SOME ENGINEERING PROPERTIES OF DIFFERENT FEED PELLETS

A.H. Bahnasawy* and Mostafa, H. M**

ABSTRACT

Due to lack of information about the physical and mechanical properties of feed pellets which are very important to understand the behavior of the product during the processing operations such as transporting, packaging and storage processes and also, it is necessary in processing operations. The main objective of this work was to study the physical and mechanical properties to form an important database for four of the most popular feed pellets in Egypt. These properties include: linear dimensions, mean diameter, surface area, volume, mass, density, static friction coefficient, repose angle and crushing load.

The engineering parameters results showed that the length and mean diameters were in the range of 0.50-2.44 and 0.40-1.24 cm for all pellet sizes with CV of 12-33 and 2-3 %. Feed pellet types in all sizes were cylindrical in shape. The surface areas ranged from 0.86-11.95 cm^2 and the feed pellet mass ranged from 0.07-3.01 g depending on the feed pellet size. The volume ranged from 0.06-2.96 cm^3 with CV of 11-31%, the bulk density ranged from 0.64-0.74 g/cm^3 with CV of 23-36% and real density ranged from 1.02-1.15 g/cm^3 with CV of 9-14% for all feeds. The repose angle ranged from 25.67-38.7^o. The coefficient of static friction (C.S.F) ranged from 0.48-0.80 for all sizes and surfaces. The highest C.S.F was offered by concrete surface followed by the plywood and the galvanized steel surfaces. Crushing load increased with the pellet size ranged from 90.74 to 454.13 and from 29.5 to 348.35 N in vertical and horizontal position, respectively, depending on the feed pellet size.

Keywords: *Feed pellets; Physical; Mechanical; Properties; Repose angle; Crushing load; Friction coefficient.*

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INTRODUCTION

The physical and mechanical properties of feed pellets are not the first thought in the mind of dairy producers, cattlemen, or feed professionals as they plan feed rations. It does however have an impact in the decisions that need to be made when planning and designing the on farm feed storage. The discussion of some physical and mechanical properties of feed pellets should help the farmer or feed professional recognize the important considerations such as volume of storage required and handling options and transporting that need to be addressed in planning for storage (Kammel, 1991).

Different processes occurring during harvest and manufacturing of a product will impact the properties of the end product or by-product used as animal feed. Feed pelleting consists of a series of unit operations, including grinding, mixing, conditioning with moisture, addition of heat of both thermal and mechanical origin, expander treatment, pelleting and subsequent cooling of the product (Thomas et al., 1997). Technical pellet quality is controlled by the operations at the feed mill, but also by the raw material quality and addition of binders (Aarseth and Prestlokken, 2003; Thomas et al., 1999).

Studies regarding the physical characteristics of the feed pellets involved in seawater (Findlay & Watling, 1994; Chen et al., 1999a) and freshwater (Elberizon and Kelly, 1998) fish farming sand systems have been previously published but there is a complete lack of information regarding the characteristics of the feed employed in the rearing of Mediterranean species.

Optimization of feed processing requires methods to measure the mechanical properties and the technical quality of the feed. The Holmen durability test and the Kahl hardness test are frequently used for this purpose (Payne et al., 1994; Thomas and van der Poel, 1996). Knowledge of technical pellet quality is also important relative to transportation and handling of the product. It is known that pellets can be damaged during transportation (Fasina and Sokhansanj, 1996), but it is desirable that the product retains its structure during handling and conveying, until eaten by the animal (Behnke, 1996).

Due to the lack of information about the physical and mechanical properties of feed pellets which are very important to understand the behavior of the product during processing, transporting, packaging and storage processes operations, the main objective of this work was to study the physical and mechanical properties to form an important database for four of the most popular feed pellets in Egypt (large animal, rabbit, poultry growing and finishing feed pellets). These properties include: linear dimensions, mean diameter, surface area, volume, mass, bulk and real density, static friction coefficient, repose angle, and crushing load.

EXPERIMENTAL PROCEDURES

Four feed pellet recipes were produced at the feed processing unit, the Agricultural Engineering Department, Faculty of Agriculture, Moshtohor, Benha University. The feed processing unit includes: milling unit, weighing unit, mixing unit and pelletizing unit. The feed ingredients of these recipes are shown in table (1) and Fig. (1). Those categories were used to measure the linear dimensions, mass, volume, bulk density, angle of repose, static friction and crushing load.

Table (1): Feed ingredients of four feed pellet recipes.

Ingredients	Large animal feed	Rabbit feed	Grower poultry feed	Finisher poultry feed
Yellow corn (9% protein), %	40	13	65	65
Soybean meal (44% protein), %	10	24	25	10
Hay (15% protein), %	-	21	-	-
Wheat bran (11% protein), %	40	19	-	10
Barley (10% protein), %	-	23	-	-
Cotton seed meal (41% protein), %	10	-	-	-
Concentrate, %	-	-	10	10

Measuring instruments and Procedure:

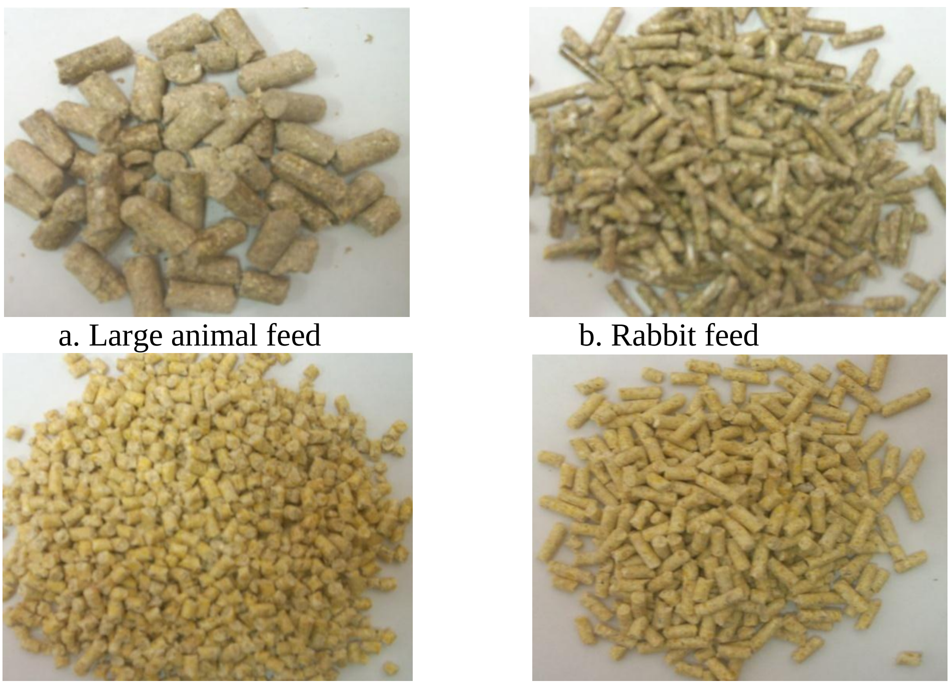
Linear Dimensions:

Pellets are considered cylindrical in the shape. The two dimensions: height (h) and radius (r) of each 10 feed pellets were measured with a caliper reading to ±0.01 mm.

Surface Area

Surface area is defined as the total area over the outside of the pellet. The surface area is calculated by measuring the height (h) and radius (r) of 10 feed pellets for each category and using the following relationships given by Mohsenin (1970), as follows:

$$\text{cm}^2\ Surface\ area\ (SA) = 2\pi r(h + r),$$



a. Large animal feed b. Rabbit feed

c. Poultry grower feed d. Poultry finisher feed

Fig. (1): Feed pellets

Moisture Content:

The moisture content of randomly selected feed pellets of each category was determined according to ASAE Standard (1984). Three samples of each feed pellets were randomly selected and weighed on an electronic balance to a precision of 0.01g. Drying oven (Fisher Scientific Isotemp Oven- Model - 655F Cat. No. 13-245-655, Fisher Scientific, Toronto, Ontario, Canada) at 105 ^{o}C until a constant weight was used to measure the moisture content.

Volume and Density:

The "bulk density" or "apparent density" is a measurement of a feed's mass (weight) per unit volume of space the feed occupies. The bulk density is measured by weighing a specific volume of feed (a one liter bucket filled with feed pellets and weighed) and calculating the density (Appel, 1985). For each case, the determination was replicated three times and the mean was considered. The real volume of each category was calculated as follows:

$$\boldsymbol{Volume = 2}, \ \text{cm}^3$$

Angle of repose:

The angle of repose is the minimum angle at which any piled-up bulky or loose material will stand without falling downhill. One way to demonstrate this would be to pour feed pellets from a bag to three different surfaces (steel, wood and concrete). There is a minimum angle or maximum slope the pellets will maintain due to the forces of gravity and the effect of friction between the particles of pellets. The angle is calculated between the peak of the pile and the horizontal ground as shown in Fig (2) (Ghazavi et al., 2008).

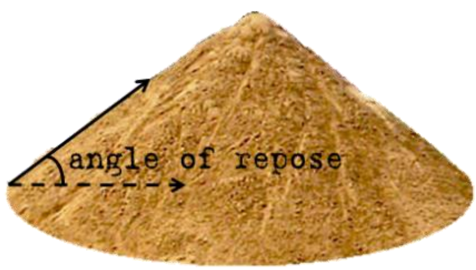


Fig.(2). Angle of repose

Coefficient of Friction

The coefficient of friction between feed and a wall is the ratio of the normal force to the friction force along the wall surface. It is dependent on the feed stored, and the type of surface in contact with feed (Appel, 1985, ASAE, 1987 and Oje and Ugbor, 1991).

Coefficients of friction were determined for feed pellets on three surfaces: concrete, galvanized steel and plywood and these were calculated as a tangent of the slope angle (angle of repose).

Crushing load:

Crushing implies the partial or complete destruction of pellet. Feed pellet was sat upon a flat plate until the cross-head of a handmade apparatus (Fig. 3) was brought in contact with the pellet and a compression force was applied by adding weights or loads until permanent (destruction) was caused and then the loads were recorded (Mostafa and Bahnasawy, 2009). The test was run in horizontal and vertical directions for each pellet type.

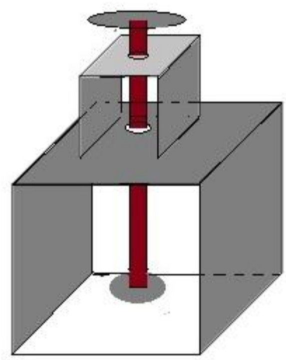


Fig. 3. Handmade crushing load device.

RESULTS AND DISCUSSIONS

1. Physical Properties

1.1 The length, mean diameter and mass:

Table (2) shows the mean values, standard deviation (SD) and coefficients of variation (CV) of the length, mean diameter and mass of the feed pellets. It shows that the average of length and diameter of the large animal feed pellets were 2.44 ± 0.09 and 1.24 ± 0.02 cm respectively, while they were 1.5 ± 0.34 and 0.4 ± 0.01 cm for rabbit feed pellets. The coefficients of variation (CV) values of rabbit feed were higher than those of for large animal feed pellets.

For poultry feeds, there is a big difference between the average length for grower and finisher feeds (0.5 and 1.38 cm respectively) but there are slightly small differences between the mean diameters (0.39 and 0.40 cm respectively). Also the CV values were higher in finisher feed than those of grower feed for both length and diameter.

Table 2: The length, diameters and mass for feeds.

	Length (cm)	Diameter (cm)	Mass (g)
	Large animal feed		
Mean	2.44	1.24	3.01
SD	0.29	0.02	0.33
CV	0.12	0.02	0.11
	Rabbit feed		
Mean	1.5	0.40	0.20
SD	0.34	0.01	0.05
CV	0.23	0.03	0.24
	Poultry grower feed		
Mean	0.50	0.39	0.07
SD	0.06	0.01	0.01
CV	0.12	0.02	0.21
	Poultry finisher feed		
Mean	1.38	0.40	0.20
SD	0.45	0.01	0.05
CV	0.33	0.03	0.27

SD is the standard deviation, CV is the coefficient of variation, %

Table 3: The volume, surface area, bulk density and real density of feed

	Volume (cm^3)	**Surface area (cm^2)**	**Bulk density (kg/l)**	**Real density (g/cm^3)**
		Large animal feed		
Mean	2.96	11.95	0.64	1.02
SD	0.34	1.08	0.017	0.06
CV	0.11	0.09	0.027	0.06
		Rabbit feed		
Mean	0.20	2.20	0.66	1.10
SD	0.04	0.41	0.02	0.10
CV	0.20	0.18	0.30	0.09
		Poultry grower feed		
Mean	0.06	0.86	0.74	1.14
SD	0.01	0.08	0.017	0.15
CV	0.13	0.09	0.023	0.14
		Poultry finisher feed		
Mean	0.17	1.95	0.73	1.15
SD	0.05	0.53	0.026	0.11
CV	0.31	0.27	0.36	0.09

The mean mass values of large animal feed ranged from 2.68 to 3.34 g, while they were from 0.15 to 0.25g for rabbit and poultry finisher feeds and from 0.06 to 0.08 g for poultry grower feeds. The CV values were the lowest (0.11) while they were the highest in the case of poultry finisher feed (0.27).

1.2 Volume, surface area, bulk and real density of the feed pellets

Table (3) shows the mean values, SD, and CV of the volume, surface area, bulk and real density of the feed pellets. The overall mean volumes were 2.96 ± 0.34, 0.20 ± 0.04, 0.06 ± 0.01 and 0.17 ± 0.05 cm^3 for large animal, rabbits, poultry grower and finisher feed pellets, respectively. The average surface areas were 11.95 ± 1.08, 2.2 ± 0.41, 0.86 ± 0.08 and 1.95 ± 0.53 cm^2 for the same pervious order. The average of bulk and real densities were lower than the others because of the high spacing value (porosity) results from the large volumes.

The coefficients of variation (CV) values of the volume readings for poultry finisher feed pellets (0.31) were higher than those of other feed pellets. The same trend was happened with the surface area, bulk and real density values.

2. Mechanical Properties

2.1 Repose angle (RA):

Table (4) shows the mean values of repose angle of four feed pellets on three surfaces (galvanized steel plywood, and concrete). The results indicate that the repose angle increased with increasing the feed pellets size at all surfaces under study. The repose angle values ranged from 25.67-35 degrees on the galvanized steel surface, whereas, it ranged from 25.67-36.7 and 27-38.7 degrees on the plywood and concrete surfaces, respectively. It could be noticed that the values of repose angles recorded on the concrete surface were higher than those obtained on both galvanized and plywood surfaces for all feed pellets, which maybe due to the roughness of the concrete surface which is higher than both galvanized and plywood surfaces.

The CV of the repose angle data recorded the highest value (0.1) on the galvanized steel surface for rabbit feed, while the minimum value (0) was recorded for the large animal feed on the galvanized surface.

2.2 Coefficient of Friction:

Table (5) shows the mean values of coefficient of static friction for feed pellets on three surfaces (galvanized steel plywood, and concrete). The results indicate that the coefficient of static friction increased with increasing the feed pellets size at all surfaces under study. The coefficient of static friction values ranged from 0.48 to 0.7 on both of the galvanized steel and the plywood surfaces, whereas, it ranged from 0.51 to 0.80 on concrete surfaces.

It could be noticed that the values of coefficient of static friction recorded on the concrete surface were higher than those obtained on both galvanized and plywood surfaces for all feed pellets, due to the roughness of the concrete surface which is higher than both galvanized and plywood surfaces. The CV of the coefficient of static friction was highest (12%) on the galvanized steel surface for rabbit feed while, the minimum value (0) was recorded for the large animal feed pellets on the same surface.

Table 4: The repose angle of different types of feed on different surfaces.

	Galvanized steel	Plywood	Concrete
		Large animal feed	
Mean	35	36.7	38.7
SD	0	2.89	3.21
CV	0	0.08	0.08
		Rabbit feed	
Mean	28.3	25.7	29
SD	2.90	1.20	1.7
CV	0.10	0.04	0.06
		Poultry grower feed	
Mean	25.67	25.67	27.33
SD	1.15	1.15	2.52
CV	0.04	0.04	0.09
		Poultry finisher feed	
Mean	26.33	26.33	27.0
SD	1.15	1.15	2.00
CV	0.04	0.04	0.08

Table 5: The coefficient of static friction of feed on different surfaces.

	Galvanized steel	Plywood	Concrete
Large animal feed			
Mean	0.7	0.7	0.8
SD	0	0.08	0.09
CV	0	0.11	0.11
Rabbit feed			
Mean	0.5	0.5	0.6
SD	0.10	0	0
CV	0.12	0.05	0.07
Poultry grower feed			
Mean	0.48	0.48	0.52
SD	0.02	0.02	0.06
CV	0.05	0.05	0.11
Poultry finisher feed			
Mean	0.50	0.50	0.51
SD	0.02	0.02	0.05
CV	0.05	0.05	0.10

2.3. The crushing load

Table (6) shows the mean values, SD and CV of the crushing load of four feed pellets. The results show that the crushing load increased with the increasing of feed size in both vertical and horizontal position. The average crushing load values were 454.13±81.19, 177.89±17.12, 90.74±18.23 and 91.99±14.48 N in vertical position for the large animal, rabbit, poultry grower and finisher feed pellets, respectively. In horizontal position, The average crushing load values were 348.35±93.49, 32.20±9.88, 29.50±5.09 and 31.08±4.13 N for the large animal, rabbit, poultry grower and finisher feed pellets, respectively. The CV of the crushing load data was the highest (31%) in horizontal position, while it was the lowest (10%) in the vertical position for the rabbit feed. The results indicate that the mean force required for crushing the large size (large animal feed) was 6.7 times what the small size (poultry grower feed) had.

Table 6: The mean values, SD and CV of the crushing force of feed.

Feed	Position	Crushing Load (N)		
		Mean	SD	CV
Large animal feed	Vertical	454.13	81.19	0.18
	Horizontal	348.35	93.49	0.27
Rabbit feed	Vertical	177.89	17.12	0.10
	Horizontal	32.20	9.88	0.31
Poultry grower feed	Vertical	90.74	18.23	0.20
	Horizontal	29.50	5.09	0.17
Poultry finisher feed	Vertical	91.99	14.48	0.16
	Horizontal	31.08	4.13	0.13

CONCLUSIONS

- The length and mean diameters were in the range of 0.50-2.44 and 0.40-1.24 cm for all pellet sizes with CV of 12-33 and 2-3 %. Feed pellet types in all sizes were cylindrical in shape.
- The surface areas ranged from 0.86-11.95 cm^2. Feed pellet mass ranged from 0.07-3.01 g depending on the feed pellet size.
- The volume ranged from 0.06-2.96 cm^3 with CV of 11-31%, the bulk density ranged from 0.64-0.74 g/cm^3 with CV of 23-36% and real density ranged from 1.02-1.15 g/cm^3 with CV of 9-14% for feeds.
- The repose angle ranged from 25.67-38.7^o.
- The coefficient of static friction (C.S.F) ranged from 0.48-0.80 for all sizes and surfaces. The highest C.S.F was offered by concrete surface followed by the plywood and the galvanized steel surfaces.

- Crushing load increased with the pellet size. It ranged from 90.74-454.13 and from 29.5-348.35 N in vertical and horizontal position, respectively, depending on the feed pellet size.

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الملخص العربى

بعض الخصائص الهندسية لمصبعات الاعلاف المختلفة

عادل بهنساوى* ، حربى مصطفى*

نظرا لعدم وجود معلومات كافية عن الخواص الطبيعية والميكانيكية للأعلاف التي هي غاية فى الأهمية لفهم سلوك المنتج خلال عمليات التعبئة والتغليف والنقل وعمليات التخزين وأيضا ضروريه في عمليات التجهيز والعمليات الحرارية المختلفة أثناء التصنيع، لذا كان الهدف من هذا البحث هو دراسة بعض الخصائص الطبيعية والميكانيكية لإنشاء قاعدة بيانات لأربعة أنواع من الأعلاف (مصبعات) الأكثر شيوعا فى مصر (علف ماشية حلابة، علف دواجن نامى ، علف دواجن ناهى، علف أرانب) . وتشمل هذه الخصائص : الأبعاد الخطية، المساحة السطحية، الأقطار، الحجم والكتلة والكثافة، معامل الاحتكاك ، زاوية التكويم و قوة السحق.

وكانت أهم النتائج المتحصل عليها أن المتوسط العام للأطوال والأقطار الهندسية تراوح ما بين ٠.٥٠- ٢.٤٤ و ٠.٤٠- ١.٢٤ سم على التوالي حسب الفئات المختلفة تحت الدراسة بمعامل اختلاف ١٢-٣٣ % و ٢-٣ %. جميع انواع المصبعات تأخذ الشكل الاسطوانى من حيث الشكل، وتراوحت المساحة السطحية بين ٠.٨٦-١١.٩٥ سم٢ فى حين تراوح متوسط الاوزان ٠.٠٧- ٣.٠١ جم حيث تعتمد على حجم المصبعات. تراوح المتوسط العام للحجم بين ٠.٠٦ - ٢.٩٦ سم٣ بمعامل اختلاف ١١-٣١%، للكثافة الظاهرية ٠.٦٤-٠.٧٤ جم/سم٣ والكثافة الحقيقية ١.٠٢-١.١٥ جم/سم٣ و زاوية التكويم ٢٥.٦٧-٣٨.٧ درجة. بلغ المتوسط العام لمعامل الاحتكاك ٠.٤٨-٠.٨٠ لجميع الفئات على الاسطح المختلفة. سجلت أعلى قيم لمعامل الاحتكاك على الاسطح الخرسانية يليها الاسطح الخشبية وسجلت اسطح الصلب المجلفن أقل قيمة لمعامل الاحتكاك. يزداد حمل السحق زيادة طردية مع زيادة الحجم، وتراوح حمل السحق بين ٩٠.٧٤- ٤٥٤.١٢ نيوتن على الوضع الرأسى و ٢٩.٥-٣٤٨.٣٥ نيوتن على الوضع الافقى مع اختلاف الحجم.

*قسم الهندسة الزراعية- كلية الزراعة بمشتهر – جامعة بنها.