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Earthworm Excreta: A Helping Hand for the Production of Fuel Ethanol

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Abstract: ***Today it is necessary to emphasize that "Wastes are sources of pollution and therefore, their management and effective utilization is a must". In sugar industries bagasse is a major industrial waste which is reused for generation of steam. But large amount of surplus bagasse is available which poses serious problems to sugar industry if unutilized. It creates fire hazards and storage problems. Another sugar industry by product is press mud which is also a very good, rich material. The output of press mud occupies 4% of the total sugarcane crushed. Approximately, it works out to 100 tons per day for a 2500 TCD factory. Therefore, it is an ideal and beneficial no-loss situation if bagasses and press mud can be utilized productively and profitably. To meet these twin problems of fuel oil scarcity and air pollution caused by the growing use of petroleum fuels, alternate renewable clean burning fuels should be explored for use in motor vehicles. Most prominent eco-friendly fuel candidates are the bio-solar fuels (ethanol), natural gas and hydrogen. Amongst these, the most suitable for a developing agricultural country like India is ethanol. We used Earthworm Excreta for the Production of Ethanol from the deteriorated sugar. The result obtained shows that the earthworm excreta is fully capable in producing significant amount of ethanol.***

Keywords: Earthworm Excreta, Ethanol, Deteriorated sugar

1. Introduction

Today it is necessary to emphasize that "Wastes are sources of pollution and therefore, their management and effective utilization is a must". In sugar industries bagasse is a major industrial waste which is reused for generation of steam. But large amount of surplus bagasse is available which poses serious problems to sugar industry if unutilized. It creates fire hazards and storage problems. Another sugar industry by product is press mud which is also a very good, rich material. The output of press mud occupies 4% of the total sugarcane crushed. Approximately, it works out to 100 tons per day for a 2500 TCD factory. Therefore, it is an ideal and beneficial no-loss situation if bagasses and press mud can be utilized productively and profitably.

Converting this waste into a usable compost material through earthworms is called vermicomposting. These wastes contain high amounts of lignin, cellulose, hemi cellulose and carbon apart from macro and micro nutrients. Lignin and cellulosic materials are not easily decomposable. This can be overcome by treating them with thermophillic microbes at the initial state.

Earthworms can act as bio-concentrators of heavy metals and toxic materials. The toxic materials are stored in the tissues of earthworms (Edwards and Thompson, 1973). Edward and Lofty (1977) and Lee (1985) reported that the use of vermicompost and vermicast as suitable manures in crop production for maintenance of balanced soil health. Microorganisms and other eco-friendly organisms like earthworms add life to soil and these microbes work as scavengers for many industry wastes which are to be disposed then and there (Bhawlker, 1991)[1]. Since vermicompost is contaminated with earthworm excreta and can be separated physically. Therefore we can best utilize earthworm excreta, replacing urea which is generally used in the process of fermentation which is very costly and toxic as well.

2. Earthworm and their Digestion

"Earthworm" is the common name for the largest member of Oligochaeta in the phylum Annelida. Folk names for the earthworm include "dew-worm", "Rainworm", "night crawler" and "angleworm" (due to its use as fishing bait).

An earthworm is a tube-shaped, segmented animal that is commonly found living in soil. Its digestive system runs straight through its body; it conducts respiration through the cuticle covering its skin, and has a simple, closed blood circulatory system. Earthworms are hermaphrodites - each individual carries both male and female sex organs.

Earthworms obtain their nourishment from organic material present in the soil, but as the proportion of organic matter in ordinary soil is very small, earthworm ingest large quantities of earthy matter and that is why their gut is always full of earth.

The swallowed earth passes through the buccal chamber into the pharynx where it receives the salivary secretion poured into the pharyngeal cavity by the gland-cells of the pharyngeal bulb. The "Saliva" of the earthworm contains mucin and a proteolytic ferment. The mucus lubricates the food and helps in the formation of the food-bolus, while the proteolytic ferment starts the digestion of proteins. When the food reaches the gizzard, its strong muscles contract and, with the help of the thick internal cuticle, grind up the food and reduce it to a fine state of division, so that it is easily acted upon by the digestive ferments secreted by the stomach, the intestinal caeca, and the intestine[2].

Several kinds of ferments have been found in the intestine of the earthworm: proteolytic ferment converting proteins into peptones, a diastase converting starch into sugar, a glycogen hydrolysing ferment, a lipase splitting fats, invertine acting on cane-sugar, and an oxidising ferment catalase (Winterstein, 1911). It will thus be seen that the intestinal

digestive fluid corresponds in its essential features to the pancreatic juice of higher animals. All these ferments act upon the finally ground earthy food and help in the digestion of organic matter therein. The digested food is absorbed by the intestinal epithelium and passes into the blood-stream through the extensive capillary network of the intestine. Both digestion and absorption, therefore, take place in the intestine.

Earthworm Castings (Excreta)

The excreta of earthworms, known as castings, are a rich, all-natural source of organic matter with lots of nutrient and moisture-holding capacity. Importantly, it adds active microbial life to plant growth enhancers.

The Yelm Earthworm & Castings Farm has completed an extensive search of the scientific literature about worm castings. The search shows the extraordinary value of worm castings compared to many other soil amendments.

Earthworm castings provide many special benefits beyond what farmers or gardeners can expect from just manure or compost. In fact, most specialists recommend that castings be used as a top dressing or supplement. In this way, castings help make the most effective use of all your bulk soil amendments. "A little goes a long way" because the benefits of castings are so concentrated.

In nature, composting worms tend to be highly localized, thriving in pockets of highly enriched, organic materials. They will consume a great variety of organic wastes and excrete "worm castings" - a highly valued soil conditioner. Composting worms also tolerate a wide range of environmental conditions, which helps explain their adaptability.

Here are the results of research conducted by leading researchers around the world:

- “Scientific studies show that worm-worked composts have better texture and soil-enhancing properties; hold typically higher percentages of nitrogen, potassium, and phosphorous; and may offer plants disease-fighting properties.” [Edwards, 1988] [3]
- "Earthworm excreta (castings) are an excellent soil-conditioning material with a high water holding capacity and a natural time release' for releasing nitrogen into the soil." [Harris, et. al., 1990] [4]
- “Vermicompost (castings) is a finely divided peat like material with excellent structure, porosity, aeration, drainage and moisture-holding capacity." [Dominguez, et. al., 1997] [5]
- "Among the blessings of castings, vermiphiles count a smaller particle size than thermophilic compost, lower odor, enhanced microbial activity, and as a bonus, the vermicompost often contains worm cocoons, meaning a free work force for the future." [Riggle and Holmes, 1994] [6]
- "Through vermicomposting the humic substances showed an increase of 40 to 60 percent which was higher than the value obtained for the composting process." [Dominguez, 1997]
- “An important feature is that during the processing of the wastes (manure) by earthworms, many of the nutrients they contain are changed to forms more readily taken up by plants, such as nitrate nitrogen, exchangeable phosphorus and soluble potassium, calcium, and magnesium. The most surprising result was that even 5% of worm-worked animal waste in the worm-worked waste/commercial mixture had a significant effect on the growth of plants." [Edwards and Lofty, 1977] [7]
- In a study, researchers reported, "Passage of organics through the earthworm's gut significantly alters the physical structure of the material. Large particles are broken down into numerous smaller particles, with a resultant enormous increase in surface area." [Camp, Dresser and Mckee, 1980] [8]
- “The results obtained for the germination index showed a beneficial effect of earthworms and the highest values of this index were recorded at the final stages of the process. The germination index was 65 to 70 percent higher in the treatments with earthworms than in the control (no earthworms)." [Dominguez, 1997] [9]
- "By shredding organic matter and contributing nitrogen, earthworms stimulate microbial decomposition. Soil micro-organisms live in the worm's gut as well as the surrounding soil and so the microbial content of casts is usually more concentrated than in surrounding soil. Microbial activity in casts improves soil structure by encouraging aggregation of particles. Microbial secretions (gums) and growth of fungal hyphae stabilize the worm cast. Worm-worked soil is relatively water-stable and will resist soil compaction and run-off due to rains.” [Edwards and Lofty, 1977] [10]
- “In sum, earthworms must be seen not as a ‘miracle pill,’ a panacea for better soil and crop yields, but as an integral part of intelligent organic soil management practices. As earthworms are dependent upon organic matter for food, and mulches for protection from heat cold, and drought, so do growing plants depend upon the earthworm, in combination with bacteria and other microorganisms, to maintain and improve soil structure and fertility. When earthworms are seen as part of a living soil, existing in and contributing to a vital ecosystem." [Minnich, 1977] [11]
- **Biological.** In many soils, earthworms play a major role in converting large pieces of organic matter (e.g. dead leaves) into rich humus, and thus improving soil fertility. This is achieved by the worm's actions of pulling down below any organic matter deposited on the dried dirt, such as leaf fall or manure, either for food or when it needs to plug its burrow. Once in the burrow, the worm will shred the leaf and partially digest it, then mingle it with the earth by saturating it with intestinal secretions [12].
- **Chemical.** As well as dead organic matter, the earthworm also ingests any other soil particles that are small enough—including sand grains up to 1/20 of an inch (1.25mm) across—into its gizzard wherein minute fragments of grit grind everything into a fine paste which is then digested in the intestine. When the worm excretes this in the form of casts which are deposited on the surface or deeper in the soil, minerals and plant nutrients are made available in an accessible form. Investigations in the US show that fresh earthworm casts are 5 times richer in available nitrogen, 7 times richer in available phosphates and 11 times richer in available potash than the surrounding upper 6 inches (150 mm) of soil. In conditions where there is plenty of available humus, the weight of casts produced may be greater than 4.5 kg

(10 lb) per worm per year, in itself an indicator of why it pays the gardener or farmer to keep worm populations high [13] [14] [15].

- **Physical.** By its burrowing actions, the earthworm is of great value in keeping the soil structure open, creating a multitude of channels which allow the processes of both aeration and drainage to occur. Permaculture co-founder Bill Mollison points out that by sliding in their tunnels, earthworms "act as an innumerable army of pistons pumping air in and out of the soils on a 24 hour cycle (more rapidly at night)". Thus the earthworm not only creates passages for air and water to traverse, but is itself a vital component in the living biosystem that is healthy soil. Earthworms continue to move through the soil due to the excretion of mucus into the soil that acts as a lubricant for easier movement of the worm [16] [17].
- Famous biologist and my idol 'Sir Charles Robert Darwin' estimated that arable land contains up to 53,000 worms per acre (13/m²), but more recent research from Rothamsted Experimental Station has produced figures suggesting that even poor soil may support 250,000/acre (62/m²), whilst rich fertile farmland may have up to 1,750,000/acre (432/m²), meaning that the weight of earthworms beneath a farmer's soil could be greater than that of the livestock upon its surface [18] [19].

Ethanol Sources

Ethanol is a renewable, cleaner burning, alternate fuel which can be produced from an astonishingly wide range of raw materials. These include vegetable matter, growing crops, industrial waste like sulphite liquor from paper and pulp industry and molasses from sugar industry, waste organic matter such as straw and saw dust, cassava-a wild growth, agricultural waste, rotten fruits, etc. In fact any substance which contains sugar, starch or cellulose can be a raw material for production of ethanol, although the highest yield per ton of raw material is from sugar containing substances, such as molasses [20].

India where ethanol (alcohol) is mainly being produced from molasses, in the 200 and odd distilleries operating at 40-45% of their installed capacity, is one of the largest producers of alcohol in the world, with potential to increase its production manifolds by raising the production level in the distilleries up to their installed capacity and utilizing abundantly available other raw materials such as cassava-a wild growth down south and millions of tons of countries annual agricultural and farm waste [21].

Ethanol as Motor Vehicle Fuel

The principal interest in ethanol as motor vehicle fuel lies in its use as blends with gasoline. Its very high octane rating makes it an effective knock suppresser like TEL (Tetra Ethyl Lead) with an additional advantage of being a fuel in itself with no hazardous component like lead in TEL which causes lead pollution. Its blends can permit higher compressor operation of the engine without knock. Thus, for example, a 30% ethanol gasoline blend can effectively operate on engine compression ratio about 23% higher than that for gasoline, with consequent improvement in engine power output and efficiency. Its higher latent heat of vaporization, uniform composition, stoichiometric air requirement, higher flash point etc. impart to its blends certain useful properties which not only improve engine performance but also reduce engine emission and make the blends safer as compared to gasoline. Its lower calorific value, higher surface tension, greater solvent power etc. restrict its use as a complete motor vehicle fuel. It can be best utilized as a blend constituent with up to around 30% ethanol - gasoline blends usable in the present day automobiles without requiring any major engine modification; and giving reduced level of exhaust CO and HC (Hydro Carbon) Emissions [22].

Ethanol Blended Fuel's Field Trials

With a view to achieve the twin objectives of reducing gasoline fuel consumption and motor vehicle exhaust pollution in Delhi, the author undertook at the behest of Government of India, Ministry of Non-conventional Energy Source (MNES) a three year long field demonstration-cum-monitoring trials of a fleet of government vehicles filled with a ten percent ethanol gasoline blend, dispensed from a captive petrol pump. Indian Oil Corporation provided the necessary infrastructure facilities for storage and dispensing of blend, and Govt. of National capital region of Delhi provided the fleet of around 100 vehicles of various makes and age group for these trials [23].

The fleet of vehicles comprising of Ambassador cars, Mahindra Jeeps, Maruti gypsy and Maruti Vans, belonging to various departments of the government, continued to play on their respective routine routes/duties assigned by their parent department with the obligation to run on blended fuels with their kilometerage, fuel and lub. oil consumption, exhaust CO and HC emissions, regularly monitored, recorded and analyzed to assess the effect of ethanol substitution on their performance, fuel economy/consumption, exhaust emissions, lub oil deterioration and engine components materials compatibility/wear [24].

Present Investigation

Chemical fertilizers like disodium hydrogen phosphate, urea, and ammonium sulphate are generally used as nutrients in the production of molasses because micro-organism yeast cannot grow and ferment well without minerals nitrogen and phosphorous present in these nutrients.

Since earthworm excreta is also the rich source of nitrogen and phosphorous (as discussed above), it may be considered as alternative of these chemicals fertilizers required for the growth of yeast during fermentation of various feedstocks like molasses, potatoes, water nut, guava, beet root and even deteriorated sugar.

Therefore, in the present investigation fermentation of deteriorated sugar was experimentally done in presence of earthworm excreta.

Our country needs to tap renewable energy sources to fulfill its requirements; deteriorated sugar which is usually unfit for human consumption and is generally disposed off by the factories at very low price, can solve the energy problem of the country if managed and utilized in a planned way. The production of ethanol in this manner has the potential to counter the sky rocketing prices of crude oil and emerge as an alternative to fossil fuel which is damaging the ecology.

The large scale availability of earthworm excreta in rural areas can be used to produce ethanol from deteriorated sugar in an organized way and can serve as an excellent nutrient replacing expensive chemical fertilizers which are creating substantial health problems to mankind all over the world.

India is the world's larger producer of Sugar with output of 33 million tonnes. Therefore Indian sugar mills face a severe storage crisis of cane sugar and many have to leave the sugar under canvas covers due to large carryover stocks [25] under humid/warm condition, which lead to its quality deterioration. The deteriorated sugar is usually unfit for human consumption; therefore, it is generally disposed off by factories at very low price. The Government has decided to produce 1,061.04 million litre of ethanol from sugar mills at a flat rate of ₹ 21.50/- a litre over next three years. Government has allowed oil companies to supply 10% ethanol blended petrol across the country under its ethanol blending programme. By blending 10% ethanol, India stands to save 10 billion litres of petrol annually [26]. The import price of ethanol is ₹ 25/- a litre, higher than the domestic price of ₹ 21.50/- a litre. Hence there will be little chance of importing ethanol [27].

The deteriorated sugar is used for the production of ethanol by fermentation process using baker's yeast in presence of nutrients like disodium hydrogen phosphate, urea and ammonium sulphate and in some cases vitamins are also added [28].

The fermentation medium is necessary to be supplemented with nutrients, as micro organism yeast cannot grow and ferment well in absence of minerals nitrogen and phosphorus present in nutrients like disodium hydrogen phosphate, ammonium sulphate and urea, which are also found to be used as chemical fertilizers and mixed in the soil during manuring.

Since earthworms feed on the soil which contains organic content and chemical fertilizers, their excreta contain rich quantity of nitrogen and phosphorus in their alimentary canal, and their excreta may be considered as alternative source of mineral required for the growth of yeast during fermentation of deteriorated sugar to produce ethanol.

With the advent of chemical fertilizers and utilization of tractors for farm operations, the need of the earthworms to plough the soil has reduced [29]. Therefore, an attempt has been made to produce the ethanol during fermentation of deteriorated sugar by using earthworm excreta which is also a cheap source of required nutrients for the fermentation of deteriorated sugar to produce ethanol [30].

As we enter the new millennium, the country faces two major challenges namely the energy crisis and environmental degradation. The crying need of the day is energy, more energy and cheaper energy, which in simple terms means fuels, more fuels and cheaper fuels. The ever increasing expenditure on fuel oil imports is causing economic imbalance, price hike and hardship for people. Price of items like gasoline has increased manifolds and the oil import bill has shot up to Rs. 54,000/- crores from Rs. 29,000/- crores two years back. Moreover, the growing use of petroleum fuels in the ever-increasing number of automobiles is causing rapid degradation of the air environment in our major metropolitan cities, due to vehicular exhaust pollution.

To meet these twin problems of fuel oil scarcity and air pollution caused by the growing use of petroleum fuels, alternate renewable clean burning fuels should be explored for use in motor vehicles. Most prominent eco-friendly fuel candidates are the bio-solar fuels (ethanol), natural gas and hydrogen. Amongst these, the most suitable for a developing agricultural country like India is ethanol.

3. Materials and Methods

14% (w/v) of deteriorated sugar solution was supplemented with 0.5% earthworm excreta. The solution was sterilized at 15 psig (pounds per square inch gauge; 1 atmosphere is approximately 14.696 pounds per square inch) for 15 minutes and cooled at room temperature. Addition 0.05% active dry yeast was done in the solution and contents were fermented for 72 hours at 30^0C.

The yeast cells were able to ferment the deteriorated sugar solution with 0.9% increase in ethanol yield, when supplemented with earthworm excreta.

The measurement of ethanol percent from the fermented deteriorated solution was done by acetylation method [31].

10 ml of the above fermented liquid was transferred in a 250 ml conical flask, 10 ml of water was transferred in another conical flask (blank flask). Then 2 cc of acetic anhydride and 50 cc's of N – NaOH were added in each flask and excess of NaOH was titrated against N - HCl using phenolphthalein as indicator, till last drop of HCl gave off a pink color.

Volume of HCl required by excess NaOH in blank flask = 4.6 c.c.

1.2.2 Reactions

$$R-OH+(CH_3CO)_2 \longrightarrow ROCOCH_3+CH_3COOH$$
(Acetic Anhydride)

$$(CH_3CO)_2O+\ 2NaOH \xrightarrow[\text{Phenolphthalein}]{} 2CH_3COONa$$

$$\text{Excess of NaOH+HCl} \longrightarrow \text{Till Pink Color gives off}$$

4. Results and Discussion

The worm castings were rich in certain components when compared to wormless agricultural and industrial wastes. The composition of worm casts varied with the type of waste material used in the compost process. The reason for increased organic matter in the compost may be due to effective activity of earthworms.

Vol. of N/2 HCl required by 10 ml. of fermented liquid = 14.6
Vol. of N/2 HCl required to neutralize excess of NaOH = 14.6 -4.6 =10
1000 c.c. N-HCl = 46 gram ethanol

5.0 c.c N HCl = 0.23 gram ethanol
% Ethanol yield from fermented liquid =2.3

% Ethanol yield from deteriorated sugar =16.42

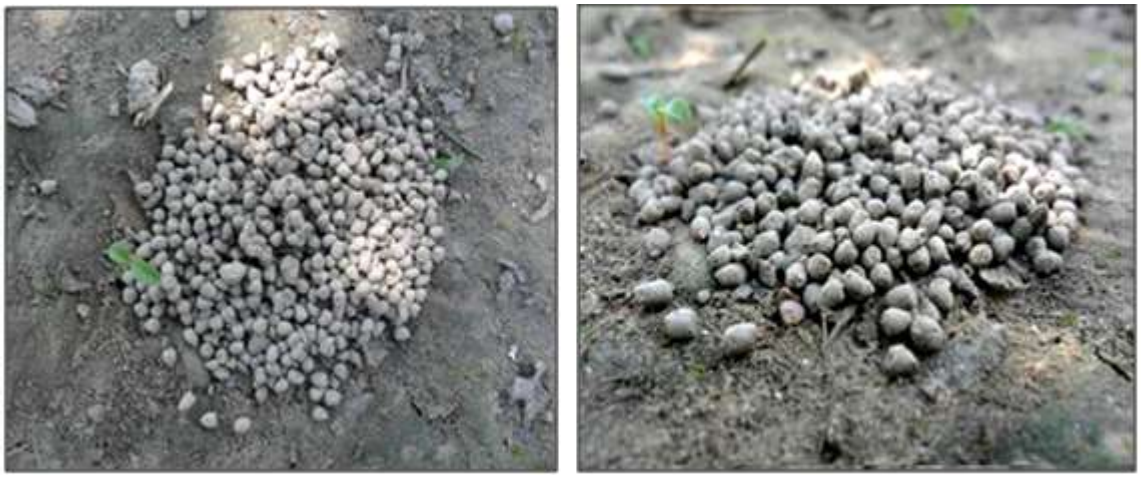

Figure 1.1: Earthworm faeces in form of casts *(Pheretima posthuma)*

Figure 1.2: A huge wave of earthworm excreta in form of castings (*Eutyphoeus waltoni*)

5. Conclusion

- The result obtained shows that the earthworm excreta is fully capable in producing significant amount of ethanol, from the deteriorated sugar.
- The result obtained is encouraging.
- The import price of ethanol is ₹ 25/- a litre, higher than the domestic negotiated price of ₹ 21.50/- a litre. Hence, there will be little chance of importing ethanol.
- With the utilization of tractors for farm operations the need of earthworms to plough the soil have got reduced therefore use of earthworm excreta may be considered as viable option to reduce cost of commercial production of bio fuel from feedstock's other than deteriorated sugar.
- Detailed studies and extensive test runs on ethanol blended fuels conducted by the author have convincingly shown that in ethanol we have a motor fuel which, in spite of its limitations, can provide the low knock fuel with power to withstand high compression ratios and give reduced exhaust emissions.
- Capable of being produced within the country from a wide variety of available raw materials including by-products of tropical zones, this "Home Grown" fuel provides a satisfactory motor spirit at minimum cost in imported low-knock fuels.
- Its use in present-day automobiles in the form of ethanol-gasoline blends can be an immediate mid-term measure to help reduce vehicular pollution in Delhi and at the same time add more energy to automobile energy supply and stretch the fast dwindling gasoline availability.

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