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EFFECT OF PARTICLE SIZE AND DIE HOLES DIAMETER IN THE MACHINE ON BROILER FEED PELLETS QUALITY

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ABSTRACT

Due to the need for controlling and regulating of feed pellet. Pellet that is imported or locally manufactured is accompanied by cracking and crumbling percentage that occur during transporting and distributing to animals, using conveyors and mechanical feeders. This study aimed to determine the effect of particle size and die holes diameter in the machine on broiler feed pellets quality in pellet durability, pellet direct measurement, pellet expansion, and pellet length. Three particle size 2, 4, and 6 mm, and three diameters of die holes in the machine 3, 4, and 5 mm, have been used. The results showed that changing the particle size from 2 to 4 then to 6 mm led to a significant decrease in pellet durability and pellet lengths, pellet expansion was increased, whereas it did not significantly effect on pellet direct measurement. Increasing the die holes diameter from 3 to 4 to 5 mm led to a significant decrease in pellet durability, pellet direct measurement and pellet lengths, increased pellet expansion. The particle size of the diet 2 mm and die holes diameter of 3 mm recorded the highest pellet durability at 93.40%, pellet direct measurement at 95.12%, pellet lengths at 86.96%, and less pellet expansion at 0.88%. The minimum particle size and die holes diameter gave the highest pellet durability, pellet direct measurement, pellet lengths, and lowest pellet expansion with all the considered indicators.

Keywords: Particle size, Pellet durability, pellet expansion, pellets quality, pellet lengths.

تأثير حجم الدقائق وقطر ثقوب القالب في الآلة على نوعية الحبيبات العلفية لدجاج اللحم

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الخلاصة

بسبب الحاجة للتحكم وتنظيم الحبيبات العلفية المستوردة أو المصنعة محلياً المصحوبة بنسبة تكسير وتفتت تحدث أثناء النقل والتوزيع على الحيوانات باستخدام النواقل والمغذيات الميكانيكية. هدفت هذه الدراسة إلى بيان تأثير حجم الدقائق وقطر الثقوب في الآلة على نوعية حبيبات علف دجاج اللحم في متانة الحبيبات العلفية، القياس المباشر للحبيبات، تمدد الحبيبات وأطوال الحبيبات. تم استخدام ثلاثة احجام للدقائق 2 ، 4 و 6 ملم ، وثلاثة أقطار من ثقوب القالب في الآلة 3 ، 4 و 5 ملم. أظهرت النتائج أن تغيير حجم الدقائق من 2 إلى 4 ثم إلى 6 ملم أدى إلى انخفاض معنوي في متانة الحبيبات وأطوال الحبيبات وزيادة تمدد الحبيبات، بينما لم يكن لها تأثير معنوي على القياس المباشر للحبيبات. أدت زيادة قطر ثقوب القوالب من 3 إلى 4 ثم إلى 5 ملم إلى انخفاض معنوي في متانة الحبيبات وقياس الحبيبات المباشر وأطوال الحبيبات وزيادة تمدد الحبيبات. سجل حجم دقائق العليقة 2 ملم وقطر ثقوب القالب في الآلة 3 ملم أعلى متانة للحبيبات

93.40%، وقياس الحبيبات المباشر 95.12%، وأطوال الحبيبات 86.96%، وأقل تمدد للحبيبات 0.88%. أعطى الحد الأدنى لحجم الدقائق وقطر ثقوب القالب في الآلة أعلى متانة للحبيبات والقياس المباشر للحبيبات وأطوال الحبيبات، وأقل تمدد للحبيبات مع جميع المؤشرات المدروسة.
الكلمات المفتاحية: حجم الدقائق، متانة الحبيبات العلفية، تمدد الحبيبات العلفية، نوعية الحبيبات العلفية، اطوال الحبيبات العلفية.

INTRODUCTION

The pelleting operation is one of the most expensive processes. For this reason, process of pellet production is aimed to should a high quality of pellet of dust free and resistant to fragmentation **(Muramatsu *et al*., 2015).** The physical feed form has a beneficial effect on broiler performance; it reduces feed waste and energy waste during feed intake **(AL-Tamemy *et al.,* 2021)**. Feed is 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 **(Al-Hachami *et al.,* 2022)**. Poultry is one of the primary sources of income in agricultural production and is associated with many other industries, including the animal feed industry **(Mansour & Elsebaei, 2020)**. Broilers are an important source of protein and a good source of income in countries that suffer from a lack of food because it is high growth rate compared to the rest of the animals in addition to the speed of the capital cycle, therefore, researchers tended to use some techniques to improve production **(Al-Hatheel & Ibrahim, 2020)**. It mainly used broiler for meat consumption only **(Shnain & Ezzat, 2022)**. As modern technology provides new feeding methods to closely suit the nutritional needs of poultry, thus reducing the cost of feed **(Aljebory & Naji, 2021)**.

The improvement in the means of measuring the quality of pellets can contribute significantly to the growth of this industry because of the positive results gained out of the commercial handling of these pellets after their production, transportation, and during the presentation to poultry, as measuring the physical quality of feed pellet can significantly help to produce strong pellet after organizing operations Production (**Salas-Bringas *et al.,* 2007**). According to **Muramatsu *et al.* (2016)** feed particle size and other factors, such as heat treatment, affect pellet physicochemical properties. The exposure of the feed to pressure for a shorter period inside the machine, along with an increase in the diameter of the forming perforation, leads to an acceleration of its exit, which results in a lack of tightness of the cohesion of its components that resulted in a decrease in the durability of the manufactured pellet (**Oduntan *et al.,* 2012**).

Defined **Dozier (2001)** durability as the amount of the whole pellet relative to the crumbled one constituted, after mechanical or pneumatic friction. The pellet durability index is one of the leading indicators used to determine the pellets quality indicating the percentage of pellets 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 **(Lowe, 2005)**. Measuring the crumbling immediately after the pellet leaves the machine can indicate the quality of pellets for poultry feed. In a study conducted on broiler chicken feed, the durability of a pellet was measured by the amount of intact pellet per kilogram of total feed **(Muramatsu *et al.,* 2013)**.

Indicated **Evans (2019)** that pellet lengths represent a method for quality control, longer pellets indicates greater durability and lower crumbling. Also, the pellet lengths can indicate rougher handling in the handling system. **Rolfe *et al.* (2000)** showed that among the factors affecting the expansion of feed pellets, the particle size of the diet components. The research aims to study the effect of particle size and die holes diameter in the machine on broiler feed pellets quality.

MATERIALS AND METHODS

1. Experimental Procedure

The experiment was conducted in the feed lab of the animal production department, college of agricultural engineering sciences, University of Baghdad, from 9/12/2021 to 19/1/2023.

2. Diets

Feed pellets 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 (NRC, 1994). Its components were purchased from the local market, and it included many feed materials in the proportions specified in Table (1):

Table (1): Composition and calculated analysis of the diet

Components	(%)
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 (CP 19.7%, En 3206 Kcal/kg,meth+cys 0.91, Lys 1.18%, Ca 0.85 and P 0.42%), 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.

3. Feed pellet manufacturing

The grains were grinding individually. Then all the feed components were thoroughly mixed using a mechanical mixer, a modern machine of Chinese origin, to produce a feed pellet. (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, the machine weight is 70 kg. (**Jannasch & Samson, 2003)** mentioned the necessity of adopting modern equipment to work on pilot projects.

The feed was steam conditioned at 60 C_o 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 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 (**Idan *et al.*, 2020).** Where a digital infrared laser thermometer measured the temperature, random subsamples were selected and tested. These steps were by the **(ASAE, 1997)**, which specifies the testing of the pellet after cooling.

4. Data Analysis

The experimental design was 3 * 3 factorial arrangement of treatments evaluating three particle size of mill sieve holes diameter (2, 4, and 6 mm) and three die holes diameter (3, 4 and 5 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, 2009)** available program was used for statistical analysis.

3 mm 4 mm 5 mm

Figure (1): Feed pellets manufactured in the experiment

Pellet durability

The durability of the 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 to be placed in a sieve whose diameters are smaller than the diameter of the pellet placed in it to be sieved according to **ASAE(2007)**.

Pellet durability = Residual weight after testing (g) / Initial sample weight (g)* 100… (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, measured according to the **Muramatsu *et al.* (2013)**.

Pellet direct measurement = weight of pellet after processed (g) / weight of raw feed placed into the machine (g)* 100 … (2)

Pellet expansion

It represents the change in the diameter of the produced feed pellets to the diameter of the holes die in the machine. It was calculated using the Micrometer device to measure material diameters according to the method of (Misra et al., 2002) and by applying the following equation:

Pellet expansion $= (D_{pellet})^2 / (D_{die})^2 - 1 * 100$ … (3)

Where, D_{pellet}= pellet diameter (mm), D_{die}= die diameter (mm).

Pellet lengths

The pellet lengths were 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 (1995)**.

RESULTS AND DISCUSSION

1. Pellet Durability

Table 2 shows the effect of particle size and die holes diameter in the machine on pellet durability (%). Changing the particle size from 2 to 4 then to 6 mm, led to a significant decrease in the pellet durability from 91.37 to 90.27 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 **Rolfe *et al.* (2000)**. Table 2 shows increasing the die holes diameter from 3 to 4 then to 5 mm also led to a significant decrease in the pellet durability from 92.06 to 89.87 to 88.25%. The reason is the exposure of the feed to pressure for a shorter period inside the machine, along with an increase in the diameter of the forming perforation, which leads to an acceleration of its exit, which results in a lack of tightness of the cohesion of its components, which resulted in a decrease in the durability of the manufactured pellet, this is consistent with the study conducted by **Abbas (2018)**.

Table (2): Effect of particle size and die holes diameter in the machine on pellet durability (%)

Particle size (mm)	Die holes diameter (mm)			Mean effect of particle size
	3	4	5	
2	93.40 [a]	91.35 [bc]	89.36 [de]	91.37 [A]
4	92.26 [ab]	90.06 [cd]	88.48 [e]	90.27 [B]
6	90.51 [cd]	88.21 [ef]	86.92 [f]	88.55 [C]
Mean effect of die holes diameter	[A] 92.06	[B] 89.87	[C] 88.25	
L.S.D. 0.05				
Particle size: 0.41	Die holes diameter: 0.41	Interaction:1.34		

* 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 0.05.

(Table, 2) also shows the interaction between the effect of the particle size and the die holes diameter, which significantly affected pellet durability. The highest durability of the pellet was recorded at 93.40% with the particle size of 2 mm and the die holes diameter of 3 mm, whereas the lowest durability of the pellet reached 86.92% with a particle size of 6 mm and a die holes diameters of 5 mm.

2. Pellet direct measurement

(Table, 3) shows the effect of particle size and dies holes diameter in the machine on direct pellet measurement (%). It is obvious that the particle size 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. It is also obvious from Table 3 that the increasing the die holes diameter from 3 to 4 than to 5 mm, led to a significant decrease in the pellet direct measurement from 94.54 to 93.46 then to 91.80%. The reason for this is that increasing the die holes diameter leads to a faster speed of its projecting in the form of a pellet, with exposure to pressure and heat for a shorter period of time, to come out with less durability. This result is consistent with what was shown by **Rokey (2002)**.

Table (3): Effect of particle size and die holes diameter in the machine on pellet direct measurement (%)

Particle size (mm)	Die holes diameter (mm)			Mean effect of particle size
	3	4	5	
2	95.12 [a]	93.61 [abc]	92.26 [cde]	93.66 [A]
4	94.37 [ab]	93.47 [abcd]	91.87 [de]	93.24 [A]
6	94.12 [ab]	93. 30 [bcd]	91.28 [e]	92.90 [A]
Mean effect of die holes diameter	[A] 94.54	[B] 93.46	[C] 91.80	
L.S.D. 0.05				
Particle size: N.S	Die holes diameter: 0.77	Interaction:1.65		

* N.S: There are no significant differences within the same column.

From the same table, it is clear that the interaction effect of the particle size and die holes diameter significant affectly the pellet direct measurement, The highest pellet direct measurement was 95.12 %, with a particle size of 2 mm and a die holes diameter of 3 mm, whereas the least pellet direct measurement was 91.28 %, with a particle size of 6 mm and a die holes diameter of 5 mm.

3. Pellet expansion

(Table, 4) shows the effect of the particle size and die holes diameter in the machine on pellet expansion (%). as the changing in the particle size from 2 to 4 than to 6 mm, led to a significant increase in the pellet expansion from 1.11 to 1.30 then to 1.58 %. The reason for this may be density the density of the pellets with increasing the particle size of the diet, thus increasing the expansion of the pellets after them from the die holes. The results are consistent with the results of **Rolfe *et al.* (2000)**. It is also obvious from table 4, indicates that the increase in the die holes diameter from 3 to 4 then to 5 mm, led to a significant increase in the pellet expansion from 1.12 to 1.28 than to 1.59%. 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 expansion of the pellet. This result is in agreement with **Rolfe *et al.* (2000)**.

Table (4): Effect of speed and die holes diameter in machine on pellet expansion (%)**.**

Particle size (mm)	Die holes diameter (mm)			Mean effect of particle size
	3	4	5	
2	0.88 [c]	1.07 [bc]	1.38 [abc]	1.11 [B]
4	1.08 [bc]	1.28 [abc]	1.56 [ab]	1.30 [AB]
6	1.40 [abc]	1.51 [ab]	1.82 [a]	1.58 [A]
Mean effect of die holes diameter	1.12 [A]	1.28 [AB]	1.59 [A]	
L.S.D. 0.05				
Particle size: 0.34	Die holes diameter: 0.34	Interaction:0.60		

It was apparent from Table 5 that the interaction between the particle size and a die holes diameter significantly affect the pellet expansion. The highest pellet expansion was recorded at 1.82% with particle size of 6 mm and die holes diameter of 5 mm, whereas the lowest pellet expansion reached 0.88% with particle size of 2 mm and holes diameters of 3 mm.

4. Pellet lengths

(Table, 5) shows the effect of particle size and die holes diameter in the machine on the pellet lengths (%). whereby it turns out that the changing of particle size from 2 to 4 then to 6 mm, led to a significant decrease in the pellet lengths from 85.61 to 84.34 than 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 (2003)**. It is also obvious from table 5, increasing the die holes diameter from 3 to 4 then to 5 mm, had a significant effect on the pellet lengths, the average pellet length decreased from 85.83 to 84.12 then to 83.25%. The reason for this is due to the large pores between the particles with the increased die 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 increased in the pores that give less the pellet lengths, thus increasing the rates of crumbling. This result is consistent with what was mentioned by **Kaddour (2003)**.

Table (5): Effect of particle size and die holes diameter in the machine on pellet lengths (%)

Particle size (mm)	Die holes diameter (mm)			Mean effect of particle size
	3	4	5	
2	86.96 ^{a}	85.26 ^{bc}	84.60 ^{bc}	85.61 ^{A}
4	85.99 ^{ab}	84.00 ^{cd}	83.03 ^{de}	84.34 ^{B}
6	84.55 ^{bc}	83.08 ^{de}	82.10 ^{e}	83.24 ^{C}
Mean effect of die holes diameter	85.83 ^{A}	84.12 ^{B}	83.25 ^{C}	
L.S.D. 0.05				
Particle size: 0.81	Die holes diameter: 0.81	Interaction:1.44		

* N.S: There are no significant differences within the same column.

It was also noted that the interaction between the particle size and the die holes diameter had a significant effect on the pellet lengths. The highest length of the pellet were recorded 86.96% with a particle size of 2 mm and a die holes diameter of 3 mm, whereas the lowest lengths of the pellet reached 82.10% with the particle size of 6 mm and the die holes diameter 5 mm.

CONCLUSIONS

This study measured pellet durability (%), pellet direct measurement (%), pellet expansion (%), and pellet length (%). Three particle size 2, 4, and 6 mm, and three diameters of die holes in the machine 3, 4, and 5 mm, have been used. The results showed that changing the particle size from 2 to 4 then to 6 mm led to a significant decrease in pellet durability and pellet lengths, pellet expansion was increased, whereas it did not significantly effect on pellet direct measurement. Increasing the die holes diameter from 3 to 4 to 5 mm led to a significant decrease in pellet durability, pellet direct measurement and pellet lengths, increased pellet expansion. The particle size of the diet 2 mm and die holes diameter of 3 mm recorded the highest pellet durability at 93.40%, pellet direct measurement at 95.12%, pellet lengths at 86.96%, and less pellet expansion at 0.88%. The minimum particle size and die holes diameter gave the highest pellet durability, pellet direct measurement, pellet lengths, and lowest pellet expansion with all the considered indicators.

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