Effect of Mash Particle Size and Die Speed on Machine Performance and Pellet Durability for Broiler Chickens

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Abstract. The aim of this study was to investigate the effects of mash particle size and die speeds on the performance of machine and pellet quality for broiler chickens. Machine productivity (kgh^{-1}), power consumption (kW), specific energy consumption (kwh kg^{-1}), pelleting efficiency (%), pellet durability (%) and operating cost ($/h), were studied. The experiment consisted of a factorial arrangement of three mash particle sizes (2, 4, and 6 mm), with three die speeds (280, 300, and 320 rpm). Results showed that varying the mash particle size from 2 to 6 mm resulted in a significant increase ($P < 0.05$) in machine productivity, while power consumption, specific energy consumption, pelleting efficiency, pellet durability and operating cost significantly ($P < 0.05$) decreased. By increasing the die speed from 280 to 320 rpm, the machine productivity significantly increased ($P < 0.05$), while power consumption, specific energy consumption, pelleting efficiency, pellet durability and operating cost significantly decreased ($P < 0.05$). The highest machine productivity of 86.01 $kg.h^{-1}$ and the lowest power consumption, of 2.65 kW, specific energy consumption 0.029 kwh kg^{-1}, operating cost 1.29 $/h was achieved with a mash particle size of 6 mm and a die speed of 320 rpm. Meanwhile, the highest pelleting efficiency of 92.92 % and pellet durability of 91.87% were recorded with a mash particle size of 2 mm and a die speed of 280 rpm. It was concluded that the mash particle size and die speeds significantly impact machine performance and pellet quality.

Keywords. Machine productivity, Power consumption, Pelleting efficiency, Pellet durability.

1. Introduction

Pelletizing is the most widely used processing method in the poultry feed manufacturing industry. Pelleting is done with the intention of condensing tiny feed particles into larger particles by pressing them through small holes to increase feed consumption by poultry and other livestock [1,2]. During production, storage, and transportation, it is common for pelleted diets to get damaged [3]. Pellet quality is defined as the ability to resist abrasion and fragmentation and the ability to avoid fines during production and transportation. Therefore, it is crucial to assess the quality of pelleted feed to

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improve poultry productivity [4,5]. Poultry is regarded as a basic food for humans, due to its higher vitamin and protein content, over other nutritional products and short life cycle [6].

Improving the physical feed form into pellets enhances broiler performance by reducing feed wastage and minimizing energy loss during feed intake [7]. Pelleted feed is generally easier for birds to consume compared to mash feed, which can lead to an increased feed intake [8]. Additionally, various factors influence the physical quality of pelleted feed, including particle size and the specific characteristics of the machine die [9].

Research indicates that further studies are required to determine the factors that positively or negatively affect the pellet formation process and to develop new strategies for improving the physical quality of pellets [10]. Wilson [11] asserts that factors such as die speed, die hole diameter, and the fineness of grind significantly influence pellet quality. Moreover, Baker [12] highlighted the importance of die speed as a key operating parameter that is correlated to die hole diameter. It is important to note that die speed plays a pivotal role in regulating the interaction between temperature and humidity, both of which are essential determinants of pellet quality.

According to [13] production efficiency in the feed industry is an important metric for evaluating the effectiveness of pellet machines, and this is significantly impacted by the stability of the pellet forming process. Evans et al. [14] demonstrated that increasing the rotational speed of pellet machine die enhanced output while lowering the buildup of steam-conditioned feed in front of the rollers and die. Energy and fuel are consumed by agricultural machinery throughout production, and as the need for food production rises, so does the amount of energy used in agriculture [15,16]. [17] Opined that as the speed of the die increased, the energy requirements decreased. According to [14; 18] increasing the speed of the die leads to increasing the productivity of the machine. Machine productivity is defined as the ratio of the quantity of pellets produced to the time required by the machine to manufacture them [19].

Mash particle size plays a crucial role in the pressing process and pellet formation, as it is a key factor influencing pellet quality in the pellet-forming machine [20,21]. [22] Emphasized that modern production systems strive to enhance work quality while maintaining high efficiency. Pelletizing efficiency is used as a measure to evaluate the machine's effectiveness in producing pellets [23].

[24] Opined that pellet durability is a measure of the quality of the feed pellet. He defined durability as the physical cohesion of the feed manufactured in the form of pellets with the least fine particles or broken parts of those pellet during processing or transportation. Measuring pellet durability should be the first step to correcting the production process conditions to improve the quality [25]. According to [18], machine variables like die speed have a significant impact on the durability of pellet, making it one of the most important markers of feed pellet quality. Therefore, the aim of this study was to investigate the effects of mash particle size and die speeds on the machine performance and quality of pellet for broiler chickens.

2. Materials and Methods

2.1. Duration of Experiment

The experiment was conducted from December 2021 to January 2022 in the feed mill of the Department of Animal Production at the College of Agricultural Engineering Sciences, University of Baghdad.

2.2. Diets

The experiment utilized pelleted feeds prepared from a mash diet formulated to meet the fundamental nutritional requirements of broiler chickens [26]. The ingredients were sourced from the local market and included various feed components in specified quantities (Table 1).

Table 1. Ingredients and nutrient composition of mash diet.

Ingredients	Percentage (%)	Calculated chemical composition	
Maize	40.64	Energy (Kilocalories/ kg feed)	3206
Wheat	24.00	Protein	20.1
Soybean meal - hulls 48%	24.00	Fat	7.1
Protein concentrate	5.00	Fiber	2.7

Ingredients	Percentage (%)	Calculated chemical composition	
Food oil	4.50	Methionine + cysteine	0.91
Di calcium phosphate	0.40	Lysine (%)	1.18
Limestone	1.10	Calcium (%)	0.85
Methionine	0.13	Phosphorous (%)	0.42
Lysine	0.13		
Salt	0.10		
Total	100.00		

1. Soybean meal of Argentine origin was used, with a crude protein content of 48% and an energy content of 2440 Kcal kg^{-1}.
2. Protein concentrate sourced from Brocon, a Dutch company, was utilized in this study. It contains 40% crude protein and provides 2107 Calories/kg of protein-represented energy. The composition also includes 5% crude fat, 2.20% crude fiber, 5% calcium, and 2.65% phosphorus. Additionally, it features 3.85% lysine, 3.70% methionine, 4.12% methionine + cysteine, 0.42% tryptophan, and 1.70% threonine.

2.3. Mixing of Feed

Feed ingredients were mixed using a vertical feed mixer (Electric Motor (3 Phase), 5.5 kW, Skiold, Denmark) equipped with two feeding openings, one of which is connected to the mill and the other to add oil and other supplements. The mixing process takes approximately 12 minutes according to [27].

2.4. Manufacturing of Pelleted Diets

The grains were ground and mixed in a mechanical mixer to produce pellets using a modern, Chinese-made pellet machine (Shandong Jie Siming Precision Machinery Equipment Co., Ltd. Trading Company). The machine, model 125, has the following specifications: an output of 80–100 $kg.h^{-1}$, a voltage of 220 volts, and an engine capacity of 4 kW and dimensions of 10 × 27 × 78 cm (length × width × height). It weighs 70 kg, and features die holes with a diameter of 3 mm (Figure 1).

Figure 1. The pellet machine used in the experiment.

To manufacture the pellets, the mash feed was steam-conditioned at 60°C for 20 to 30 seconds. The temperature at the conditioner's outlet was recorded, with the ambient air temperature during the experiment ranging from 0 to 5°C. Once the pellets were discharged from the machine, they were immediately collected and cooled on the ground using a fan-powered air stream for ten minutes or until their temperature approximated the surrounding air, as described by [28]. A digital infrared laser thermometer was used to measure the temperature, with subsamples randomly selected for testing. After cooling, the quality of the pellets was evaluated following the procedures outlined in the Standard [29].

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2.5. Experimental Design and Statistical Analysis

This study utilized a 3 × 3 factorial design within a completely randomized design (CRD) to evaluate the effects of three mash particle sizes (2 mm, 4 mm, and 6 mm) and three die speeds (280 rpm, 300 rpm, and 320 rpm) in the pellet machine. Each treatment was replicated three times resulting in a total of 27 experimental units. The experimental data were subjected to analysis of variance (ANOVA) using the
GLM procedure of SAS program [30]. The statistical model included the different particle sizes of mash and die speeds and their interactions. The least significant difference (L.S.D) was used to separate means when the factors or their interactions were deemed statistically significant at $P < 0.05$.

2.6. Parameters Measured

2.6.1. Machine Productivity (kg.h^{-1})

An electric digital scale, with a capacity ranging from 1 g to 40 kg, to measure the mass of pellet production (kg), each experimental unit, was used alongside a timer (minutes). A fixed collection time of 3 minutes for each experimental unit machine productivity was calculated using the equation provided by [31,32]:

$$P = W/T \tag{1}$$

Where:
P is the machine productivity (kg.h^{-1}), W is the weight of sample production (kg), and T is the pelleting time (h).

2.6.2. Power Consumption (kW)

An AC digital multi-function meter was used to measure the power consumed by the machine engine during each experimental unit. Figure (2) shows the digital screen that displays the voltage, current, and power consumed. The readings were obtained by taking a mobile phone photo of the meter screen after the machine was turned on and the production rate stabilized.

Figure 2. AC digital multi-function meter.

2.6.3. Specific Energy Consumption (kwh kg^{-1})

The specific energy consumption was calculated during pellet machine operation after determining the machine productivity and the consumed engine power, thus the specific energy consumption is calculated according to the equation provided by [15,33]:

$$S.E = P/C \tag{2}$$

Where:
$S.E$ is the specific energy consumption (kwh kg^{-1}), P is the power consumption (kw), C is the machine productivity (kg).

2.6.4. Pelleting Efficiency (%)

The ratio of the weight of the pellets to the weight of the recovered feed gives the pelletizing efficiency. Using the technique described by [23], the weight of the pellets was determined by weighing the pellets produced and then manually separated from the recovered mash feed. The mechanical damage, resulting from poor kneading during the feed pelletizing, was calculated using the following equation:

$$\eta = WP/(WR) \times 100 \quad (3)$$

Where:

η is the Pelleting efficiency (%), WP is the Weight of pellet sample (g), and WR is the Recovered weight after pelleting (g).

2.6.5. Pellet Durability (%)

Pellet durability was determined using a double-action feed pellet durability measuring device. First, a 100 g sample of pellets was weighed using a digital scale, then the pellets were placed in the device's cylinder and securely tightened. The device was set to rotate at the designated speed for ten minutes. Afterward, the sample was released and reweighed to calculate durability using the method described by [34] and the following equation:

$$\text{Pellet Durability (\%)} = (\text{Remained weight after testing (g)})/(\text{Initial sample weight (g)}) \times 100 \quad (4)$$

2.6.6. Operating Cost ($/h)

Operating cost was calculated according to the equation given by [35; 36], in the following equation:

$$C = P/h \ (1/a + i/2 + t + r) + W.e + m/144 \quad (5)$$

Where:

C is the Operating cost ($/h), P is price of machine ($), h is Yearly working hours (h), a is life expectancy of the machine / year, i is Interest rate / year, t is taxes and over heads ratio (%), r is repairs and maintenance ratio (%), W is power of motor (kW), e is hourly cost (kW.h), m is the monthly average wage ($), 144 is The monthly average working hours.

3. Results and Discussion

3.1. Machine Productivity (kg.h^{-1})

Table 2 shows the effect of mash particle size and die speed on pellet machine productivity (kg.h^{-1}). Increasing the mash particle size from 2 mm to 4 mm and then to 6 mm resulted in a significant rise ($P < 0.05$) in machine productivity, from 80.45 kg.h^{-1} to 82.36 kg.h^{-1} and finally to 83.67 kg.h^{-1}. This increase is attributed to the widening of the pores within the pellet structure due to the larger mash particle size, resulting in lower durability and density, which allows the pellets to exit the die holes more quickly. This result is consistent with those obtained by [37], which showed that the productivity of the pellet machine decreases as the mash particle size decreases. It is also obvious from the results obtained that the die speed had a significant effect on the machine productivity, with an increase in the speed of die from 280 to 300 and 320 rpm, resulting in a significant increase ($P < 0.05$) in the machine productivity from 80.05 kg.h^{-1} to 81.78 kg.h^{-1} and finally to 84.65 kg.h^{-1}. This improvement is due to the higher quantity of pellets exiting the die holes per unit of time as die speed increases, thereby enhancing overall machine productivity. Additionally, the result obtained in the current study is consistent with what [14,31] found, that increasing the die speed in the machine was accompanied by an increase in the machine productivity.

Table 2. Effect of mash particle size and die speed on machine productivity (kg.h^{-1}).

Mash particle size (mm)	Die speed (rpm)			Main effects of mash particle size (mm)
	280	300	320	
2	78.45 ^{e}	80.28 ^{de}	82.63 ^{bcd}	80.45 ^{B}
4	80.20 ^{de}	81.58 ^{cd}	85.32 ^{ab}	82.36 ^{A}
6	81.50 ^{cd}	83.50 ^{abc}	86.01 ^{a}	83.67 ^{A}
Main effects of die speed	80.05 ^{C}	81.78 ^{B}	84.65 ^{A}	

Mash particle size (mm)	Die speed (rpm)			Main effects of mash particle size (mm)
	280	300	320	
LSD at 0.05				
2.84 :Interaction		1.64 Die speed:		1.64 Mash particle size:

* LSD: Least significant difference at probability level of 0.05.
* Means in a row that have different superscripts are significantly different at 0.05 probability level.

The interaction effect of mash particle size and die speed had no significant effect on the machine productivity as shown in Table 2. The highest pellet machine productivity was 86.01 kg.h^{-1} with a mash particle size of 6 mm and die speed of 320 rpm, whereas the least pellet machine productivity was 78.45 kg.h^{-1} with a mash particle size of 2 mm and die speed of 280 rpm.

3.2. Power Consumption (kW)

The effect of the mash particle size and die speed on the power consumption (kW) is shown in Table 3. From the results obtained, changing the mash particle size from 2 to 4 and to 6 mm, caused a significant decrease ($P < 0.05$) in the power consumption from 3.96 to 3.58 and to 3.09 kW. This can be attributed to the low durability and density of the pellets, resulting from the increased particle sizes of feed components combined with the reduced mash particle size. These results are consistent with those reported by [36] on the effect of particle size of mash on energy consumption during the pelleting process, indicating that energy consumption was significantly affected by the change in particle size of mash. Furthermore, the results obtained by [39] in terms of the effects of energy consumption during the pelleting process and changes in particle size of mash on pellet durability and density aligns with the findings of the current study.

Furthermore, Table 3 clearly demonstrates that die speed has a significant effect on power consumption. From the results obtained, increasing the die speed from 280 to 300 and then to 320 rpm resulted in a notable decrease ($P < 0.05$) in power consumption, from 4.31 kW to 3.26 kW and finally to 3.06 kW. This reduction can be attributed to the die's influence on the duration feed remains in the machine during pelleting, which reduces feed accumulation in front of the die and rollers while increasing output. This explains why, when die speed increases, more pellets are released from the die holes in each amount of time, reducing the strain on the engine. This result is consistent with the findings of [14; 18], who explained that the basic energy requirements for forming pellets depend on productivity and are affected by some different operating factors such as the rotation die speed which leads to a decrease in energy requirements with increasing die speed.

Table 3. Effect of mash particle size and die speed on power consumption (kW).

Mash particle size (mm)	Die speed (rpm)			Main effects of mash particle size (mm)
	280	300	320	
2	4.64 ^{a}	3.71 ^{d}	3.53 ^{e}	3.96 ^{A}
4	4.42 ^{b}	3.33 ^{f}	3.01 ^{g}	3.58 ^{B}
6	3.88 ^{c}	2.74 ^{h}	2.65 ^{i}	3.09 ^{C}
Main effects of die speed	4.31 ^{A}	3.26 ^{B}	3. 06 ^{C}	
LSD at 0.05				
0.04 :Interaction		0.02 Die speed:		0.02 Mash particle size:

Interaction between the mash particle size and the die speed significantly affected power consumption as presented in Table 3. The lowest power consumption was recorded at 2.56 kW with the mash particle size of 6 mm and die speed of 320 rpm, whereas the highest power consumption reached 4.64 kW with the mash particle size of 2 mm and the die speed of 280 rpm.

3.3. Specific Energy Consumption (kwh kg^{-1})

The effect of the mash particle size and die speed on the specific energy consumption (kwh kg^{-1}) is shown in Table 4. From the results obtained, changing the mash particle size from 2 to 4 and to 6 mm, caused a significant decrease ($P < 0.05$) in the specific energy consumption from 0.049 to 0.042 and to 0.036 kwh kg^{-1}. This is attributed to the widening of pores within the pellet structure as mash particle size increases, leading to lower durability and density. As a result, pellets exit the die holes more quickly, increasing machine productivity and reducing specific energy consumption due to the inverse

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relationship between productivity and specific energy use. These results are consistent with those reported by [15].

Furthermore, Table 3 clearly demonstrates that die speed has a significant effect on specific energy consumption. From the results obtained, increasing the die speed from 280 to 300 and then to 320 rpm resulted in a notable decrease ($P < 0.05$) in power consumption, from 0.051 to 0.040 and finally to 0.035 kwh kg^{-1}. This reduction can be attributed to the die's influence on the duration feed remains in the machine during pelleting, which reduces feed accumulation in front of the die and rollers while increasing output. This explains why, when die speed increases, more pellets are released from the die holes in each amount of time, reducing the strain on the engine. This result is consistent with the findings of [14,18], who explained that the basic energy requirements for forming pellets depend on productivity and are affected by some different operating factors such as the rotation die speed which leads to a decrease in energy requirements with increasing die speed.

Table 4. Effect of mash particle size and die speed on specific energy consumption (kwh kg^{-1}).

Mash particle size (mm)	**Die speed (rpm)**			**Main effects of mash particle size (mm)**
	280	**300**	**320**	
2	0.058 ^{a}	0.048 ^{bc}	0.043 ^{cd}	0.049 ^{A}
4	0.052 ^{ab}	0.040 ^{de}	0.034 ^{ef}	0.042 ^{B}
6	0.045 ^{bcd}	0.033 ^{ef}	0.029 ^{f}	0.036 ^{C}
Main effects of die speed	0.051 ^{A}	0.040 ^{B}	0.035 ^{C}	
		LSD at 0.05		
0.006 :Interaction		0.0008 Die speed:		0.0008 Mash particle size:

Interaction between the mash size of particle and the die speed had a significant effect on the specific energy consumption is noted that from Table 4. The lowest specific energy consumption was recorded at 0.029 kwh kg^{-1} with the mash particle size of 6 mm and die speed 320 rpm, whereas the highest specific energy consumption reached 0.058 kwh kg^{-1} with the mash particle size 2 mm the die speed 280 rpm.

3.4. Pelleting Efficiency (%)

The effects of mash particle size and die speed on the pelleting efficiency (%) is presented in Table 5. Changing the mash particle size from 2 to 4 and to 6 mm resulted in a significant decrease ($P < 0.05$) in the pelleting efficiency from 91.65 to 90.86 and to 90.25%. This is because finer grinding gives more durability and hardness to the pellets, as it affects the pressure and temperature inside the machine, which are affected by the mash particle size. As a result, all mash particles are subjected to uniform temperature and pressure before pelleting, enhancing the efficiency of the pelleting process which are consistent with the results by [40,41]. Furthermore, Table 5 shows that increasing the die speed from 280 to 300 and to 320 rpm led to a significant decrease ($P \leq 0.05$) in the pelleting efficiency from 91.91 to 90.78 and to 90.07%. This is attributed to a decrease in the pressure applied to the feed components as die speed increases, which in turn reduces pelleting efficiency. These results are consistent with those reported by [18].

Table 5. Effect of mash particle size and die speed on pelleting efficiency (%).

Mash particle size (mm)	**Die speed (rpm)**			**Main effects of mash particle size (mm)**
	280	**300**	**320**	
2	92.92 ^{a}	91.45 ^{ab}	91.37 ^{ab}	91.91 ^{A}
4	91.93 ^{ab}	90.76 ^{b}	90.54 ^{b}	91.08 ^{AB}
6	91.14 ^{ab}	90.34 ^{b}	90.18 ^{b}	90.55 ^{B}
Main effects of die speed	92.00 ^{A}	90.85 ^{AB}	90.70 ^{B}	
				LSD at 0.05
2.00 :Interaction		1.15 Die speed:		1.15 Mash particle size:

Also, the interaction between the effect of the mash particle size and die speed had a significant effect on pelleting efficiency as shown in Table 5. The highest pelleting efficiency was recorded at 92.92 % with mash particle size of 2 mm and die speeds of 280 rpm, whereas the lowest pelleting efficiency recorded 90.18 % with mash particle size of 6 mm and die speed of 320 rpm.

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3.5. Pellet Durability (%)

The effects of the mash particle size and the die speed on the pellet durability (%) are shown in Table 6. From the results, changing the mash particle size from 2 to 4 and to 6 mm, resulted in a significant decrease ($P \leq 0.05$) in the pellet durability from 90.27 to 88.43 and to 87.95 %. The reason can be attributed to the reduced surface area of the feed pellets exposed to moisture and heat during the pelleting process. This weakens the cohesion forces between the particle components as they exit the die in pellet form, thereby decreasing pellet durability. These findings align with those reported by [42].

Furthermore, the increase in the die speed from 280 to 300 and to 320 rpm, resulted in a significant decrease ($P \leq 0.05$) in the pellet durability from 90.51 to 88.51 and to 87.63 % as represented in (Table 6). This is attributed to variations in the duration of the pellets' exposure to pressure and heat during the pelleting process, driven by changes in the machine's die speed. Additionally, die speed is a key factor influencing both the pelleting process and the quality of the pellets produced. The results are consistent with those obtained by [43,44], who explained the expected occurrence of a weakness in the physical pellet quality with the increase in the production rate due to the reduction in the retention time of the feed material inside the conditioner, which negatively affects the rate of pressure and gelatinization of starch.

Table 6. Effect of the mash particle size and die speed on pellet durability (%).

Mash particle size (mm)	**Die speed (rpm)**			**Main effects of mash particle size (mm)**
	280	**300**	**320**	
2	91.30 ^{a}	90.18 ^{bc}	89.32 ^{d}	90.27 ^{A}
4	90.54 ^{b}	87.74 ^{e}	87.01 ^{fg}	88.43 ^{B}
6	89.69 ^{cd}	87.61 ^{ef}	86.55 ^{g}	87.95 ^{C}
Main effects of die speed	90.51 ^{A}	88.51 ^{B}	87.63 ^{C}	
		LSD at 0.05		
0.63 :Interaction		0.36 Die speed:		0.36 Mash particle size:

There was significant interaction between the mash particle size and die speed on the pellet durability as can be found in (Table 6). The highest pellet durability was recorded at 91.30 % with the mash particle size of 2 mm and die speed 280 rpm, whereas the lowest pellet durability of 86.55 % was recorded with a 6 mm mash particle size and 320 rpm die speed.

3.6. Operating Cost ($/h)

The effects of the mash particle size and the die speed on the operating cost ($/h) are shown in Table 7. From the results obtained, changing the mash particle size from 2 to 4 and to 6 mm, resulted in a significant decrease ($P \leq 0.05$) in the operating cost from 1.80 to 1.58 and to 1.43 $/h. The reason can be attributed to the reduced surface area of the feed pellets exposed to moisture and heat during the pelleting process and weakens the cohesion forces between the particle components, thereby decreasing pellet durability as they exit the die in pellet form and decrease the power consumption. These findings align with those reported by [36].

Furthermore, the increase in the die speed from 280 to 300 and to 320 rpm, resulted in a significant decrease ($P \leq 0.05$) in the operating cost from 1.79 to 1.56 and to 1.46 $/h as represented in (Table 7). This is attributed to variations in the duration of the pellets' exposure to pressure and heat during the pelleting process, driven by changes in the machine's die speed. Additionally, die speed is a key factor influencing the pelleting process and the power consumption. The result is consistent with those obtained by [36], who found the decrease of operating cost with the decrease in the power consumption, due to the reduction in the retention time of the feed material inside the die and lower motor load.

Table 7. Effect of the mash particle size and die speed on operating cost ($/h).

Mash particle size (mm)	**Die speed (rpm)**			**Main effects of mash particle size (mm)**
	280	**300**	**320**	
2	1.94 ^{a}	1.78 ^{b}	1.67 ^{c}	1.80 ^{A}
4	1.80 ^{b}	1.54 ^{e}	1.41 ^{f}	1.58 ^{B}
6	1.62 ^{d}	1.37 ^{g}	1.29 ^{h}	1.43 ^{C}
Main effects of die speed	1.79 ^{A}	1.56 ^{B}	1.46 ^{C}	

Mash particle size (mm)	Die speed (rpm)			Main effects of mash particle size (mm)
	280	300	320	
LSD at 0.05				
0.030 :Interaction	0.017 Die speed:		0.017 Mash particle size:	

There was significant interaction between the mash particle size and die speed on the operating cost as can be found in (Table 7). The lowest operating cost was recorded at 1.94 $/h with the mash particle size of 6 mm and die speed 320 rpm, whereas the highest operating cost of reached 86.55 $/h with the mash particle size of 2 mm and die speed 280 rpm.

Conclusions

The results of the study showed that changing the mash particle size from 2 to 6 mm resulted in an increase in machine productivity, while power consumption, specific energy consumption, pelleting efficiency, pellet durability and operating cost decreased. Additionally, increasing the die speeds from 280 to 320 rpm led to an increase in machine productivity, while power consumption, specific energy consumption, pelleting efficiency, pellet durability and operating cost decreased. The highest machine productivity and the least power consumption, specific energy consumption and operating cost was recorded with mash particle size of 6 mm and speed of die 320 rpm. Furthermore, the mash particle size of 2 mm and speed of die 280 rpm produced the highest pelleting efficiency and pellet durability. It was concluded that the mash particle size and die speed of the pellet machine have a significant effect on the performance of machine and the pellet quality.

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