Original Research Article

Microbial Inoculation Influencing Physical Properties of Composts Produced from Different Agro-wastes

Abstract:

A laboratory experiment was carried out on composting of three organic substrates viz; paddy straw, vegetable waste and maize Stover by using three isolated cellulose degrading bacteria viz; CBG2, CBD4 and CBC9. The physical properties after final products were examined. Irrespective of the strains inoculation the bulk density (BD) of paddy straw was highest (0.82 Mg m^{-3}) followed by maize stover compost (0.74 Mg m^{-3}) and vegetable waste compost (0.73 Mg m^{-3}). Irrespective of the substrates, the PD of the composts, was highest (1.55 Mg m^{-3}) in uninoculated control followed by CBC9 (1.02 Mg m^{-3}), CBD4 (0.97 Mg m^{-3}) and CBG2 (0.91 Mg m^{-3}). The porosity of the compost was highest (39 %) where CBG2 was inoculated followed by CBD4 (36%), CBC9 (35%) and uninoculated control (23%). The highest (42^0) angle of repose was in CBG2 treated compost followed by CBD4 (39^0), CBC9 (36^0), and lowest (34^0) was in uninoculated control. The tab density of compost from control was highest (1.15 Mg m^{-3}) followed by CBC9 (0.63 Mg m^{-3}), CBD4 (0.59 Mg m^{-3}) and lowest was in CBG2 (0.52 Mg m^{-3}). The highest (0.96) Husners ratio (HR) was estimated in the uninoculated- control followed by CBC9 and CBD4 (0.95). The lowest (0.94) HR was in CBG2 inoculated compost.

Key Words: Agro-waste; Angle of repose; Composting; Hausner ratio; Physical properties

Introduction:

The production of required food to feed the burgeoning population of India is a great challenge now a day. The soil is the main factory for producing the required amount of food. The unbalanced and intensive cropping without taking proper care of soil has resulted in degradation of its quality [1]. Maintaining good soil health is required for sustainable crop production. The application of organic fertilizer to the soil is essential for maintaining soil quality [2]. In India around 600 to 700 million tonnes of agricultural wastes are available per annum which are disposed mainly by open dumping, landfilling and incineration [3]. These practices result in greenhouse gas emission and create unhygienic environment [4] In-situ crop residue incorporation is also an important approach for crop residue management [5] While, composting ie: the practice of creating humus like organic materials outside the soil by mixing, piling or otherwise storing organic materials under conditions conducive to aerobic decomposition and nutrient conservation [6] is also an eco-friendly approach to maintain the crop residue [7]. To produce compost from waste, several additives like microbes, sewage sludge and animal waste are used [8].

The quality of compost has great influence on soil properties. Apart from biological and chemical properties the physical properties of compost are important parameters for enhancing quality of soil. Compost production enriched with good quality, ensure improved chemical and physical properties [9], as well as degree of stability and maturity [10]. The beneficial effects of compost on crop production and maintaining soil quality reported in literature [11] are directly related to the physical, chemical and biological properties of the composts [12] by considering above facts an attempts have been made in this experiment to evaluate the physical properties of compost produced from different agro-waste inoculated with isolated cellulose degrading bacteria.

Materials and Methods:

The experiment was conducted in the Soil Microbiology Laboratory of the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar. The substrates were collected from the nearby agricultural field. The substrates were selected as per the availability and production capacity. The fresh substrates were collected and chopped into small pieces. The cellulose degrading bacteria were isolated from different waste dumping yard and moringa hairy caterpillar gut by serial dilution and spread plate method by using Leuria Bertani (LB) medium with 1% Carboxymethyl cellulose. The freshly prepared the growth medium of selected strains were inoculated with the substrates.

The samples of final matured composts were collected after sieving through 4mm sieve. The bulk density [13] and particle density by pycnometer method was estimated. The porosity was calculated by using the formulae (Eqn-1).

$$\text{Porosity (\%)} = 1 - \frac{BD}{PD} \text{X100} \qquad \text{Eqn.} \quad 1$$

Maximum water holding capacity (%) was estimated by keen raczkowski box method by keeping 100g of fresh compost in hot air oven at 70^0c and taking weight after 5 hrs till getting a constant weight. The tab density was measured by taking 100g compost in a 250 ml capacity plastic measuring cylinder hitting on a rigid surface @ 300 times per minute and at the end the volume of compost inside the beaker was measured and expressed in Mg m^{-3} [13]. Angle of repose was measured by piling method as described by [14]. The Hausner ratio (HR) was calculated by taking the ratio of tab density (TB) and bulk density (Eqn-2) [10]**.**

$$HR = \frac{TB}{BD} \qquad \text{Eqn.} \quad 2$$

Statistics: The statistical analysis of data were analysed by using SPSS version 25 software.

Results and Discussion:

Bulk density, particle density and porosity :

The bulk density is an important physical parameter for composts. The bulk density of compost indicates the compactness of the compost which directly reflects on the air space of the compost. The data regarding bulk density of composts has been presented in table 1.

Irrespective of the substrates the bulk density of uninoculated control was the highest (1.2 Mg m^{-3}) followed by CBC9, CBD4 and CBG2 inoculated treatments. The BD of CBC9 and CBD4 were statistically at par (P=0.05). Whereas, uninoculated control and CBG2 were significantly different from other strains inoculation. Irrespective of the strains inoculated the BD of paddy straw compost was highest (0.82 Mg m^{-3}) which was significantly different (P=0.05) from other composts. The BD of the vegetable waste compost (0.73 Mg m^{-3}) and maize stover compost (0.74 Mg m^{-3}) were statistically at par. The BD of paddy straw compost (1.32 Mg m^{-3}) produced without inoculation of any strains was highest among all the composts followed by maize stover compost and vegetable waste compost produced from uninoculated strain (1.15 Mg m^{-3}). Among the compost from CBC9 inoculated strain the highest (0.69 Mg m^{-3}) BD was estimated in the maize stover compost followed by those from paddy straw (0.68 Mg m^{-3}) and vegetable waste (0.63 Mg m^{-3}). A similar trend was observed in CBG2 stain inoculated composts. Among the CBD4 inoculated composts the highest BD (0.66 Mg m^{-3}) was estimated in paddy straw compost followed by those from vegetable waste (0.61 Mg m^{-3}) and maize stover (0.60 Mg m^{-3}). According to the Fertilizer Control Order, India, all the composts produced by the inoculation of isolated strains could be utilized for agricultural purpose [15]. Therefore, only uninoculated composts were unable to meet the standard of FCO, India. The microbial inoculation increases the degradation of organic matter so the bulk density was reduced. Therefore, we can assume that the bulk density of composts depends on the substrate type and efficiency of the microbe inoculation. The microbe inoculation influences the overall properties including physical properties of compost [16]. According to [17] the bulk density of final composts produced from green wastes was around 0.4 Mg m^{-3}. The bulk density of initial substrates was also reported to influence the quality of the cucumber stalk compost [18] The BD reflects the looseness and porosity of the final product [19]. The particle density (PD) of composts produced from different agro-wastes inoculated with cellulose degrading bacterial strains has been presented in table 1. The PD of the composts, irrespective of the substrates was highest (1.55 Mg m^{-3}) in uninoculated control followed by those inoculated by CBC9 (1.02 Mg m^{-3}), CBD4 (0.97 Mg m^{-3}) and CBG2 (0.91 Mg m^{-3}). The PD of compost from control treatment was significantly different (P=0.05) than other composts. The composts of CBD4 and CBG2 inoculated treatment were statistically at par (P=0.05). Similarly, the PD of CBC9 and CBD4 treated compost were at par whereas CBC9 and CBG2 treatments were significantly different. Irrespective of the strains inoculation, the PD of the paddy straw compost was the highest (1.17 Mg m^{-3}), followed by that of maize stover compost (1.09 Mg m^{-3}), and vegetable waste compost (1.08 Mg m^{-3}). The PD of the composts of different substrates are statistically nonsignificant (P=0.05). The highest PD (1.67 Mg m^{-3}) was estimated in the compost where paddy straw was composted without any strains followed by vegetable waste and maize stover. In CBC9 inoculated compost, the highest PD was estimated in maize stover (1.04 Mg m^{-3}), followed by paddy straw (1.03 Mg m^{-3}) and vegetable waste (0.98 Mg m^{-3}). In CBD4 inoculated strains the highest PD was estimated in paddy straw (1.01 Mg m^{-3}), followed by vegetable waste (0.96 Mg m^{-3}) and maize stover (0.95 Mg m^{-3}). Likewise, in CBG2 the PD was highest in paddy straw (0.97 Mg m^{-3}), followed by maize stover (0.89 Mg m^{-3}) and vegetable waste (0.87 Mg m^{-3}). The variation in particle density of the compost depends on the nature and quality of compost substrate [20]. The PD also depends on the ash and volatile solid content during composting of organic substances [21]. Similarly, Van Ginkel et al [21] and Mohee & Mudhoo [22], reported the variation of PD among the composts. The porosity of the composts was calculated and presented in table 1. Irrespective of the substrates, the porosity of the compost was the highest (39 %) where CBG2 was inoculated followed by CBD4 (36%), CBC9 (35%) and uninoculated control (23%). The porosity of the CBG2 inoculated compost was statistically at par (P=0.05) with CBD4 treatment and significantly different from CBC9 and uninoculated control treatment. Whereas, the porosity of compost from CBC9 treatment was statistically at par with CBD4 treated compost. Among all the composts, the highest porosity (41%) was estimated in case of vegetable wastes inoculated with CBG2 strain and the lowest (21%) was calculated in uninoculated paddy straw compost. Irrespective of the stain inoculation the porosity of maize stover compost was highest (34%) and vegetable waste compost (34%). The lowest (32%) was calculated in paddy straw compost. The porosity of composts from different substrate was statistically nonsignificant. The porosity of the compost from depends on both the BD and PD. The total and air-filled porosity directly affect the availability of water and oxygen (O_2) and are determining factors for the biological activity of the microorganisms involved in the composting process [23].

Table 1: Influence of different cellulose degrading bacteria on bulk density, particle density (Mg m^{-3}) and porosity (%) of composts produced from different agro-wastes.

Bulk Density (Mg m^{-3})					
Substrates	Control*	CBC9	CBD4	CBG2	Mean
Rice straw	1.32	0.68	0.66	0.62	0.82
Vegetable waste	1.15	0.63	0.61	0.52	0.73
Maize stock	1.15	0.69	0.60	0.54	0.74
Mean	1.20	0.67	0.62	0.56	
LSD (P=0.05): Strain-0.047; Substrate-0.041; Strain x Substrate-0.082					CV (%):7
Particle Density (Mg m^{-3})					
Rice straw	1.67	1.03	1.01	0.97	1.17
Vegetable waste	1.50	0.98	0.96	0.87	1.08
Maize stock	1.50	1.04	0.95	0.89	1.09
Mean	1.55	1.02	0.97	0.91	
LSD (P=0.05): Strain-0.098; Substrate-0.085; Strain x Substrate-0.169					CV (%):9
Porosity (%)					
Rice straw	21	34	35	36	32
Vegetable waste	23	36	37	41	34
Maize stock	23	34	37	40	34
Mean	23	35	36	39	
LSD (P=0.05): Strain-3.29; Substrate-2.85; Strain x Substrate-5.71					CV (%):6

*Control: No strains

Maximum water holding capacity

The data related to maximum water holding capacity (WHC) of compost from different treatments have been presented in table 2. The highest WHC was estimated in the vegetable waste compost inoculated with CBC9 (50 %) and CBG2 (50 %) followed by maize stover compost inoculated with CBG2 (49%), paddy straw compost with CBC9 (47%), Maize stover compost with CBD4 (43%) and the lowest was estimated in paddy straw with CBD4 (25 %). Irrespective of the substrates, the highest WHC was in case of CBG2 (43 %) and CBC9 (43%) followed by CBD4 (34 %) and the lowest (32%) was in uninoculated control. The WHC of CBC9 and CBG2 inoculated composts were at par (P=0.05) with each other and significantly different from CBD4 inoculated compost and uninoculated control. Irrespective of the strains, WHC of the vegetable waste compost was the highest (42%) followed by maize stover compost (38%) and paddy straw compost (35%). The WHC of vegetable waste compost was significantly higher than maize stover compost and paddy straw compost. The WHC of maize stover compost and paddy straw compost were statistically at par. Among CBC9 inoculated treatment the highest WHC (50%) was estimated in compost from vegetable waste followed by that from paddy straw (47 %) and maize stover (31%). In CBD4 inoculated compost the highest WHC (43%) was estimated in maize stover compost followed by vegetable wastes compost (35%) and paddy straw compost (25%). In CBG2 inoculated compost, the highest (50%) was estimated in vegetable wastes compost followed by that from maize stover compost (49%) and paddy straw compost (31%). Irrespective of the substrates the CBD4 (79%) stain inoculated compost had highest water holding capacity followed by CBC9 (76%), CBG2 (74%) and lowest was in uninoculated control (46%). The WHC is an essential parameter which influences the physico-chemical and biological properties of [20]. The moisture content of compost depends up on its WHC which could influence the quality but nonsignificant [24].

Table 2: Influence of different cellulose degrading bacteria on maximum water holding capacity (%) and moisture content (%) of composts produced from different agro-wastes

WHC (%)					
Substrates	**Control***	**CBC9**	**CBD4**	**CBG2**	**Mean**
Rice straw	49	77	75	71	**68**
Vegetable waste	48	81	83	79	**73**
Maize stock	40	70	78	73	**65**
Mean	**46**	**76**	**79**	**74**	
LSD (P=0.05): Strain-6.70; Substrate-4.21; Strain x Substrate-8.42					CV (%):9

*Control: No strains

Angle of Repose, tab density and HR:

The angle of repose of the composts has been presented in table 3. The angle of repose was the highest in the paddy straw compost inoculated with CBG2 strain (43^0) followed by that of vegetable wastes compost (41^0) inoculated with CBG2 strain and maize stover (41^0) inoculated with CBD4 strain. The lowest (30^0) was in vegetable wastes compost without any strain inoculation (control). Irrespective of the substrate types, the highest angle of repose (42^0) was in CBG2 treated compost followed by CBD4 (39^0), CBC9 (36^0), and lowest was in uninoculated control (34^0). The angle of repose of CBG2 compost was statistically at par with CBD4 compost but significantly different from other isolated strains and control. Compost from CBD4 inoculated treatment was significantly different from control but statistically at par with CBC9 and CBG2 treated compost. The highest angle of repose (40^0) was measured in paddy straw compost followed by maize stovor compost (38^0) and vegetable waste compost (35^0). The results of the angle of repose indicate that by reducing the particle size, the coefficient of internal friction increases and the angle of repose increases [25].

The data related to tab density has been presented in table 3. Irrespective of the substrates type, the tab density of compost from control was highest (1.29 Mg m^{-3}) followed by that from CBC9 (0.74 Mg m^{-3}), CBD4 (0.69 Mg m^{-3}) and lowest was in CBG2 (0.62 Mg m^{-3}) treated compost. The tab density of compost from control was significantly different from the compost from inoculated treatments. The tab density of compost from CBC9 inoculated treatment was at par with CBD4 treated compost and significantly different from control and CBG2 inoculated compost. The tab density of the CBG2 treated compost was significantly different from other isolated strains inoculation and control. Irrespective of the isolated strains inoculation, the highest tab density (0.88 Mg m^{-3}) was estimated in paddy straw compost followed by maize stover compost (0.82 Mg m^{-3}) and lowest was in vegetable waste compost (0.80 Mg m^{-3}). The tab density of each substrate was statistically at par. Tab density depends upon the interaction effect of moisture and particle size. The volume of particles increases due to increasing moisture content and with multiple strikes, even with the displacement of particles; the distances between them are more than that of low moisture content [13].

The Hausner ratio (HR) of the composts produced from different agro-wastes inoculated with isolated cellulose degrading bacteria has been presented in table 3. Among the strains inoculated composts the highest HR (1.13) was estimated in the CBG2 inoculated compost followed by CBC9 (1.12) and CBD4 (1.11) and the lowest HR (1.08) was in un-inoculated compost. The HR of CBC9, CBG2 and CBD4 inoculated compost were statistically at par whereas it was significantly different from control. Irrespective of the isolated strains inoculation, the HR of the vegetable waste was highest (1.13) which was statistically at par with maize stover (1.12) and significantly different from paddy straw (1.08). The Hausner ration decreases with decrease in tab density. The mass particles that are a set of fine and coarse particles have lower Hausner ratio due to lower tab density which indicates high compressibility and low flowability [13]. Hausner ratio decreases by increasing the particle size which indicates an increase in flowability rate with increasing particle size.

Table 3: Influence of different cellulose degrading bacteria on Angle of Repose (^{0}) tab density (Mg m^{-3}) and HR of composts produced from different agro-wastes

Angle of Repose					
Substrates	**Control***	**CBC9**	**CBD4**	**CBG2**	**Mean**
Rice straw	37	39	41	43	40
Vegetable waste	30	34	36	41	35
Maize stock	34	35	40	41	38
Mean	34	36	39	42	
LSD (P=0.05): Strain-4.61; Substrate-4.00; Strain x Substrate-8.00					CV (%):8
Tab density (Mg m^{-3})					
Rice straw	1.43	0.72	0.71	0.67	0.88
Vegetable waste	1.22	0.71	0.67	0.61	0.80
Maize stock	1.23	0.78	0.69	0.59	0.82
Mean	1.29	0.74	0.69	0.62	
LSD (P=0.05): Strain-0.11; Substrate-0.09; Strain x Substrate-0.19					CV (%):6
HR					
Rice straw	1.09	1.05	1.08	1.09	1.08
Vegetable waste	1.07	1.16	1.10	1.19	1.13
Maize stock	1.08	1.14	1.16	1.11	1.12
Mean	1.08	1.12	1.11	1.13	
LSD (P=0.05): Strain-0.03; Substrate-0.04; Strain x Substrate-0.13					CV (%):9

*Control: No strains

Conclusion:

Inoculation of cellulose degrading bacteria to agricultural wastes resulted in the production of high-quality compost in terms of physical properties like bulk density, particle density, porosity, maximum water holding capacity, angle of repose, tab density and Hausner ratio. Among the strains the CBG2 strain was found more efficient stains for composting than CBC9 and CBD4. Among the substrate, the vegetable waste compost was most desirable compost for crop production. The inoculation of CBG2 with vegetable waste was found to be the best compost among all the tested combinations.

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