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The Effect of Locally Fabricated Pelletizing Machine on the Chemical and Microbial Composition of Organic Fertilizer

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Author's contribution

All aspects of this work including: study design, literature search, data gathering, statistical analysis and manuscript correction were performed by the author TBH.

Research Article

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ABSTRACT

In order to make organic fertilizer more quantifiable and attractive to farmers, a pelletizing machine was fabricated locally to produce pellets from powdery fertilizer. However, concerns have been raised on the potential impacts this process could have on the quality of organic fertilizer. An experimental study design with laboratory analysis was adopted. The study took place at Alesinloye market solid waste recycling complex, Ibadan Nigeria, in April, 2012. Samples of both powdery fertilizer and pellets were collected for chemical analysis. Total bacterial count was also determined in the laboratory. The results were subjected to student t- test statistics to compare the means. The variations in the levels of N (2.14 ± 0.02%; 2.39 ± 0.01%), C (37.19 ± 0.01%; 39.25 ± 0.01%), Na (0.1 ± 0.01%; 0.12 ± 0.01%), Ca (1.09 ± 0.01%; 1.16 ± 0.02%) and all heavy metals analyzed: Mn (123.50 ± 0.50 mg/kg; 131.50 ± 0.50 mg/kg), Fe (2,083.00 ± 8.00 mg/kg; 2,135.50 ± 1.50 mg/kg), Cu (224.50 ± 1.50 mg/kg; 238.00 ± 1.00 mg/kg), Zn (305.00 ± 1.00 mg/kg; 330.00 ±1.00 mg/kg), Pb (13.75 ± 0.15 mg/kg; 15.70 ± 0.10 mg/kg), Cd (0.82 ± 0.02 mg/kg; 1.08 ± 0.02 mg/kg), Ni (6.68 ± 0.02 mg/kg; 7.12 ± 0.02 mg/kg), and Cr (7.88 ± 0.03 mg/kg; 8.81 ± 0.01 mg/kg) for pellet and powdery fertilizers respectively was significant (P =.05). The microbial count was significantly lower in pellets than powdery fertilizer. It is evident in this study that pelletizing improved the quality of organic fertilizer due to the significant reduction of heavy metals and bacterial. Though pelletizing significantly reduced the

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levels of major nutrients as well, the effects were minimal as the pelletized fertilizer still fulfilled the standards organic fertilizer requirements. It is therefore recommended that organic fertilizers should be pelletized before their usage.

Keywords: Bacterial count; heavy metals; organic fertilizer; pelletizing machine; ultimate analysis.

1. INTRODUCTION

Organic fertilizer contains essential nutrients that are required by plant for better fruit yield and higher growth. Earlier on, Tejada et al. [1] reported that compost is a good fertilizer on soil that requires P and N to produce high yields. This is attributed to compost's slow release of plant nutrients like N and P [2]. Previous studies had also found that slow-release nitrogen fertilizer gave the highest grains number in maize and wheat [3,4]. In Nigeria, organic fertilizer is usually available in powdery form. However, with the development of pelletized organic fertilizer by a company in Ibadan, Nigeria, the use of pellet form is gradually gaining ground in the hearts of local farmers. The pellet possesses valuable qualities that both the powdery and liquid forms lack. The microbes that are responsible for composting include various bacteria and fungi that are pathogenic and parasitic. Pelletizing of powdery fertilizer has potential to kill pathogens and enteric parasites. It can also reduce the impact of biological aerosols (bio aerosols) and endotoxins on the manufactures and the end users. According to Reza-Bagheri et al. [5], pellet is safer due to removal of these pathogens and is easier to handle, store, transport and apply than powder organic fertilizer [6,7]. Suppadit [8] has earlier reported that pelletizing was a process that could eliminate microorganisms and odor in broiler litter. In addition to this, a study had been conducted in an organic fertilizer plant in Ibadan, Nigeria, to determine the energy requirement for production of both powdered and pelletized organic fertilizer [9]. The study revealed that the electrical and manual energy required for the production of powdered fertilizer were 94.45 and 5.55% of the total energy, respectively, with corresponding 93.9 and 5.07% for the production of pelletized fertilizer.

From a practical point of view, dry pellets contain greater nutrient density in terms of N, P, and K per kg of product as delivered and used [10]. Furthermore, pelletized fertilizer has low moisture content, and hence low bulk density per dry ton delivered to the end users. As flooding and erosion continue to affect agricultural land in considerable parts of the country, the marketing radius of pelletized fertilizer has been on increase as compared to the unpelletized powdery fertilizer. Act as a slow release fertilizer, pelletized fertilizer allows nutrients to stay in the soil for a longer period. This will enable plant roots to consume nutrients as they are needed. In addition, there will be no danger of over fertilizing plants. However, against these benefits, serious concerns are being raised on the impacts of pelletizing on the qualities of organic fertilizer with regards to nutrients, potentially harmful pollutants as well as microbial contents. Very few studies have been carried out in view of these concerns. Reza-Bagheri et al. [5] carried out a field experiment to assess the effect of pelleted fertilizer, produced by mixing urea and dry cow dung manure, on corn yield and its components. They concluded that the use of pelleted fertilizer was a better alternative to uncoated nitrogen fertilizer due to its slow and continuous nutrient release for plant uptake at different stages of its growth. In another study, pelletized broiler litter met all qualifications as an organic fertilizer on account of high fertilizer value [11].

These studies were not conducted in Nigeria and not focused on mixed organic waste from municipality. Perhaps, studies on municipal organic waste that accounts for over 70% [12, 13] of total waste generated in Nigeria vis-à-vis levels of micro nutrients, heavy metals and microbial contents in pelletized organic waste are of considerable importance. The study therefore investigated the effects of pelletizing method on the qualities of pelletized organic fertilizer produced from municipal organic waste in terms of its nutrient, heavy metal contents and microbial load.

2. METHODOLOGY

2.1 Construction and Operation of Pelletizing Machine

The pelletizing machine worked on the principle that was very similar to that described in a similar study [5]. It used biomass densification in form of mechanical pressure to reduce the volume of grind material and conversion of this material to a solid form (pellets). The machine (Fig. 1) was designed by an Engineer from the University of Ibadan and constructed by a local fabricator who was properly guided. The machine components were made mostly from scrap metal (Fig. 2). It used electrical power supply for its operation. Cured and matured powdery fertilizer was fed into the machine through the hopper. The loaded material moved by gravity into the auger which forced it through the stationary die in the compression chamber to produce the desired shape (Fig. 3). The speed was regulated by a special gear box. In order to obtain well-formed pellets in the absence of binder, moisture content of fertilizer for pelletizing was increased to 20% instead of normal 10-12%. At the end of each operation, or after each electrical outage, the barrel would be opened and remnant material packed out to prevent caking.

2.2 Production of Organic Fertilizer

An aerobic windrow composting technique was used to decompose mixed organic waste to maturity. The waste which was sourced from municipal refuse collection bins in Ibadan metropolitan area, Nigeria, included food remnants, fruits, vegetables, leaves, grass clipping and kitchen waste. In this process, the sorted organic waste was mixed up with nitrogenous waste from an abattoir in order to maintain initial carbon to nitrogen ratio of 3:1 which fell within the range of 20: 1 to 35: 1 recommended for rapid composting (14,15). Composting was monitored in windrow chambers through the use of specified tools and direct observation as described in a previous study [16,17]. The matured compost was sun dried and ground in a hammer milling machine prior to pelletizing.

2.3 Procedures for Laboratory Analyses

Grab samples were taken from different sides, depth and at the centre of both powdery and pelletized fertilizers produced. The grab samples were then mixed together to form composite samples that were analyzed for chemical and microbial contents. Determination of total phosphorus as P_2O_5 in samples was done spectrophotometrically, using the Mo (molybdovanadate) blue colour method of Murphy and Riley [18]; total carbon content was determined according to Walkey Black wet oxidation method [19]; total nitrogen was determined, through regular micro Kjeldahl method [20]; while potassium was determined titrimetrically, using sodium tetraphenylboron volumetric method as described by APHA methods of analysis [21]. Prior to phosphorus and potassium determination, mixture of concentrated nitric, perchloric and sulphuric acids in a ratio of 5:1:1 respectively was used to digest 2 g of each sample as reported in a previous study [16]. Ca, Mg, Cu, Zn, Fe and Mn were measured by atomic-absorption spectrophotometry [17].

For the isolation of bacteria from the samples, the pour plate method of Waksman and Fred [22] was used. The composite samples were mixed together and 1 g of the sample was weighed and dissolved in 9 ml of sterile distilled water and shaken vigorously for about one minute into a suspension. Serial dilution was made by transferring 1ml from the suspension into 9 ml sterile water blanks until dilution of 10^6 was reached. The dilution factor of 10^6 was transferred onto the sterile petri dish and mixed with about 15 ml of the molten nutrient agar (45ºC). The plates were swirled round for homogenous mixing of the inoculum and the medium. The plates were incubated at 37ºC for mesophilic organisms and 55ºC for thermophilic organisms for 48 hours. Counts of abundance, expressed as log of bacteria number per g of material (cfu/g), were then performed.

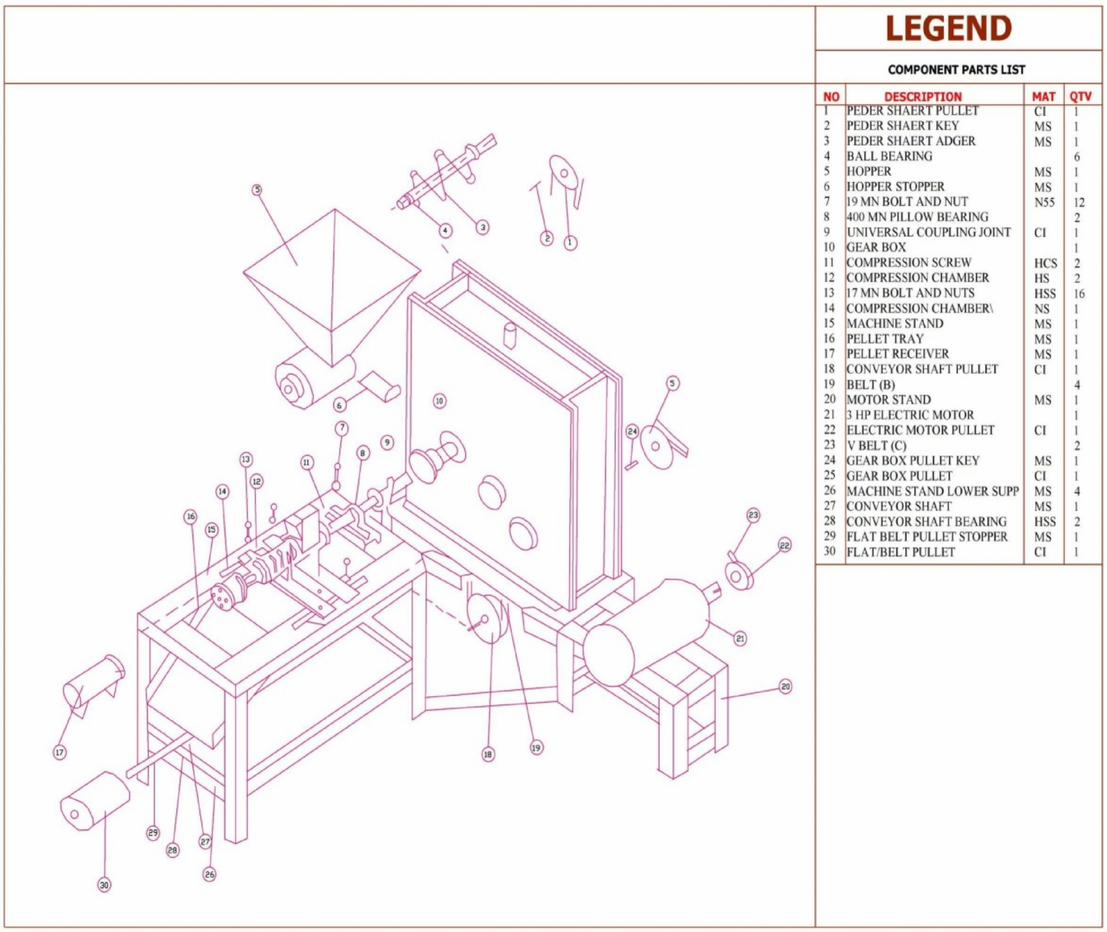

Fig. 1. Exploded view of pelletizing machine

Fig. 2. Picture of the pelletizing machine

Fig. 3. Pelletized organic fertilizer

3. RESULTS

The results of nutrient composition of both pellet and powdery organic fertilizers are shown in the Table 1. Virtually, all the nutrients analyzed were higher in powdery organic fertilizer. The mean differences of the nutrients were significant (*P*= *.05*) with respect to nitrogen, organic carbon, sodium and calcium.

Table 1. Nutrient composition of fertilizer

Parameter	Mean ± standard deviation (%)		Mean difference (X-Y)
	Pellet organic fertilizer (X)	Powdery organic fertilizer (Y)	
Nitrogen	2.14 ± 0.02	2.39 ± 0.01	-0.25*
Phosphorus	0.83 ± 0.07	0.96 ± 0.01	-0.13
Organic carbon	37.19 ± 0.01	39.25 ± 0.01	-2.06*
Potassium	0.30 ± 0.02	0.32 ± 0.01	-0.02
Sodium	0.1 ± 0.01	0.12 ± 0.01	-0.02*
Magnesium	0.29 ± 0.01	0.32 ± 0.01	-0.03
Calcium	1.09 ± 0.01	1.16 ± 0.02	-0.07*

** The mean difference is significant at the 0.05 significant level (P= .05)*

Table 2 shows heavy metal composition of the fertilizer samples analyzed. Also, there were variations in the values of heavy metals found in the two types of the fertilizers. The values were found higher in the powdery fertilizer and the differences were significant (*P*= *.05*). The highest mean difference was found in iron while cadmium showed the least mean difference. In addition to higher nutrient and heavy metal values, powdery organic fertilizer also had higher microbial load (54%) than its pellet counterpart (Fig. 4). In order to ascertain the suitability of applying both types of fertilizers to plants, their levels of pollutants in terms of heavy metal compositions are compared with some international standards (Fig. 5). The samples showed comparatively lower values of heavy metals, especially in parameters like Cd, Ni, Cr, and Pb.

Table 2. Heavy metal composition of fertilizer

Parameter	Mean ± standard deviation (mg/kg)		Mean difference (X-Y)
	Pellet organic fertilizer (X)	Powdery organic fertilizer (Y)	
Manganese	123.50 ± 0.50	131.50 ± 0.50	-8*
Iron	2,083.00 ± 8.00	2,135.50 ± 1.50	-52.5*
Copper	224.50 ± 1.50	238.00 ± 1.00	-13.5*
Zinc	305.00 ± 1.00	330.00 ±1.00	-25*
Lead	13.75 ± 0.15	15.70 ± 0.10	-1.95*
Cadmium	0.82 ± 0.02	1.08 ± 0.02	-0.26*
Nikel	6.68 ± 0.02	7.12 ± 0.02	-0.44*
Chromium	7.88 ± 0.03	8.81 ± 0.01	-0.93*

** The mean difference is significant at the 0.05 significant level (P=.05).*

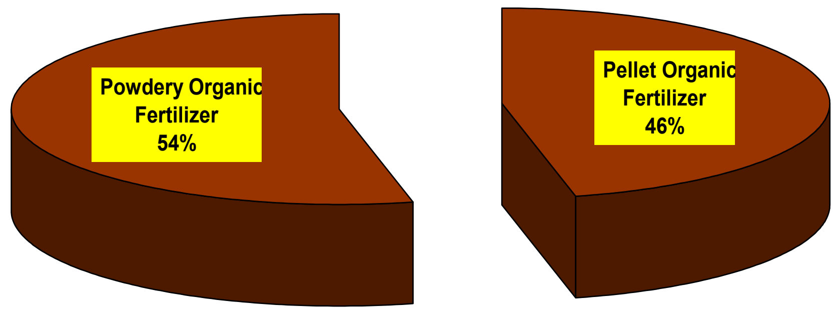

Fig. 4. Microbial composition of fertilizer

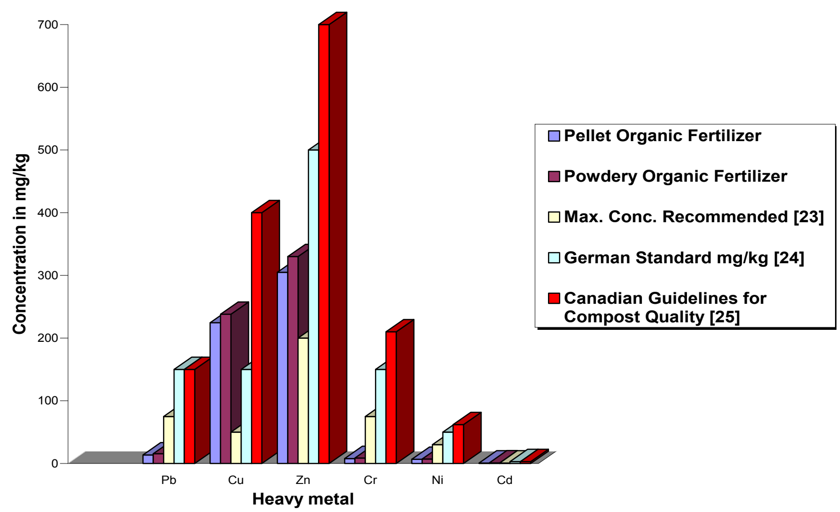

Fig. 5. Comparison of selected heavy metal in the fertilizer with respect to some international standards

4. DISCUSSION

4.1 Nutrient Composition of Fertilizer

All nutrient constituents, especially N, P, and K, determined in this study were lower than those obtained from the previous study [11]. The reason could be due to the effect of broiler litter used as feedstock. Also, the disparity in the values of nutrients in both powdery and pellet samples could be due to effects of heat and pressure from the pelletizing process. According to Suppadit and Panomsri [26], pelletized fertilizer had high value that met all requirements as an organic fertilizer even if some components were denatured by the heat during the pelleting process (90ºC). Heat and pressure from the pelleting process occurred only for a short period (~5-10 second). Though the higher values of N, C, Na, and Ca observed in the powdery sample over the pellet sample were statistically significant ($P = .05$), both forms met requirement for organic fertilizer [16,17]. In Nigeria, standards for organic fertilizer have not yet established. However, the results are in consonance with standards from other countries [24,25].

From the practical point of view, pelletizing of cured and matured compost will lead to an additional cost of production. In other to offset the cost of production of the pellets, a less stable and fairly decomposed material can be pelletized. This will lower composting costs as a consequence of less frequency of turning and wetting. In addition, higher nitrogen content, including ammonia, an immediately available nitrogen source, in the less mature organic waste can compensate for nitrogen loss during pelletizing. However, more researches are required to validate this observation. Immature and poorly stabilized could be potentially harmful to young crops in the farm due to reduced oxygen in the soil-root zone, reduced available nitrogen, or the presence of phytotoxic compounds [27].

4.2 Heavy Metal Composition of Fertilizer

Heavy metals are trace elements whose concentrations are regulated by the EPA due to the potential for toxicity to humans, animals, and plants [28]. There were significant differences in all heavy metals analyzed: Mn, Fe, Cu, Zn, Pb, Cd, Ni, and Cr. The lower values were found in the pelletized sample. Pelletizing of fertilizer further reduced the levels of heavy metals below some notable international standards [24,25]. As stated earlier, these components were denatured by the heat during the pelleting process (90ºC) [26]. In their study, heating at 90ºC led to significant reductions in Fe, Mn, B and Cu contents of fresh broiler litter. The results is also in agreement with the study of Lopez-Mosquera et al. [29], which showed that B, Mn, Cu, Cr and Cd contents of broiler litter were affected by pelleting temperatures of up to 90ºC. On the other hand, the values obtained for heavy metals in this study were higher than what obtained by Tawadchai [11] and maximum allowable concentration for heavy metals in Thailand [25] with regards to Cd, Ni, and Pb. Meanwhile, the value obtained for Cr was lower than both cases. In contrary to the opinion that pelletizing process reduced heavy metal contents of organic fertilizer, it has been observed that Cd, Ni, Pb, and Cr increased due to pelletizing which was related to a decrease in moisture content [26]. This observation has also been explained in terms of the contamination of the apparatus used in the pelletizing process in the previous study [29].

4.3 Microbial Composition of Fertilizer

In terms of total bacterial count, the difference between the two samples analyzed was significant. Most of the bacterial could have been denatured by the heat during the pelletizing [26]. Different types of microorganisms are active at different phases in the composting pile. Bacteria have the most significant effect on decomposition of readily decomposable substrates (e.g., proteins, carbohydrates, and sugars) faster than any other group. However, introduction of selected strains of bacteria to inoculate compost piles has not been found to bring about completion any more rapidly [14,28,30,31]. Most of these bacterial are pathogenic and can pose potential health hazard if not removed before reaching the end users, including farmers and horticulturists. In this study, significant reduction in the total bacterial count in the pellet sample showed that pelletizing could be effective for pathogen reduction in organic fertilizer, thereby making it safer for health.

5. CONCLUSIONS

It is evident in this study that pelletizing had effects on the chemical and microbial composition of organic fertilizers. Though pelletizing significantly reduced the levels of major nutrients required by plants due to heat and pressure involved in the process, the effects were minimal as the pelletized fertilizer still fulfilled the standards organic fertilizer requirements. Pelletizing also reduced the quantity of pollutants like heavy metals and bacterial. This gave pelletizing additional advantage for improving the quality of the fertilizers apart from making organic fertilizers more quantifiable and attractive to farmers. So, it could be recommended that organic fertilizers should be pelletized before their usage.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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