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To study the physical and engineering properties of vermicompost

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Abstract
Vermicomposting is an emerging sector in developing country and also help in the promotion toward of the organic farming. Vermicomposting is one of the best options available at present for the treatment of organic wastes. Vermicomposting refers to natural bioconversion of biodegradable garbage into high quality manure with the help of earthworms, this methodology is sustainable agriculture production and income of farmers significantly. When design and developed of prototype machine (churning and sieving), it is necessary to study the physical and engineering properties of organic fertilizer (vermicompost) to know their manner such as, moisture content, bulk density, dry matter content, porosity, angle of repose and coefficient of friction and clods size of vermicompost were determined. Data collected of four replications with 6 different depths of heap (Treatments) in one factor FRBD design were analyzed using online Opstate statistical software. Results showed that treatment as a depth of vermicompost heap was significantly higher ($p < 0.05$) of significance. Analyzed data of physical and engineering were observed at different depth of heap *viz*., The moisture content of 13.75, 19.54, 25.47, 29.01, 34.22 and 38.48% db., bulk density of 646, 658, 683, 690, 711 and 724 kg m^{-3}, true density of 1215, 1176, 1083, 981, 867 and 834 kg m-3, dry matter content of 86.25, 80.48, 74.55, 71.00, 65.80 and 61.53%, porosity of 47.34, 44.02, 36.93, 29.64, 18.03 and 13.25%, angle of repose of 30, 32, 35, 37, 38 and 40 °, coefficient of friction of 0.41, 0.42, 0.47, 0.48, 0.53 and clods size of vermicompost of 0.58, 0-50 mm, 50-60 mm, 60-80 mm, 80-100 mm, and 100-160 mm, respectively. The study is important to design and developed a different component of breaking and sieving machine for organic fertilizer (Vermicompost). Results are likely to be useful in assessing the quality of vermicompost used to all agricultural farming sector.

Keywords: Depth of heap, moisture content, bulk density, true density, porosity, dry matter content, angle of repose, coefficient of friction and size of clods etc.

Introduction
Organic fertilizer (vermicompost) is a foreign material-free compost with good eco-friendly and chemical free organic compost (Erdal *et al.* (2020)) [6]. Having multipurpose uses as agriculture sector like gardening, horticultural and vegetable crops (Junaif *et al.* (2016) [9], it covers area under organic agriculture around 72.2 thousand ha of world and in India 2.2 thousand ha (FAO. (2021) [7]. Hence, during 20-21, 24.27 lakh MT in Chhattisgarh as against 429.4 lakhs MT in India, vermi compost was produced (Anon, 2021). Organic fertilizers such as vermicompost are largely produced on-farm by the farmers and the doses of vermicompost application depend upon the type of crop grown in the field/nursery - Field crops 5-6 t/ha, fruit crops 3-5kg/plant, pots 100-200g/pot. (Anon, ICAR Research Complex). Vermicompost application helps in adding of plant nutrients (macro and micro) and growth regulators (Rekha, *et al.* (2018) [15]. It helps in plant growth also by increasing soil water retention, microbial population, nutrient content and soil physical properties such as soil structure, porosity and density (Maan, 2022) [12]. The vermicompost passes through various operations *viz*. harvesting, churning, sieving, handling, conveying, and storage (Bordoloi *et al.* (2017) [4]. Efficient unit operations are possible through optimizing the design of concerned equipment, machineries or structures. These design features are functions of properties of vermicompost, which are moisture dependent. The clods size and density are important while developing the machineries for churning and sieving. Zaki *et al.* (2017) [17]. Emphasised on physical properties of vermicompost. While crushing force, moisture content and coefficient of friction are needed for design of churning unit; angle of repose, porosity, bulk density and true density are required for designing of feeding, collection tray and churning cylinder. Besides, equipment's for mass flow and storage structures use the angle of repose data.

The friction coefficient between vermicompost and surfaces is helpful for separation on rotary sieve, movement on surface on collection tray, loading and unloading. The physical properties are also important for developing churning and sieving machine for testing of machineries. Acknowledged the importance of physical properties for storage and processing operations. The irregular shapes and composition for most of the biological materials further signifies the utility of these characteristics. Therefore, the objective of the current research was work was to study the physical properties of vermicompost produced in Chhattisgarh and establish their relationship with different depth of vermi heap.

Materials and methods

The past reviews of vermicompost have been worked by many researchers and their study indicate that such type physical and engineering properties influence the vermicompost sieving and churning machine operation which were such as moisture content, bulk density, true density, porosity, dry matter content, angle of repose, coefficient of friction and clods size were determination. The dairy barns were scraped twice a day. Cow dung and agricultural wastes was dumped into the trench daily after remove heat from the dumped materials spreads worms onto the trench surface. The vermicompost becomes ready for use in about three to four months. Samples of vermicompost were not treated for sieving and breaking etc. prior to testing. Samples were collected at different depths of heap 0-90 cm and measured all physical and engineering properties.

Moisture content

Moisture content of vermicompost was determined by oven drying method. The different depth of heap of vermicompost sample was weighed with crucible and placed in the oven at 105°C for 24 hours. After taking out from the oven, the samples were cooled in a desiccator and weighed.

The samples were again kept in the oven, heated for 2 hours cooled and weight was recorded. This procedure was repeated till a constant weight of the sample was attained. The average moisture content on dry basis of these samples was calculated using the following equation 1 (Sahay and Singh, 2001) [16].

$$M_c = \frac{W_2 - W_3}{W_3 - W_1} \times 100 \qquad (1)$$

Where,
M_c= Moisture content,% db;
M_1= Weight of crucible, g;
M_2= Weight of crucible + wet sample, g; and
M_3= Weight of crucible + oven dried sample, g.

Bulk density

Bulk density affects handling of vermicompost in the machine. The bulk density of a vermicompost like tea powder is the ratio of the mass of an untapped powder sample and its volume including inter particulate void volume. The bulk density is expressed in kilogram per cubic metre. A 500 ml empty cylinder is weighed and measure the volume of the cylinder. Carefully scrape the excess powder from the top of the cylinder. The cylinder and the sample are then weighed. Repeat this procedure for 3-5 replications. The bulk density is found out by measuring the weight of the sample by volume of the cylinder. The bulk density of the sample is calculated from the following equation 2 (Landry *et al*., 2004) [11].

$$\rho_b = \frac{W_2 - W_1}{V} \qquad (2)$$

Where,
ρ_b = Bulk Density, kg m^{-3};
W1 = the weight of the cylinder, g;
W2 = the weight of the cylinder and sample, g; and
V = the volume of the cylinder, cm^3.

$$V = \frac{\pi}{4} \times d^2 \times h$$

Where,
d = diameter of cylinder, cm;
h = height of cylinder, cm.

True density

The true density defined as the ratio of mass of the vermicompost sample to its true volume, was determined using the toluene displacement method. Toluene was used in place of water because it is absorbed by vermicompost sample to a lesser extent 30 ml of toluene were placed in a 100 ml graduated measuring cylinder and 10 g vermicompost sample were immersed in the toluene (Mohsenin, 1986 and Bhise *et al*., 2014) [13, 3]. The amount of displaced toluene was recorded from the graduated scale of the cylinder. The ratio of weight of vermicompost sample to the volume of displaced toluene gave the true density by using equation 3 to calculate the true density

$$\rho_t = \frac{M}{V} \qquad (3)$$

Where
ρ_t = true density, kg m^{-3};
M = mass of the vermicompost sample, kg; and
V = volume of vermicompost including void space, m^3.

Porosity

The porosity of the vermicompost is a measurement of the void space in the material and a fraction of the volume of voids over the total volume. The porosity depends on the true density and bulk density. Porosity of vermicompost sample were calculated from the bulk density and true density values that were found earlier by using the following formula was given in equation 4 (Mohsenin, 1986) [13]:

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \qquad (4)$$

Where
ε = Porosity,%;
ρ_b = Bulk density, kg m^{-3}; and
ρ_t = True density, kg m^{-3}.

Dry mater content

Dry matter of vermicompost refers to material remaining after removal of water. Vermicompost gradually becomes non-Newtonian with increasing total solids content. It was expressed using the formula given by Reddy and Dronachari, (2014) [14]. Choudhary (2015) [5] also used this method to determine dry matter content of vermicompost

$$DM_c = 100 - M_c \qquad (5)$$

Where
DM_c = Dry matter content,%;
M_c = Moisture content,% db.

Angle of repose

The angle of repose is the angle between the base and the slope of the cone formed on a free vertical fall of the mixture to a horizontal plane. It is the ability of the product to flow and each product has its own angle of repose. The size, shape, moisture content and orientation of the particles influence the angle of repose. Angle of repose was found out using the equation 6 (Sahay and Singh, 2001) [16]

$$\Phi = \tan^{-1}\left(\frac{2H}{D}\right) \quad (6)$$

Where,
Φ = angle of repose in degree;
H = height of the cone, cm; and
D = diameter of the plate, cm.

Coefficient of friction

Coefficient of friction of vermicompost was determined with respect to mild steel surfaces. It is the ratio of the frictional force between two surfaces to the force forcing them together. The component for measuring coefficient of friction made up of a bottomless open component with a horizontal surface.

$$\mu = \tan \alpha \quad (7)$$

Where,
μ = Coefficient of friction;
α = Tilt angle of vermicompost, degree.

Clod size of vermicompost

The digital vernier calliper instrument used to determine the clod size of vermicompost and through it measured the different size of collected clod samples. It was categorised as maximum, medium and minimum size in mm. In the range of clod <160-80 mm, 80-50 mm and >50 mm respectively, collected sample of vermicompost clod was measured by used vernier calliper and measuring tap, respectively.

Results and Discussion

Physical properties of vermicompost

Physical properties were studied of vermicompost at different depth of heap *viz*., 0-90 cm and after physical and engineering properties were determined. The detail observation is shown in Table 01.

Table 1: Mean table of physical properties of vermicompost at different depth of vermicompost heap.

Depth of heap, cm	Moisture content, % (db)	Bulk density, kg/m³	True density, kg/m³	Porosity, %	Dry matter Content,%	Angle of repose, degree	Coefficient of friction
0-15	13.75	646	1,215	47.34	86.25	30	0.41
15-30	19.54	658	1,176	44.02	80.48	32	0.42
30-45	25.47	683	1,083	36.93	74.55	35	0.45
45-60	29.01	690	981	29.64	71.00	37	0.48
60-75	34.22	711	867	18.03	65.80	38	0.53
75-90	38.48	724	834	13.25	61.53	40	0.58
Factors							
C.D.	2.214	1.37	13.57	1.76	2.10	1.22	0.028
SEm±	0.728	0.45	4.46	0.57	0.69	0.40	0.009
SE(d)	1.029	0.637	3.31	0.81	0.97	0.57	0.013
C.V.	5.442	0.131	0.85	3.64	1.84	2.27	3.893

Moisture content

The moisture content of vermicompost was found 13.75 to 38.48 per cent dry basis (db) at 0 to 90 cm depth of vermicompost (Fig.1). From the mean Table-01 shown that 38.48 per cent (db) was high moisture content at 75-90 cm depth of heap and minimum was 13.75 per cent (db) at 0-15 cm depth of heap respectively. coefficient of variation of moisture content 5.442, coefficient of determination 2.214 and standard error 0.728 was obtained

It was noticed from the Fig. 1 that the moisture content of vermicompost was higher at bottom depth of heap. The similar results were reported by Zaki *et al.* (2017) [17].

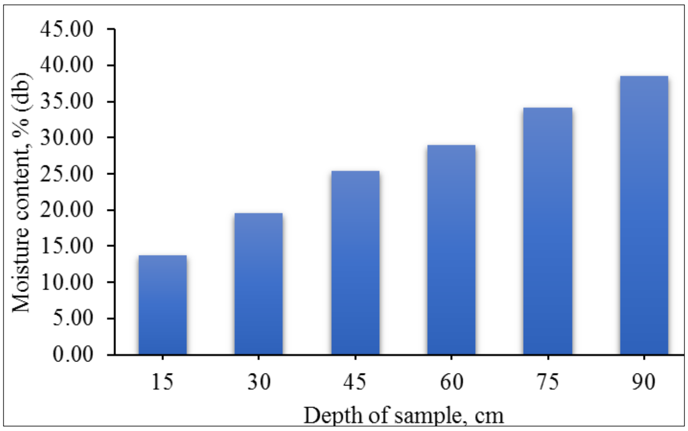

Fig 1: Moisture content at dry basis of vermicompost at different depth of vermi heap

Bulk density

The information about bulk density is required in determination of the weight of vermicompost in the feeding hopper. The bulk density of vermicompost is also suitable in the design of churning unit. Bulk density at different depth of heap is presented in Fig.2. It was measured by using a cylindrical container having 500 ml volume.

It was shown from the mean Table 01 that, the bulk density was 646, 658, 683, 690, 711 and 724 kg m^{-3} at different depth in the range of 0 to 90 cm of heap. The maximum bulk density was found 724 kg m^{-3} at 75-90 cm depth of heap and minimum were found 646 kg m^{-3} at 0-15 cm depth of heap.

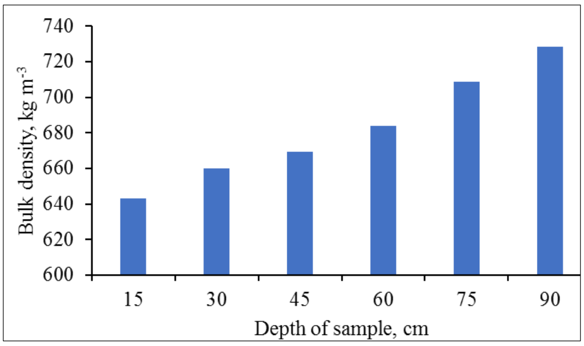

Fig 2: Bulk density of vermicompost at different depth of vermi hea

Bulk density was found variance with respect to the depth of heap. The bulk density increased with increasing depth of vermicompost. The bulk density was inversely proportional to the dry matter content (DMC) i.e., bulk density was increased with decreasing the dry matter content as shown in Fig. 4.4. The less bulk density was observed in top surface of the vermi heap. This may be due to the fact that presence of air was higher at top surface of vermi heap. The similar results were reported by Reddy and Dronachari (2014) [17], Zaki *et al.* (2017) [17].

True density

True density of vermicompost at different depth of vermi heap is presented in Fig.3. This information is more useful in the design of machines like cleaning and sieving and also relatively useful in calculation product yield and output in processing machinery. It was measured by using a cylindrical container having 500 ml volume. The mean Table is presented in Table 1 respectively. The true density was found as 1215, 1176, 1083, 981, 867 and 834 kg m^{-3} at different depth in range of 0 to 90 cm of heap. Similar result was observed by Landry *et al.* (2004) [11] and Reddy and Dronachari (2014) [14].

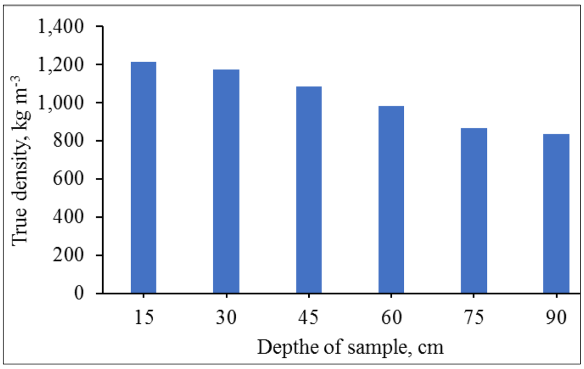

Fig 3: True density of vermicompost at different depth of vermi heap

Porosity

Porosity of vermicompost at different depth of vermi heap is presented in Fig.4. Information about on porosity are needed in the design of aeration systems during storage and the quantity of vermicompost that will enter a feeding hopper of churning unit. It was obtained from the mean table that the porosity of vermicompost 47.34, 44.02, 36.93, 29.64, 18.03 and 13.25 per cent at the depth of heap in range of 0-15 cm to 75-90 cm respectively, the same result was agreement through Sing and Singh (2005). Obtained porosity was varies with respect to depth of vermi heap. From the Fig. 4 show the porosity was decreased with increasing the depth of vermicompost heap. The less porosity was observed in top surface of the vermi heap. This may be due to the fact that presence of air and void ratio is higher on top surface of vermi heap. It was also observed that the reduction of porosity with an increase in depth of the heap. The obtained values of porosity from the result are dependent on the bulk density and true density.

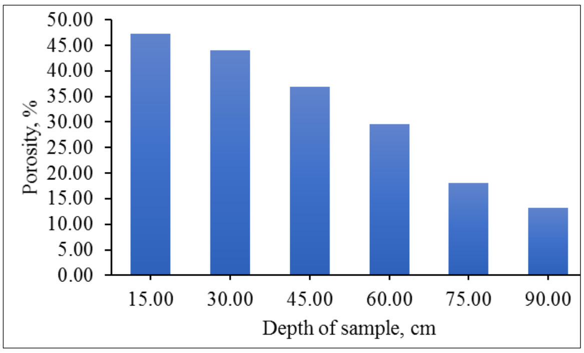

Fig 4: Porosity of vermicompost at different depth of vermi heap

Dry matter content

The dry matter content of vermicompost was calculated in the laboratory test. It was found from the mean table that the dry matter content measured for vermicompost was 86.25, 80.48, 74.55, 71.00, 65.80 and 61.53 per cent at different depth range from 0 to 90 cm of heap as shown in Fig.5.

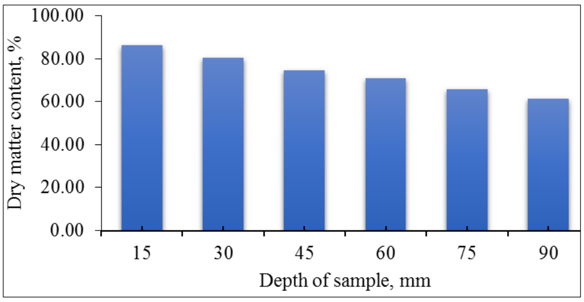

Fig 5: Dry matter content of vermicompost at different depth of vermi heap

Dry matter content was linearly related with bulk density at decreasing dry matter content of vermicompost. Same result also found by Zaki *et al.* (2017) [17] and Landry *et al.* (2004) [11].

Angle of repose

The effect of different depth of heap on the angle of repose are shown in Fig. 6. The obtained result data on angle of repose may be used to design size of conveyor belt for transporting agricultural materials and also useful for design of hopper, the angle of repose of vermicompost was measured. Vermicompost was poured on circular plate of 5.5 cm diameter. The height and base radius of cone formed after pouring vermicompost was measured. It was found from the mean table, angle of repose in the range of 30° to 40° at different depths of heap in range of 0 to 90 cm as shown in Fig.6.

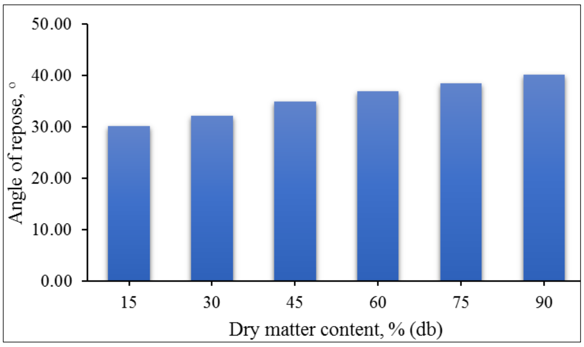

Fig 6: Angle of repose vermicompost at different depth of vermi heap

The average minimum angle of repose 30° was observed in the depth of 0-15 cm while average maximum angle of repose 40° was observed in the depth of 75-90 cm of heap. Similar results were also agreement by Ilori *et al.* (2016) [8].

Coefficient of friction

. It was found from the mean table that the coefficient of friction was 0.41, 0.42, 0.47, 0.48, 0.53 and 0.58 with different depth of vermicompost heap in the range of 0 to 90 cm as given in Table 01. These data show that coefficient of friction increased at increasing depth of heap and decreasing at decreasing the depth of heap. Similar observation was agreement by Zaki *et al.* (2017) [17], Ilori *et al.* (2016) [8] and Reddy and Dronachari (2014) [14].

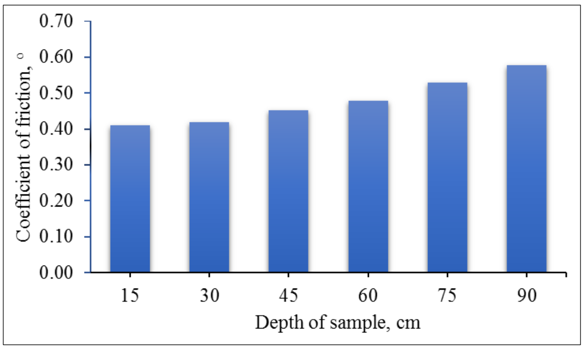

Fig 7: Coefficient of friction of vermicompost at different depth of vermi heap

The data was observed that the coefficient of friction is more useful in the design of hopper and in choosing appropriate materials for different units of machinery particularly the components needful flow of the vermicompost. The design of container for loading and unloading through handling such as feeding hopper is dependent on the information of the friction properties.

Clod size of vermicompost

The digital vernier calliper instrument used to determine the clod size of vermicompost and it was found different size of clod presented in the Fig.4.15. It was categorised as large, medium and lower size in mm. The resulted range of clod size was in the range of 160-80 mm as large, 80-50 mm as medium and >50 mm as lower obtained respectively.

Conclusion

Based on laboratory experiment results that were statistically analysed to figure out the physical and engineering properties of vermicompost, the size of vermicompost clods had an impact on the design of the churning blade assembly and the rotary sieve size opener. The design volume of the churning drum, rotary sieve, and churning blade, particularly in the design of the churning unit, is also influenced by the moisture content, bulk density, and porosity of vermicompost. The dry matter content of vermicompost reduced quickly as the vermicompost's moisture level rises. The designs of feeding hopper and collection tray flow properties of vermicompost are influenced by the angle of repose and coefficient of friction. All these parameters could be presented as linear equations of regression with depth of heap as independent variable.

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