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Study on physical and frictional properties of farmyard manure (FYM) to develop mechanized application and handling unit of FYM

Manisha Sahu, Victor VM, Ajay Verma and Sunil Agrawal

Abstract
Organic farming is adopted in recent days by the farmers. The farmyard manure is the major alternatives for organic farming with higher plant nutrients. However application of farmyard manure is not easy due to their variable physical and frictional properties. Therefore, it is need of today to study the physical and frictional properties of farmyard manure to design the FYM application and handling machine. A study was carried out to determine the physical and frictional characteristics of farmyard manure at laboratory of SVCAET&RS, FAE, IGKV, Raipur. The physical and frictional properties of FYM were determined at different depth of manure pit viz. 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm. The average moisture content, bulk density, dry matter content, angle of repose and angle of friction of FYM at different depth of manure pit were 28.97 per cent db, 421.21 kg/m^3, 71.03 per cent, 35˚ and 34˚, respectively.

Keywords: Bulk density, dry matter content, farmyard manure, frictional characteristics

Introduction

Recycling the animal residue is importance to increase the social acceptance of livestock production. As per agronomical requirements and precise land application of farmyard manure, equipments are subjected to higher performance expectations. Farmyard manure is alternative to minimize the environmental pollution that may be due to inorganic fertilizers. Chemical fertilizers are creating agricultural pollutant. Equipments designed to handle and land application of manure do exhibit large coefficients of variation for distribution [4, 20] and [22]. Appropriate knowledge of the physical properties of the FYM to be handled is fundamental to the design and operation of efficient systems. Past reviews are available on manure chemical properties. Fewer research targeted on physical properties of FYM. Bulk density of all manure products was found to increase with total solid [12]. Results of a series of laboratory experiments performed three types of sand [9]. Angle of repose and friction angle was then correlated. They concluded that the angle of repose can be correlated to the internal friction of the sand and for correlate these two an empirical expression was presented and enabled to users to estimate the friction angle of the sand in the field. Average values of the angle of wall friction (AWF) or angle of repose of poultry litter on the friction surfaces were in the range of 25 to 39 degree [21]. Increasing the moisture content and particle size the AWF was decreased. Bulk density of FYM at different moisture content viz. 20.5, 27.2 and 36.4% db was found 292, 510 and 680 kg/m^3, respectively. The angle of repose was 32 º, 37º and 42º. The angle of friction with MS sheet was 33°, 37° and 42º with increasing moisture content respectively and the angle of friction with GI sheet was 33°, 36° and 44º [21]. Effect of manure properties on the performance of various mechanisms was studied by few researchers. Spreader distribution patterns for poultry litter was studied and observed the effect of particle size on spreading distances [22]. They concluded that large particles were distributed more evenly and on a larger width when compared to smaller particles that landed closer to the spreader. Their gravity flow metering system was not appropriate for FYM application due to the presence of clumps blocking the flow of material from the hopper [23]. Their design of an applicator application of manure with solid wastes, identified maximum lump size and moisture content as the physical properties presenting potential problems in manure conveying [7]. Physical properties of poultry manure and compost were measured and investigated the trends of manure physical properties related with moisture content to design and development of spreader and their handling purpose [8]. They were concluded that wet

bulk density was dependent on moisture content. Static friction had variable for different products. These factors were creating design problems to develop manure handling applicator. An air pycnometer was used to measure the air volume and density of compost. The free air space (FAS) and bulk density of manure compost, municipal solid waste compost, and mixtures of biosolids and amendment materials were measured at various moisture contents and compressive loads. Results indicated that the FAS decreased with loading and increasing moisture content while the wet bulk density increased with loading and increasing moisture content. A linear relationship was established between FAS and bulk density for all the materials tested under loads [1].
The literature review clearly demonstrates the variability that exists in physical properties of FYM and the lack of widely accepted and used methods to measure those physical properties. More data are required to highlight general trends and to develop design guidelines for manure handling and land application equipment.

Objective
The objective of the work reported herein was to measure selected physical and frictional properties of farmyard manure at different levels of total solids concentration.

Materials and Methods
Reviews of past work indicate that such type properties influence the farmyard manure application on the field which were moisture content, bulk density, dry matter content, angle of repose, angle of friction, mean mass diameter. Farmyard manure was collect from the facilities on the IGKV University. The dairy barns were scraped twice a day. Cow dung was dumped into the trench daily. The manure becomes ready for use in about four to five months [10]. Samples of FYM were not treated for separation, screening etc. prior to testing. Samples were collected at different depths of manure pit 0-90 cm. The dry matter content was measured with all physical properties.

Fig 1: View of FYM for study

Dry matter content of FYM
The dry matter content (solid matter content) of the FYM represents the proportion on a mass basis of the dissolved and suspended materials in the FYM. Manure gradually becomes non-Newtonian with increasing total solids content [11]. It is expressed using the following formula.

$$b_d = \frac{W_t}{L \times (\frac{\pi d^2}{4})} \quad (3)$$

where, DM_c= Dry matter content,%, M_c= Moisture content (db),%

Moisture Content
Moisture content of FYM was determined by oven drying method. The FYM sample is weigh with crucible and placed in the oven at 55°C for 24 hours [16]. Moisture content was calculated by using the following relationship.

$$M_c = \frac{W_2 - W_3}{W_3 - W_1} \times 100 \quad (2)$$

where, M_c= Moisture content,%, W_1= Weight of crucible, g, W_2= Weight of crucible + wet sample, g.

Bulk density
Bulk density affects handling of manure in the machine. Bulk density influences the volume requirement of manure box and moisture content. The bulk density was found out by measuring the volume of given weight of the sample. The manure samples were collected by using core cutter method at different depths in storage pits. It was calculated by dividing mass of manure (kg) to the volume of cylinder (m^3). Bulk density of sample was determined by placing the sample of FYM in a cylinder container which has 18 cm of diameter and 31.4 cm of length [14]. This method was used for find out bulk density of FYM [6, 13]. The sample placed in the cylinder is then weighed by using electronic balance with least count of 1g. Bulk density was calculated by using the following relationship.

$$b_d = \frac{W_t}{L \times (\frac{\pi d^2}{4})} \quad (3)$$

Where, b_d = Bulk density, kg/m^3, W_t = Weight of sample, kg,
L = Length of cylinder, m; and
d = Diameter of cylinder, m.

Mean Mass Diameter (MMD)
A modified soil sieves shaker and a screen set were used to determine the particle size distribution of FYM samples [3, 17]. Collected sample of FYM was weighed and pass through a different set of sieves. Aperture size of sieves was range 60, 50, 40, 30 and 20 mm. The samples were placed on the top screen and shaken for 90 seconds as shown in Fig.2. FYM retained on each screen was weighed on a laboratory scale. Amount of material retained on the 5 screens and in the pan was used to calculate the mean mass diameter. The following expression was used to calculate Mean Mass Diameter (MMD):

$$MMD = \left(\sum_I M(I) \times (D(I-1) + \frac{D(I)}{2}\right) / \sum_I M(I) \quad (4)$$

$$= \frac{\left[\frac{\{M(1) \times D(0) + D(1)\}}{2} + \frac{\{M(2) \times D(1) + D(2)\}}{2} + \cdots \ldots\right]}{M(1)} + M(1)$$

$$= M(2) + \cdots \ldots \ldots$$

where, M (I) = mass of the FYM retained on I'th sieve from top, kg, D (I) = size of I'th sieve, mm, D (0) = size (second major dimension) of the largest clod on top sieve, mm

Fig 2: Sieve analysis of FYM

Angle of repose

Angle of repose is a term used to describe the maximum angle, measured upwards from the horizontal, at which a pile of a particular material will remain stable without any of the material sliding downward. It is useful in designing storage and transportation machinery for granular materials as it can give an engineer insight into the appropriate size and shape of such devices. It was calculated by pouring the FYM on a plate of 45 cm diameter from height of 50 cm, the material get settled in conical form. After the material get settled the height of the cone was measured. This method was used for find out angle of repose of FYM [6, 13] and seeds [15]. Finally the angle of repose was measured by using following relationship.

$$A = \tan^{-1}\frac{H}{R} \quad (5)$$

where, A = Angle of repose, °, H = Height of cone, cm, R = Radius of base of cone, cm.

Angle of friction

The value of the angle of friction of FYM was measured using the inclined plane method [15]. Angle of friction was measured with MS sheet. FYM filled in a rectangular frame was placed on a MS sheet placed on flat surface. The coefficient of friction of frame material and MS sheet was negligible. One end of the MS sheet was tilted until the frame containing material just tends to slide. This method was used for find out angle of friction of FYM [6, 13] and seeds [15]. The angle formed by the sheet with horizontal is called angle of friction of FYM and calculated by following relationship.

$$B = \sqrt{L^2 - H^2} \quad (6)$$

$$F = \tan^{-1}\left(\frac{H}{B}\right) \quad (7)$$

where, B = Base width of triangle formed, cm, L = Length of MS sheet, cm, H = Vertical height of free end of MS sheet from ground, cm and F = Angle of friction, °;

Results and Discussion

Physical properties of FYM

Physical properties were studied of farmyard manure at different depth of manure pit. Moisture content varies at different depths of manure pit viz., 0-90 cm and measured their physical properties.

Table 1: Physical properties of Farm Yard Manure at different depth of manure pit

Depth of samples (cm)	Moisture content, db (%) $\frac{W_1 - W_2}{W_2 - W_3} \times 100$	Dry matter content, %	Bulk density (kg/m^3)	Angle of repose, $\tan^{-1}(\frac{H}{R})$	Angle of friction, $\tan^{-1}(\frac{H}{B})$	MMD, mm
0-15	23.55	76.45	346.25	29.00	30.00	22.00
15-30	24.63	75.37	380.00	32.00	32.00	28.00
30-45	26.81	73.19	403.75	36.00	34.00	30.00
45-60	29.73	70.27	433.75	37.00	35.00	35.00
60-75	33.65	66.35	461.25	38.00	36.00	44.00
75-90	35.42	64.58	496.25	39.00	37.00	35.00
MEAN	28.97	71.03	421.21	35.00	34.00	37.00
STDEV	4.83	4.83	54.79	3.50	3.00	7.50

Dry matter content

Dry matter content measured for FYM was 76.45, 76.37, 74.19, 70.27, 66.45 and 64.68 percent at different depth 0 to 90 cm of manure pit. Dry matter content was linearly related with bulk density at decreasing dry matter content of FYM. Moisture content was inversely proportional to the dry matter content of FYM as shown in Fig.3. The standard deviation of dry matter content was small i.e. ±4.84, which indicated that the most of the dry matter content values are very close to the mean value as shown in Table 1. Predictive equations (1) for the dry matter content of different depth of manure pit were obtained by polynomial regression analysis, using third order models as shown in Fig.4. The regression analysis revealed that all parameters of the third order polynomials were statistically significant. The relationship for dry matter content and depth of sample was obtained and presented in

eq.1. Average dry matter content of FYM samples was found to be 71.03.

$$\text{Dry matter content} = 4E - 06x^4 - 0.007x^2 + 0.201x + 74.94, R^2 = 0.997 \ (1)$$

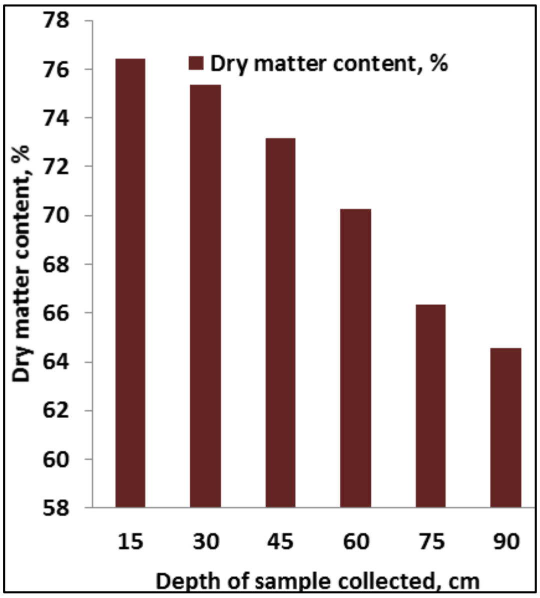

Fig 3: Dry matter content of FYM at different depth of manure pit

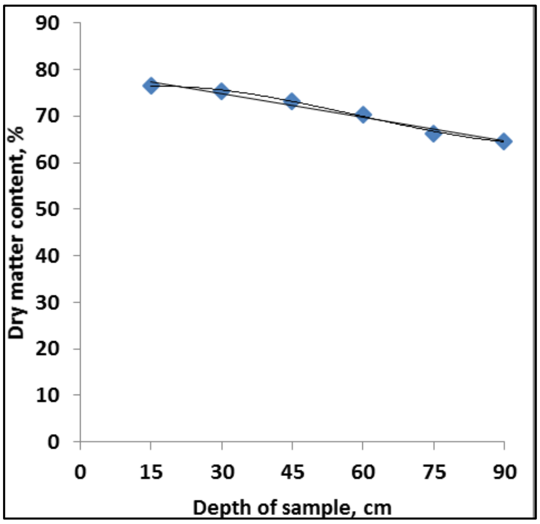

Fig 4: Dry matter content of FYM manure as a function of depth of manure pit

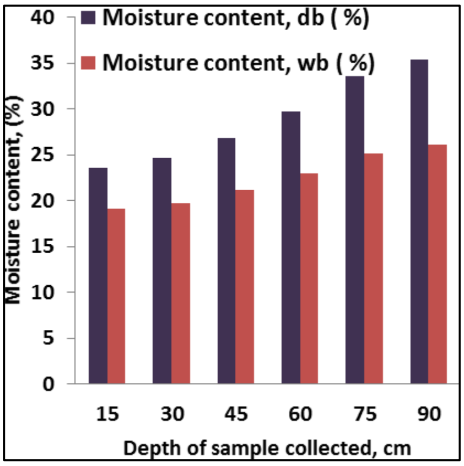

Fig 5: Moisture content at dry and wet basis of FYM at different depth of manure pit

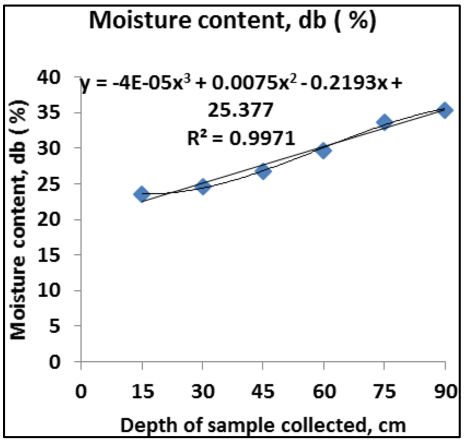

Fig 6: Moisture content, percent db of FYM manure as a function of depth of manure pit

Moisture content

Oven drying method was used for determining moisture content. The moisture content of FYM was 23.55, 24.63, 26.81, 29.73, 33.65 and 35.42 percent db at, 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm depths of farmyard manure, respectively are presented in Fig.5. The moisture content of FYM was more at bottom depths of compost pit. The moisture content was inversely proportional to the dry matter content i.e. moisture content was increased with decreasing the dry matter content. Depth of sample and moisture content were linearly related as shown in Fig.6. Data presented in Table 1 shows that standard deviation of moisture content was 4.83. This value indicates that moisture content at different depth were close to the mean value. The following equations were obtained by polynomial regression analysis, using third order models. The regression analysis revealed that all parameters of the third order polynomials were statistically significant. The relationship between moisture content and depth of sample of FYM was obtained and presented in eq.2.

$$\text{Moisture content, percent db} = -4E - 06x^4 + 0.007x^2 + 24.48, R^2 = 0.997 \quad (2)$$

Five sets of observation were taken to determine the moisture content. The average moisture content of FYM was found to be 28.97 percent on dry basis.

Bulk density

Bulk density of FYM at different depths of manure pit is presented in Fig.7. The bulk density is important parameters to design farm implements and other machines. It was measured by using a cylindrical container having diameter 18 cm and height of 31.4 cm. The bulk density of FYM was determinate as 346.25, 380.00, 403.75, 433.75, 461.25 and 496.25 kg/m^3 at moisture content of 23.55, 24.63, 26.81, 29.73, 33.65 and 35.42 percent db, respectively at different depths (0 to 90 cm) of manure pit. Obtained bulk density was variable with respect to depth of manure pit. Bulk density was increased with increasing the depth of manure pit. The bulk density was inversely proportional to the dry matter (DM) content i.e. bulk density was increased with decreasing the dry matter content as shown in Fig.8. The less bulk density was observed in top layer of the manure pit. This may be due to the fact that presence of air is higher on top surface of manure pit. Obtained bulk density was linearly related with dry matter content of farmyard manure as shown in Fig.8. Therefore it can also be concluded that the bulk density was linear relationship to the moisture content. Wet bulk density was dependent on moisture content for all the solid products [8]. Therefore moisture content was more important as compare to the source of manure. Following equations were obtained by polynomial regression analysis, using third order models and forcing the density at zero percent dry matter (DM) to be 1000 (the density is in kg/m^3). The regression analysis revealed that all parameters of the third order polynomials were statistically significant. A result of an analysis to found bulk density of manure with its dry matter content was similar [5]. The relationship between bulk density and dry matter content was obtained and presented in eq.3.

$$\text{Bulk density} = -0.449x^2 + 48.26x - 622.6, R^2 = 0.980 \quad (3)$$

Bulk density of FYM was calculated as 420.21 kg/m^3.

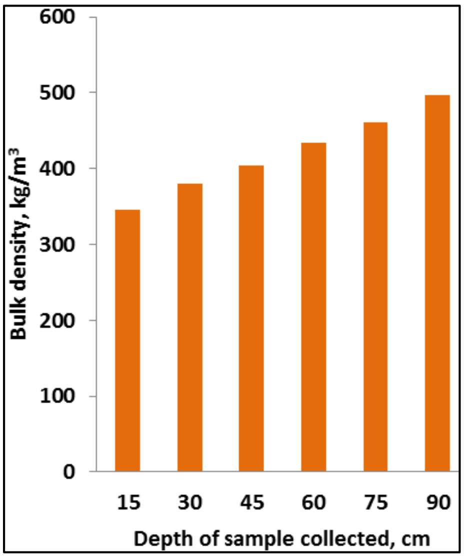

Fig 7: Bulk density of FYM at different depth of manure pit

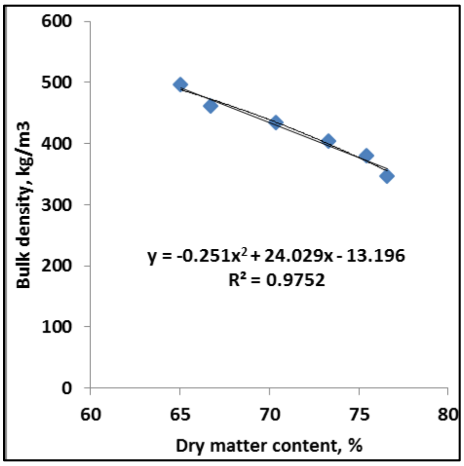

Fig 8: Bulk density of FYM as a function of dry matter content

Sieve analysis

The data collected on mean mass diameters (MMD) of FYM during laboratory test are presented in Table 1. It was noticed from the results that clump size increased with decreasing dry matter content. This result obtained because aggregation ability was increased with increase in moisture content of manure. The clump size will affect the conveying behavior of FYM during actual operation. The mean mass diameter was inversely proportional to the dry matter content. Predictive eq.4 for the mean mass diameters of different depth of manure pit was obtained by the graph shown in Fig. 10. The relationship for mean mass diameter and dry matter content was obtained and presented in eq.4.

Mean mass diameter

$$= -0.148x^4 + 29.64x^2 - 2114x + 60244, R^2 = 0.966 \quad (4)$$

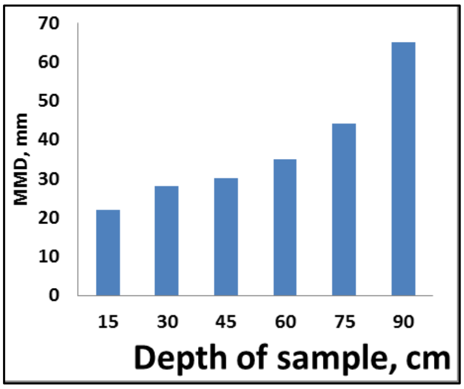

Fig 9: Mean mass diameter of FYM at different depth of manure pit

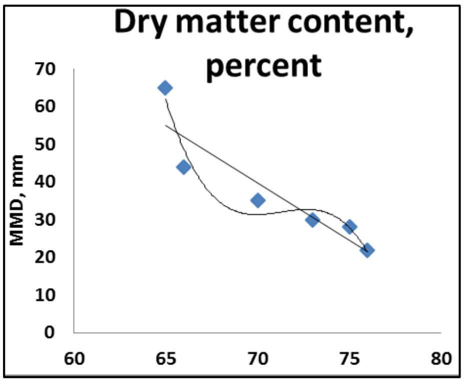

Fig 10: Mean mass diameter of FYM as a function of dry matter content

Angle of repose

FYM was poured on circular plate of 45 cm dia. The height and base radius of cone formed after pouring FYM was measured. Angle of repose of FYM was 29.4°, 32.4°, 35.5°, 36.7°, 37.9° and 38.5° at different depths of manure pit 0-90 cm as shown in Fig.11. Average angle of repose was found 35.1°. It was revealed from Fig.12 that the angle of repose was increased with decreasing the dry matter content. The relationship for angle of repose and depth of sample was obtained and presented in eq.5.

$$\text{Angle of repose} = 4E-06x^4 - 0.007x^2 + 0.201x + 74.94, R^2 = 0.997 \quad (5)$$

Significant difference was obtained for overall average angle of repose at different depth of manure pit. Standard deviation was ±3.5, which is closely related to mean value. Predictive eq.5 for the angle of repose of different depth of manure pit was obtained by the graph shown in Fig. 12. The relationship for angle of repose and dry matter content was

$$\text{Angle of repose} = -0.016x^4 + 4.604x^2 - 242.9x + 6662, R^2 = 0.996 \quad (6)$$

Average value of angle of repose of FYM was found 35.10°.

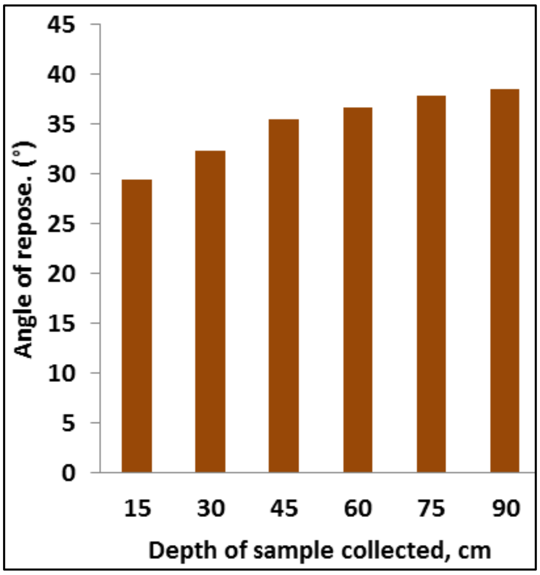

Fig 11: Angle of repose of FYM at different depth of manure pit

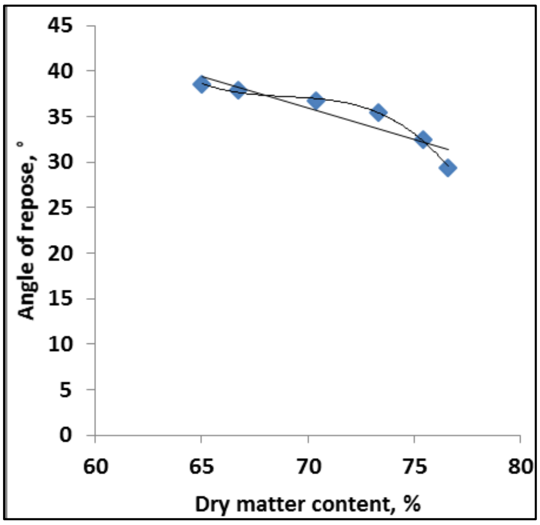

Fig 12: Angle of repose of FYM as a function of dry matter content

Angle of friction

Angle of friction was 30, 32, 34, 35, 36 and 37° with dry matter content from 76.45 per cent db to 64.58 per cent db. These data shows that angle of friction increased with decreasing dry matter content

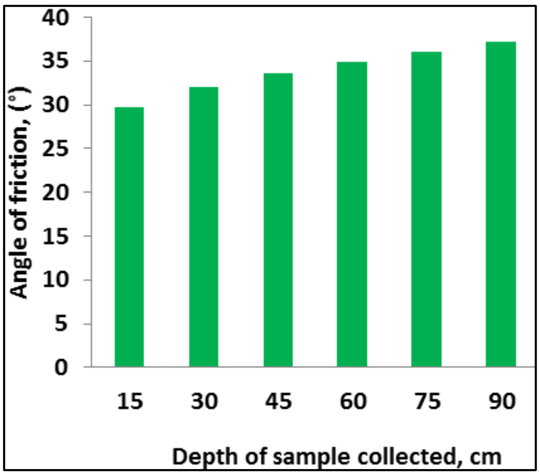

Fig 13: Angle of friction of FYM at different depth of manure pit

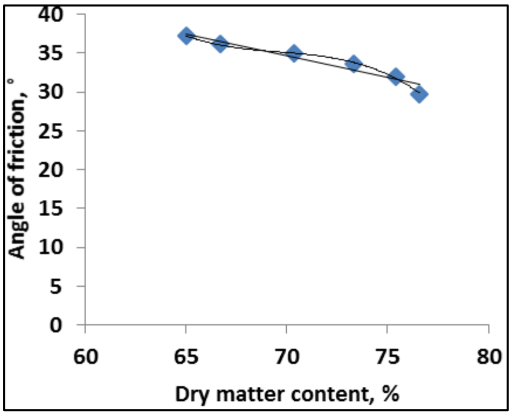

Fig 14: Angle of friction of FYM as a function of dry matter content

Average angle of friction was significantly difference at different depth of manure pit as given in Table 1. Standard deviation was ±3 for angle of friction. Therefore these values indicate that the angle of friction at different depth was closely related to the mean value. Predictive eq.7 for the angle of friction of different depth of manure pit was obtained by the graph shown in Fig.14 by polynomial regression analysis, using third order models. Results revealed that angle of friction were make linear trend with dry matter content of FYM. Regression analysis shows that all parameters of the third order polynomials were statistically significant.

$$\text{Angle of friction} = -0.014x^4 + 2.797x^2 - 196.0x + 4570, R^2 = 0.992 \quad (7)$$

Average angle of friction of FYM was found 34.00°.

Conclusions

Physical properties of farmyard manure were measured over a wide range of dry matter content. Based on the results obtained, the major findings are noted as the density of farmyard manure was in agreement with other published results. Predictive equations based on dry matter content were obtained. A method was proposed to calculate a modified value of the mean mass diameter obtained by screening. Significantly larger mean mass diameters were observed as the dry matter content of the farmyard manure decreased. Therefore it is concluded that dry matter content and bulk density influences the design volume of manure box and agitator mechanism for farmyard manure applicators. To control the flow characteristics to design of farmyard manure applicator there are angle of repose and angle of friction is measured.

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