels of 13%. Besides that, the highest percentages for the paper were occurred in Cairo (Egypt) and Johannesburg, with a percentage value of 18%. However, the lowest percentage of plastics occurred in Accra (Ghana) with a percentage value of 3.5%. Also, the degree of country development influences the waste composition as a result of different reasons which including increasing incomes and modern lifestyles. Larger consumption leads to produce more packaging materials, which are paper and plastic content. Also, this country's urbanization adopts the overall generation rate of solid waste (Friedrich & Trois 2011) [41].

Organic waste generation sources, problems, and challenges

Some problems that may have a negative effect on the management of waste especially organic type (Westerman & Bicudo 2005; Sen *et al.* 2013; Kaszycki *et al.* 2021) [94, 81, 48]. One of them is the Un-proper waste management practices, especially widespread waste dumping in bodies of water and unregulated dumpsites, which magnifies the problems of low hygiene levels across the African region. Also, growth and development are increasing in Africa today and this trend is expected to continue in the future. Besides, the simultaneous growth in urbanization along Africa, the land use and infrastructure of proper waste management will not meet the best environmental practices (BEP) which will lack the best available technology (BAT) in waste management (Onibokun & Kumuyi 1999; Achankeng 2003; Datta *et al.* 2018) [67, 6, 30]. So, the improvements in infrastructure and processing of waste management are urgently needed to struggle the elevated costs of health services, avoid poverty, and reduce rural-urban immigration. In addition to, the wide gap between polices and legislation of waste management programs and real practical waste management, as a result of absence the existence of waste management facilities to handle various waste streams. Also, there is a critical point associated with waste management system from collection step, till reach disposal, and dumping sites persist unexplained in many large cities and countries (Alves *et al.* 2014; Pini *et al.* 2018; Salmenperä *et al.* 2021; Hajipour *et al.* 2021) [9, 70, 76, 44]. Besides that, the most effective one is the problems related to the relatively wet climate in many countries, which accompanied by organic waste decomposition and leads to rivers and groundwater pollution. Finally, but not least, the lack of national collection infrastructure and the non-profitable market for waste recycling byproducts. Nowadays, the generation rate of MSW depends on the economy and welfare of the region (Abou Taleb & Al Farooque 2021; Fereja & Chemeda 2021) [5, 40]. For example, in Egypt varies between 50 k and 60 k ton /day generated waste (Abdel-Shafy & Mansour 2018; Abdallah *et al.* 2019) [3, 2].

As Fig. 1 showed, the highest percentage of waste occurred as organic waste. Organic waste may include food loss and waste from different activities such as shopping, storage, cooking habits, food choices, and different lifestyles (Emenike *et al.* 2013; Adebayo Bello & bin Ismail 2016) [7]. This food loss and waste have direct and indirect environmental, economic and social consequences. The cycle of food waste which is considered as an organic waste category will end in the landfill, these anaerobic digestions of organic wastes will lead to methane gas emission, which considered a greenhouse gas with a 21x fold toxicity compared to carbon dioxide. Many countries have decided. To proceed into proper management of waste such as Egypt. Egypt goes aboard on a mission to manage waste properly as a replacement for consuming traditional open-air incineration or dumping waste in unsanitary landfills. In addition to, giving the great opportunity to the private sector as an incentive of waste management into transitional raw materials.

The methodology used in the organic waste's treatment

The proper management of organic has become a rising problem in the majority urban of cities, so, the need for organic waste recycling has grown up recently (Dinham 2003; Sankoh *et al.* 2013; Menyuka *et al.* 2020; Aziz & Ameen 2021) [3, 77, 61, 14]. There are various methods dealing with different technologies in organic waste recycling, each one of these produces has a unique set of valuable products and disadvantages applications (Table 1). Some of the most common methods are described as the following

Table 1: Different methodology of recycling of organic waste which includes method, advantages, disadvantages, products, and references.

Method	Advantages	Disadvantages	Products
1. Landfilling	✓ simple methodology	• Loss resources • Methane gas emission	-
2. Alternative waste treatment	✓ Recovery of resources	• More money to develop facilities	Biofertilizer
3. Insect-based treatment	✓ Biologically based technology ✓ Energy, cost, infrastructure saving ✓ Multiple products from a single source	• Ethical aspects • Issues related to biosafety	Biofertilizer, Biogas, biodiesel, Chitosan, Proteins, Sugars
4. Composting	✓ Biological technology based on microbes	• Single products • Complicated controlling procedures	Composite
5. Vermicomposting	✓ Biological technology based on earthworms and microbes	• Single products	Vermicompost
6. Anaerobic digestion	✓ Biological technology based on microbes ✓ Absence of oxygen	• double products	Biogas nutrient-rich digestate
7. Rendering	✓ Multiple input waste category	• Initial heat source • Single product • Selected input	Biofertilizer
8. Rapid thermophilic digestion	✓ Faster in time than other biodigesters	• High consumption of heat • Single product	Biofertilizer
9. Immobilized enzyme reaction	✓ Cost-effective and efficient	• Difficulty of maintaining enzyme stability and performance • High initial energy demand	Single product

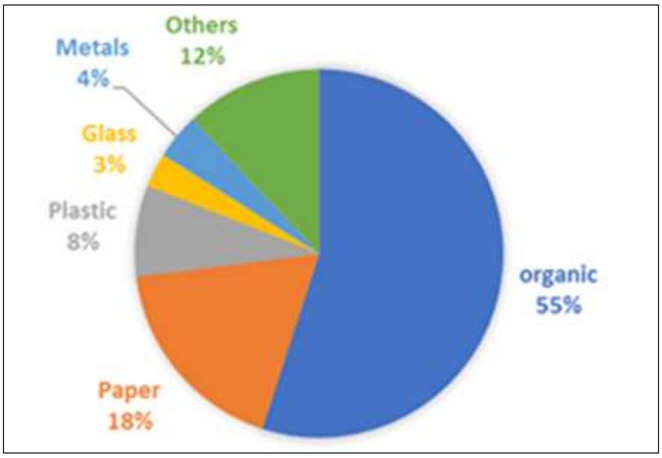

Fig 1: Cairo (Egypt)

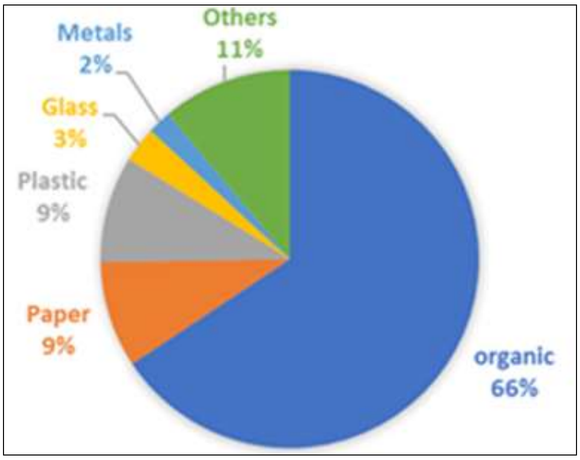

Fig 2: Sousse (Tunisia)

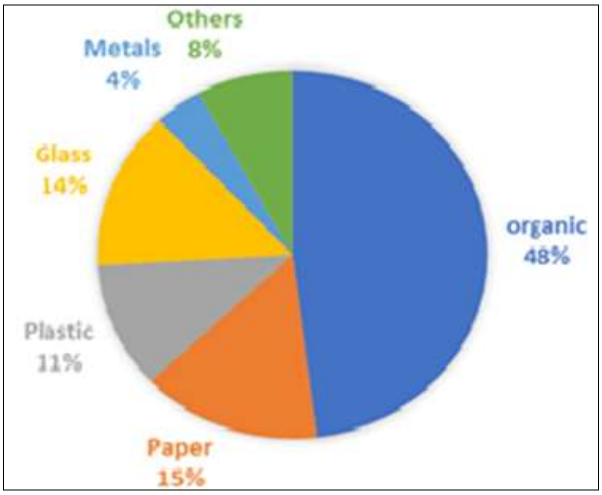

Fig 3: Windhoek (Namibia)

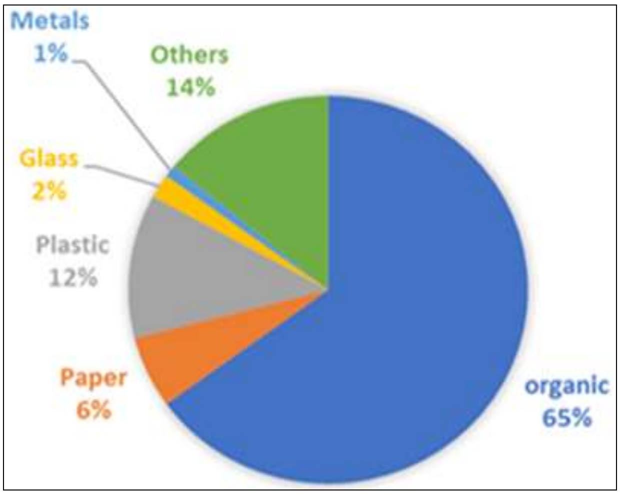

Fig 4: Nairobi (Kenya)

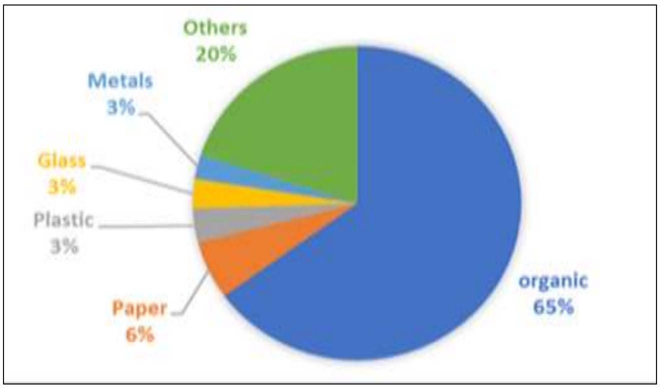

Fig 5: Accra (Ghana)

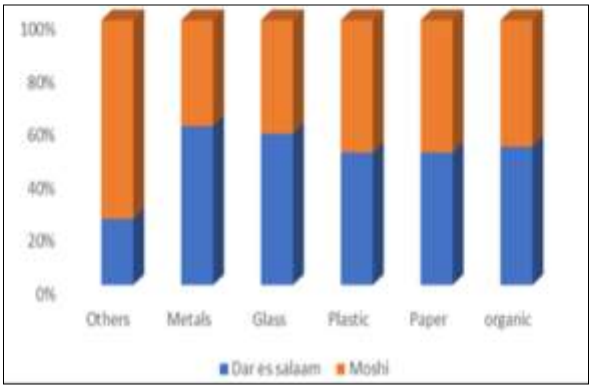

Fig 6: Tanzania

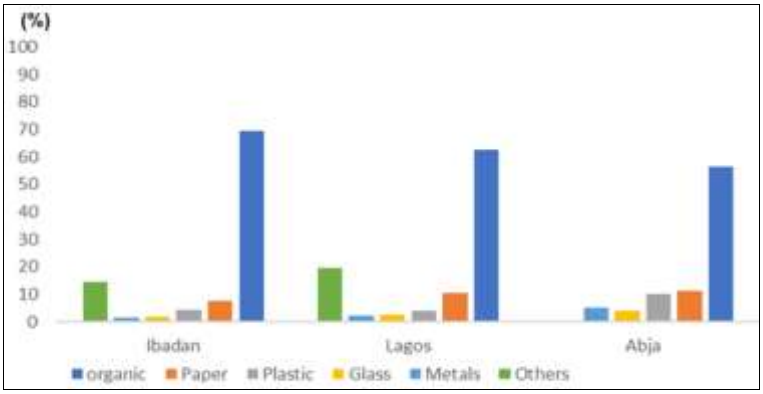

Fig 7: Nigeria

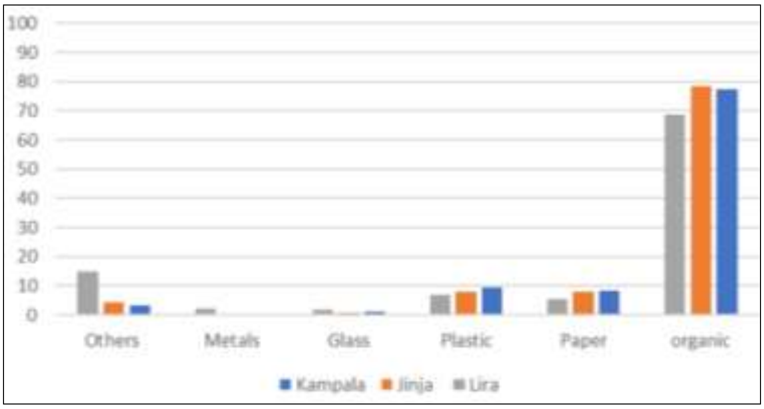

Fig 8: Ugenda

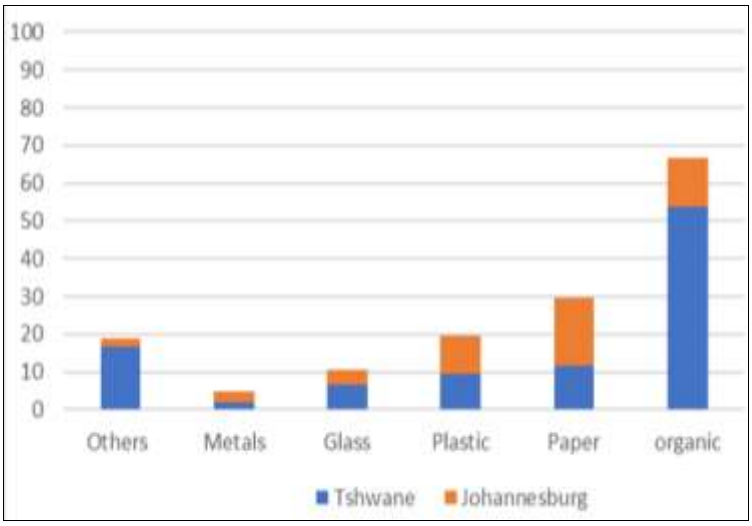

Fig 9: South Africa

Landfilling of organic waste

The landfill is considered as a big obstacle issue related to environmental aspects of achieving sustainability, due to various reasons especially methane generation as a result of anaerobic decomposition resources loss. The toxicity of methane gas is estimated as 25 times more potent greenhouse gas than carbon dioxide when exposed directly to the atmosphere. In another hand, Methane is considered a valuable resource to produce natural gas which piped into the homes (Barnes *et al.* 2004; Mou *et al.* 2014; Amritha & Anilkumar 2016; Duan *et al.* 2021) [17, 62, 11, 35].

Alternative waste treatment (AWT)

Organic waste can also be treated to make compost and soil conditioning products, which are used in the garden. One of these technologies is called high-tech Alternative Waste Treatment Facilities (AWT), which focused on the improvement of the number of resources from the waste recovery process. This methodology includes enthusiastic facilities to recycle organic waste (green AWTs) and other facilities to sort and recover material from a wider spectrum of waste streams (dirty AWTs), there is a catch principle of this methodology. This method takes a lot of money to develop these facilities. However, the facilities development could offer an incentive to maintain the amount of waste generated. This methodology is often extremely high-tech which used in case of the separation of organic material is difficult (Schmidt 2009; Begum 2016; Yonli & Godfrey 2018) [80, 19, 97].

Insect- based organic waste treatment

Sarcosaprophagous macro invertebrates which involve earthworms, termites and several Diptera larvae, can enhance alternation in the organic materials' physical and chemical properties. The process of composting can involve degradation and balanced processes, which leads to a decrease in the molecular weights of the input compounds. This essential process activity leads to consider these organisms as an excellent recycler of organic material. Approximately 11,732 individuals, from 3 orders, Diptera, Coleoptera and Hymenoptera, were belonging to the class Insecta, are considered recyclers. The highest number of families, which was the most abundant and diverse group occurred in order Diptera, are around 16 families that include Calliphoridae, Drosophilidae, Psychodidae, Fanniidae, Muscidae, Milichiidae, Ulidiidae, Sepsidae, Scatopsidae, Heleomyzidae, Sphaeroceridae, Syrphidae, Stratiomyidae, Phoridae, Curtonotidae and Tephritidae (Čičková *et al.* 2015; Smetana *et al.* 2016; Surendra *et al.* 2016; Ites *et al.* 2020; Dzepe *et al.* 2021) [26, 86, 89, 45, 36].

Also, *Ornidia obesa* is described to be a great substance to composting process as a result of the appearance of its stage. This species, also, has been linked with organic materials decomposition, especially coffee pulp (Lardé 1990) [57]. Besides that, the presence and development of beneficial species, *Hermetia illucens* (Diptera, Stratiomyidae), for example, is involved in domestic fly growth control in the substrate kind (Calvert *et al.* 1970; Booram *et al.* 1977; Chio & Chen 1982; Sheppard 1983; Newton *et al.* 1992) [23, 22, 24, 82, 65].

Windrow Composting

This technique of composting is based on a microbiological process that converts organic materials into a stable, dark brown, soil-like material defined as compost. This methodology is done under aerobic conditions, with the presence of microbial activity. Temperatures in this method can reach up to 70°C during the material degradation process. There are a lot of control parameters in this methodology such as organic material composition (carbon-nitrogen ratio), particle size, free air space, aeration, temperature, moisture, and pH. All these parameters should be optimized to achieve rapid degradation and good compost quality (Kuhlman 1990; Andersen *et al.* 2010; Thyberg & Tonjes 2017; Yengong *et al.* 2021) [54, 12, 91, 96].

Vermicomposting

Vermicomposting is recognized as the aerobic degradation of organic material by microorganisms and earthworms under controlled conditions. In which the microbial societies contribution to the aerobic degradation of organic materials, first, then earthworms encourage microbial activity by developing vermicompost. *Eisenia fetida* is the most commonly used worm species in vermicomposting. It has a 70-day through the whole life cycle (Parthasarathy & Narayanan 2014) [68].

Anaerobic Digestion

Anaerobic digestion is reflected as a microbiological process that produces biogas and nutrient-rich digestate. This methodology is based on the biochemically decomposing of organic materials, under anaerobic conditions. This technique is caused by microbial activity.

Rendering. The process of converting organic waste especially, waste animal tissues into stable and usable forms such as feed protein is known as rendering. During this process, fatty tissues, bones, and animal carcasses are intended to heat up to 130°C and then be pressed to destroy pathogens. One of the most advantages of rendering methodology, its ability to be done on various scales, a large one and a small one. The products of the rendering process include input materials of pet food and soap-making operations (Angelidaki *et al.* 2003; Khalid *et al.* 2011; Cremonez *et al.* 2021) [13, 51, 27].

Rendering

Has a lot of advantages in waste treatment includes, multiple input waste category, initial heat source is very simple, single product requirements, selected input assessment, ability to produce biofertilizer (Sindt & Engineer 2006; Bayr *et al.* 2012) [85, 18].

Rapid Thermophilic Digestion

Rapid thermophilic digestion is defined as the rapidly fermenting of organic wastes by activating a fermenting process of microorganisms at high temperatures. One of the most advantages of this process is the low consumption rate with respect to conventional biodigester. The other advantage of this thermophilic digestion process is the exothermic process that keeps a thermophilic temperature of 55-65°C. Sewage sludges treatment is considered the most common application of this methodology (Angelidaki *et al.* 2003; Khalid *et al.* 2011; Cremonez *et al.* 2021) [13, 51, 27].

Immobilized Enzyme Reaction

It defines as the using of enzymes to recycle organic matter. The enzyme-catalyzed reactions are less efficient than the chemical catalysts in the formation of by-products and substantial energy inputs. This is maybe due to the instability of maintaining enzyme performance, and the initial essential stabilized energy systems. Immobilization of enzymes permits biocatalysts to be reused for different processes, which is enhances decreasing the cost of the recycling process. There are a lot of examples involves in immobilization techniques which include adsorption, entrapment, and encapsulation. When enzymes are used to convert organic waste into reusable forms, there are a lot of alterations can be occurred such as oxidation, hydrolysis, acylation, and phosphorylation (Karam & Nicell 1997; Nisha *et al.* 2012; Amari *et al.* 2021) [47, 66, 10].

BSF technology as an example of insect-based food waste treatment methods

Black soldier fly (BSF) processing is considered one of the emerging insect-based technology in organic waste treatment. It focuses on biologically transforming biological waste into insect larvae biomass and a treated organic waste residue using the larvae of the Black Soldier Fly (BSF), *Hermetia illucens*. BSF Larvae consists of approximately 45% protein and 30% crude fat. This insect protein may be used as a source of feed for animal, chicken and fish farmers. The BSF larvae feed on biowaste and mature until pupation. The average development time from egg to adult takes around 20–35 days under controlled conditions (28°C, 75% relative humidity). After that adult stages can spend a week as flies, which focused during this stage on reproduction. One of these outputs of the colonized insect is waste reduction efficiency, also, the residue, which seems like compost, which is rich in nitrogen, carbon ratio, also it is rich in nutrients and organic matter. Additionally, a high waste-to-biomass conversion rate besides that this facility does not require sophisticated high-technology equipment to run, also, it is suitable for low- and middle-income fields. Briefly, Organic waste management with BSF is a cost-effective and environmentally friendly method which is enhancing the eco, social, and economic- friendly attractive industry around the world. Insect Larvae, additionally, grown on a wide range of waste materials, animal manures, human excrement, fruit and vegetable wastes, and carrion are all examples of waste (Rozkosny 1983) [82]; also, it can produce the raw material of animal feed production and therefore, It has the potential to generate revenue for waste management programs that are financially viable (Gold *et al.* 2018) [42]. In addition to the production of animal feed, BSFL can produce immature compost (Xiao *et al.* 2018; Zurbrügg *et al.* 2018) [95, 100].

A lot of recent studies examined the environmental impacts of BSFL's bioconversion of food waste through a flow analysis of materials. The results showed that every tone of organic waste can produce 31 kg dried pre-pupae BSF totals and 300 kg matured compost (Guo *et al.* 2021) [43]. Another study showed the possibility of making an alternative feeding-protein for fishes and promoting healthy aquaculture. The results of the present study showed that (*Hermetia illucens* prepupae meal) and poultry by-product meal can be successfully used as a replacement for vegetable diets of rich protein for dormancy seabreams without affecting the output and benefits of fish development Furthermore BSF prepupae meal has been shown to have interesting results with regard to improving the fish intestine, while poultry by-product meal has beneficial effects on the absorption of intestine nutrients, indicating that this component can be used to minimize the negative effects caused by the high quantity of plant ingredients in diets for gilthead seabream (Randazzo *et al.* 2021). Also, the results of another study showed the same effect of replacing the dietary fish meal with insect meal from *Tenebrio molitor* (Terova *et al.* 2021) [90]. This may due to the bacterial diversity in the BSFL intestine to this ability to play an important role in surviving and organic waste conversion into valuable products. (Zhineng *et al.* 2021) [99]. Besides that, there was a study focused on the treatment of municipal solid waste and how to convert it to recyclable materials rich in elements like B, Cr, Cu, Zn, As, Sb, Ba, and Pb through decreasing the organic matter in waste components (Klammsteiner *et al.* 2021) [53]. Also, the effect of canteen wastes and oil cooked food in addition to oil wastes and how could be recycled, and the impact of food waste bioconversion of these sources will effect on the product of BSFL, the study of that research found that a better average and stable composition of larval feed could be achieved by pre-measuring the waste collected from different sources. The high content of Fat, Oil and Grease was found to be deadly by BSFL in the fraction of canteen waste, but the conversion of the food waste fraction was efficient (Egnew *et al.* 2021) [37].

Regarding to analyzing and Purging black solider fly larvae compromises their nutritive value as a feedstuff is a matter that had to be studied to open more keys to us to understand the full nature and composition of our BSFL, The BSFL lipid content in this study was 41% but was considerably increased over time. This discovery may reflect the translation of carbohydrates into glycogen and later into fatty acids which will lead to a higher level of raw fat overall times. Using the BSFL for obtaining useful products is one of the most important parts of the bioconversion process, another study focused on safeguard using of *H. illucens* and *B. mori* oils' quality and antimicrobial properties. The results showed that the alternative methods were first tested for obtaining a good oil extraction from *H. illucens* larvae dried biomass (Saviane *et al.* 2021) [79]. The growth of BSFL can be observed during the treatment of organic wastes by analyzing aspects of larval growth. The development time, the final weight, the rate of growth and the survival rate of larvae are reported at 15–36.7 days, 154–271 mg, 2.3–37 mg/day and 85.6–97.1%. For example, when fed food waste, fruits and vegetables, or poultry feed, the survival rate of BSFL was 87%, 90%, and 93%, respectively. The survival rate was however as low as 39% when fed with digested sludge.

Factors affecting BSF growth

Genetic and environmental influences, which work through complex molecular and physiological mechanics, influence the size of the individual insect growing up. In response to different stimuli, including the availability of resources, competence, presence of predators, season times, humidity and temperatures, growth rates vary considerably. When it comes to food quality, feeding is an essential factor for BSFL growth, and during the larval stage, diet influences the growth of adults. BSF larval size, survival rate, adult size, and fertility are all affected by food the quality. Therefore, BSFL cultivation requires pretreatment of the substrate. For example, food processing, for instance, heat treatment and crushing, modify substrates structure to enhance the digestion of food waste by BSFL. Slower development time of the larvae fed on organic wastes could be related to the quality of the food especially balance in nutritional contents. In contrast, the chicken food, which has all its nutrient content for growth, all organic waste has an excess of nutrition while lacking in others. Nutritional imbalance in nutrition can contribute to increased insect larvae consumption, in order to offset nutrient deficiency, especially proteins and carbohydrates. Lack of nutrients influenced the time when larvae reaching a critical developmental stage. In insects, larval weight is attained to the critical stage of development. At this stage, a shift in hormonal level occurs that induce further development. The high content of cellulose, added as non-nutritive bulk to dilute nutrients, consumes the diet for the low- and medium-nutrient concentrations. Regarding to relative humidity and temperature, when relative humidity falls below the optimal range, the survival rate drops. When temperatures rise above the optimum limit, adult life span and pupal growth time decrease. BSF is a eurythermal insect that can adapt to various temperatures (15–47 ºC), despite being sensitive to temperature. Temperature and humidity have a significant impact on BSF's growth, mating and spawning. The survival rates of BSFL larvae, adult emergence, and adult emergence reared on brewer's spent grain and cow dung were investigated, and the optimum temperature range was 25–30 ºC. At temperatures higher than 30 ºC, the lifespan of the adults decreased. Studies have also stated that if not properly monitored, the temperature and humidity could have serious effects on egg hatching and BSFL growth. Specifically, it was reported that BSFL grown at 27 ºC showed a slower development rate than BSFL grown at 30 ºC. Additionally, the egg membrane was dehydrated when humidity was poor, and the egg survival rate was reduced. The impact of humidity on the hatches of eggs and adult BSF development was studied at a relative humidity of 25, 40, 50, 60 and 70%. The more humidity is subjective, the better the rate of hatching and adult growth, and the slower the time of development. Another important factor is light intensity, light is needed for BSF to mate. As BSF cannot mate in winter owing to the weak intensity of light, artificial light is required. Artificial lighting may be provided by fluorescent lamps, halogen lamps, light-emitting diode (LED) lamps, and oxo bulbs. However, mating did not occur when rare earth-lamps were used. Regarding to salinity of substrate, when food waste containing NaCl was fed to BSFL, the larvae's growth and development, as well as the substrate's decomposition rate, were lower than when food waste without NaCl was fed. This was since NaCl slowed larval growth. Also, larval density is so important factor as, larvae ingested food for a longer period, increasing their developmental time to obtain sufficient nutrition for pupation. At the maximum NC and lowest density, the shortest development period (13 days) was achieved, which was quite close to the time recorded for BSF larvae fed with chicken feed, besides the degradation rate decreases when moisture is higher than the optimal range (Abduh *et al.* 2018; Kumar *et al.* 2018; Lalander *et al.* 2019; Bekker *et al.* 2021) [4, 55, 56, 20].

Applications of BSFL

Depending on Black soldier fly in the treatment of organic wastes has a variety of benefits are that treating organic materials in a rapid and easy way and reduce the growth of bacteria and odor (Liu *et al.* 2016; Kim *et al.* 2021) [59, 52]. in addition, adult BSFs can't transmit pathogens to humans (Banks *et al.* 2014; Dortmans 2015; Kenis *et al.* 2014) [16, 34, 50]. Larvae and prepupa also contain a large amount of fat and protein represent 40% and 30%, respectively (St-Hilaire *et al.* 2007; Cummins *et al.* 2017; Kim *et al.* 2021) [87, 28, 52] which can be a protein source for feeding animals while the compost can be biofertilizer (Diener *et al.* 2011; Katongole *et al.* 2011; T. Liu *et al.* 2020) [32, 49, 60].

Composting is defined as the biological oxidative decomposition of organic matter (Stoffella & Kahn 2001) [88] based on the catalytic activity of Environmental organisms responsible for the decomposition of organic matter. Compost system phases. Three phases can be differentiated during the process of compost according to Zbytniewski & Buszewski (2005: 1) easily biodegradable substances decomposition, 2) humic-like substance formation and 3) organic matter stabilization. During the current study, these steps were also differentiated and associated with characteristic insects at each stage of the decomposition process: Stage 1: Weeks 1 – 3. As possible indicators for this stage, Phoridae and *O. aenescens* are present. During this stage, all recorded families were observed, higher diversity, mainly represented by Syrphidae, Milichiidae, S. *calcitrans* (Muscidae), Drosophilidae, *M. domestica* (Muscidae), Fanniidae, Stratiomyidae and Scatopsidae. Stage 2: Weeks 4 – 5. Families of Milichiidae, Fanniidae, S. showed important increases. *calcitrans* (Muscidae), Stratiomyidae, Sphaeroceridae, Uliiddidae, Psychodidae and Heleomyzidae. The latter two, as well as Curtonotidae, are important yet not exclusive at this stage. Stage 3: 6 to 7 weeks. This stage is characterized by a low diversity without most of the families: Fanniidae, Tephritidae, Uliididae, Curtonotidae, Sepsidae, Phoridae, Scatopsidae, Calliphoridae, Psychodidae, *O. aenescens* (Muscidae) and Heleomyzidae. Throughout this stage, the remaining families remain stable without major changes.

Hermetia illucens has a high protein and fat content, increasing its ability for use in poultry feed formulation and positioning it as one of the most promising insect species for commercial production. BSF can transform organic waste into a valuable source of nutrients including proteins, lipids, and chitin, which helps to reduce the environmental burden and contamination risk associated with organic waste accumulation. As a result, we may consider this insect as a "green" technology in the highly variable recycling of organic waste that provides a sustainable protein source, as well as the significance of its use as a protein-rich feedstuff replacement in poultry feed manufacturing (Abd El-Hack *et al.* 2020) [1]. Also, the accumulation of organic wastes will lead to an increase in pollution. BSF can turn a wide range of organic waste into a protein source for livestock. BSF larvae may also prevent house fly reproduction, which is a major disease vector. The oviposition of the house fly around poultry manure containing BSF larvae is supposed to be prevented by interspecific chemical communication. Bacteria or pathogens such as Escherichia coli in dairy manure and Salmonella enterica and Escherichia coli in chicken manure may be disposed of and inactivated by BSF larvae. Decontamination can occur as a result of the release of certain compounds in larvae secretions that have a bactericidal effect. It has been proposed that larvae secrete antimicrobial substances with a wide spectrum of action as a natural response to increased bacteria concentrations. This guarantees adequate protection when used as an organic fertilizer in crop cultivation. When organic waste has been digested by larvae in one digestion period, it is considered completely processed. The residue compost has great value for agriculture as a soil fertilizer. so can consider that BSF as waste reduction index and environmental efficiency (Abd El-Hack *et al.* 2020) [1]. Regarding to implications for the Economy When compared to raw manure, the use of BSFL in waste management may be a more economically viable choice. The economic value of BSFL by-products (fat, protein, and compost) is 100-200 times that of unprocessed manure. Furthermore, it is possible that some of the benefits of the BSF technology will be used to cover the costs of waste collection and management in general (Mutafela 2015) [63].

Energy consumption and demand have been increasing around the world as fossil fuel reserves have been depleted, and these reserves are predicted to be depleted soon. This is despite a rapid increase in global population and economic development (Zheng *et al.* 2012) [98]. This explains why the world has been transitioning away from fossil fuels and toward more environmentally friendly fuels. Many alternatives are being researched to have better feedstock for biodiesel production, among them microalgae, waste grease, *Madhuca Indica*, *Jatropha curcas* and muskmelon seed oil. In this regard, the potential for BSFL to contribute to renewable energy provision and thus minimize the use of non-sustainable sources is being investigated, and its use as a feedstock in biodiesel production shows promising results. BSFL has the potential to recycle waste into clean energy, and thus reduce the environmental pollution of manure and other organic wastes (Mutafela 2015; Zheng *et al.* 2012) [63, 98]. Besides that, the potential for use as nutrient sources because of their high concentrations of lipids, proteins, polysaccharides, and calcium, BSFL has the ability to be used as a feedstock or to make biodiesel (Popa & Green 2012) [71]. BSF is a suitable animal food source because its prepupae are made up of roughly 40% protein and 30% fat. Since their protein content is equivalent to that of fishmeal, they could be used as a protein source in the animal feed, fish, and pet industries (Mutafela 2015) [63]. BSFL's high protein level makes it an excellent animal feed nutrient source, after defatting; BSFL's raw protein content was 60%. Even then, given that substrate characteristics significantly affect the BSFL's composition, the impacts of the substrate to produce BSFL biomass with the effective nutritional composition are important to identify [2]. The growth of the Global population led to an increase in organic wastes generated. Each year More than 2.1 billion tons of solid waste is generated worldwide. The accumulation of this waste leads to a lot of big environmental and health problems especially in the African countries where high temperature and these increase the dangerous effect of the organic waste and carbon dioxide emissions. Moreover, increase the cost to get rid of and treatment of this waste. So, researchers try to find ways to get rid of these waste and benefit from it. Insect production may be a feasible source of animal protein. Insects can be farmed in high densities with minimal space and have a high bioconversion ratio. One of the very important insects used in this trend is the black soldier fly (BSF) or (*Hermetia illucens*) (Raksasat *et al.* 2020) [72]. Black solider fly larvae are a cost-efficient and safe method to decompose various types of organic waste and Conversion to high-quality biomasses like oils and proteins. The adult black solider fly can typically live for one to two weeks without the need to feed as can depend on fat body reserve that was taken during larval stages and can live more when fed with water. The biomass of the mature BSFL can be used to serve as the protein, lipid and other biochemicals production feedstock. These proteins can be used as aquatic meal and poultry feed and these reduce the cost of protein sources derived from soybean or fish meals. The lipid comes from BSFL biomass which used as high-quality biofuel to sate the rising demand for energy (Lalander *et al.* 2019) [56]. The dry weight of larvae of Black Soldier Fly (BSFL) contain up to 50% crude protein (CP) and up to 35% lipids and amino acid profile that are identified and used as alternative protein sources for chickens, goats, and a variety of fish and shrimp species. The composition of amino acids may vary between different species due to different feed requirements (Shumo *et al.* 2019) [84]. The produced oil is very similar to coconut oil as they both contain glutamic acid. It can be used in gut supplements for weaning pigs, and it can be used in the chemical industry for things like candles.

Food futurists predict that more environmentally conscious humanity will incorporate insects as an alternative protein source. The most researched and easily reared species are not always the most sustainable, acceptable, or tasty. The black soldier's literature, which is capable of efficiently converting a wide range from food waste to manure organic materials, into insect biomass, is reviewed here (Guo *et al.* 2021) [43]. They are pest-free and can be grown and harvested without specialized equipment (Diclaro & Kaufman 2012) [31]. Insect cuticles are made up of chitin in a matrix with cuticular protein, lipids, and other compounds. Chitin is commercially appealing due to its high nitrogen percentage (6.9%) when compared to synthetically substituted cellulose (1.25%) (Diener *et al.* 2011) [32]. As a result, chitin can be used as a chelating agent in products such as medicine, cosmetics, and even biotechnology. However, the economic feasibility of extracting chitin from soldier fly pupae has yet to be determined. Throughout metamorphosis, there have been variations in the physiochemical structure of chitin in several insects, whereas black fly (BSF), a recognized resource insect for manufacturing and organic waste management, remains a mystery. Its larvae feed on a variety of decaying organic material, including rotting fruits and vegetables, animal manure, and human excreta. The final larval stage, known as the prepupa, migrates away from the feed source in search of a dry, protected pupation site (Wang & Shelomi 2017) [93]. Within the larval skin, pupation occurs, and the adult emerges after about 14 days. The adults are sluggish and poor flyers (Diener *et al.* 2011) [32]. Females mate two days after hatching and lay their eggs in dry cracks and crevices near a food source (Sheppard *et al.* 2002) [83]. Larvae are rich of nutrients, depending on the amount of protein and fat they can store throughout a larval stage in their bodies (Surendra *et al.* 2016) [89]. The typical fat composition of black soldier fly prepupae was around 32%, while the main fatty acids group in which lauric acid was found were saturated fatty acids (SFA) (C12:0) is the predominant one accounting for 67% of total SFA (Ramos-Bueno *et al.* 2016; Surendra *et al.* 2016) [73, 89]. Larvae can be milled and transformed into a textured protein with a strong flavor for commercial use in human foods. Their most significant advantage over other insects is their ability to transform waste into food, value generation and nutrient loop closure while reducing pollution and costs. This general advantage is also the major weakness because the addition of social stigma and a legal ban on foodstuffs that consume waste are added to the already existing taboos against eating insects (Wang & Shelomi 2017) [93]. Hermetia illucens L. (Diptera: Stratiomyidae) develops in decomposing organic matter in temperate and tropical areas of the world (Sarpong *et al.* 2019) [78]. Adults do not feed except to drink water, obtaining the nutrition required for reproduction during larval development (Wang & Shelomi 2017) [93]. Males congregate at lekking sites, where they meet flying females. Females produce 320-620 eggs within 2 days of mating, oviposit in decomposing organic matter, and die within hours. In the southeastern United States, three generations are produced each year (Sheppard *et al.* 2002) [83]. Biowaste contains a large number and a variety of microbes. Furthermore, Pesticide parts and vegetable waste, badly stored friction and brewery flux, mycotoxin, heavy metals and other toxins, such as dioxins, and municipal organic solid wastes, polychlorinated biphenyls (PCBs), and polyaromatic hydrocarbons can be found in human and animal manures (PAHs). This new industry is concerned about the transfer and accumulation of these feed and food chain BSFL contaminants. Several studies have shown that inoculating biowaste with microbes can improve BSFL process performance. Because the volume of biowaste is reduced during BSFL treatment, heavy metals concentrate in the residue, potentially limiting its use as a soil conditioner or compost. Unlike other biowaste treatment technologies, the process mechanisms in BSFL treatment are poorly understood. BSFL have an ecological and phylogenetic niche similar (relative to well-studied insects from other orders) to larvae of well-studied fly species, implying that their digestion evolved from the same original digestive process (Gold *et al.* 2018) [42]. BSFL organic waste production process is an emerging biowaste processing technology (Tomberlin *et al.* 2015) [92] which can produce high-value marketable products which can contribute to the improvement and cost-effective waste-recovery systems. One technology challenge includes an efficient operation of BSFL treatment and safe, multi-biowaste stream larval and residue production with variable properties (Gold *et al.* 2018) [42].

Conclusion
As the world's population is growing rapidly and is expected to reach 9 billion by 2050, global demand for food will increase by double from 2005 to 2050, As a consequence, food and animal feed production is projected to be affected by an increased 60%. As food consumption is increasing due to improvements in living standards and the growth of the human population, food waste is also increasing. About 1.3 billion tons of consumed food annually are wastes, which represent one-third of produced food for humans. Therefore, finding a promising solution for both the treatment of food waste and the need for essential molecules is an urgent need. The Food and Agriculture Organization recommended edible insects used for human food and animal feed as a solution to achieve stability in feed price and environment. Edible insects worldwide have benefits of food conversion rate is ideal, have abundant content of proteins. In addition, they don't take a long time to reproduce and with the potential food source. Among the insects, great attention has been paid to the treatment of food waste by means of black soldier fly (BSFL) larvae. Black soldier fly larvae, Hermetia illucens (L., 1758) (Diptera: Stratiomyidae), showing a great interest in the last recent years. BSF live in tropical, subtropical, and temperature regions worldwide and pupate as little as 2 weeks under ideal food, temperature and moisture conditions. By using their strong mouthparts and digestive enzymes decompose effectively different organic material. Depending on Black soldier fly in the treatment of organic wastes has a variety of benefits are that treating organic materials in a rapid and easy way and reduce the growth of bacteria and odor. In addition, adult BSFs can't transmit pathogens to humans. Larvae and prepupa also contain a large amount of fat and protein represent 40% and 30%, respectively which can be a protein source for feeding animals while the compost can be a biofertilizer.

Author Contribution
All authors had been worked as teamwork in this review paper.

Conflict of Interest
The authors declare that they have no known competing interests or personal relationships that could have appeared to influence the work reported in this paper.

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