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IMPACT OF COMPOSTING ON THE PHYSICAL FACTORS OF MUNICIPAL SOLID WASTE MATERIALS WITH ORGANIC ADDITIVES IN IHIALA ANAMBRA STATE

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Abstract

Nowadays, solid waste disposal is the most pressing problem facing mankind throughout the world and its management is presently an issue of global concern. The present study was designed to evaluate the impact of composting on the physical factors of compost from Municipal solid waste with organic additives in Ihiala local Government Area, Anambra State, Nigeria. Effective microorganisms (bacteria and yeast strains) isolated from plant root, soil and fruit samples were employed in the biosynthesis of nanocomposites. The nanocomposites and effective microbes were further developed and used in the biocomposting and biodegradation of 5.5 kg shredded and dried final waste mixture of approximately 55 % food waste, 15 % saw dust waste, grass chopping waste 22 % and 8 % paper with or without inoculation (control) for 56 days or 8 weeks. The feedstocks and end products of humus like compost were characterized and analysed for physical characteristics like texture, colour, odour, compactness (height), temperature, conductivity and moisture content using standard procedures.The final compost was found to be fine and homogenous in texture, dark brown to black in colour, slightly foul to earthy smell in odour. There were decrease in mass, temperature, conductivity (EC) and moisture content, respectively. Statistical significant differences ($P < 0.05$) were found only in the conductivity parameters only among the means of treatment set ups relative to control set up. Thus, it could be concluded that the quality of compost of this present study is good and consortium of effective microbes and magnesium nanocomposite is said to be the suitable agent for biocomposting and biodegradation of solid wastes materials.

Keywords: Biocomposting, Biodegradation, Effective Microbes, Nanocomposites, Organic additives.

INTRODUCTION

The steady growth of industrial production and trade in many countries of the world has led to a rapid increase in the generation of municipal and industrial waste in the last decade. About 50 % of the waste generated worldwide consists of organic matter, generally from food, human and animal waste, garden and wood products. A significant portion of this waste ends up in landfills and, if not properly treated, can pose a significant threat to the environment and human health. The main producers are the agriculture and food sectors. Their waste can be used as a raw material to produce high value-added products, opening up a range of opportunities for sustainable production (Sakac *et al*., 2022).

Composting of agricultural waste and municipal solid waste has a long history and is commonly employed to recycle organic matter back into the soil to maintain soil fertility. The recent increased interest in composting however has arisen because of the need for environmentally sound waste treatment technologies. Composting is seen as an environmentally acceptable method of waste treatment. It is an aerobic biological process which uses naturally occurring microorganisms to convert biodegradable organic matter into a humus like product (Tweib *et al*., 2011). The process destroys pathogens, converts N from unstable ammonia to stable organic forms, reduces the volume of waste and improves the nature of the waste. It also makes waste easier to handle and transport and often allows for higher application rates because of the more stable, slow release, nature of the N in compost. The effectiveness of the composting process is influenced by factors such as temperature, oxygen supply (i.e. aeration) and moisture content (Tweib *et al*., 2011).

The products of the composting process are carbon dioxide and stable carbon forms that lead to the decomposition and mineralization of organic matter and the production of humic substances. During the composting process, microorganisms release heat and energy as they decompose material. The heat generated increases the temperature of the compost pile, which ensures the inactivation of pathogenic microorganisms. For this reason, measuring the temperature of the pile is very important in evaluating the composting process (Sokac *et al*., 2022). The performance of the composting process is influenced by factors such as temperature, pH, moisture content, C/N ratio, particle size, nutrient content and oxygen supply (Barros *et al*., 2021; Li *et al.* 2013). The listed process variables can change frequently during the composting process. The largest and most significant temperature variation is observed during the thermophilic phase of the process. In addition, moisture content has a significant effect on the physical and chemical properties of the composting substrate (Sokac *et al*., 2022). The C/N ratio and aeration are also very important for the multiplication of microorganisms. Thus, to achieve maximum efficiency in composting, all these factors and their interactions must be considered.

Effective microorganisms (EM) are commercially available. The technology has been distributed to over 90 countries in the world. In general, EM suspension contains a group of microorganisms, in particular, lactic acid bacteria, yeast, and photosynthetic bacteria, which are mainly used in agriculture (EM Research Organization, 2014). Two more species of microorganisms were found in EM suspension namely as fermenting fungi and actinomycetes (Talaat, 2014). These microorganisms have specific function. For example, bacteria producing lactic acid inhibit the growth of pathogenic microorganisms and other various microorganisms by reducing the pH through lactic acid production. Yeast produces many biological active agents such as amino acids and polysaccharides which feed other microbe. The phototrophic bacteria involved in various metabolic systems play a major role in nitrogen cycle and carbon cycle. The application of EM to the soil or plant ecosystem also can improve soil quality and soil health. It also encourages the plant growth, increase the yield and improve the quality of crops (Hu and Qi, 2013).

Several studies published reports on physical factors effect during composting with effective microorganisms as organic additives only. Those studies are limited in that there is paucity of nano-agents of biological origin either as single or combined additives during composting, hence justify the present study. Thus, the objective of this paper is to evaluate the impact of composting on the physical factors of compost made of different materials with organic additives in Ihiala local Government Area, Anambra State, Nigeria.

MATERIALS AND METHODS

Material and Sample Collection

Pure magnesium nitrate ($MgNO_3$) reagents and other chemicals of analytical grade that will be used in this study will obtained from Loba Chemie, Mumbai India. Rhizospheric soil samples and roots of soy beans were aseptically collected with sterile hand trowel and knife from the school garden within premises of Chukwuemeka Odumegwu Ojukwu, Uli Campus Ihiala Anambra State while ripe queen pineapple (*Ananas comosus*) specimens were bought from Nkwo Ogbe Market Ihiala Anambra State. All the samples were placed into sterile polyethylene bags and transported on ice to the Microbiology Laboratory of Chukwuemeka Odumegwu Ojukwu University Uli Campus, Nigeria for further analysis.

Enrichment and Isolation of Effective Microbial Species

The methods of Ogbo and Okonkwo *et al*. (2012), Jahangir *et al*. (2019) and Umeh *et al.* (2019) were adopted in the isolation of rhizospheric bacterial (RB) species, phosphate solubilizing bacteria (PSB) and yeast using nitrogen free biotin medium (NFb), Pikovaskaya (PVK) agar medium and Yeast Extract Dextrose Peptone broth, respectively. After incubation, discrete colonies were selected and purified cultures were preserved in 20 % glycerol contained in Bjou bottle and stored at - 70 °C.

Magnesium Nanoparticle and Nanocomposite Biosynthesis

The modified methods of Kazemi *et al.* (2020), Hassan *et al*. (2021) and Saied *et al.* (2021) were adopted in the biosynthesis of magnesium nanoparticles and nanocomposites using mixture of bacterial and fungal filtrates under magnetic stirrer for 120 min, 70 °C and 80 rpm.

Composting

Seed culture

The modified methods of Limaye *et al.* (2017) was adopted for the composting method. Four strains selected for the formation of consortium were designated as: Rhizospheric bacteria (RB), Phosphate solubilizing bacteria (PSB) and Yeast strain (YS). These strains were used as the seed culture for composting.

Inoculum build up and formulating the consortium of selected strain

The three selected strains were grown at room temperature for 36 h on nutrient broth medium until maximal exponential growth was reached. For each strain, bacterial and yeast suspensions were prepared in saline with 0.01 % Tween – 80. Pooled bacterial and yeast suspensions were prepared by adding 100 mL suspension of each strains.

Substrate collection and preparation

The food waste consisting of leftover food, fruit and vegetable were collected from the eatery centres, restaurants, local markets and vendors in Uli town. Saw dusts were collected from timber sheds and local carpentry workshops at Ihiala town. The grass straws were collected within Chukwuemeka Odumegwu Ojukwu University, dried and chopped into pieces. The paper waste consisting mostly of unused office paper and tissue paper were gathered from within the Chukwuemeka Odumegwu Ojukwu University Uli campus. All safety measures when handling these wastes such as wearing rubber gloves and face masks are observed. All the non - compostable materials contained in the waste were sorted out and not included in the compost preparation. The food waste samples were then rinsed with the tap water for removing the oil and impurities. The organic wastes were air - dried for a couple of days to remove the excessive moisture. The sorted organic materials were crushed to fine particles and then transferred to a rectangular composter as a raw material for composting (Ali *et al.* 2013; Limaye *et al.* 2017; Njoku *et al.,* 2019a, b; Saleh *et al.* 2020). All sample collection centers were located in Ihiala Local Government Area, Anambra State, Nigeria, respectively.

Composting unit

The passive aeration composting experiment was carried out in 13 L laboratory made plastic bin composter with dimensions 43 cm x 32 cm x 25 cm (length x width x height) and aeration holes (0.6 cm diameter) at the sides of the bin. Each experiment contained 5.5 kg shredded and dried final waste mixture of approximately 55 % food waste, 15 % saw dust waste, grass chopping waste 22 % and 8 % paper with or without inoculation as described by Aslanzadeh *et al*. (2019). The first set up was added the bacterial and yeast suspension labelled effective microorganisms, the second set up was magnesium nanoparticles labelled Mg nanocomposite, the third set up was added a combination of both microbial suspension and magnesium nanocomposite labeled consortium while the fourth set up labelled uninoculated control was maintained with saline of 0.01 % Tween -80, respectively (Zhao *et al.* 2017; Saleh *et al.* 2020).

Maintaining the moisture and aeration level

Composting units were kept in the laboratory shade. Composting was allowed to take place for 8 weeks. Moisture level was maintained by addition of 20 mL sterile water to the pile every day. All the samples were aerated by turning the pile using sterile plastic rod every day in the first two weeks and after that only once a week for the rest of the experimental period. The experiment was carried out in triplicates (Limaye *et al.* 2017; Aslanzadeh *et al.* 2020).

Analysis of the composted material

During the 56 days composting period, the following parameters for the experiments were measured as follow:

Compost texture, colour, odour, compactness and mass reduction determination

The texture, colour, odour, compactness **(**height) of the compost pile set ups were determined at the beginning and end of the composting using calibrated meter rule and values were recorded in centimeter scales (Limaye *et al*., 2017). The percentage in compost height or compactness was determined. Also, the whole composted samples were weighed using weighing balance every 2 weeks for 8 weeks and the percentage of mass loss or reduction was determined (Zhao *et al*., 2017).

Temperature, conductivity and moisture content determination

The analyses of temperature, conductivity and moisture content were carried out according to the method of FAO (2008). The temperature was determined using handheld thermometer, conductivity was determined using conductivity meter while moisture content was determined using oven drying.

Statistical Management

Data were analyzed using GraphPad Prism Version 8.0.2. Descriptive statistics were performed to summarize the data in the form of mean. The Two Factor Analysis of Variance (ANOVA) followed by Dunnett's multiple comparison test was adopted in comparing the decomposition and removal efficiencies of the consortium, effective microorganisms and magnesium oxide nanocomposite with respect to their controls at 95 % confidence interval and P values below 0.05 were considered significant.

RESULTS AND DISCUSSION

The past literatures revealed that an increase in the composting rate and microbial activity intensification can be achieved by Effective Microorganisms (EM) which creates the suitable environmental conditions for decomposition of organic materials used. The microbial activity is influenced by the particle size of the feedstock material, pH, moisture content, temperature, height of compost bed as well as other physicochemical and biochemical factors (Pushpa *et al*., 2016). In this study, the physical parameters were used in characterization and monitoring of the composting materials during 56 days composting period. Table 1 represents the changes in the physical parameters of composted materials before and after 56 days of composting period. All the composting units had fine homogenous materials in texture, dark brown to black in colour, slightly foul to earthy smell in odour, 12.0, 7.2, 7.2, 5.5 cm in compactness (height) and 4.067, 2.595, 3.318, 2.648 kg in mass reduction for control, effective microorganisms, magnesium nanocomposite and consortium after the composting period. The result in Table 1 revealed that all the composting materials in both treated and control composting units were fine and homogenous in texture, dark brown to black in colour, slightly foul to earthy smell in odour. These changes in texture and colour of the composted materials indicate the maturation of the final compost while the earthy smell odour indicates the absence of anaerobic conditions and is in agreement with the published work of Karanja *et al*. (2019) who reported that by the 62nd day of composting, all the composting materials showed temperature stability, pleasant earthy smell, fine texture, much darker brown or black colours and homogeneity of materials. Also, there were significant ($P < 0.05$) percentage decrease in compactness (height) of control (36.80 %), effective microorganism (64.40 %), magnesium nanocomposite (62.5 %) and consortium (71.73 %), respectively after 56 days of composting using T – Test statistical analysis which indicates the decomposition has taken place at constant rates. Previous study by Pushpa *et al*. (2016) reported that the height of the compost bed or compactness or height substantially decreased with increase in decomposition rate until the bed height was no longer reduced due to the maturity of compost. Similarly, there were significant ($P < 0.05$) percentage decrease in mass reduction of control (26.05 %), effective microorganism (52.82 %), magnesium nanocomposite (39.67 %) and consortium (51.85 %), respectively after 56 days of composting using T – Test statistical analysis which indicates that microbial decomposition has taken place at continuous rates. The substantial decrease in mass loss could further be explain in such a way that in the initial stage of fermentation, abundant nutrients and vigorous microbial metabolism resulted in a rapid mass loss. Thereafter, during the composting process, the readily decomposable organic matter was consumed by microorganisms, resulting in exhaustion of the available carbon and nitrogen sources and the remaining mass was more difficult to decompose (Zhao *et al*., 2017). Previous study by Zhang *et al*. (2013) reported that microbial metabolic activity was the primary reason for organic waste mass loss. Microbes decomposed organic components into micro-molecular organics such as glucose and produced and emitted large amounts of CO_2. Saad *et al.* (2013) reported that maturity of compost product can also be achieved by observation of physical parameters such as temperature, odor, texture and color. As the compost product is matured, the temperature will drop at certain degree which is in this case 30 °C, and will be in fixed value even after applying turning process. Compost product will produce an earthy smell with the texture and color are similar to soil and therefore upholds the observation made in this study.

Temperature stimulates the growth and metabolic activity of the microbial community within compost mass (Ralstogi *et al*., 2020). Compost temperatures largely depend on how the heat generated by the microorganisms is offset by the heat lost through controlled aeration, surface cooling and moisture losses (Pushpa *et al*., 2016). In this study, Figure 1 represents the changes in temperature of composted materials during composting period. At the startup, the magnesium nanocomposite setup had the highest temperature value of 30.00 °C followed by the control setup with 28.00 °C, effective micro-organisms setup with 28.00 °C and consortium setup with 27.00 °C. After the eighth week, the control had the highest temperature value of 31.00 °C followed by the magnesium nanocomposite setup with 28.00 °C, effective micro-organisms setup with 26.00 °C and consortium set up with 25.00 °C, respectively. The result in Figure 1 revealed that all the composting units except control set up reached their thermophilic phase, with the temperature readings increasing more than 45 °C in the treated compost. Thereafter, the temperature declined to mesophilic phase as the metabolic processes of the microorganisms slightly inhibited, indicating that the compost was nearing its mature phase. Therefore, three phases (mesophilic, thermophilic and cooling) in relation to temperature changes were observed in all the treatments of the present study. Statistically, no significant ($P > 0.05$) differences was detected among the means of treatment set ups relative to control set up using two factor Analysis of Variance (ANOVA). Previous studies by Saad *et al*. (2013), Salama *et al*. (2017) and Karanja *et al*. (2019) pointed out that temperature ranging between 45 - 55 °C promote waste decomposition and maximal sanitization during composting and in this study, the composting temperature in all treatment except control set up were within this range.

The electrical conductivity affects the quality of compost in a large way because it reflects their salinity and suitability for crop growth (Pushpa *et al.*, 2016). In this investigation, Figure 2 represents the changes in conductivity of composted materials during composting period. At the startup, the consortium setup had the highest conductivity value of 1746.00 mS/cm^3 followed by the effective micro-organisms setup with 1069.00 mS/cm^3, control setup with 920.00 mS/cm^3 and magnesium nanocomposite setup with 840.00 mS/cm^3. After the eighth week, the consortium setup had the highest conductivity value of 440.00 mS/cm^3 followed by effective micro-organisms setup with 280.00 mS/cm^3, the control set up with 270.00 mS/cm^3 and magnesium nanocomposite set up with 160.00 mS/cm^3, respectively. The result in Figure 2 demonstrated that there were substantial and continuous decrease in the conductivity values in all the composting units after 56 days and the reason for these changes could be due to release of mineral salts and free ions such as nitrate, phosphate and ammonium during the microbial metabolic activity on the composting materials. The conductivity values obtained for all composting units in this study were found below 4000 µS/cm maximum limit recommended by Diacono and Montemurro (2015) as the plant growth sustainable and saline soil remediation limit. Low values indicate a lack of available salts, while high values indicate a large number of soluble salts that may inhibit biological activity or may be unsuitable for land application if large quantities of the material are used (Tibu *et al.*, 2019). Statistically, significant ($P < 0.05$) changes was detected among the means of treatment set ups relative to control set up using two factor Analysis of Variance (ANOVA). Previous studies by Tibu *et al.* (2019) and Anukam *et al*., (2020) reported negative trends in the conductivity values throughout their composting periods and therefore is in agreement with the observation made in this study.

Water is the key ingredient that transports substances within the composting mass and makes the nutrients physically and chemically accessible to the microbes. If the moisture level is below 45 %, the nutrients are no longer in an aqueous medium and not easily available to the microorganisms and hence their microbial activity decreases and the composting process become slow. Below 20 % moisture, very little microbial activity occurs (Pushpa *et al*., 2016). Therefore, an effective composting will need about 50 – 60 % (v/w) moisture content in accordance with the composition of the raw material (Ralstogi *et al*., 2020). In this investigation, Figure 3 represents the changes in moisture content of composted materials during composting period. At the startup, the consortium setup had the highest moisture content value of 91.19 % followed by the magnesium nanocomposite setup with 88.39 %, effective micro-organisms setup with 87.46 % and control setup with 85.29 %. After the eighth week, the control setup had the highest moisture content value of 64.13 % followed by magnesium nanocomposite setup with 62.56 %, the effective micro-organisms set up with 53.40 % and consortium set up with 51.90 %, respectively. The result in Figure 3 revealed that the moisture content of the composting units drastically declined during the 56 days composting process for all samples studied. This remarkable decrease in the moisture contents especially at the end of the composting process is a positive indication of decomposition and an important pointer to mature and stable compost. Also, non - significant ($P > 0.05$) differences was detected among the means of treatment set ups relative to control set up using two factor Analysis of Variance (ANOVA). Previous studies by Aslanzadeh *et al*. (2019) and Anukam *et al*., (2020) reported a continuous and remarkable decrease in moisture contents of their composted materials and corroborated with the observation made in this study.

Table 1: Changes in the physical parameters of composted materials before and after composting period

Compost unit	Initial		Final
		Texture	
Control	Course heterogenous material		homogenous material

Effective microorganisms	Course heterogenous material		Fine homogenous material
Magnesium nanocomposite	Course heterogenous material		Fine homogenous material
Consortium	Course heterogenous material		Fine homogenous material
		Colour	
Control	Brown		Dark brown
Effective microorganisms	Brown		Black
Magnesium nanocomposite	Brown		Black
Consortium	Brown		Black
		Odour	
Control	Foul smell		Slightly foul smell
Effective microorganisms	Foul smell		Earthy smell
Magnesium nanocomposite	Foul smell		Earthy smell
Consortium	Four smell		Earthy smell
		Compactness (Height) (cm)	
Control	19.00		12.00
Effective microorganisms	18.80		7.20
Magnesium nanocomposite	19.20		7.20
Consortium	19.10		5.50
		Mass reduction (kg)	
Control	5.500		4.067
Effective microorganisms	5.500		2.595
Magnesium nanocomposite	5.500		3.318
Consortium	5.500		2.648

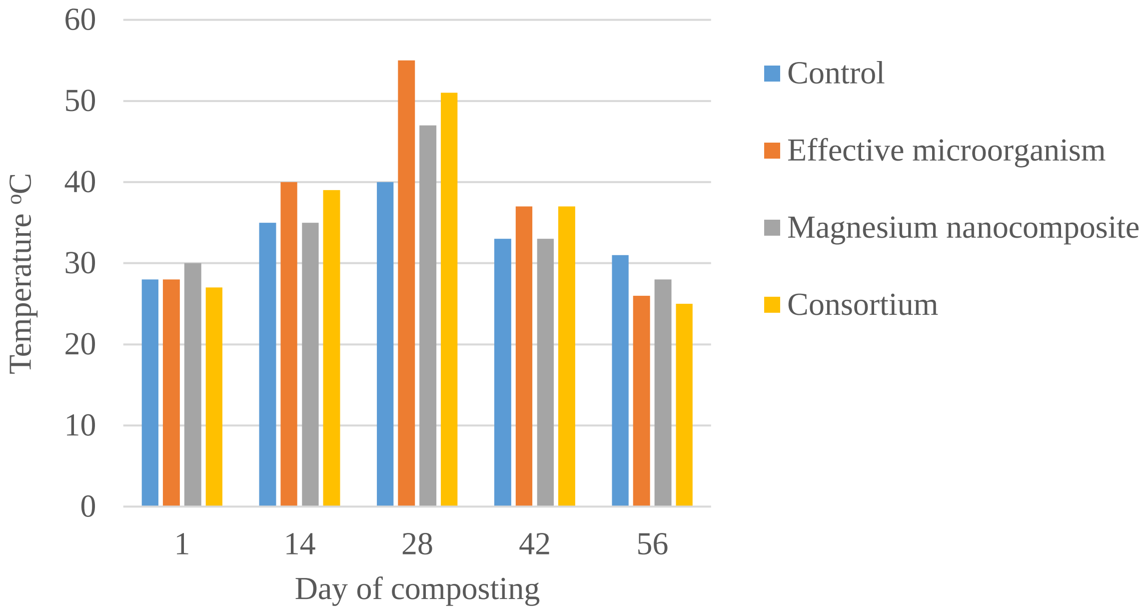

Figure 1: Changes in temperature of composted materials during composting period

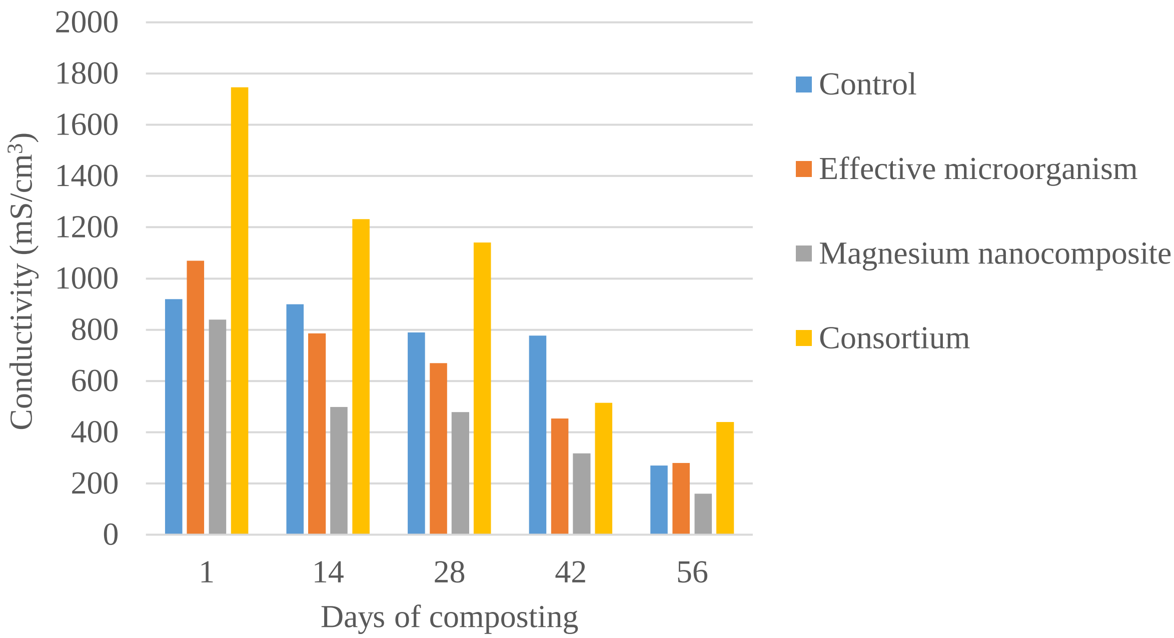

Figure 2: Changes in conductivity of composted materials during composting period

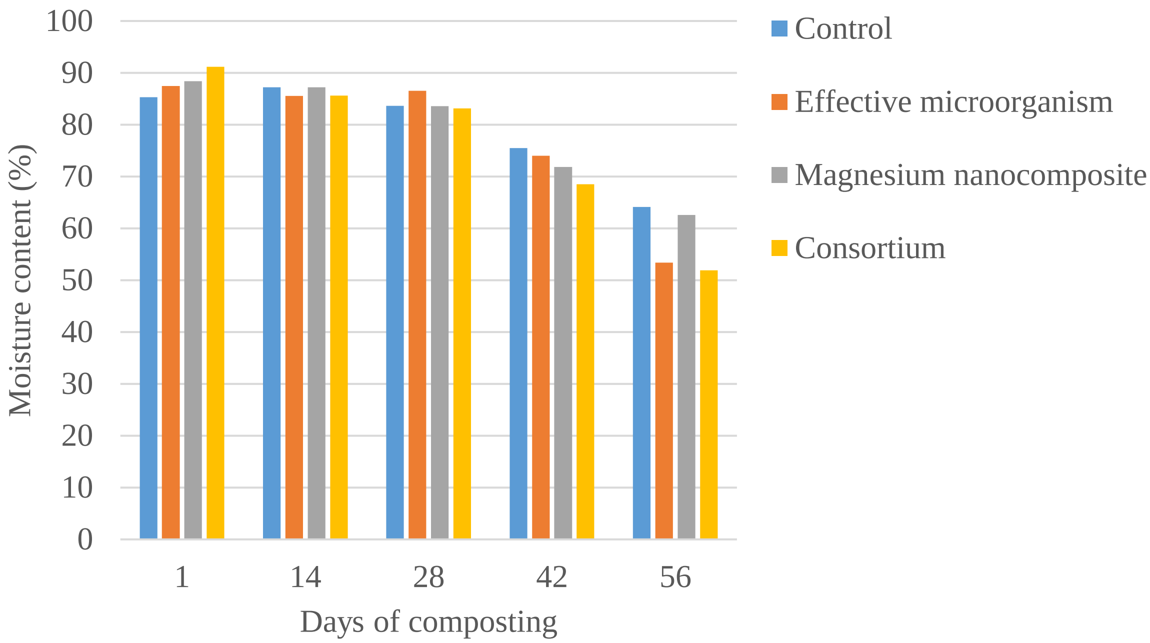

Figure 3: Changes in moisture content of composted materials during composting period

CONCLUSION

The whole study revealed that the organic additives were promising in the decomposition of the composted material. These materials undergo changes in their physical qualities. The facts that conductivity and moisture content decreased the process of composting validate the stability value of our final treated compost products as biofertilizer. Statistical significant differences ($P < 0.05$) were found only in the conductivity among the means of treatment set ups relative to control set up revealing their potentials for agricultural purposes.

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