2025 SCIENCELINE

Online Journal of Animal and Feed Research

Volume 15, Issue 6: 363-370; November 30, 2025

ISSN 2228-7701

DOI: https://dx.doi.org/10.51227/ojafr.2025.41

IMPACT OF PELLET BINDER TYPE ON THE QUALITY AND PERFORMANCE OF PELLET MILLS WITH DIFFERENT LEVELS OF OIL AND FAT POWDER

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Supporting Information

RESEARCH ARTICLE

PII: S222877012500041-15

Received: August 16, 2025

Revised: November 26, 2025

Accepted: November 28, 2025

ABSTRACT: The current study aimed to assess the effects of fat powder levels, oil levels, and two types of pellet binders, including bentonite and gum Tragacanth on the physical quality and pellet durability index (PDI) over 75 days. The experiment was conducted using a completely randomized design with a factorial arrangement. Experimental treatments included 5 to 10 kilograms of fat powder, 7 to 11 kilograms of oil, and pellet binders. The pellet binders consisted of bentonite, plant-based binders such as gum Tragacanth, and their combination. The present results indicated that using fat powder and oil levels, with pellet binders, significantly increased PDI in the starter period. The concentration and type of pellet binder were effective parameters in treatments during the experiment. Fat powder significantly improved the physical quality of the pellet on days 15, 30, 60, and 75, while oil notably improved the effects of the pellet on all days except day 0. Fat powder, oil, and pellet binder played crucial roles in determining the physical quality of pellets during the finisher period across all days. The interaction between fat powder and oil substantially affected finisher pellet quality on all days except days 15 and 45. Oil levels did not have impacts on the physical quality of the finisher pellets. Gum Tragacanth binder demonstrated the highest average physical pellet quality on days 0, 45, 60, and 75, while bentonite exhibited the best performance on days 15 and 30. The utilization of pellet binders combined with adding oil and fat powder to the diet, improve the physical qualities of the produced pellets.

Keywords: Pellet binder, Pellet durability index, Pellet hardness, Fat powder, Oil

INTRODUCTION

Pelletizing involves the process of compressing feed particles to form a solid unit into different shapes. Throughout the pelletizing process, applying the incremental pressure results in adhesion of the feed particles, thereby decreasing the void space between particles and increasing the density of the materials. Pelletizing the diet balances the protein-to-energy ratio and adjusts nutrient levels, which improves weight gain and breast meat yield by affecting feed and amino acid intake (Noll, 2002). The pellet durability index (PDI) is one of the primary parameters that assesses the physical quality of pellets. The PDI indicates the percentage of pellets that remain intact after transportation from the feed mill to poultry farms and while subjected to different mechanical forces (Mina-Boac et al, 2006; Löwe, 2007). Essentially, PDI is used to evaluate pellet abrasion and fracture into smaller particles, and the fineness of the fracture point. Pellets should be manufactured to be as robust and sturdy as possible to withstand heavy handling (Pourreza et al., 2014). Poor physical pellet quality (PPQ) results in more fine particles during feed transportation to poultry farms (Hancock, 2010). Several studies have demonstrated that increasing mixer fat level from 1 to 18.2% substantially reduces the PDI by 13%. Soybean oil and saturated fat powder, which consists of 65% palmitic acid (Acofeed), have distinct effects on PDI, indicating that each type of fat possesses unique factors influencing pellet quality (Loar et al, 2014). Increasing soybean oil levels reduces starch gelatinization (Behnke et al., 2006), while Muramatsu et al. (2014) indicated that increasing soybean oil up to a level of 3.5% results in a parabolic increase in starch gelatinization.

Moreover, utilizing pellet binders can influence pellet quality. Pellet binders are used to improve the strength, integrity, and stability of pellets, thereby preventing their breakage and abrasion during handling, transportation, and storage. There are different types of pellet binders, including colloidal binders, molasses, and fats, that have been used for many years, and their effects on PDI have been thoroughly documented (Young et al., 1962). Considering the importance of pellet quality, the impact of various factors, including the type and quantity of feed ingredients, the type and amount of fat incorporated into the mixture, the type and quantity of pellet binders, dicalcium phosphate, and processing parameters such as feed particle size, conditioner retention time, production rate, and die thickness, on the PDI has been investigated. In industrial poultry nutrition, high-fat diets are often necessary; however, increasing fat content in the diet is inversely related to pellet durability, thereby reducing pellet strength. Considering that pellets alone do not directly

Citation: Emadi M, Sephri Moghadam H, and Salehen M. (2025). Impact of pellet binder type on the quality and performance of pellet mills with different levels of oil and fat powder. *Online J. Anim. Feed Res.*, 15(6): 363-370. DOI: https://dx.doi.org/10.51227/ojafr.2025.41

influence poultry performance, the physical quality of pellets, particularly their durability index, serves as a crucial factor of animal performance and production. Numerous studies have demonstrated that the type and quantity of fat are among the primary factors influencing pellet quality. One study found that increasing the level of bentonite as a pellet binder in a diet containing 1.5% soybean oil improved pellet durability and physical quality, while increasing bentonite in a diet with 1.5% calcium fat powder only enhanced physical quality. The same study demonstrated that increasing bentonite from 1 to 2% in diets containing 3% of soybean oil and 3% of calcium fat powder was not effective in preventing a reduction in pellet durability (Abadi et al., 2019). Additionally, utilizing 1.5% of bentonite in corn-soy-based diets improved PDI and physical pellet quality during the growth period (Attar et al., 2016). Therefore, the present study aimed to investigate the effects of different levels of fat powder and oil, along with pellet binders, on the quality of pelleted feed.

MATERIALS AND METHODS

The current experiment was conducted in 2022 utilizing a completely randomized design with a 4×2×2 factorial arrangement, encompassing two types of pellet binders (Sodium bentonite, plant-based compounds such as gum Tragacanth, and a combination of both), as well as two levels of oil, 7 and 14 kg, and two levels of fat powder, 5 and 10 kg. The experimental treatments are reported in Table 1. The present study evaluated qualitative pellet indices over 75 days at the Gohar daneh Shargh Livestock and Poultry feed mill, located in Khorasan Razavi, Iran.

Feeds were produced at the mill using high-capacity equipment across three growth phases. The horizontal ribbon mixer of the mill encompasses a production capacity of up to 2500 kg. The steam pressure in the DDC (Yemuack) model conditioner boiler was configured at 6-8 bar, subsequently decreased to 2-3 bar before to entering the conditioner. Additionally, the cooking temperature for all feeds was consistently maintained at an appropriate level of 70°C. This conditioner enabled the control of temperature and feed retention time. The pellet mill used for feed production was manufactured by Feed Tech (Turkey) with a pellet diameter of 850 mm. To ensure precision in the production of experimental treatments, and considering the capacities of the mixer, conditioner, pellet mill, and cooler, a quantity of 1250 kg of feed was produced per treatment, resulting in a total of 20,000 kg. Starter and finisher diets were produced using dies with hole diameters of 2 mm and 4 mm, respectively. Pellet physical quality was determined using a hardness tester (Model K6432-0054, Kahl, Germany). To precisely evaluate the PDI (%) on days 0, 15, 30, 45, 60, and 75 post-production, four replicate samples of 1 kg each were collected from under the cooler after cooling. The samples were then transferred to the laboratory for PDI measurement. The Holmen NHP100 tester (Tekpro; Norfolk, UK) was used for durability testing. For each sample, 100 g of pellets without fines were weighed and placed in the Holmen tester. The feed was subjected to several shocks for 30, 60, 90, and 120 seconds. The resulting fines were collected and weighed, and the PDI was calculated using the following formula.

PDI (%) = (Weight of intact pellets after tumbling / Initial weight of pellets) × 100

Table 1 - Arrangement of experimental treatments

Treatment 1	7 kg oil + 5 kg fat powder
Treatment 2	7 kg oil + 10 kg fat powder
Treatment 3	14 kg oil + 5 kg fat powder
Treatment 4	14 kg oil + 10 kg fat powder
Treatment 5	1% Bentonite + 7 kg oil + 5 kg fat powder
Treatment 6	1% Bentonite + 7 kg oil + 10 kg fat powder
Treatment 7	1% Bentonite + 14 kg oil + 5 kg fat powder
Treatment 8	1% Bentonite + 14 kg oil + 10 kg fat powder
Treatment 9	1% Gum Tragacanth + 7 kg oil + 5 kg fat powder
Treatment 10	1% Gum Tragacanth + 7 kg oil + 10 kg fat powder
Treatment 11	1% Gum Tragacanth + 14 kg oil + 5 kg fat powder
Treatment 12	1% Gum Tragacanth + 14 kg oil + 10 kg fat powder
Treatment 13	1% Combination (Both) + 7 kg oil + 5 kg fat powder
Treatment 14	1% Combination (Both) + 7 kg oil + 10 kg fat powder
Treatment 15	1% Combination (Both) + 14 kg oil + 5 kg fat powder
Treatment 16	1% Combination (Both) + 14 kg oil + 10 kg fat powder

Statistical analysis

All data were analyzed using SAS software (2004, SAS 9.1, Cary, NC) with the Proc GLM procedure. Differences between treatments were examined using Tukey's test at a 5% significance level ($P < 0.05$). The statistical model used was: $Yijk = \mu + Ai + Tj + (A\times T)ij + eijk$

Yijk is the observation, μ is the overall mean for each parameter, Ai is the effect of the i, Tj is the effect of the j, i means the pellet binder type, j means the fat level, (A×T)ij is the interaction effect between the i and j, and eijk is the experimental error.

RESULTS

Pellet durability index and physical quality in the starter and finisher periods

The present results regarding the effects of two levels of oil and fat powder, along with three types of pellet binders, on the PDI in the starter period are reported in Table 2. Utilizing fat powder and oil levels in combination with pellet binders significantly increased PDI in the starter period ($P < 0.05$). The effect of the concentration and type of pellet binder significantly influenced the treatments across all experimental days, while the effect of fat powder was significant on days 0, 60, and 75 ($P < 0.05$). The interaction effect of fat powder, oil, and pellet binder was significantly influenced by the experimental treatments on days 15 and 75 ($P < 0.05$). The highest PDI concerning the effect of fat powder on days 45, 60, and 75 was linked to a level of 5 kg/ton, and for the effect of oil, the highest value on days 15, 30, and 60 was associated with a level of 7 kg. Treatments without pellet binders (control) exhibited the lowest PDI values during the starter period among all experimental groups. From day 0 to 30, incorporating pellet binders led to the highest average PDI.

Table 2 - The effects of fat and oil powder levels, along with pellet binders, on the pellet durability index in the starter period.

Main effects		Day 0	Day 15	Day 30	Day 45	Day 60	Day 75
Fat levels	5	89.66^{a}	88.4	88.15	87.96	85.84^{a}	84.64^{a}
	10	88.87^{b}	88.8	86.93	87.65	83.44^{b}	83.15^{b}
SEM		0.4	0.25	0.27	0.36	0.45	0.63
Oli levels	7	91.79^{a}	91.76^{a}	83.06^{a}	83.06^{a}	88.58^{a}	80.94
	14	86.76^{b}	85.5^{b}	80.07^{b}	80.07^{b}	80.70^{b}	77.03
SEM		0.49	0.25	0.82	0.82	0.45	0.02
Pellet binder	Control (no Pellet Binder)	87.38^{a}	87.1^{a}	86.25^{a}	84.93^{a}	83^{a}	81.94^{a}
	Bentonite	89.4^{b}	88.68^{b}	87.65^{b}	87.92^{b}	88.45^{b}	85.64^{b}
	Gum tragacanth	89.69^{b}	88.04^{b}	88.08^{b}	88.69^{bc}	84.63^{b}	84.98^{bc}
	Both	90.56^{c}	90.03^{c}	90.06^{c}	88.26^{c}	85.49^{b}	83.91^{c}
SEM		0.498	0.265	0.259	0.3	0.3	0.3
Interaction effect of fat powder + oil + pellet binder levels							
Treatment 1		90.47	89.64	89.52	87.42	87.2	85.15
Treatment 2		85.25	84.2	84.65	84.22	8345	81.97
Treatment 3		89.15	89.87	88.15	82.9	79.45	78.6
Treatment 4		84.65	84.65	82.7	85.17	81.9	82.05
Treatment 5		91.125	91.95	91.12	92.35	91.22	89.77
Treatment 6		85.42	84.6	83.92	83.17	79.7	80.05
Treatment 7		93.125	92.8	90.95	93.57	90.45	91.77
Treatment 8		88.1	85.4	84.62	82.6	80.27	80.27
Treatment 9		91.65	91.57	92.12	93.1	91.32	82.35
Treatment 10		87.4	85.4	83.75	84.92	81.05	80.8
Treatment 11		92.07	91.25	91.65	9165	87.4	87.77
Treatment 12		87.45	85.4	84.8	85.1	78.75	79.02
Treatment 13		92.6	93.17	93.15	94.12	90.97	89.6
Treatment 14		87.1	86.82	87.02	84.42	81.75	77.42
Treatment 15		94.17	93.85	93.62	93.95	90.55	89.07
Treatment 16		88.37	87.52	87.02	84.95	78.7	79.55
P value							
Effect of fat powder		0.031	0.031	0.1	0.6	0.01	0.0018
Effect of oil		0.001	0.0001	0.0001	0.0001	0.001	0.009
Effect of pellet binder		0.001	0.0001	0.0001	0.001	0.0001	0.007
Fat powder with oil		0.74	0.71	0.77	0.0006	0.3	0.6
Fat powder with binder pellet		0.011	0.01	0.52	0.0001	0.0001	0.0001
Oil with binder pellets		0.57	0.57	0.51	0.0001	0.04	0.22
Fat powder with oil and a type of pellet binder		0.92	0.9	0.9	0.001	0.0001	0.0005

Treatment 1: 7 kg oil + 5 kg fat powder; Treatment 2: 7 kg oil + 10 kg fat powder; Treatment 3: 14 kg oil + 5 kg fat powder; Treatment 4: 14 kg oil + 10 kg fat powder; Treatment 5: 1% bentonite + 7 kg oil + 5 kg fat powder; Treatment 6: 1% bentonite + 7 kg oil + 10 kg fat powder; Treatment 7: 1% bentonite + 14 kg oil + 5 kg fat powder; Treatment 8: 1% bentonite + 14 kg oil + 10 kg fat powder; Treatment 9: 1% gum Tragacanth + 7 kg oil + 5 kg fat powder; Treatment 10: 1% gum Tragacanth + 7 kg oil + 10 kg fat powder; Treatment 11: 1% gum Tragacanth + 14 kg oil + 5 kg fat powder; Treatment 12: 1% gum Tragacanth + 14 kg oil + 10 kg fat powder; Treatment 13: 1% both binders + 7 kg oil + 5 kg fat powder; Treatment 14: 1% both binders + 7 kg oil + 10 kg fat powder; Treatment 15: 1% both binders + 14 kg oil + 5 kg fat powder; Treatment 16: 1% both binders + 14 kg oil + 10 kg fat powder. In each column, values not sharing similar letters are significantly different ($P < 0.05$).

The results regarding the effects of two levels of oil and fat powder, along with three types of pellet binders, on the physical quality of pellets in the starter period are reported in Table 3. The effect of fat powder on days 15, 30, 60, and 75, and the effect of oil on all experimental days except day 0, significantly improved the physical quality of pellets ($P< 0.05$). The interaction effects of fat powder and oil on day 30 and fat powder and pellet binder on days 15 and 45 did not significantly affect physical pellet quality ($P > 0.05$). However, the three-way interaction of all factors (1% pellet binder levels, 5 and 10 kg of fat powder, and 7 and 14 kg of oil) signifycantly improved the physical quality of pellets during the starter period on all experimental days except days 15 and 30 ($P < 0.05$).

Table 3 - The effects of fat and oil powder levels, along with pellet binders, on pellet physical quality in the starter period.

Main effects		Day 0	Day 15	Day 30	Day 45	Day 60	Day 75
Fat levels	5	4.17	7.28^{a}	4.36	4.28^{a}	4.23^{a}	4.34^{a}
	10	4.18	4.22^{b}	4.32	4.19^{b}	4.05^{b}	4.12^{b}
SEM		0.0048	0.0036	0.004	0.006	0.45	0.0097
Oli levels	7	4.17	4.26	4.28^{a}	4.11^{a}	4.12^{a}	4.15^{a}
	14	4.17	4.18	4.25^{b}	4.36^{b}	4.70^{b}	4.31^{b}
SEM		0.008	0.07	0.004	0.007	0.45	0.009
Pellet binder	Control (no Pellet Binder)	4.06^{a}	4.037^{a}	4.13^{a}	4.01^{a}	3.981^{a}	3.98^{a}
	Bentonite	4.25^{b}	4.36^{b}	4.21^{b}	4.41^{b}	4.250^{b}	4.2^{b}
	Gum Tragacanth	4.025^{a}	4.16^{c}	4.2^{b}	4.25^{c}	4.100^{b}	4.1^{ab}
	Both	4.27^{b}	4.23^{b}	4.42^{c}	4.27^{c}	4.200^{b}	4.64^{c}
SEM		0.035	0.030	0.004	0.0062	0.01	0.0097
Interaction effect of fat powder + oil + pellet binder levels							
Treatment 1		3.97	3.95	4.075	4.00	4.02	4.05
Treatment 2		4.02	4.17	4.125	3.85	3.95	3.97
Treatment 3		4.32	4.20	4.350	3.95	3.95	3.97
Treatment 4		3.95	4.30	3.975	4.25	4.00	3.95
Treatment 5		4.20	4.40	4.300	4.35	4.10	4.10
Treatment 6		4.4	4.30	4.370	4.35	407	4.25
Treatment 7		4.42	4.40	4.570	4.10	4.02	3.97
Treatment 8		4.37	4.37	5.150	4.85	4.65	4.50
Treatment 9		4.17	4.25	4.300	4.02	4.22	4.35
Treatment 10		4.07	4.22	4.500	4.80	4.52	4.12
Treatment 11		4.00	4.27	4.170	4.15	4.02	3.82
Treatment 12		3.85	3.90	4.00	4.05	4.35	4.00
Treatment 13		4.25	4.55	4.250	4.20	4.25	4.35
Treatment 14		4.32	4.45	4.900	4.72	4.70	5.42
Treatment 15		4.15	4.35	4.250	4.12	4.00	4.85
Treatment 16		4.37	4.45	4.300	4.05	4.55	3.95
P value							
Effect of fat powder		0.928	0.03	0.04	0.09	0.0001	0.006
Effect of oil		0.65	0.007	0.0001	0.0001	0.0001	0.0001
Effect of pellet binder		0.001	0.0001	0.0001	0.0001	0.001	0.0001
Fat powder with oil		0.04	0.007	0.50	0.01	0.012	0.002
Fat powder with binder pellet		0.005	0.16	0.02	0.07	0.0001	0.0001
Oil with binder pellets		0.005	0.17	0.01	0.0001	0.0001	0.0001
Fat powder with oil and a type of pellet binder		0.03	0.0001	0.40	0.001	0.0004	0.006

Treatment 1: 7 kg oil + 5 kg fat powder; Treatment 2: 7 kg oil + 10 kg fat powder; Treatment 3: 14 kg oil + 5 kg fat powder; Treatment 4: 14 kg oil + 10 kg fat powder; Treatment 5: 1% bentonite + 7 kg oil + 5 kg fat powder; Treatment 6: 1% bentonite + 7 kg oil + 10 kg fat powder; Treatment 7: 1% bentonite + 14 kg oil + 5 kg fat powder; Treatment 8: 1% bentonite + 14 kg oil + 10 kg fat powder; Treatment 9: 1% gum Tragacanth + 7 kg oil + 5 kg fat powder; Treatment 10: 1% gum Tragacanth + 7 kg oil + 10 kg fat powder; Treatment 11: 1% gum Tragacanth + 14 kg oil + 5 kg fat powder; Treatment 12: 1% gum Tragacanth + 14 kg oil + 10 kg fat powder; Treatment 13: 1% both binders + 7 kg oil + 5 kg fat powder; Treatment 14: 1% both binders + 7 kg oil + 10 kg fat powder; Treatment 15: 1% both binders + 14 kg oil + 5 kg fat powder; Treatment 16: 1% both binders + 14 kg oil + 10 kg fat powder. In each column, values not sharing similar letters are significantly different ($P < 0.05$).

The influence of different levels of fat powder, oil, and pellet binders on the PDI during the finishing period is documented in Table 4. The current results indicated that the effects of fat powder, oil, and pellet binder significantly influenced the PDI in the finisher period on all experimental days ($P < 0.05$). The interaction effects of fat powder and oil significantly affected the PDI in the finisher period on all days except days 15 and 45. The interaction effects of fat powder with the pellet binder and oil with the pellet binder were significant only on day 0 and day 60, respectively, leading to an increase in the pellet durability index on those days ($P < 0.05$). The three-way interaction between fat powder with oil and pellet binder demonstrated statistically significant effects on days 0, 30, and 75 ($P < 0.05$). However, it had no noticeable effect on the PDI on days 15, 45, and 60 ($P > 0.05$). A significant difference was observed between the levels of 5 and 10 kg fat powder and the levels of 7 and 14 kg oil across all treatments. The 5 kg level of fat powder from days 0 to 45 and the 7 kg level of oil on days 0, 15, 30, 45, and 75 yielded the highest PDI. Among the pellet binders, the control treatment exhibited the lowest mean value.

The results from the analysis of the effects of fat powder and oil levels, along with pellet binders, on the physical quality index of pellets during the finisher period are reported in Table 5. The current findings indicated that oil levels did not affect the physical quality of finisher pellets (P>0.05). The levels of fat powder and the effects of pellet binders significantly influenced the physical quality of pellets on all experimental days except on days 0 and 75 (P < 0.05). The gum Tragacanth binder on days 0, 45, 60, and 75, as well as the bentonite binder on days 15 and 30, yielded the highest mean values (4.56 and 4.531, respectively), thereby enhancing the physical quality of the pellets. The 5 kg level of fat powder on day 30 indicated a lower mean value (4.12) in comparison to the 10 kg level (4.22). The Treatment 2 on days 45, 60, and 75, the Treatment 7 on days 15 and 30 (with mean values of 4.15 and 4.22, respectively), the Treatment 14 on day 45 (with a mean value of 5), and the Treatment 15 on day 0 (with a mean value of 4.85) demonstrated the highest physical pellet quality.

Table 4 - The effects of fat and oil powder levels, along with pellet binders, on the pellet durability index in the finisher period.

Fat levels		Day 0	Day 15	Day 30	Day 45	Day 60	Day 75
Fat levels	5	84.25^{a}	84.42^{a}	84.45^{a}	83.08^{a}	81.46^{a}	81.08^{a}
	10	81.19^{b}	82.29^{b}	80.22^{b}	80.06^{b}	87.15^{b}	77.66^{b}
SEM		0.052	1.8	0.67	0.822	0.71	0.64
Oli levels	7	84.7^{a}	84.48^{a}	83.19^{a}	83.06^{a}	81.22^{a}	80.94^{a}
	14	81.49^{b}	82.22^{b}	80.51^{b}	80.07^{b}	87.29^{b}	77.80^{b}
SEM		0.528	1.803	0.677	0.822	0.718	0.648
Pellet binder	Control (no pellet binder)	80.43^{a}	81.12^{a}	77.66^{a}	76.58^{a}	75.52^{a}	74.86^{a}
	Bentonite	83.20^{b}	84.01^{b}	81.97^{b}	80.42^{b}	78.65^{b}	78.63^{b}
Pellet binder	Gum Tragacanth	83.70^{b}	84.25^{a}	85.64^{c}	85.46^{c}	84.02^{c}	83.81^{c}
	Both	85.07^{c}	84.008^{b}	82.30^{b}	82.30^{d}	81.03^{d}	80.25^{d}
SEM		0.528	1.803	0.677	0.822	0.715	0.650
Fat levels	5						
Interaction effect of fat powder + oil + pellet binder levels							
Treatment 1		83.72	84.07	80.80	80.15	78.20	77.50
Treatment 2		79.92	79.72	77.82	76.32	75.77	76.40
Treatment 3		80.45	81.40	77.70	77.05	75.80	75.00
Treatment 4		77.62	79.30	74.35	72.80	72.32	70.55
Treatment 5		87.20	86.20	84.95	82.05	80.05	80.00
Treatment 6		83.20	83.70	82.45	80.55	79.70	79.80
Treatment 7		82.70	84.45	82.20	81.05	80.15	80.25
Treatment 8		79.70	81.70	78.30	78.50	74.70	74.50
Treatment 9		85.80	87.20	89.55	90.05	88.02	87.50
Treatment 10		83.85	84.95	83.95	85.55	83.27	83.00
Treatment 11		84.20	83.77	83.67	87.30	84.52	84.25
Treatment 12		81.20	55.81	84.70	83.60	80.27	79.50
Treatment 13		88.95	86.65	85.70	86.05	83.77	83.25
Treatment 14		81.70	82.87	72.45	83.85	82.95	80.50
Treatment 15		84.70	82.12	80.90	80.80	79.30	79.75
Treatment 16		84.77	95.86	80.10	79.87	78.12	77.52
P value							
Effect of fat powder		0.0001	0.002	0.0001	0.001	0.0001	0.0002
Effect of oil		0.001	0.001	0.001	0.001	0.0001	0.001
Effect of pellet binder		0.0001	0.004	0.0001	0.0001	0.001	0.0001
Fat powder with oil		0.007	0.15	0.03	0.960	0.08	0.006
Fat powder with binder pellet		0.01	0.65	0.800	0.140	0.30	0.520
Oil with binder pellets		0.60	0.60	0.610	0.127	0.04	0.380
Fat powder with oil and a type of pellet binder		0.001	0.30	0.005	0.700	0.10	0.040

Treatment 1: 7 kg oil + 5 kg fat powder; Treatment 2: 7 kg oil + 10 kg fat powder; Treatment 3: 14 kg oil + 5 kg fat powder; Treatment 4: 14 kg oil + 10 kg fat powder; Treatment 5: 1% bentonite + 7 kg oil + 5 kg fat powder; Treatment 6: 1% bentonite + 7 kg oil + 10 kg fat powder; Treatment 7: 1% bentonite + 14 kg oil + 5 kg fat powder; Treatment 8: 1% bentonite + 14 kg oil + 10 kg fat powder; Treatment 9: 1% gum Tragacanth + 7 kg oil + 5 kg fat powder; Treatment 10: 1% gum Tragacanth + 7 kg oil + 10 kg fat powder; Treatment 11: 1% gum Tragacanth + 14 kg oil + 5 kg fat powder; Treatment 12: 1% gum Tragacanth + 14 kg oil + 10 kg fat powder; Treatment 13: 1% both binders + 7 kg oil + 5 kg fat powder; Treatment 14: 1% both binders + 7 kg oil + 10 kg fat powder; Treatment 15: 1% both binders + 14 kg oil + 5 kg fat powder; Treatment 16: 1% both binders + 14 kg oil + 10 kg fat powder. In each column, values not sharing similar letters are significantly different (P < 0.05).

Table 5 - The effects of fat and oil powder levels, along with pellet binders, on the pellet physical quality in the finisher period

Main effects	Day 0	Day 15	Day 30	Day 45	Day 60	Day 75	Day 0
Fat levels	5	4.25^{a}	4.28	4.12	4.44^{a}	4.28^{a}	4.26
	10	4.10^{b}	4.18	4.22	4.20^{b}	4.19^{b}	4.15
SEM		0.008	0.07	0.13	0.006	0.008	0.022
Oli levels	7	4.17	4.17	4.29	4.33	4.20	4.20
	14	4.15	4.21	4.24	4.32	4.21	4.10
SEM		0.092	0.08	0.13	0.062	4.008	0.023
Pellet binder	Control (no Pellet Binder)	4.03^{a}	3.96^{a}	4.24^{ab}	4.40^{ab}	4.33^{a}	4.331^{a}
	Bentonite	4.05^{a}	4.56^{b}	4.51^{c}	4.32^{a}	4.15^{b}	4.168^{ab}
	Gum Tragacanth	4.29^{b}	4.20^{ab}	4.39^{ba}	4.47^{b}	4.35^{a}	4.343^{a}
	Both	4.51^{b}	4.18^{ab}	4.10^{b}	4.11^{c}	4.13^{b}	3.993^{b}
SEM		0.008	0.071	0.12	0.006	0.008	0.91
Interaction effect of fat powder + oil + pellet binder levels							
Treatment 1		4.025	3.225	4.270	4.350	4.050	4.075
Treatment 2		4.100	4.325	4.550	5.000	5.000	4.850
Treatment 3		3.970	4.150	4.000	4.450	4.075	4.000
Treatment 4		4.050	4.160	4.150	3.800	4.200	4.400
Treatment 5		4.350	4.550	4.550	4.170	3.970	3.970
Treatment 6		4.370	4.850	4.670	4.520	4.300	4.850
Treatment 7		4.420	4.700	4.680	4.300	4.200	4.220
Treatment 8		4.020	4.150	4.220	4.300	4.100	4.050
Treatment 9		4.200	4.500	4.380	4.540	4.470	4.470
Treatment 10		4.140	4.370	4.720	5.000	4.470	4.550
Treatment 11		4.850	3.925	4.270	4.400	4.310	4.350
Treatment 12		4.000	4.075	4.200	4.360	4.100	4.000
Treatment 13		4.200	4.325	4.000	4.00	4.002	3.970
Treatment 14		4.570	4.150	4.150	4.100	4.980	3.800
Treatment 15		4.400	4.175	4.170	4.450	4.540	4.420
Treatment 16		4.100	4.075	4.078	3.990	3.980	3.770
P value							
Effect of fat powder		0.003	0.42	0.001	0.0001	0.04	0.14
Effect of oil		0.9	0.5	0.36	0.88	0.228	0.56
Effect of pellet binder		0.0001	0.02	0.0001	0.0001	0.001	0.005
Fat powder with oil		0.01	0.12	0.004	0.0001	0.0001	0.002
Fat powder with binder pellet		0.4	0.18	0.08	0.001	0.001	0.06
Oil with binder pellets		0.17	0.23	0.125	0.013	0.0001	0.0002
Fat powder with oil and a type of pellet binder		0.009	0.21	0.53	0.0005	0.12	0.94

Treatment 1: 7 kg oil + 5 kg fat powder; Treatment 2: 7 kg oil + 10 kg fat powder; Treatment 3: 14 kg oil + 5 kg fat powder; Treatment 4: 14 kg oil + 10 kg fat powder; Treatment 5: 1% bentonite + 7 kg oil + 5 kg fat powder; Treatment 6: 1% bentonite + 7 kg oil + 10 kg fat powder; Treatment 7: 1% bentonite + 14 kg oil + 5 kg fat powder; Treatment 8: 1% bentonite + 14 kg oil + 10 kg fat powder; Treatment 9: 1% gum Tragacanth + 7 kg oil + 5 kg fat powder; Treatment 10: 1% gum Tragacanth + 7 kg oil + 10 kg fat powder; Treatment 11: 1% gum Tragacanth + 14 kg oil + 5 kg fat powder; Treatment 12: 1% gum Tragacanth + 14 kg oil + 10 kg fat powder; Treatment 13: 1% both binders + 7 kg oil + 5 kg fat powder; Treatment 14: 1% both binders + 7 kg oil + 10 kg fat powder; Treatment 15: 1% both binders + 14 kg oil + 5 kg fat powder; Treatment 16: 1% both binders + 14 kg oil + 10 kg fat powder. In each column, values not sharing similar letters are significantly different ($P < 0.05$).

DISCUSSION

Based on the current results, it was found that utilizing two levels of fat powder (5 and 10 kg), two levels of oil (7 and 14 kg), and two types of pellet binders (Bentonite, gum Tragacanth, and both) significantly affected the PDI in both starter and finisher periods of poultry feed. In both periods, lower levels of fat powder (5 kg) and oil (7 kg) resulted in higher mean PDI and physical pellet quality. In all treatments with the highest concentrations of added fat powder and oil, such as Treatments 4, 8, 12, and 16, lower mean values of PDI and physical quality were observed in both the starter and finisher periods. During the starter phase, the bentonite pellet binder demonstrated superior performance, whereas in the final phase, the gum Tragacanth pellet binder exhibited the most advantageous outcomes.

It was found that adding vegetable oils through the mixer negatively affected the physical quality of feed pellets (-40; Thomas et al., 2001). Increasing soybean oil levels from 1.5% to 3% resulted in a 21% reduction in PDI (Pope, 2016). Similarly, increasing fat content from 1% to 18.2% in the mixer reduced PDI by up to 13% (Loar et al., 2014), which may be attributed to the reduction of force within the die holes caused by oil, resulting in lower quality pellets. Additionally, high oil levels form a coating on feed particles that prevents steam from penetrating and stops starch from gelatinizing (Lowe, 2005). The present findings are entirely consistent with the previous findings, as both conclusively demonstrated that increasing the fat or oil levels in feed formulations significantly reduces PDI, an adverse effect that persists even when using specialized binders

Based on the present study, fat powder demonstrated a more advantageous effect on pellet quality in comparison to oil. This observation aligns with the findings of Zimonja et al. (2007), who indicated that different types of fat exert differing impacts on pellet quality. Additionally, it was found that adding 0.5% of calcium lignosulfonate to treatments containing 3% soybean oil improved pellet quality (Abadi et al., 2019). Evaluating two types of fat, including soybean oil and saturated fat powder containing 65% palmitic acid, at levels of 2.5% and 5% on the PDI of broiler diets revealed that adding fat powder increased starch gelatinization and enhanced PDI outcomes compared to soybean oil. It has been demonstrated that soybean oil decreases starch granule gelatinization because calcium fat powder has a higher melting point than soybean oil, which allows superior steam penetration into feed components (Zimonja et al., 2007). The higher glycerol concentration in fat powder (approximately 10%), which acts as an emulsifier or surfactant, may improve PDI, consistent with the findings of Tavernari et al. (2013).

Based on the present findings, adding pellet binders to the treatments increased the PDI and physical quality. However, no significant difference was observed between the types of pellet binders across the tested treatments on different days. Although each treatment employed several methods on different experimental days, these differences were not statistically significant. Similar to the current findings, Abadi et al. (2019) have demonstrated that treatments containing 3% calcium fat powder without a pellet binder exhibited a reduction in PDI, aligning with the outcomes of the present investigation study. Additionally, adding 1.5% calcium fat powder along with 2% bentonite improved pellet quality indices (Abadi et al., 2019). Corey et al. (2014) indicated that adding fat along with calcium lignosulfonate as a pellet binder resulted in an increase in post-extrusion pellet temperature and an enhancement in pellet quality. The differential responses of each pellet binder to different ranges of oil and fat powder suggested that the selection of pellet binders should be based on the specific types and concentrations of mixed fats (Corey et al., 2014).

CONCLUSION

The utilization of 5 and 10 kg of fat powder and 7 and 14 kg of oil, along with three varieties of pellet binders, including bentonite, gum Tragacanth, and a combination of both, exerted a significant influence on the pellet durability index (PDI) and physical properties quality. Throughout all starter and finisher periods, the treatment devoid of any pellet binder demonstrated the lowest PDI and physical quality, highlighting the influence of pellet binders in treatments that include fat powder and oil. Treatments containing lower levels of fat powder and oil yielded higher-quality pellets. Furthermore, an increase in the quantity of fat powder and oil in the feed typically resulted in a decrease in the PDI and physical quality. During the starter phase, the bentonite pellet binder demonstrated optimal performance, whereas in the final phase, the gum Tragacanth pellet binder produced the most promising outcomes.

DECLARATION

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Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Acknowledgments

The authors extend the deepest gratitude to all those who assisted us in conducting this research, especially the Gohar daneh Shargh factory and Sepehri Moghadam Noavaraneh Sanat for their invaluable support and cooperation.

Authors' contribution

M. Emadi, H. Sepehri and M. Salehan contributed to the research, data analysis, and manuscript writing.

Conceptualization and data curation: M. Emadi, H. Sepehri and M. Salehan

Formal analysis, funding acquisition, investigation, project administration, software, writing original draft, review & editing: M. Emadi

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Funding

The authors declare that no funds, grants, or other support were received during the preparation or publication of this manuscript.

Competing interests

The authors declare no competing interests in this research and publication.

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