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Preparation of Pellets by Urban Waste Compost

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ABSTRACT: Determination of physical properties of municipal waste compost is necessary to obtain the parameters related to designing and constructing a suitable pelleting machine for producing compost pellets. The purpose of this study is determining some physical properties such as; bulk density, coefficient of friction, porosity, angle of repose for compost and density and expansion for compost pellets. These parameters are determined at three moisture content level (15, 20 and 25 %), four particle sizes (normal size, 10, 30 and 100) and three pressure level (23.4, 36 and 47.7 MPa) with three replications. According to the table of analysis of variance (ANOVA), effect of mesh size on angle of repose using emptying method was significant, but for filling method was not (P=0.01). The effect of mesh size on friction coefficient using four surfaces, was significant (P=0.01). It was determined that the effect of particle size, moisture content and pressure on density of pellets was significant (P=0.01). Also using compost with low porosity, particle size at 100, moisture content at 25% and pressure at 47.7 MPa will results producing best pellets.

Key word: Density, Porosity, Friction, Repose, Expansion

INTRODUCTION

The compost and vermicompost quality is the most essential criterion in recycling organic waste, as well as its marketing and utilization in agriculture as organic amendments (Campitelli *et al.*, 2008). More than 50% of the waste generated by the Brazilian population is composed of matter susceptible to organic composting (Barreira *et al.*, 2008). The importance of this problem increases with the increment of population. Therefore several processes can be done on waste, such as burning, burying, recycling converting to usable materials such as compost and etc. In production processes, converting the municipal waste to compost is very important, because useful materials like compost can be produced from rubbish that has wide use in agricultural and horticultural activities. Compost means the herbaceous, bestial and municipal waste that decay, their toxic materials refine, materials powder and lose their original shapes. Compost maturity is related to suitability for plant growth, although some authors also relate it to humification (Tognetti *et al.*, 2006). For economic use of compost, it can be used for producing pellets. Some of the benefits of compost pellets are:

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1- Reducing the conservation space because of densification.
2- Suitable for mechanization and compatible with farmer's implements for implanting or scattering.
3- Suitable for residential places because of producing no dust and no pollution for environment.
4- More precision with spreaders and reducing manure consumption.
5- Suitable for transporting to long distances.
6- Suitable for planters and no needing to separate operation.
7- Ability of long time conservation.
8- Ability of adding chemical materials for increasing the quality of pellets.

Since last years, several studies performed on physical properties of various biological materials. Most of these studies evaluate the effect of moisture content, porosity, angle of repose, coefficient of friction, density and etc on several agricultural products. One of the important results that can be obtained is the effect of moisture content. Increasing the moisture content, increases bulk density, angle of repose, and coefficient of friction for woodchip (Ima *et al.*, 2007), compressibility in poultry litter (Bernhart *et al.*, 2008), the filling and emptying angles of repose for cocoa beans (Bart-Plange *et al.*, 2002), coefficient of static friction for Pistachio kernel (Kashaninejad *et al.*, 2005), true density for peanut fruit and kernel (Aydin, 2006) and density and angle of repose for caper fruit (Sessiz *et al.*, 2006), but decreases the true density and porosity for Pistachio kernel (Kashaninejad *et al.*, 2005), Densities in poultry litter (Bernhart *et al.*, 2008), porosity for woodchip (Ima *et al.*, 2007), bulk density for peanut fruit peanut fruit (Aydin, 2006), true density, porosity and the coefficients of static and kinetic friction for caper fruit (Sessiz *et al.*, 2006). Particle size and moisture content significantly affected the pellet density of barley straw, corn stover and switchgrass but different particle sizes of wheat straw did not produce any significant difference on pellet density (Mani *et al.*, 2006). Bulk density and particle density of peanut hull pellets significantly affected by moisture content (Fasina, 2007). Fraczek valuated a computer image analysis method to determine the angle of repose of grains (Fraczek *et al.*, 2006). Also some physical properties such as bulk density, moisture content, free airspace and etc, evaluated for feedstock compost (Mohee *et al.*, 2005) and groundnut kernels (Olajide *et al.*, 2002).

The objects of this study is to determine bulk density, angle of repose, friction angle and porosity of compost and expansion of pellets in order to obtain best conditions for designing and constructing a suitable pelleting machine.

MATERIALS & METHODS

Compost used in this study was obtained from composting factory located at Kahrizak of Tehran. The particle sizes used in this study were investigated in normal size and three mesh sizes (10, 30 and 100) and the percent for each mesh size obtained (Shaw *et al.*, 2007). Normal size is the compost without using meshes. The dimension properties of each mesh sizes are shown in Table 1.

Table 1 Dimensions of mesh sizes according to ASTM E-11-70 (Part 41)

Mesh size	10	30	10	100
Diameter (mm)	2	0.6	0.425	0.15

Moisture is a key environmental factor that affects many aspects of the composting process (Richard *et al.*, 2002). The moisture content of compost used in this study was 15% that obtained from placing the compost samples in oven at 105±3ºC for 48 hours (ASAE Standards. 1998. S269.4). The moisture content was calculated using the following equation:

$$MC = \frac{W_1 - W_2}{W_1} \quad (1)$$

MC = Moisture content in percent (db)
W_1= Primary weight of sample in grams
W_2= Secondary weight of sample in grams

Porosity is the ratio of pore space to the total volume of sample. Kaptso determined the porosity of the seeds as the fraction of the space in the bulk seed which is not occupied by the grain can be computed from the values of seed true density and bulk density (Kaptso *et al.*, 2007). Porosity can be calculated from dry matter content, true density of dry matter and total bulk density (Van Ginkel, 1999). Porosity is also one of the most important physical properties that characterize the quality of dried, crispy foods (Hofsetz *et al.*, 2007). A method similar to 5 gallon pail method used to determine the porosity of compost. Level of water in a container, containing two liters of water, was marked inside of it. After emptying the water, the container filled with compost about one-third full. The pail was dropped 10 times from a height of 15 cm on the floor. Compost was added to fill the pail two-thirds full and the pail was dropped 10 times from a height of 15 cm on the floor. Compost was added to the full line mark, which was previously made on the container, and the container was dropped again 10 times from a height of 15 cm on the floor. Compost was finally added to fill the container to the full line mark. Water was added to the pail to the full line mark. The volume of water added was recorded.

$$P = \frac{V_1}{2} \times 100 \quad (2)$$

P= Porosity of sample in percent.
V_1= Volume of water added in liter.

Bulk density refers to the mass in volume unit. In this method a 20 liter container was fully filled with the test material and the mass of the material was recorded. Bulk density was calculated by dividing the mass of the material by the volume of the material (Equation (3)) (Asoewgu *et al.*, 2006; Pechon *et al.*, 2007). Three replications were completed and the average value was recorded.

$$\rho = \frac{M}{V_2} \quad (3)$$

ρ = bulk density in $\frac{kg}{m^3}$

M= Mass of sample in kg,

V_2= Volume of container in m^3.

Angle of repose is the maximum angle from horizon that the sample would place on without any sliding or rolling. In this study the angle of repose determined using two methods, filling and emptying. A cylinder with approximately 15 centimeters diameter filled with compost and used in filling method, then the cylinder placed on a surface and moved upward slightly until the cone of compost formed. The angle of repose can be determined by using equation (4):

$$\theta_f = \tan^{-1}\left[\frac{h}{100}\right] \qquad (4)$$

θ_f = Angle of repose in degree

h= height of cone in centimeters

In emptying method the cylinder hanged from 30 centimeters height and its bottom covered with a metal sheet and filled with compost. To form the compost cone in this method the metal sheet pulled quickly. With the equation (4) the angle of repose can be determined. A digital camera used in this method to calculate the angle of repose from each photograph of compost cone (Fraczek, 2007). After forming the compost cone, a digital camera placed on a surface justified with horizontal face of triangle made by cross sectional of compost cone. After the photography, two accurate lines traced on diagonal faces of triangle and the third line traced on horizontal face of triangle. The angle between the horizontal line and two other lines can be determined easily by smart dimension toolbox in Auto CAD software (Fig. 1). White calculated the angle of repose from measurements of horizontal and vertical scale readings (White *et al.*, 2001).

Fig. 1. Tracing lines on diagonal faces of compost triangle

Coefficient of friction is the ratio of friction force to normal force. A sliding apparatus used to measure the coefficient of friction (Fig. 2).

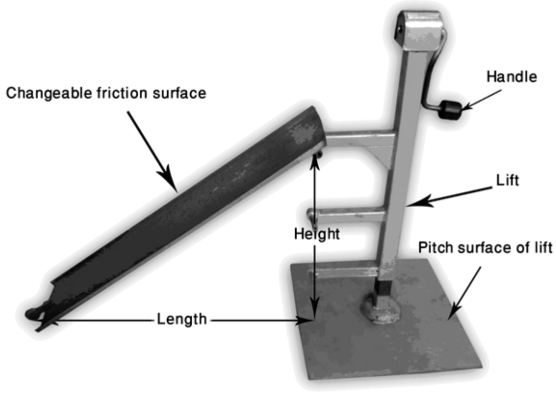

Fig. 2. Apparatus used to measure the coefficient of friction

The friction surfaces used in this study were iron, aluminum, Teflon and plywood. For performing the test a metal square frame with 10×10 centimeters cross section and five centimeters height, while its top and bottom faces was open, used and filled with compost. For preventing friction between frame and friction surfaces, frame moved about five millimeters upward. The slope of sliding can be increased by spinning the handle on apparatus. At the position that frames with compost started to move, the tangent of angle made by height and length, showed in fig. 2. can be determined by:

$$\mu = \tan\theta \qquad (5)$$

Density of compost can be determined by compacting in order to exhaust the air in pore spaces. A hydraulic press apparatus (Fig. 3) used for compacting compost into dies. This experiment performed at four particle size (Normal size, 10, 30 and 100), three moisture content levels (15, 20 and 25 percent) and three pressure level (23.4, 36 and 47.7 MPa) with three replications.

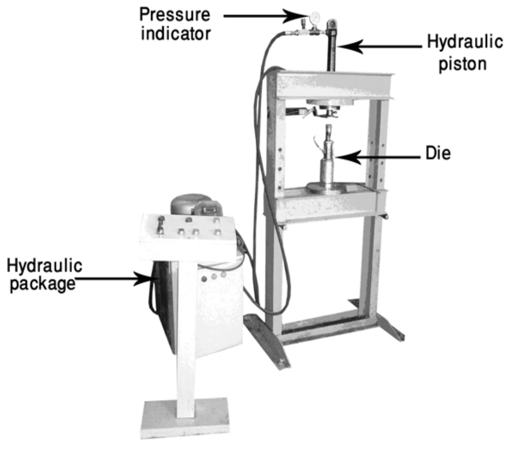

Fig. 3. Apparatus used to produce pellets

Die used for this study had internal diameter of 15 millimeters. Equation (6) used to determine density of compost pellets using diameter and length of pellets that calculated using a digital caliper with 0.001 millimeters accuracy. Sample pellets were weighted by a digital balance with 0.01 gram accuracy. Data analyzed and diagrams depicted.

$$V_p = \frac{\pi}{4} d^2 L \quad (6)$$

$$\rho_t = \frac{m_p}{V_p} \quad (7)$$

To determine the expansion of pellets, samples were placed in a refrigerator at 5±1 °C for two weeks. After two weeks the pellets were weighted and their dimensions were calculated.

$$E = \frac{\rho_1 - \rho_2}{\rho_1} \% \quad (8)$$

RESULTS & DISCUSSION

Results from particle size analysis are shown in fig.4 . It was determined that the most percent of particle size belongs to mesh size of 30 and the least percent belongs to mesh size of 100. Table 2. shows the average bulk density and porosity of compost. Results from analysis of angle of repose, which are shown in Fig.5 and Table.3 shows that with decrease in particle size in filling and emptying methods the angle of repose will decrease. Data obtained for coefficient of friction and Analysis of data are shown in fig. 6 and Table 4.

Table 2. Results of Porosity and bulk density

	Bulk density	Porosity
Unit	kg/m^3	
Compost	940	39

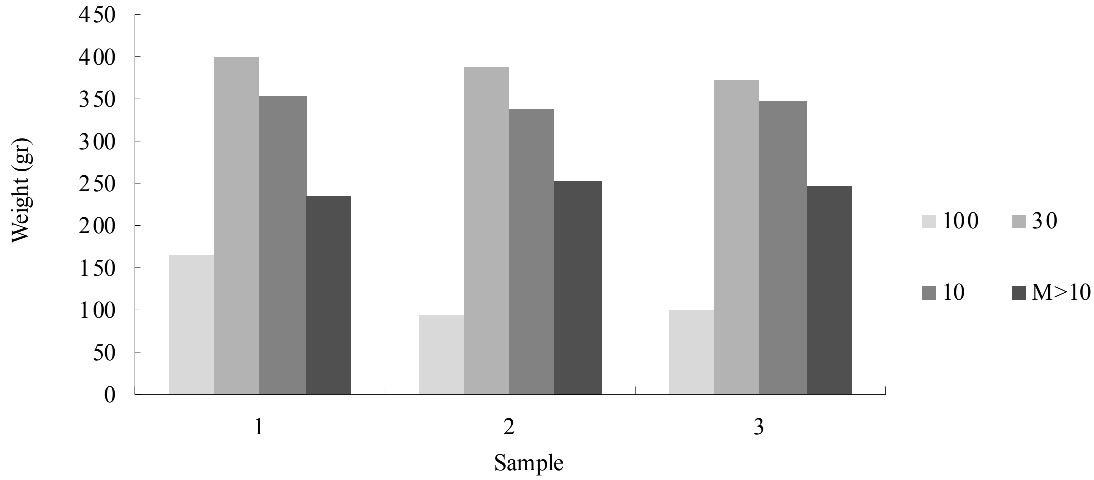

Fig. 4. Results of particle size for compost

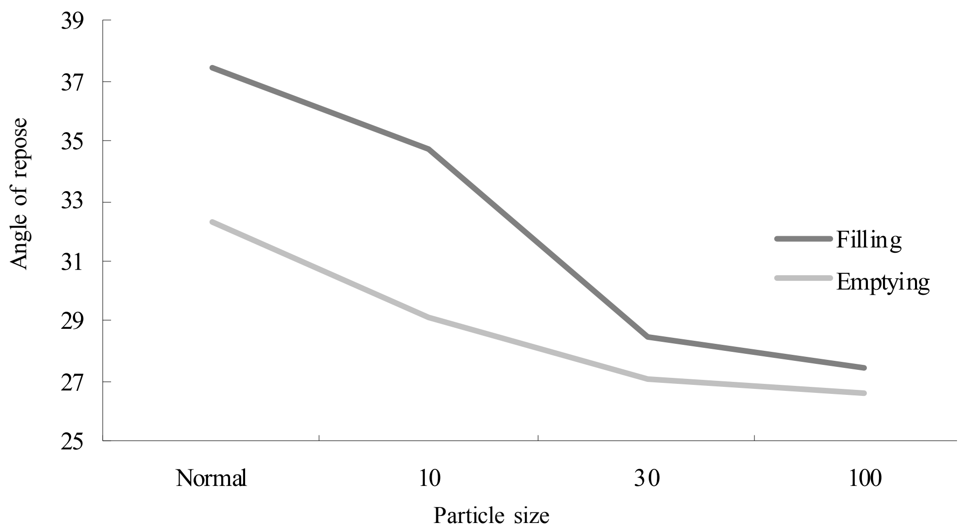

Fig. 5. Diagram of angle of repose

Table 3. Statistical analysis for filling and emptying method

Filling method				
Source of variation	DF	SS	MS	P
Treatment	3	69.66	21.47**	<0.001
Error	8	18.15	3.4	
Total	11	87.81		
Emptying method				
Source of variation	DF	SS	MS	P
Treatment	3	57.11	19.55**	<0.001
Error	8	57.43	6.67	
Total	11	114.54		

** Significant at P=0.01, * Significant at P=0.05, ns Not significant

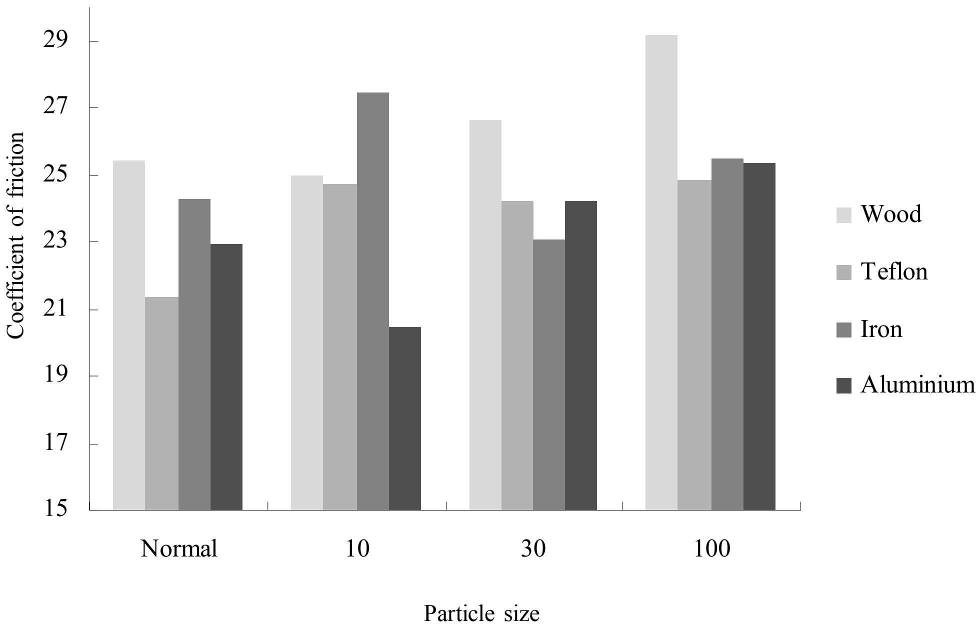

Fig. 6. Diagram of coefficient of friction

Table 4. Statistical analysis for coefficient of friction

Source of variation	DF	SS	MS	P
Mesh size (M)	3	45.87	15.29**	< 0.0001
Friction surfaces (F)	3	47.71	15.91**	< 0.0001
M*F	9	47.70	5.30**	< 0.0001
Error	31	25.78	0.83	
Total	46	167.06		

** Significant at P=0.01, * Significant at P=0.05, ns Not significant

Results showed that the effect of particle sizes and friction surfaces on coefficient of friction are significant at (P=0.01). Increase in coefficient of friction will increase the contact between compost and internal surface of die. The results of Duncan's Multiple Range Test for coefficient of friction are shown in Table 5. According to statistical analysis, the simple effect of particle size 100 on coefficient of friction was more than other particle size levels. Also effect of particle sizes 10 and 100 on coefficient of friction was the same. The effect of wood on coefficient of friction was more than other friction surfaces, also effect of aluminium and iron on coefficient of friction was same. Table 5. showed that use of particle size 100 and wood had the most effect on coefficient of friction. Analysis of data for density of compost is shown in Table 6. Analysis showed that effect of moisture content, particle size, pressure and their interaction on density of compost was significant (P=0.01). Therefore using moisture content level at 25%, particle size level at 100 and pressure level at 47.7 MPa will result producing pellets with more density. This result agrees with experiment done by Ima et al. (2007) on woodchip and Aydin (2006) on peanut fruit and kernel. According to Table 7. moisture content at 20%, particle size at 100 and pressure at 47.7 MPa had the most effect on density of compost pellet. The best condition for density of compost pellet was at particle size of 100 and moisture content at 25% (Table (7a)), pressure at 47.7 MPa and moisture content at 20% (Table (7b)) and particle size at normal and pressure at 47.7 MPa (Table (7c)). Tables 8 and 9 show the ANOVA and Duncan's Multiple Range Test for expansion of pellets. According to these tables moisture content at 20%, particle size at 10 and pressure at 47.7 MPa had the most effect on expansion of pellet. The most expansion was at particle size of 10 and moisture content at 25% (Table (9a)), pressure at 47.7 MPa and moisture content at 25% (table (9b)) and particle size at 10 and pressure at 23.4 MPa (table (9c)).

Table 5. Effect of interaction between particle size and friction surfaces on coefficient of friction

Particle size	Friction surface			
	Wood	Teflon	Iron	Aluminium
Normal	25.45^{CD}	21.35^{G}	24.3^{FDE}	22.93^{F}
10	25.98^{CD}	24.73^{DE}	27.44^{B}	25.65^{CD}
30	26.64^{BC}	24.23^{FDE}	23.08^{FE}	24.22^{FDE}
100	29.14^{A}	24.86^{D}	25.5^{CD}	25.37^{CD}

*** Letters indicate that means with the same letters in a column are not significantly different at P = 0.01**

Table 6. Statistical analysis of data of density

Source of variation	DF	SS	MS	P
MC	2	225092.26	112546.13^{**}	<0.0001
Particle size (S)	3	136836.83	45612.3^{**}	<0.0001
Pressure (P)	2	438167.4	219083.7^{**}	<0.0001
MC*S	6	96266.34	16044.39^{**}	<0.0001
MC*P	4	22223.85	5555.96^{**}	<0.0001
S*P	6	107199.67	17866.61^{**}	<0.0001
MC*P*S	12	59170.74	4930.89^{**}	<0.0001
Error	72	0	0	
Total	107	1084957.08		

** Significant at P=0.01, * Significant at P=0.05, ^{ns} Not significant

Table 7. Effect of Interaction between particle size, moisture content and pressure on density

Table 7a Interaction of particle size and moisture content			
Particle size	Moisture content		
	15	20	25
Normal	1326[K]	1416[E]	1442[D]
10	1341[I]	1352[G]	1341[H]
30	1282[L]	1444[C]	1372[F]
100	1339[J]	1488[B]	1491[A]
Table 7b Interaction of particle size and moisture content			
Pressure	Moisture content		
	15	20	25
23.4	1237[I]	1318[H]	1348[F]
36	1327[G]	1461[C]	1420[D]
47.7	1402[E]	1465[A]	1467[B]
Table 7c Interaction of particle size and pressure			
Particle size	Pressure		
	23.4	36	47.7
Normal	1269[K]	1403[F]	1511[A]
10	1316[J]	1334[I]	1383[G]
30	1258[L]	1427[D]	1413[E]
100	1362[H]	1446[C]	1511[B]

* Letters indicate that means with the same letters in a column are not significantly different at P = 0.01

Table 8. Statistical analysis of data of expansion of pellets

Source of variation	DF	SS	MS	P
MC	*2*	*4676787.445*	*2336893.723***	*<0.0001*
Particle size (S)	*3*	*4233914.254*	*1411304.751***	*<0.0001*
Pressure (P)	*2*	*273439.816*	*136719.908***	*<0.0001*
MC*S	*6*	*3252423.979*	*542070.663***	*<0.0001*
MC*P	*4*	*791365.582*	*197841.396***	*<0.0001*
*S*P*	*6*	*3037872.233*	*506312.039***	*<0.0001*
*MC*P*S*	*12*	*2697808.521*	*224817.377***	*<0.0001*
Error	*72*	*0*	*0*	
Total	*107*	*18960611.83*		

** Significant at P=0.01, * Significant at P=0.05, ns Not significant

Table 9. Effect of interaction between particle size, moisture content and pressure on expansion of pellets

Table 9a Interaction of particle size and moisture content on expansion of pellets			
Particle size	Moisture content		
	15	20	25
Normal	8002[H]	8036[G]	8457[C]
10	7894[K]	8769[B]	8809[A]
30	7959[I]	8394[D]	8046[F]
100	7697[L]	8170[E]	7952[J]
Table 9b Interaction of pressure and moisture content on expansion of pellets			
Pressure	Moisture content		
	15	20	25
23.4	7719[I]	8384[B]	8375[C]
36	7903[H]	8334[D]	8168[F]
47.7	8043[G]	8309[E]	8404[A]
Table 9c Interaction of particle size and pressure on expansion of pellets			
Particle size	Pressure		
	23.4	36	47.7
Normal	7983[I]	8227[E]	8285[D]
10	8812[A]	8143[G]	8518[B]
30	7919[K]	8306[C]	8174[F]
100	7924[J]	7864[L]	8031[H]

* Letters indicate that means with the same letters in a column are not significantly different at P = 0.01

CONCLUSION

The various properties measured will serve as a useful tool in process and equipment design and this will go a long way in assisting to improve yield and quality of pellets. There are some major results in this study. All the physical properties of compost pellet depend on their moisture contents. Decrease in particle size in filling and emptying methods causes decrease in angle of repose. The effect of particle sizes and friction surfaces on coefficient of friction are significant at (P=0.01). The best condition for density of compost pellet was at particle size of 100 and moisture content at 25% and pressure at 47.7 MPa. Moisture content at 20%, particle size at 10 and pressure at 47.7 MPa had the most effect on expansion of compost.

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REFERENCES

ASAE Standards, (1998). S269.4 Cubes. Pellets and Crumbles-Definitions and Methods for Determining Density, Durability and Moisture Content ASAE DEC96. Standard S358.2 Moisture Measurement-forages. ASAE, St. Joseph, MI.

ASTM E-11-70 (Part 41) and U.S. National Bureau of standards official sieve designations.

Asoewgu, S., Ohanyere, S., Kanu, O. and Iwueke, C. (2006). Physical properties of African oil bean seed (Pentaclethra macrophylla). Agricultural Engineering International, the CIGR Ejournal, v.8.

Aydin, C. (2006). Some engineering properties of peanut and kernel. J. Food Engineering, **79,** 810-816.

Bart-Plange, A. and Baryeh, E. A. (2002). The physical properties of Category B cocoa beans. J. Food Engineering, **60**, 219–227.

Barreira, L. P., Philippi Junior, A., Rodrigues, M. S. and Tenorio c, J. A. S. (2008). Physical analyses of compost from composting plants in Brazil. Waste Management, **28 (8),** 1417-1422.

Bernhart, M. and Fasina, O. O. (2008). Moisture effect on the storage, handling and flow properties of poultry litter. Waste Management, **29**, 1392–1398.

Campitelli, P. and Ceppi, S. (2008). Chemical, physical and biological compost and vermicompost characterization: A chemometric study. Chemometrics and Intelligent Laboratory Systems, **90 (1),** 64-71.

Fraczek, J., Złobecki, A. and Zemanek, J. (2007). Assessment of angle of repose of granular plant material using computer image analysis. J. Food Engineering, **83**, 17-22.

Fasina, O. O. (2007). Physical properties of peanut hull pellets. Bioresource Technology, **99**, 1259-1266.

Hofsetz, K, Lopes, C. C., Hubingera, M. D., Mayo, L. and Sereno, A. M. (2007). Changes in the physical properties of bananas on applying HTST pulse during air-drying. J. Food Engineering, **83**, 531-540.

Ima, C. S. and Mann, D. D. (2007). Physical Properties of Woodchip: Compost Mixtures used as biofilter media. Agricultural Engineering International: the CIGR Ejournal. Manuscript BC 07 005. v.9.

Kaptso, K. G., Njintang, Y. N., Komnek, A. E., Hounhouigan, J., Scher, J. and Mbofung, C. M. F. (2007). Physical properties and rehydration kinetics of two varieties of cowpea (Vigna unguiculata) and bambara roundnuts (Voandzeia subterranea) seeds. J. Food Engineering, **86**, 91-99.

Kashaninejad, M., Mortazavi, A., Safekordi, A. and Tabil, L. G. (2006). Some physical properties of Pistachio (Pistacia vera L.) nut and its kernel. J. Food Engineering, **72,** 30-38.

Mani, S., Tabil, L. G. and Sokhansanj, S. (2006). Effects of compressive force, particle size and moisture content on mechanical properties of biomass pellets from grasses. Biomass and Bioenergy, **30**, 648-654.

Mohee, R. and Mudhoo, A. (2005). Analysis of the physical properties of an in-vessel composting matrix. Powder Technology, **155**, 92-99.

Olajide, J. O. and Igbeka, J. C. (2002). Some physical properties of groundnut kernels. J. Food Engineering, **58**, 201-204.

Pechon, R. R., Ito, N., Kito, K. and Jinyama, H. (2007). Effect of hand tractor implements on soil physical properties in upland conditions. Agricultural Engineering International: the CIGR Ejournal. Manuscript PM 07 005. v. 9.

Richard, T. L., Hamelers, H. V. L., Veeken, A. and Silva, T. (2002). Moisture Relationships in Composting Processes. Compost Science & Utilization, **10 (4)**, 286-302.

Sessiz, A., Esgici, R. and Kizil, S. (2006). Moisture-dependent physical properties of caper (Capparis ssp.) fruit. J. Food Engineering, **79**, 1426-1431.

Shaw, M. D. and Tabil, L. G. (2007). Compression, Relaxation, and Adhesion Properties of Selected Biomass Grinds. Agricultural Engineering International: the CIGR Ejournal. Manuscript FP 07 006. v.9.

Tognetti, C., Mazzarino, M. J. and Laos, F. (2006). Improving the quality of municipal organic waste compost. Bioresource Technology, **98**, 1067-1076.

Van Ginkel, J. T., Raats, P. A. C. and Van Haneghem, I. A. (1999). Bulk density and porosity distributions in a compost pile. Netherlands Journal of Agricultural Science, **47**, 105-121.

White, N. D. G. and Jayas, D. S. (2001). Physical properties of canola and sunflower meal pellets. Canadian Biosystems Engineering, **43**, 49-52.