Comparing Different laboratory Methods for Measuring the Feed Pellet Durability

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Abstract
The experiment aimed to compare different methods of measuring the Feed pellet durability through the effect of pellet die speeds and the particle size (mill sieve holes diameter). Feed pellet durability was studied in four different ways: pellet direct measurement (%), pellet lengths (%), pellet water absorption (%), pellet durability by drop box device (%), pellet durability by air pressure device (%). Three pellet die speeds 280, 300, and 320 rpm, three mill sieve holes diameter 2, 4, and 6 mm, have been used. The results showed that increasing the pellet die speeds from 280 to 300 then to 320 rpm led to a significant decrease in the feed pellet durability by direct measurement, drop box device, and air pressure device, while pellet water absorption a significant increased, whereas it did not significantly affect the pellet lengths. Increasing the sieve holes diameter from 2 to 4 then to 6 mm led to a significant decrease in the feed pellet durability in pellet lengths, drop box device, and air pressure device, pellet water absorption increased, whereas it did not significantly affect the direct measurement of pellet. Pellet die speeds of 280 rpm and the sieve holes diameter of 2 mm recorded the highest pellet durability for all ways: direct measurement 94.66 %, pellet lengths 85.94%, the drop box device 93.42% and the air pressure device 91.21%, less pellet water absorption 38.98%.

Keywords: Pellet durability, Pellet process, Pellet lengths, Die speeds, Particle size.

Introduction

The feed industry depends on concentrated raw feed materials that are rich in energy or protein or both. Manufactured feeds are homogeneous mixtures of raw feed -materials with some mineral salts and some nutritional-additives may be added to them, such as vitamins, antibiotics, urea, and antioxidants, and other materials (7). Feed are produced either in mash or pellet form, or even other forms for chicken, which has become one of the most important Sources of consumed meat in the world (4), The poultry is one of the main pillars of the economies of many countries because of its advantages, include a rapid turnover of capital and a significant contribution to limiting consumers' food needs (8), and is one of the main pillars for providing food to the world's population (6). Therefore, the production process requires high experience in the period of care, and the use of the latest technology to meet the poultry production and improvement of poultry nutrition (17). The different feed ingredients are combined into rations to meet the nutritional requirements and increase production, whereby the cost of feed poultry represents about 70% of the total production cost (12). As modern technology's provides new feeding methods to closely suit the nutritional needs of poultry, thus reducing the cost of feed (5). According to Kaddour (11) who studied different engineering parameters, such as the speed of the forming mechanism and the degree of fineness of the grinding, he noted that they affected the quality of the produced pellet. The die speeds is one of the factors that affect the duration staying of the feed in the machine during the formation, the amount of frictional heat generated, heat transfer rates, and shear forces on the product (10) .

The feed is grinded by the repeated effects of the collision between the hammers and the walls of the grinder as well as the sieve. As soon as the diameter of the mill sieve holes is reduced to a smaller size, the size of the mash will decrease, hence passing through the sieve and separating from the rest of the feed, the fineness of the mash is regulated by using sieves with different screen diameters (19). The improvement in the means of measuring the quality of pellet can contribute significantly to the growth of this industry, because of the positive results gained out of the commercial handling of these pellet after their production, transportation, and during the presentation to poultry, as measuring the physical quality of feed pellet can greatly help to produce strong pellet after organizing operations Production (25).

The method of measuring the crumbling immediately after pellet leave the machine can provide an indication of the quality of pellet for poultry feed, in a study conducted on broiler chicken feed, the durability of pellet measured by the amount of intact pellet per kilogram of total feed, with increas diet's particle sizes from 743 microns for the medium grinding to 1,041 microns for the coarse grinding led to amount of intact pellets was reduced from 773 g/kg to 746 g/kg of feed (17).

Winowiski (28) indicated that pellet lengths represent a simple method for quality control, longer pellet indicate greater durability and lower crumbling. Also the pellet lengths can indicate rougher handling in the handling system. Determining the average pellet lengths by measure the weight of number pellet in a sample of a known and calculates the number of pellet per gram. Usually, a 10 - 20 g sample of pellet is sufficient.

Thomas and Vander Poel (27) defined durability as the amount of whole pellet relative to the crumbled one constituted out of it, after mechanical or pneumatic friction. The pellet durability index is one of the main indicators used to determine the quality of pellet, whereby it indicates the percentage of pellet that remain intact after being subjected to mechanical forces. The pellet is subject to friction, shock, and pressure during storage, transportation, and transmission from the processing machine to the farms (15).

The only documented comparison of the drop box device and the air compressor was provided by Winowiski (29) who described the relationship that the air compressor was more destructive than the standard drop box test, furthermore, there is a good correlation between them, it also recorded from the presented data that both devices were more sensitive For changes in pellet quality, that may be due to changing factors in manufacturing or production practices. The drop box device has been the preferred pellet durability testing method in the United States and is the only method specified as a standard method. However, the portability and shorter time of each test made the pneumatic method an attractive option. If there are significant correlations between drop box results and air pressure, the results of one test can be used to predict the results of the other test. Thus, the durability of the pellet can be compared using different test methods and equipment, to find out the compatibility of the different intervals between the two methods. It may also be found that different devices are better suited for different ranges of pellet durability. Reducing the fineness of grinding from 570 to 970 micron significantly reduced the durability of the pellet from 92.93 to 88.91(3). The research aims to study a comparative use of different devices and methods to measure the durability of the feed pellet by the effect of the pellet die speeds and the particle size (mill sieve holes diameter).

Materials and Methods

Experimental Procedure

The experiment was conducted in the feed lab of the animal production department, college of agricultural engineering sciences, university of Baghdad for the period from 12/9/2021 to 01/19/2022.

Diets

Feed pellet made from a special diet were used in the experiment, according to the basic nutritional requirements of broiler chickens, according to the National Research Council (20). Its components were purchased from the local market, it included a number of feed materials and in the proportions specified in Table (1):

Table 1. Composition and calculated analysis of the diet

Components	Percentage (%)
yellow corn	40.64
Wheat	24
soybean meal – hulls 48%	24
Protein Concentrate	5
Oil	4.5
Di Calcium Phosphate	0.4
Free Lime	1.1
Methionine	0.13
Lysine	0.13
Salt	0.1

1- The soybean meal used from an Argentine source, the percentage of crude protein is 48%, and 2440 kilocalories/kg represents energy.

2- The protein concentrate used is a product of a Dutch company (imported) Brocon that contains 40% crude protein, 2107 calories/kg protein represented energy, 5% crude fat, 2.20% crude fiber, 5% calcium, 2.65% phosphorous, 3.85% lysine, 3.70% methionine, 4.12% methionine + cysteine, 0.42% tryptophan, 1.70% threonine.

Feed pellet manufacturing

The grains were grinding individually, then all the components of the feed were thoroughly mixed using a mechanical mixer, a modern pellet machine of Chinese origin, to produce feed pellet was used. (Shandong Jie Siming Precision Machinery Equipment Co., Ltd. Trading Company), Specifications of the machine: Model 125, productivity 80-100 kg/h, voltage 220 volts, engine capacity 4 kW, dimensions (length * width * height) 10

* 27 * 78 cm, weight of the machine is 70 kg illustrated in figure (1). Jannasch *et al.,* (14) mentioned the necessity of adopting modern equipment to work on pilot projects.

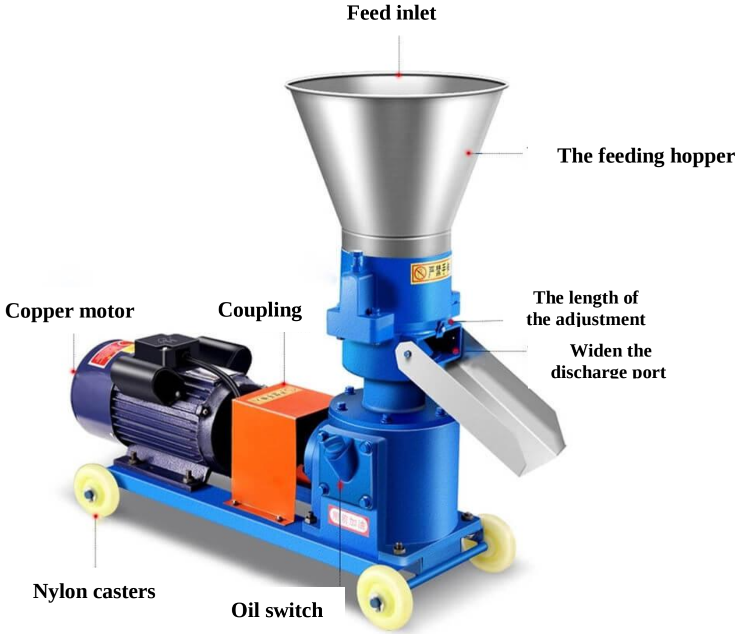

Figure (1): The pellet machine used in the experiment

The feed was steam conditioned at 60 C° for approximately 20-30 seconds. The temperature of the conditioning was measured at the outlet of the conditioner. The air temperature during the implementation of the experiment was between 0-5 C°, the feed pellet was collected immediately after they were unloaded from the forming machine, and spread on the ground for cooling using an air stream by a fan for 10 minutes to the pellet of reaching a temperature close to the surrounding temperature according to (13), where the temperature was measured by a digital infrared laser thermometer, then randomly subsamples were selected and tested. These steps were in accordance with the ASAE Standard (2) which specifies the testing of the pellet after cooling.

Data Analyses

The experimental design was a 3 × 3 factorial arrangement of treatments evaluating three speed die of the pellet machine (280, 300, and 320 rpm) and three the mill sieve holes diameter (2, 4 and 6 mm). The test parameters were arranged according to a complete randomized design (CRD) by three replications so that the number of experimental units reached 27. The differences among the treatments were tested using the least significant difference (LSD) test at the probability level of (0.05). SAS (26) available program was used to perform the statistical analysis.

1. Pellet direct measurement (%)

The Pellet direct measurement was measured by calculating the amount of intact processed pellet after removing the crumbs for each kilogram of the raw feed placed into the machine, according to the method mentioned by Muramatsu *et al.* (19).

Pellet direct measurement = weight of pellet after processed (g) / weight of raw feed placed into the machine (g)* 100 … (1)

2. Pellet Lengths (%)

The pellet lengths was measured by collecting the longest pellets in a sample of a known weight of 20 g (calculating the pellet per gram), according to the method mentioned by Winowiski (27).

3. Pellet water absorption (%)

Pellet samples of 5 g each in duplicate were placed in wire net container and immersed in 2 L beaker containing freshwater at room temperature for periods of 5 min. After each specified time period the feed samples were removed and allowed to drain for one minute followed by weighing, according to the method mentioned by Misra *et al.* (18).

Pellet Water absorption = Wet weight of pellets after immersion (g) / Dry weight of pellets before immersion (g)* 100 … (2)

4. Pellet durability by drop box device (%)

The durability of feed pellet was measured using a drop-box device by taking a sample pellet of 500 g and placing them into the device- box, provided that the box gate is tightly closed, thus enabling it to rotate on its axis through an electric motor for 10 minutes and at a fixed number of 50 rpm. Then the sample is emptied in order to be placed in a sieve whose diameters are smaller than the diameter of the pellet placed in it to be sieved according to the ASAE (1).

Durability of feed pellet (%) = Residual weight after testing (g) / Initial sample weight (g)* 100 … (3)

5. Pellet durability by air pressure device (%)

It was calculated after weighing a sample of pellet amounting to 100 g and then placing it inside the conical funnel afterward running the electric crystal for 60 seconds. Then the sample was taken and sifted in a sieve whose diameters are proportional to the diameter of the pellet placed in it according to Lowe (15), after the remainder of the Whole pellet at the top of the sieve are separated from the crumbled ones, to be weighed once, and the durability is calculated through that according to the above-mentioned equation.

Results and Discussion

1. Pellet direct measurement (%)

Table 2 shows the effect of speed of the die and the mill sieve holes diameter on the pellet direct measurement (%). The speed of die 280 and 300 rpm, with an average direct measurement of pellet 94.20 and 93.64 %, were significantly superior to the speed of 320 rpm, which gave the least direct measurement of pellet, has an average of 91.96 %. The reason for this is that increasing the speed of die leads to a faster speed of its projecting in the form of pellet, with exposure to pressure and heat for a shorter period of time, to come out with less durability, and this result is consistent with what was shown by Rokey *et al.* (23).

It is also obvious from Table 2 that the mill sieve holes diameter did not significantly effect on the pellet direct measurement. The reason for this is due to the fact that the direct measurement does not take into account what happens to the pellet after handling with mechanical conveyors. This is consistent with what was mentioned by Reimer (22).

Table 2. Effect of speed of the die and mill sieve holes diameter on the Pellet direct measurement (%)

Die speed (rpm)	Mill sieve holes diameter (mm)			Mean effect of die speed
	2	4	6	
280	94.66 a	94.15 a	93.80 ab	94.20 A
300	93.96 ab	93.64 abc	93.33 abcd	93.64 A
320	92.37 bcd	91.94 cd	91.57 d	91.96 B
Mean effect of sieve holes diameter	93.66 A	93.24 A	92.90 A	
L.S.D. 0.05				
Die speed: 0.77	Sieve holes diameter: N.S		Interaction: 1.76	

* L.S.D is the least significant difference at the 5% level.
* The different letters within the same column indicate that there are significant differences between the treatments at the probability level of (P<0.05).
* N.S: There are no significant differences within the same column.

From the same table, it is clear that the interaction effect of speed of the die and the mill sieve holes diameter had a significant effect on the pellet direct measurement. The highest pellet direct measurement was 94.66 % with a speed of 280 rpm and a holes diameter of 2 mm, whereas the least pellet direct measurement was 91.57 % with the speed of 320 and a holes diameter of 6 mm.

2. Pellet lengths (%)

Table 3 shows the effect of speed of the die and the mill sieve holes diameter on the pellet lengths (%). whereby it turns out that the speed of the die did not significantly affect the pellet lengths, whereas the mill sieve holes diameter had a significant effect on the pellet lengths. increasing the diameter of the mill sieve holes from 2 to 4 then to 6 mm, The average pellet length decreased from 85.61 to 84.34 then to 83.24%. The reason for this is due to the large size of the particles with the increase the mill sieve holes diameter moreover the lack of adhesion of the particles to each other, which results in reducing the cohesion of the components of the pellet due to the increase in the pores that give less the pellet durability, thus increasing the rates of crumbling, and this result is consistent with what was mentioned by Kaddour (11).

Table 3. Effect of speed of the die and mill sieve holes diameter on the pellet lengths (%)

Die speed (rpm)	Mill sieve holes diameter (mm)			Mean effect of die speed
	2	4	6	
280	85.94 a	84.71 abcd	83.57 cd	84.74 A
300	85.62 ab	84.28 abcd	83.22 d	84.37 A
320	85.27 abc	84.04 bcd	82.95 d	84.08 A
Mean effect of sieve holes diameter	85.61 A	84.34 B	83.24 C	
L.S.D. 0.05				
Die speed: N.S	Sieve holes diameter: 0.81		Interaction:1.78	

It was also noted that the interaction between the speed of the die and the mill sieve holes diameter had a significant effect on the pellet lengths. The highest durability of the pellet was recorded 85.94% with the speed of 280 rpm and the holes diameter of 2 mm, whereas the lowest durability of the pellet reached 82.95 with the speed of 320 and the holes diameters 6 mm.

3. Pellet Water Absorption (%)

Table 4 shows the effect of the speed of the die and the mill sieve holes diameter on the pellet water absorption (%), as the increase in the speed of the die from 280 to 300 then to 320 rpm, led to a significant increase in the pellet water absorption from 40.44 to 40.80 then to 40.96%. The reason for this may be attributed to the decrease in the pressure applied to the components of the feed with an increase in the speed of the die, which leads to an increase in their pellet water absorption. These results are consistent with what was mentioned by Rolfe *et al.* (24).Table 4, indicates that the increase in the mill sieve holes diameter from 2 to 4 then to 6 mm, led to a significant increase in the pellet water absorption from 39.37 to 40.84 then to 44.02%. The reason for this is due to the increase in the surface area of the feed particles exposed to the effect of moisture and heat in a short time, thus decreasing the cohesion between all the parts of these particles, resulting in increasing the water absorption of the pellet. This result is in agreement with Gao *et al.* (10).

Table 4. Effect of speed of the die and mill sieve holes diameter on pellet water absorption (%)

Die speed (rpm)	Grinding sieve diameter (mm)			Mean effect of die speed
	2	4	6	
280	38.98 c	40.55 abc	41.77 ab	40.44 B
300	39.43 c	40.93 abc	42.03 a	40.80 AB
320	39.70 bc	41.05 abc	42.15 a	40.96 A
Mean effect of sieve holes diameter	39.37 C	40.84 B	44.02 A	

L.S.D. 0.05

Die speed: 0.44 Sieve holes diameter: 0.44 Interaction :2.09

It was obvious from Table 4 that there was a significant effect of the interaction between the speed of the die and the mill sieve holes diameter on the pellet water absorption. The highest pellet water absorption was recorded at 42.15% with speed of 320 rpm and holes diameter of 6 mm, whereas the lowest pellet water absorption of reached 38.98% with the speed of 280 and holes diameters of 2 mm.

4. Pellet durability by drop box device (%)

Table 5 shows the effect of speed of the die and the mill sieve holes diameter on the pellet durability by the drop box device (%), increasing the speed of the die from 280 to 300 then to 320 rpm, led to a significant decrease in the pellet durability from 91.62 to 89.64 then to 88.92%. The reason for this is due to a decrease in the pressure applied to the components of the feed, accompanied by an increase in the speed of the die, which leads to a decrease in its durability. These results are consistent with what was mentioned by Baker (9). Table 5, shows increasing the mill sieve holes diameter from 2 to 4 then to 6 mm also led to a significant decrease in the pellet durability from 91.37 to 90.27 then to 88.55%. The reason for this is due to the decrease in the surface area of the feed pellet exposed to the effect of moisture and heat during the forming process, thus reducing the cohesion force between the parts of the particles that come out from the diameters of the forming disc in the form of pellet, thus reducing the pellet durability. This result is in agreement with that reported by Al-Juboory and Abbas (3).

Table 5. Effect of speed of the die and mill sieve holes diameter on the feed pellet durability by drop box device (%)

Die speed (rpm)	Mill sieve holes diameter (mm)			Mean effect of die speed
	2	4	6	
280	93.42 a	92.27 ab	89.16 cde	91.62 A
300	90.66 bc	89.60 cd	88.68 de	89.64 B
320	90.03 cd	88.94 de	87.80 e	88.92 C
Mean effect of sieve holes diameter	A 91.37	B 90.27	C 88.55	

L.S.D. 0.05

Die speed: 0.41 Sieve holes diameter: 0.41 Interaction:1.64

Table 5, also shows the interaction between the effect of speed of the die and the mill sieve holes diameter, had a significant effect on the pellet durability. The highest durability of the pellet was recorded at 93.42% with the speed of 280 rpm and the holes diameter of 2 mm, whereas the lowest durability of the pellet reached 87.80% with the speed of 320 and the holes diameters of 6 mm.

5. Pellet durability by air pressure device (%)

Table 6 shows the effect of the speed of the die and the mill sieve holes diameter on the durability of feed pellet (%) air pressure device, as the increase in the speed of the die from 280 to 300 then to 320 rpm, led to a significant decrease in the pellet durability from 89.91 to 87.78 then to 86.36%. The reason for this may be attributed to the decrease in the pressure applied to the components of the feed with an increase in the speed of the die, which leads to a decrease in their durability.

These results are consistent with what was mentioned by Baker (9). Table 6, indicates that the increase in the mill sieve holes diameter from 2 to 4 then to 6 mm, led to a significant decrease in the pellet durability from 89.10 to 88.35 then to 86.60%. The reason for this is due to the increase in the surface area of the feed particles exposed to the effect of moisture and heat in a short time, thus increasing the cohesion between all the parts of these particles, thus reducing the percentage of expansion of these pellet emerging from the formation openings, resulting in increasing the durability of the pellet. This result is in agreement with Rolfe *et al.* (24).

Table 6. Effect of speed of the die and mill sieve holes diameter on feed pellet durability by air pressure device (%)

Die speed (rpm)	Grinding sieve diameter (mm)			Mean effect of die speed
	2	4	6	
280	91.21 [a]	90.35 [a]	88.18 [bc]	89.91 [A]
300	88.47 [b]	88.25 [b]	86.63 [cd]	87.78 [B]
320	87.63 [bcd]	86.47 [de]	84.99 [e]	86.36 [C]
Mean effect of sieve holes diameter	89.10 [A]	88.35 [A]	86.60 [B]	
L.S.D. 0.05				
Die speed: 0.80	Sieve holes diameter: 0.80		Interaction:1.54	

It was obvious from Table 6 that there was a significant effect of the interaction between the speed of the die and the mill sieve holes diameter on the pellet durability. The highest pellet durability was recorded at 91.21% with speed of 280 rpm and holes diameter of 2 mm, whereas the lowest pellet durability of reached 84.99% with the speed of 320 and holes diameters of 6 mm.

Conclusion

Increasing the speed of the die led to a decrease in the pellet durability by direct measurement, drop box device and air pressure device, pellet water absorption increased, whereas it did not significantly affect the pellet lengths. Increasing the mill sieve holes diameter led to a decrease in the pellet durability, the pellet lengths, the drop box device and the air pressure device, pellet water absorption increased, whereas it did not significantly affect the direct measurement of the pellet. The minimum die speed and the minimum mill sieve holes diameter gave the highest pellet durability with all the considered indicators.

Conflict of interest

The authors have no conflict of interest.

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