Gravimetrical and frictional properties of broilers diets

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Abstract: Information on physical properties of broiler chickens diets is not available in literatures and such information is important for design and construction of poultry equipments. Some physical properties of starter, grower and finisher diet of broiler chickens, namely: gravimetrical (bulk density, true density and porosity) and frictional properties (coefficient of friction filling angle of repose, empting angle of repose and pouring angle of repose) were studied. Effect of height of falling diets to the containers at 150, 250 and 350 mm and volume of the containers at 500, 600, 1,100 and 2,000 mL on bulk density and porosity of diets were studied. Results indicated that true density of the starter; grower and finisher diets were 1,442.574, 1,512.694 and 1,541.320 kg m^3, respectively. A comparison between the three levels of height of falling for three diets indicated that with increasing height of falling, bulk density were increased and porosity were decreased. The coefficient of friction of starter, grower and finisher diet on different surfaces changed from 18.033 to 26.743°, 18.083 to 27.193° and 18.293 to 27.570°, respectively. The values obtained for pouring angle of repose of starter diet on iron, plywood and galvanized surfaces were 34.40°, 36.05° and 30.22°, respectively. The corresponding values for grower and finisher diets were 38.71°, 39.62°, and 33.72° and 36.66°, 38.21° and 33.62°, respectively.

Keywords: broilers diet, bulk density, true density, coefficient of friction, angle of repose

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1 Introduction

Modern broiler chicks have undergone great changes in growth characteristics during the past few decades. It is reported that 85%-90% of the changes in growth rate of broilers over the past 50 years are due to genetic selection, and 10%-15% due to advances in nutrition and management (Sherwood, 1977; Havenstein et al., 2003). Therefore it can be suggested that the playing field of broiler nutrition has been changed by genetic selection. With the increase in the growth potential of the broilers, broiler producers and poultry nutritionists are facing the problem to meet the nutrients requirements of modern commercials broiler chicks. Feeding cost is the largest single item in poultry production and accounts for 60% to 75% of the total cost production (Ojewola et al., 2005) and consequently the feed formulation and maintaining its uniformity and management of feeding are very important to access the maximum profitability of the operation. Poultry diets are made up of many ingredients, which are divided into providers of energy (fats, oils and carbohydrates), protein, vitamins, minerals and supplements (enzymes, growth promoters, product quality enhancement, etc.). Feed ingredients are combined in such a way as to provide the energy, protein, vitamin and mineral requirements for poultry through the process of feed formulation. Dietary nutrients composition and physical properties of diets affect the feed intake, utilization efficiency, behavior and welfare of the birds (Lal and Atapattu, 2007). Feed decomposition (or separation of the feed components) which usually takes place in mash diets during mixing, transportation,

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storage or delivery to feeder, decreases the uniformity of diets and consequently leads to inappropriate response of birds to balanced diets. Gravimetric (bulk density, true density and porosity), and frictional (coefficient of friction and angle of repose) properties are the most important physical properties that affect the uniformity and homogeneity of the mixed diets during transport, storage and feeding.

Therefore, considering these characteristics are essential for designing and manufacturing of all equipment involved in feed processes such as mixing, transport, storage and feed distribution by feeders. Porosity affects the bulk density which is also necessary factor in the design of storage and conveyer capacity while the true density is useful to design separation equipment (Sologubik et al., 2013). The angle of repose and coefficient of friction are considered by engineers as important properties for the design of powder containers and other storage structures and accessories. The static friction coefficient limits the maximum inclination angle of conveyor and storage bin. The amount of power requirement for conveyor depends on the magnitude of frictional force. Angle of repose is a useful parameter for calculation of belt conveyor width and for designing the shape of storage (Sirisomboon et al., 2007).

Numerous researches have been conducted on physical, mechanical and chemical properties of agricultural seeds, fruits, nuts, kernels, grains (Aydin, 2003; Owolarafe and Shotonde, 2004; Özgüven and Vursavuş, 2005;Çalışır et al., 2005; Altuntaş and Yildiz, 2007) and agricultural and industrial powders (Mitra, 1991; Crisp et al., 1976; Svarovsky, 1987; Uchikawa et al., 1996; Chegini and Ghobadian, 2005).

There is limited literature and information that evaluate the physical properties of broilers diets. Thus, the aim of present study was to: 1) measure true density of starter, grower and finisher diets based on toluene displacement method; 2) measure bulk density of starter, grower and finisher diets in different levels of height of fall and volume of the container; 3) calculate porosity of starter, grower and finisher diets based on true and bulk density;4) measure coefficient of static friction of starter, grower and finisher diets on plywood, iron sheet and galvanized iron sheet using image processing technique; 5) measure pouring angle of repose of starter, grower and finisher diets on plywood, iron sheet and galvanized iron sheet using image processing technique; and, 6) measure filling and empting angle of repose of starter, grower and finisher diets using image processing technique.

2 Materials and methods

2.1 Sample preparation

Three broilers diets with different components (starter, grower and finisher) were used in the present work (Table 1). The diets were immediately transported to laboratory and were stored at 5°C prior to experiment. Bulk samples were selected randomly; then all the tests including analysis of particle dimensions and shaking, measuring gravimetric properties and measuring frictional properties were done for three diets.

Table 1 Ingredient composition of experimental diets (as-fed)

Feed ingredient	Starter	Grower	Finisher
Yellow corn	58.77	59.95	65.39
Soybean meal	36.62	33.62	28.31
Soybean oil	1.44	2.96	2.81
Calcium carbonate	1.34	1.11	1.15
Dicalcium phosphate	1.74	1.50	1.56
L-Lysine	0.15	-	0.20
Sodium chloride	0.20	0.20	0.20
DL-Methionine	0.24	0.16	0.14
Vitamin-Mineral Premix[a]	0.50	0.50	0.50

Note: [a] Provided by per kg of diet: vitamin A, 12,000 IU; vitamin D3, 2,000 IU, vitamin E, 35 mg ;vitamin K3, 4 mg; vitamin B1, 3 mg; vitamin B2, 7 mg; niacin, 20 mg; vitamin B6, 5 mg; vitamin B12, 0.015 mg; folic acid, 1 mg; biotin, 0.045 mg; ascorbic acid, 50 mg; canthaxanthine, 1.5 mg;Pantotenoic acid ester 0.5 mg; choline chloride, 125 mg; manganese, 80 mg; iron, 60 mg; zinc, 60 mg copper, 5 mg; cobalt, 0.2 mg; iodine, 1 mg; selenium, 0.15 mg.

2.2 Gravimetric properties

2.2.1 True density

The true density (ρ_t) is defined as the mass of sample (M_s) divided by the volume of the sample (V_s). It was determined using the toluene (C_7H_8). Toluene was used in place of water because it is absorbed by seeds to a lesser extent, density of toluene is less than the water and its surface tension is low, so that it fills even shallow dips in a seed and its dissolution power is low (Milani et al., 2007; Garnayak et al., 2008). The volume of the individual sample was determined by weighing displacement volume of toluene (Mohsenin, 1970):

$$V_s = \frac{M_{TD}}{\rho_t} = \frac{(M_T - M_P) - (M_{PTD} - M_{PS})}{\rho_t} \quad (1)$$

$$\rho_s = \frac{M_s}{V_s} \quad (2)$$

where: M_{TD} is the mass of displacement volume of toluene (kg); ρ_t is the density of toluene (870 kgm^3); M_T is the mass of filled pycnometer with toluene (kg); M_P is the mass of pycnometer (g); M_{PTS} is the mass of pycnometer with toluene and a nut in (g); and M_{PS} is the mass of pycnometer and seeds (kg). The true density of sample of each diet was measured with 5 repetitions.

2.2.2 Bulk density

In order to determine bulk density of diets, the diets were put into 4 cylindrical containers with known weights and volumes of 500, 600, 1,100 and 2,000 mL with a constant height of 150 mm (Dash et al., 2008; Mirzabe et al., 2013a). In order to fill the containers with diets three levels of height of fall equals 15, 25 and 35 cm were used. Bulk densities (ρ_b) were calculated from the mass of bulk material divided by volume containing the mass. The diets bulk density was measured with 5 repetitions.

2.2.3 Porosity

Porosity defined as the ratio of the volume of pores to the total volume. Porosity or void fraction is a measure of the void spaces or empty spaces in a material, and is a fraction of the volume of voids over the total volume, between 0 to 1, or as a percentage between 0 to 100%. The term is used in multiple fields including pharmaceutics, ceramics, metallurgy, materials, manufacturing, earth sciences, soil mechanics and engineering. The porosity (ε) of the diets was calculated based on bulk and true density, using the following equation (Fathollahzadeh et al., 2008; Sharma et al., 2011):

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \quad (3)$$

2.3 Frictional properties

2.3.1 Angle of friction

The coefficient of external static friction was determined using plywood, iron sheet and galvanized iron sheet. A top and bottomless metallic box was put on the surface. The box was filled by samples of diets. The surface was gradually raised by a screw. When the glides of the diets on the surface were started, the angle between the frictional surface and horizon was photographed and coefficient of friction were calculated using image processing technique and Auto Cad 2007 software package.

2.3.2 Angle of repose

When bulk granular materials are poured onto a horizontal surface, a conical pile will form. The internal angle between the surface of the pile and the horizontal surface is known as the angle of repose. Material with a low angle of repose forms flatter piles than material with a high angle of repose. Angle of repose is related to the density, surface area and shapes of the particles, and the coefficient of friction of the material. However, it has been shown that the angle of repose is also gravity-dependent (Kleinhans et al., 2011). There are different methods to measure the angle of repose including pouring, filling, empting, piling, submerging and rotating drums methods.

2.3.2.1 Pouring angle of repose

Static angle of repose was measured using pouring method. The angle of repose of diets sample was determined using a top and bottomless metallic cylinder of 250 mm height and 200 mm diameter (Mirzabe et al., 2013b). The cylinder was placed on horizontal surface and was filled with diets; then, the cylinder was raised very slowly (Figure 1). The height and radius of the cone were measured using a digital caliper. The angle between the cone of diets surface and horizon was photographed and pouring angle of repose was calculated using image processing technique and Auto Cad 2007 software package.

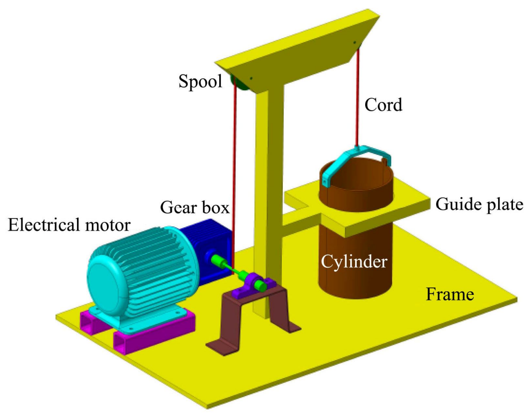

Figure 1 Experimental set up was used to measure pouring angle of repose

2.3.2.2 Filling and empting angle of repose

In order to measure filling and empting angle of repose, diets filled to wooden box of 200 mm height, 200 mm width and 100 mm thickness (Figure 2). There was a discharge valve at the bottom of the wooden box. With opening the discharge valve the materials discharged from the wooden box and the filling and empting angle of repose were formed. Front was made of the glass. The camera was placed at opposite of the front view of the wooden box then photographed from filling and empting angle of repose and these angles were calculated using image processing technique and Auto Cad 2007 software package.

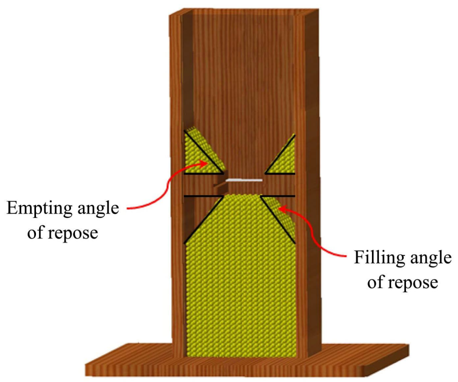

Figure 2 Experimental set up was used to measure filling and empting angle of repose

3 Results and discussion

3.1 Gravimetric properties

3.1.1 True density

True density of the starter, grower and finisher diets were 1,442.6, 1,512.7 and 1,541.3 kg m^3, respectively. A comparison between the three diets indicates that the value of true density of finisher diet was the greatest than the other diets and true density of starter diets was the least than the other diets.

3.1.2 Bulk density

Bulk density of the three diets determined when the cylindrical containers volumes were equal to 500, 600, 1,100 and 2,000 mL and heights of falling were equal to 150, 250 and 350 mm. Results of bulk density of the diets when the height of falling equals to 150 mm are shown in Figure 3. Results indicated that in four levels of volume of the container, values of bulk density of starter diet were the least than the finisher and grower diets (Figure 3). Illustrated results in Figure 3, indicated that when the volume of the container equals to 500 and 600 mL, values of bulk density of finisher diet were greater than the starter and grower diets; while when the volume of the container equals to 1,100 and 2,000 mL, values of bulk density of grower diet were less than the starter and finisher diets.

Results showed that for the three diets, when the volume of the container was 600 mL, the bulk density had greatest values; while, when the volume of the container was 500 mL, the bulk density had lowest values (Figure 3).

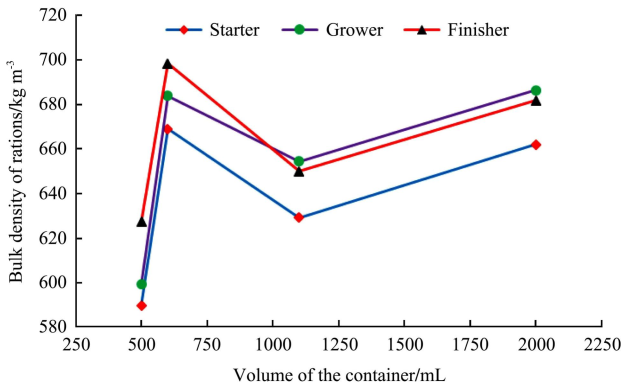

Figure 3 Effect of the volume of the container on bulk density of diets, height of fall equals 150 mm

When the height of falling equals to 250 mm, results of bulk density of the three diets are shown in Figure 4. According to the Figure 4, results indicated that in four levels of volume of the container, values of bulk density of starter diet was less than the finisher and grower diets (same as when the height of falling was equal to 150 mm). Results indicated that when the volume of the container equals to 500 mL, values of bulk density of finisher diet were greater than the starter and grower diets; while when the volume of the container equals to 600, 1,100 and 2,000 mL, values of bulk density of grower diet were less than the starter and finisher diets.

Illustrated results in Figure 4 showed that for the three diets, when the volume of the container was equal to 600 mL, the bulk density had greatest values; while, when the volume of the container was equal to 500 mL, the bulk density had lowest values (same as when the height of falling was equal to 150 mm).

When the height of falling equals to 350 mm, results of bulk density of the three diets are shown in Figure 5. Results indicated that in three levels of volume of the container (500, 1,100 and 2,000), values of bulk density of starter diet was less than the finisher and grower diets (same as when the height of falling were equal to 150 mm and 250); but when the volume of the container was equal to 600 mL, values of bulk density of finisher diet were the least than the other diets. Results indicated that when the volume of the container equals to 500 mL, values of bulk density of finisher diet were the greater than the starter and grower diets; while when the volume of the container equals to 600, 1,100 and 2,000 mL, values of bulk density of grower diet were the less than the starter and finisher diets (Figure 5).

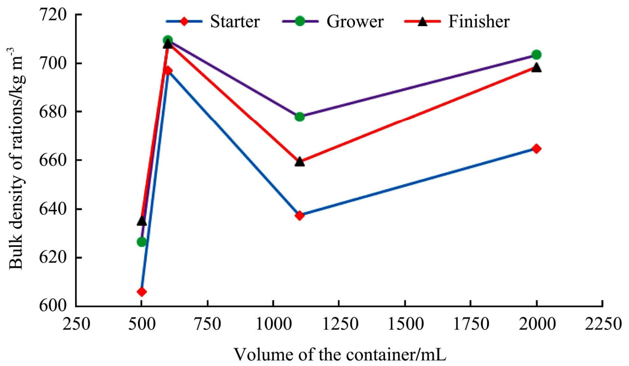

Figure 4 Effect of the volume of the container on bulk density of diets, height of fall equals 250 mm

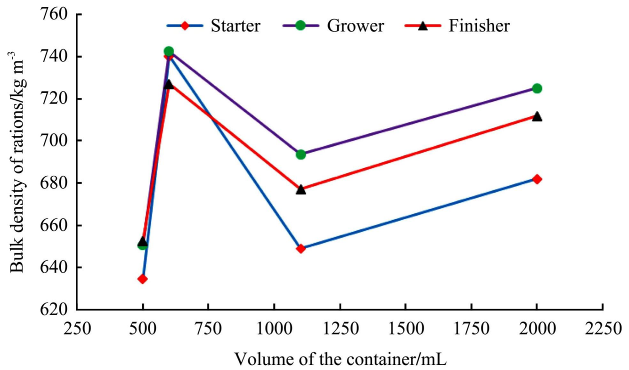

Figure 5 Effect of the volume of the container on bulk density of diets, height of fall equals 350 mm

The results showed when the volume of the container was equal to 600 mL, the bulk density had greatest values; while, when the volume of the container was equal to 500 mL, the bulk density had lowest values (same as when the height of falling were equal to 150 mm) (Figure 5).

A comparison between the three levels of height of falling for three diets indicated that bulk density increased by increasing in height of falling; for example when the volume of the container were equal to 600 mL and, bulk density of starter, grower and finisher diet increased from 668.978 to 740.039 kg m^3, 683.883 to 742.400 kg m^3 and 698.311 to 726.933 kg m^3, respectively as the height of falling increases from 150 to 350 mm.

Mirzabe et al. (2013a) used 4 cylindrical containers with known weights and volumes of 500, 1,000, 1,500 and 2,000 mL to determine bulk density of virgin olive fruits. They cited that bulk density of fruits increased from 590.784 kgm^3 to 646.508 kg m^3 as the volume container increased from 500 mL to 2,000 mL. But the changing trend in volume of the container and bulk density was not observed in the present study.

3.1.2 Porosity

Results of porosity of the diets when the height of falling equals to 150 mm are shown in Figure 6. Results indicated that in four levels of volume of the container, values of porosity of starter diet were less than the finisher and grower diets (Figure 6). Illustrated results in Figure 6, showed that for the three diets, when the volume of the container was equal to 500 mL, the porosity had the maximum values; while, when the volume of the container was equal to 600 mL, the porosity had the minimum values. When the height of falling was equal to 150 mm, porosity of the starter, grower and finisher diets were changed from 53.626% to 59.122%, 54.626% to 60.392% and 54.694% to 59.294%, respectively.

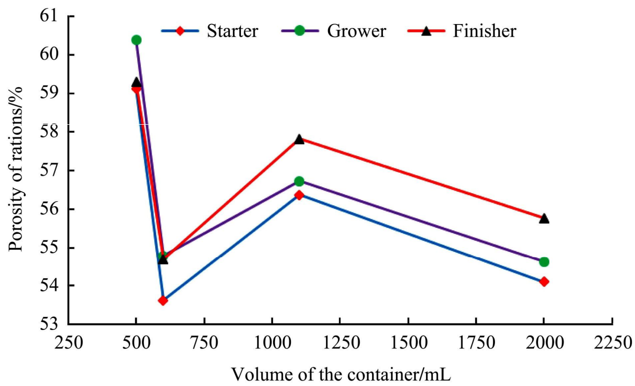

Figure 6 Effect of the volume of the container on porosity of diets, height of fall equals 15 cm

Results of porosity of the diets when the height of falling equals to 250 mm are shown in Figure 7. Results indicated that in two levels of volume of the container (500 and 600), values of porosity of starter diet were the less than the finisher and grower diets; while when the volume of the container were equals to 1,100 and 2,000, values of porosity of grower diet were less than the finisher and starter diets (Figure 7). Illustrated results in Figure 7 showed that for the three diets, when the volume of the container was equal to 500 mL, the porosity had maximum values; while, when the volume of the container was equal to 600 mL, the porosity had minimum values. When the height of falling was equal to 250 mm, porosity of the starter, grower and finisher diets were changed from 51.70% to 57.98%, 53.11% to 58.56% and 54.06% to 58.78%, respectively.

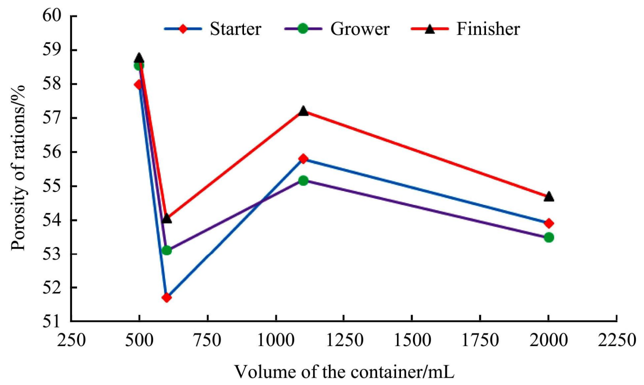

Figure 7 Effect of the volume of the container on porosity of diets, height of fall equals 25 cm

Results of porosity of the three diets when the height of falling equals to 350 mm are shown in Figure 8. Results indicated that in two levels of volume of the container (500 and 600), values of porosity of starter diet were the less than the finisher and grower diets; while when the volume of the container were equals to 1,100 and 2,000, values of porosity of grower diet were less than the finisher and starter diets (Figure 8). Results showed that for the three diets, when the volume of the container was equal to 500 mL, the porosity had the maximum values; while, when the volume of the container was equal to 600 mL, the porosity had the minimum values (Figure 8). When the height of falling was equal to 350 mm, porosity of the starter, grower and finisher diets were changed from 48.70% to 56.00%, 50.92% to 56.97% and 52.84% to 57.64%, respectively.

A comparison between the three levels of height of falling for three diets indicated porosity decreased by increasing in height of falling. Mirzabe et al. (2013a) used 4 cylindrical containers with known weights and volumes of 500, 1,000, 1,500 and 2,000 mL to determine bulk density of virgin olive fruits. They cited that porosity of fruits decreased from 44.22% kg/m^3 to 38.96% as the volume container increased from 500 mL to 2000 mL. But present study was not observed certain trends for changing in volume of the container and porosity.

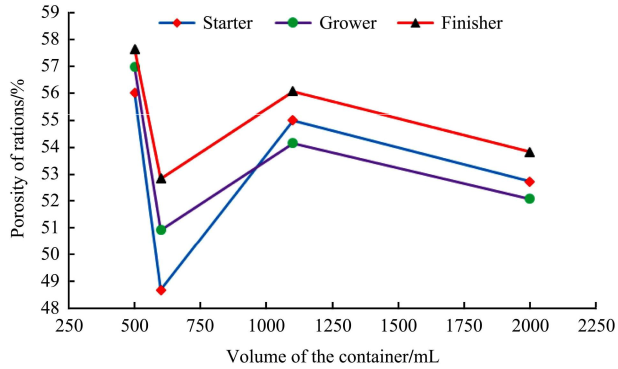

Figure 8 Effect of the volume of the container on porosity of diets, height of fall equals 350 mm

3.2 Frictional properties

3.2.1 Angle of friction

The static coefficients of friction of the diets on four surfaces (iron, plywood, galvanized and rubber) are shown in Table 3. The coefficient of friction of starter, grower and finisher diet on different surfaces changed from 18.03 to 26.74°, 18.08 to 27.19° and 18.293 to 27.570°, respectively. A comparison between the three diets indicated that angle of friction of finisher diet was greater than the other diets; while, angle of friction of starter diet was less than the other diets.

For three diets, the maximum friction is offered by plywood, followed by the rubber, iron and galvanized surfaces. The least static coefficient of friction may be owing to the smoother and more polished surface of the galvanized sheet than the other materials used. Plywood also offered the maximum friction for tef seed (Zewdu and Solomon, 2007), jatrofa fruit (Pradhan et al., 2009) and for almond (Mirzabe et al., 2013b), but the galvanized iron had higher coefficient of friction than plywood for Roselle seeds (Sánchez-Mendoza et al., 2008) and lentil seeds (Amin et al., 2004).

Table 3 Values of static coefficient of friction of diets (°)

Material	Iron	Plywood	Galvanized	Rubber
Starter diet	20.93	26.74	18.03	25.92
Grower diet	21.08	27.19	18.083	26.30
Finisher diet	21.69	27.57	18.29	26.40

3.2.1 Angle of repose

The angle of repose is an indicator of the product's flow ability. The results for the three diets based on the three methods are shown in Table 4. The value of empting angle of repose of starter, grower and finisher is found to change from 66.41° to 70.07°; while, the value of filling angle of repose of the three diets was found to change from 31.24° to 33.18° (Table 4). Results indicated that value of filling angle of repose of the finisher diet was less than the other diets; while value of empting angle of repose of the finisher diet was greater than the other diets. Also for the grower diet value of filling angle of repose was greater than the other diets; while, value of empting angle of repose of the grower diet was less than the other diets (Table 4).

Table 4 Angle of repose of diets based on different methods

(°)

Material	Filling method	Empting method	Pouring method		
			Iron	Plywood	Galvanized
Starter diet	32.42	68.13	34.40	36.05	30.22
Grower diet	33.18	66.41	38.71	39.62	33.72
Finisher diet	31.24	70.07	36.66	38.21	33.62

Different behaviors for emptying and filling angle of repose have been reported for agricultural materials. The angle of repose obtained from emptying method was greater than that of filling method for wild pistachio (Fadavi et al., 2013), but the reverse results were shown for jatropha (Karaj and Müller, 2010; Sirisomboon et al., 2007).

The values obtained for pouring angle of repose of starter diet on iron, plywood and galvanized surface were 34.40°, 36.05° and 30.22°, respectively. The corresponding values for grower and finisher diets were 38.71°, 39.62°, and 33.72° and 36.66°, 38.21° and 33.62°, respectively. A comparison between the three diets indicated that pouring angle of repose of grower diet was greater than the other diets; while, pouring angle of repose of starter diet was less than the other diets.

Pouring angle of repose is one of the frictional parameters of fruits, grain, seeds, nuts and kernels of agricultural crops. Value of angle of repose of fruits on each surface was related to the value of the static coefficient of friction of fruits on the surface (Mirzabe et al., 2013b). Value of angle of repose on galvanized surface was lower than other surfaces because the value of coefficient of friction on galvanized surface was lower than the other surfaces. Value of repose angle on plywood surface was higher when compared to other surfaces because the value of coefficient of friction on plywood surface was more than other surfaces.

4 Conclusions

Bulk density, true density, porosity, coefficient of friction, filling angle of repose, empting angle of repose and pouring angle of starter, grower and finisher diet of broiler chickens were measured. Effect of height of falling diets to the containers at 150, 250 and 350 mm and volume of the containers at 500, 600, 1,100 and 2,000 mL, on bulk density and porosity of diets were studied. Results showed that:

1) A comparison between the three diets indicates that the value of true density of finisher diet was the greatest than the other diets and true density of starter diets was the least than the other diets.

2) When the height of falling was equal to 150 mm, porosity of the starter, grower and finisher diets were changed from 53.626% to 59.122%, 54.626% to 60.392% and 54.694% to 59.294%, respectively. Corresponding values for when the height of falling was equal to 250 mm and 350 mm were 51.701% to 57.981%, 53.110% to 58.557% and 54.059% to 58.782% and 48.700% to 56.004%, 50.922% to 56.968% and 52.837% to 57.641%, respectively.

3) A comparison between the three diets indicated that pouring angle of repose of grower diet was greater than the other diets; while, pouring angle of repose of starter diet was less than the other diets.

4) Value of angle of pouring repose on galvanized surface was lower than other surfaces because the value of coefficient of friction on galvanized surface was lower than the other surfaces. Value of pouring angle of repose on plywood surface was more compared to other surfaces because the value of coefficient of friction on plywood surface was more than other surfaces.

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