RECOVERY OF NUTRIENTS FROM ORGANIC WASTE BY USING BLACK SOLDIER FLY PREPUPAE FOR SUSTAINABLE WASTE DISPOSAL AND PRODUCTION OF ANIMAL FEED.

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Abstract

Rapid increase in population of world results in urbanization and industrialization which accelerate the pace of waste generation. Waste disposal is becoming a problem for town planners, muncipalaties, civil authorities and also to public .Traditional practices like incineration and landfill creates environmental problems.In this context it is necessary to adopt environment friendly waste disposal technology. This criteria is full fill to some extent by Valorising recycling or Conversion of Organic Refuse by Saprophages). In this technology one of the candidate valorising insect is Black Soldier fly Hermetia illucens (Linnaeus).Using this insect has many benefits like it quickly reduces the volume of organic waste,preventing house fly and blow flies from laying eggs in organic waste., reduction in harmful bacteria and also produces protein rich feed for poultry and aquaculture. Conversion of organic waste into protein reducespressure on captive fishery as it is the main source of fishes from which fish meal and fish oil is been produced.. Hence the review paper highlights the ultimate role of Black Soldier Fly helps in recovery of nutrients from Organic waste and also helps to overcome the problem of organic waste disposal without disturbing the environment

Introduction

Rapid urbanization, consumer behaviour, intensive animal husbandry practices, municipalities and decision makes are confronted with new challenges in solid waste management. Organic waste management is now a big problem and many authorities find it very difficult to find a appropriate sustainable solution. Management of municipal solid waste (MSW) in low and middle-income countries remains a challenging and neglected key issue. Especially in urban and peri-urban areas, the household waste often remains uncollected on streets and drains, thereby attracting disease vectors and causing water blockages (Diaz etal.,1996 and Zurbrugy etal.,2007). Compared to other waste components, such as glass, metal and paper, the organic fraction, often amounting to 80% of the total municipal waste, is frequently looked upon as a waste fraction without market value and therefore ignored by the informal waste recycling sector (Ali,2002 and Ahmed,2002) Even if collected, MSW typically ends up in a landfill or on a more or less uncontrolled dumpsite where the material decomposes in large heaps under anaerobic conditions. To reduce the environmental burden and improve public health, new and financially attractive waste management strategies should be explored and fostered.

Another issue of faecal sludge (FS) management. FS accumulating in septic tanks, latrine and other onsite sanitation facilities contains high level of nutrients and pathogens. Despite high nutritional value of faecal sludge farmers are reluctant to apply this sludge in their farm field due to high cost transportation. If the sludge is not treated properly prior to use in farmers field it causes health hazards to the farmers and ultimately to the consumers who used to eat these contaminated vegetables. This faecal sludge is discharged into the surface water which contaminates the aquatic water bodies which are used for portable drinking water. Organic waste management can be achieved by scavenging or in other words valorising recycling activities/ CORS (Conversion of Organic Refuse by Saprophages) technologies which have many advantages over the other recycling technologies. CORS technologies (Conversion of Organic Refuse by Saprophages), such as vermicomposting or faecal sludge treatment by the aquatic worm *Lumbriculus variegatus*, could offer promising alternatives of nutrient recovery from organic waste (Elissen,2007). Organic waste digestion by the larvae of the black soldier fly (BSF), *Hermetia illucens* L. (Diptera: Stratiomyidae) is another CORS solution combining nutrient recovery and income generation (Sheppard,and Newton,1994) The larvae of this non-pest fly feed on and thereby degrade organic material of different origin. Domestic waste, chicken, pig and cow manure and even human excreta were found to be easily processed by the larvae. It has been estimated that this nonpest fly species can reduce nitrogen and phosphorus waste by up to 75% and the mass of manure residue by 50% in poultry and swine systems (Sheppard et al. 1994, 1998; Newton et al. 2005).

The by-product of this bioconversion system is an abundant amount of fly prepupae. These prepupae are approximately 40% protein and 30% fat (Sheppard et al. 1994, 1998; Newton et al. 2005), which makes for a suitable source of food for animals including commercially raised fish (Calvert et al. 1969; Newton et al. 1977; Bondari and Sheppard ,1981).

Research into alternate sources of protein and fat has focused on plant-based oils and proteins. Soybean meal is the most commonly utilized alternate protein source, comprising between10 and 50% of the protein in the diet (Tacon and Akiyama 1997; Hardy 2002). The nutritional requirements of carnivorous fish, such as rainbow trout, have made it difficult to completely eliminate the use of fish meal and fish oil in diets without compromising growth or utilizing cost-prohibitive plant protein concentrates. Total replacement of fish meal as the protein component of diets may be problematic because of the high sensitivity of carnivorous species to dietary imbalances, antinutritional factors present within plant meals (Francis et al. 2001), and palatability problems (Papatryphon and Soares 2001).Total replacement of fish oil has also not been feasible, especially with carnivorous species because of their specific dietary requirements for long-chain unsaturated fatty acids. Partial replacement of fish oil has been reported using plant and animal oils (Koshio et al. 1994; Balfryet al. 2002); however, more research is required concerning the use of finishing diets to manipulate the final tissue fatty acid profile and product quality (Bell et al. 2004; Morris et al. 2005).

Biological aspect of Black soldier fly

Black soldier flies, *Hermetia illucens* (Linnaeus), is a common fly of the Stratiomyidae family. The black soldier fly, *Hermetia illucens* (Linnaeus), was first seen in 1930 in Hilo Sugar Company in Hawaiian Islands (Sagade and Pejaver,2009).Black soldier fly is a tropical fly indigenous to the whole of the Americas, from the southern tip of Argentina to Boston and Seattle. But during World War II, the black soldier flies spread into Europe, India, Asia and even Australia. It is a sleek looking fly that's often confused with a wasp. However, like most flies, the black soldier flies only have two wings (wasps have four) and does not possess a stinger (DuPonte and Larish,2003). As adults, the black soldier fly does not possess a stinger, nor do they possess a mouthpart or digestive organs to allow them to consume waste; therefore, they do not bite either. Healthy adults are approximately 7/8 inches long (Hawkinson, 2005) with the female possessing a reddish-colored abdomen while the male's abdomen is more bronze. Their legs are black with pale yellow forelegs. Black soldier fly antennae – which are long, black, and straight – protrude from their head directly forward and do not contain an arista (bristle-like appendage at the tip of the antennae). In India, BSF larvae were found in poultry house in Punjab in 2007 (Ashuma etal.,2007)

In natural breeding, black soldier flies lay their eggs in moist organic material while in urbanized areas the black soldier fly lays eggs in dumpsters or compost, which provide similar odors and nutritional needs to naturally occurring organic matter (Diclaro and Kaufman,2009). Members of the family Stratiomyidae usually range in color from yellow, green, black or blue, with some having a metallic appearance. Many are mimics of other flying insects, such as bees and wasps. Black soldier fly adults are bristle less flies having a wasp-like appearance and are black or blue in colour. They also have two translucent "windows" located on the first abdominal segment and their scutellum is often conspicuously developed. The wing veins of fly are crowded near costa and more strongly pigmented than those behind while vein C does not entirely surround the wing. The species of *Hermetia illucens* has a fairly quick life cycle of 5-8 days. A few days after becoming an adult and emerging from a pupal case, female black soldier flies find a mate. How this would occur is a male intercepting a female mid-flight and them both descending in copula. The female does not waste any time to lay 500+ eggs in a dry environment near edges or crevices of decaying organic matter. Each egg is approximately 1 mm in length and creamy white in colouring (W. Diclaro II and Kaufman, 2009). After these eggs are laid, they remain in this stage for approximately 4.5 days or 105 hours (ESR International, 2008). Once the eggs hatch, the larvae find whatever waste they can and immediately start to consume it. Two weeks later, the larvae have reached full maturity given their environmental conditions are favorable. It may take up to six months for larvae to reach maturity due to black soldier flies' ability to extend their life cycle in hostile circumstances. The larvae can be up to roughly 27 mm in length and 6 mm in width. They have a pale white colour with a small black head containing their mouthparts (Newton, 2005) Following the maturity of the BSFL, pupae stages begin where the sixth instar (final molting phase in *Hermetia illucens*) larvae remove themselves from their feeding sites in search of a dry, sheltered environment. Once this occurs, pupation commences. As a result, the exoskeleton darkens in pigmentation and a pupa develops inside of the exoskeleton. Pupation takes another two weeks before an adult emerges from the pupae case. Then, the adult emerges to reproduce again and the cycle repeats.

Environmental Conditions

Black soldier flies are extremely sensitive to their environments; thus, their conditions need to be monitored extensively to ensure the highest yield is obtained. Considering black soldier flies are an equatorial and generally a warm-season temperate species, their lifespan is dictated by how warm their environment is. An experiment conducted by Jeffrey Tomberlin in 2009 tested the effect varying temperatures had on black soldier flies and their development. What he found was that at a temperature of 27^{o}C (80.6^{o}F) for both males and females, was when larval, prepupal, pupal, and adult longevity was at its most efficient (Tomberlin, 2009). He concluded that smaller adults and a shorter adult lifespan correlate as temperature increases due to higher rates of metabolism and growth. Once temperatures hit a higher threshold of 30-36^{o}C (86-96.8^{o}F), black soldier fly development is acutely inhibited. At a given temperature of 27^{o}C, males and females took ~2.5d more to complete a pupal stage than at 30^{o}C (86^{o}F). Also, at 27 and 30^{o}C, 83.2-91.8% and 74.2-96.7%, respectively, of individuals survived to become adults. From Tomberlin's work with black soldier fly rearing, he has concluded that from the egg stage (» 4d) to adults it takes roughly 43d total.

Humidity

L.A. Holmes, 25% RH (relative humidity) causes higher rates of desiccation and higher mortality rates on black soldier fly eggs. At 70% RH, adults lived 2-3d longer that adult black soldier flies subjected to lower RH levels (Holmes 976-977, 2012). Therefore, the higher the humidity of the proposed environment, the higher the chances are of a more successful colony. Eclosion at lower RH levels; however, is still possible. A relative humidity of 30-90% promotes mating and oviposition when eggs and larvae are reared in a 27°C environment.

Light

Naturally, black soldier flies require direct sunlight to encourage mating. Thus, operations indoors require supplemented artificial lighting. higher wavelength of 450-700 nm is recommended to produce mating behaviors out of black soldier fly adults (Zhang 3-6, 2010).

Diet

As adults, *Hermetia illucens* cannot feed; however, automatic or frequent water misting provides an adequate amount of water to the adults. The mists form droplets, which are then taken up by the adults. The adults' main energy source is the remaining fat stored from their larval stages. Larvae have a much wider range and greater demands for sustenance. Black soldier fly require a certain level of moisture in the organic matter they are consuming.

Nutritional Profile

An analysis of dried Black Soldier Fly larvae (ESR International 2008) elucidates that it contains:

Crude protein	42.1%
Ether Extract (Lipids)	34.8%
Ash	14.6%
Moisture	7.9%
Crude Fiber	7.0%
Calcium	5.0%
Phosphorus	1.5%
Nitrogen Free Extract (NFE)	1.4%

Use of Black soldier fly in aquaculture feed.

Rainbow trout, *Oncorhynchus mykiss*, diets generally consist of approximately 40% protein and 20% fat (Hardy 2002). In general the diet, contains 50% and more protein and fat is extracted from wild caught fish As global aquaculture is expanding feed requirement is also increases due to this pressure on capture fisheries increases.(Millennium Ecosystem Assessment 2005). In 2003, the Food and Agricultural Organization estimated that 52% of all fish meal and 86% of all fish oil harvested were used in fish diets (Tacon et al. in press). Commensurate with the increase in demand and price for this natural resource is the need to find alternatives for commercial aquaculture diets.

Replacement of 25% of the fish meal component with black soldier fly prepupae reduced the percentage of fish meal in the diet from 36 to 27% of the total diet with no adverse effect on the FCR of the fish. In addition, this permitted a 38% reduction in the fish oil component of the diet, which reduced the total percentage of fish oil in the diet from 13 to approximately 8%..(st-Hilair e etal.,2007)

Conclusion

Valorising recycling activities/ CORS (Conversion of Organic Refuse by Saprophages) using Black Soldier fly larvae is been used commonly in Western Countries for Organic waste disposal . Though this Black Soldier fly can thrive well in Tropical country like India so more efforts is to be given on promotion of Organic waste disposal by Black Soldier fly. It has many advantages over traditional way of waste disposal like *incineration* and land fill. The advantages like reducing the biomass of organic waste, helping in preventing harmful bacteria , and production of protein. It has a potential of waste disposal .helps in sorting the problem of much needed protein for animal feeding. More efforts are to be taken to make this technology more popular and overcome the problems encountered during scale up projects.

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