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Effects of Feed Forms of Diets on Growth Performance, Carcass Traits and Blood Parameters in Broiler Chickens

Research Article

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ABSTRACT

This study aimed to investigate the effects of feed form (mash, crumble, pellet, and extruded) on growth performance, carcass traits, and some blood parameters in broiler chickens. The experiment was conducted on 480 male broiler chickens of Ross 308 strain in a completely randomized design with 8 treatments and 5 replications from 1 to 42 days of age. Performance indices and mortality rates were evaluated. The results indicated that growth performance traits were influenced by the feed form, and a significant difference was observed in pellet feed during the rearing period ($P<0.01$). Chickens fed with extruded feed throughout the rearing period had a higher mean weight compared to other treatments, and those fed with crumbled feed in the starter diet and pellet feed in the grower and finisher diets had the highest thigh weight ($P<0.05$). The feed form did not have a significant effect on the relative weight of heart components ($P>0.05$). The highest value for gizzard weight was for chickens fed with pellet feed. In addition, a significant difference was found in abdominal fat in crumbled-fed chickens in the starter diet and extruded feed in the grower and finisher diets compared to the pellet feed treatment ($P<0.01$). In conclusion, the results showed that the performance of broiler chickens was affected by the feed form, and the use of extruded and pellet feeds, especially throughout the entire period caused improvements in growth performance, carcass traits, and blood parameters.

KEY WORDS broiler chickens, feed form, growth performance, hematological parameters.

INTRODUCTION

One of the significant issues in the poultry feed industry is the selection of feed characteristics that are essential for improving bird performance and their adaptation to the environment. Among the most important characteristics are the uniformity of feed particles and their texture. Nowadays, factories use modern processing technologies, additives, and genetically modified grains (GMOs) that affect the nutritional quality and production costs, leading to increased growth rate and production. The manufactured feed is mainly in the form of mash, crumble and pellet Moreover, in recent years the extrusion technique has been widely used in animal feed due to its many advantages (Moritz *et al*. 2005; Brenes *et al*. 2008). One significant aspect of feed formulation is the consideration of the bioavailability of essential nutrients and energy. The acceptability and consumption of feed by farm animals depend not only on its chemical composition but also on the animals' sensitivity to its ingredients. Even when feed is readily accepted, it should be formulated for nutrient balance. Additionally, the physical quality of feed can have significant effects on the stability and bioavailability of nutrients. The level of feed consumption in broilers is an important issue and the feed form and processing techniques significantly influence it (Chewning *et al*. 2012). Increasing the size of feed particles

leads to an increase in food consumption and consequently improved bird growth (Lv *et al*. 2015). Therefore, using new processing methods and changes in the physical and chemical structure of feed components can influence the accessibility and digestion of nutrients, which can improve bird performance (Reshadi-Nejad *et al*. 2015).

Some studies have shown that using pellet feed in broiler diets improves feed consumption, growth rate, and feed efficiency, leading to improved economic efficiency of production (Abdollahi *et al*. 2013a). The extrusion process, similar to pelletizing, is a process based on moisture, pressure, and heat that increases the gelatinization of feed starch and can significantly affect broiler performance (Rahman *et al*. 2015). Moreover, extrusion, as a short-term process, is important due to numerous advantages such as high productivity, efficiency, and good quality of the final product, as well as improving the usability of corn starch (Amornthewaphat *et al*. 2005; Moritz *et al*. 2005).

Based on our database search, the effect of different forms of feed (mash, crumble, pellet, and extruded) on broiler performance has not been investigated. This study aimed to examine the advantages and disadvantages of feed forms and their impact on growth performance, carcass traits, and some hematological parameters.

MATERIALS AND METHODS

Birds, diets and management

This study was conducted on 480 one-day-old male broiler chickens of Ross 308 strain with a mean weight of 42 gr. The chicks were supplied by Navaid Morgh Gilan Company. Prior arrival of the chicks, experimental diets were prepared and distributed in feeding trays, with water provided in siphon and nipple drinkers. The diets were formulated in four forms: mash, crumble, pellet, and extruded, for three stages, starter (0-10 days), grower (11-24 days), and finisher (25-42 days). Diets were formulated to meet the nutrient recommendations for Ross 308 (Aviagen, 2019). The ingredients and nutrient compositions of the experimental diets are shown in Table 1. The stocking density of rearing was 10 birds/m^2. Temperature was maintained at 33 °C for the first day and was gradually decreased by 2 °C/week until 21 °C and maintained at that level thereafter. The light condition, relative humidity, and temperature followed the Ross 308 guidelines (Aviagen, 2019). To ensure the welfare of the experimental animals, the birds had free access to food and water.

This experiment was conducted in a completely randomized design with 8 treatments and 5 replications. The experimental treatments were as follows:

Treatment 1: Mash form throughout the rearing period
Treatment 2: Crumble form throughout the rearing period
Treatment 3: Extruded form throughout the rearing period
Treatment 4: Pellet form throughout the rearing period
Treatment 5: Crumble form in the starter diet and pellet form in the grower and finisher diets
Treatment 6: Crumble form in the starter diet and extruded form in the grower and finisher diets
Treatment 7: Pellet form in the starter and grower diets and mash form in the finisher diet
Treatment 8: Extruded form in the starter and grower diets and mash form in the finisher diet

Growth performance

At the end of the experiment, chickens were weighed and feed consumption was recorded. Body weight gain (BWG), feed intake (FI), feed conversion ratio (FCR), and mortality weight were calculated for each phase. All birds were weighed individually after they arrived from the hatchery and on days 10, 24 and 42 and were averaged. To determine FI and FCR, feed bags and all remaining feed in the feeders were weighed. The daily mortality per pen was recorded. The birds were slaughtered on day 42.

Evaluation of carcass traits

On day 42 of rearing, to investigate the effect of experimental treatments on carcass traits, two chicks from each experimental group were selected (with weights close to the average weight of chicks in the same cage). Following the record of live weight, they were slaughtered and immediately dissected. After slaughtering and bleeding the chickens, their feathers were removed, the carcasses were carefully eviscerated, and each carcass was weighed. The entire breast with wings and the thighs, drumsticks, and abdominal fat were removed from the carcass and weighed individually. The weight of carcass, thigh, breast, liver, proventriculus, gizzard, abdominal fat, and heart were also recorded individually.

Measurement of blood parameters

To evaluate the effects of experimental treatments on physiological responses related to nutrient metabolism and ascites syndrome, blood samples were collected at the end of day 42. Blood samples were incubated at room temperature for 12 h to separate serum from blood clots. Then, the separated sera were centrifuged at 1500 rpm for 10 min. Then, the separated serum samples were stored at -80 °C for further tests.

Blood parameters include hemoglobin, hematocrit, uric acid, glucose, cholesterol, low-density lipoproteins (LDL), high-density lipoproteins (HDL), alanine aminotransferase (ALT), and aspartate aminotransferase (AST) were measured.

Table 1 Ingredients and chemical composition of the experimental diets

Ingredients (per kilogram per ton)	Rearing periods (days)		
	Starter (1-10)	Growth (11-24)	Finisher (25-42)
Corn	500	540	585
Wheat	25	34.50	34.50
Soybean mash (%44)	330	310	300
Corn gluten mash (%62)	45	25	0
Fish mash (%64)	25	12.50	0
Soybean oil	20	25	30
Calcium carbonate	11.50	11.50	11.50
Monocalcium phosphate	14.50	13.50	13
Vitamin supplement %10.0 for broiler chickens 1	1.25	1.15	1
Mineral supplement %25.0 for broiler chickens 2	3	2.75	2.50
Table salt	1.50	2	2
Molasses	2.20	2.20	2.20
DL-methionine	3.30	3.10	3.10
L-lysine hydrochloride	3	2.70	2.30
L-threonine	1.30	1.10	1.10
L-arginine	0.60	0.40	0.30
Choline chloride %60	0.80	0.65	0.45
Emulsifier	0.50	0.50	0.50
Coccidiostat	1	1	0
Toxin binder	1.50	1.50	1.50
Prebiotic	1.50	1	1
Acidifier	1.50	1	1
Bentonite	6.05	6.85	7.05
Total	1000	1000	1000
Chemical analysis			
Dry matter (%)	89.37	89.24	89.05
Crude protein (%)	24.35	21.60	18.90
Ether extract (%)	4.60	5.10	5.60
Crude fiber (%)	1.85	1.83	1.83
Total ash (%)	6.60	6.20	5.90
Calcium (%)	0.95	0.87	0.78
Available phosphorus (%)	0.48	043	0.61
Potassium (%)	0.88	0.85	0.82
Sodium (%)	0.16	0.16	0.15
Chloride (%)	0.24	0.24	0.21
Digestible methionine (%)	0.68	0.62	0.55
Digestible methionine + cysteine (%)	0.96	0..87	0.79
Digestible lysine (%)	1.28	1.15	1.03
Digestible threonine (%)	0.87	0.77	0.69

[1] Each kilogram also contains: Manganese: 48000 mg; Zinc: 48000 mg; Iron: 12000 mg; Copper: 6460 mg; Iodine: 502 mg and Selenium: 140 mg.
[2] Each kilogram contains: vitamin A: 10000000 IU; vitamin D3: 4000000 IU; vitamin E: 65000 mg; vitamin K3: 3000 mg; Vitamin B1: 3500 mg; vitamin B2: 7000 mg; Niacin: 55000 mg; Calcium Pantothenate: 22000 mg; vitamin B6: 4500 mg; vitamin B9: 2000 mg; vitamin B12: 20 mg; Biotin: 270 mg and Antioxidant: 150000 mg. Aqualyso®, Sodium Monensin 10%, Montmorillonite and activated charcoal, Hydrolyzed yeast, Talizyme, and ConSept® CF60 were also existed in diets.

Spectroscopy was performed by Libra S22 (Biochrom, USA), and all kits were purchased from Pars Azmoon (Tehran, Iran).

Statistical analysis

All data of each pen were considered for statistical analysis. The experimental unit was statistically analyzed under a completely randomized design using the GLM procedure of the SAS (2002).

Duncan's multiple range comparison tests were carried out to examine differences between treatments. P value lower than 0.05 was considered significant. The following model was used:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where:
Y_{ij}: trait of interest for chicken.

μ: overall mean.
T_i: treatment effect.
e_{ij}: random error associated with each observation.

RESULTS AND DISCUSSION

The obtained results regarding the growth performance of chickens indicated that the feed form had a significant effect on FI in all periods (P<0.05). From day 1 to 10 of age, the highest feed consumption was related to the crumbled feed throughout the rearing period, while the lowest FI was observed with pellet feed during the entire rearing period (P<0.05). From day 11 to 24 of age, the highest feed consumption was related to the mash form throughout the rearing period, while the lowest FI was for crumbled feed in the starter diet and pellet form in the grower and finisher diets. However, no significant difference was observed compared to the extruded treatment throughout the rearing period and crumbled feed in the starter diet and extruded form in the grower and finisher diets (P>0.05). In addition, birds fed with extruded feed in the starter and grower diets and mash form in the finisher diet during the 25 to 42-day feeding period had the highest feed consumption, while the lowest FI was related to mash feed throughout the entire rearing period. Results of FI (1 to 42 days of age) during the overall period showed birds fed with extruded feed in the starter and grower diets and mash form in the finisher diet had the highest feed consumption, while the lowest FI was observed in treatments that consumed mash feed throughout the entire rearing period (Table 2).

Researchers investigated three feed diets including mash, pellet, and a combination of mash and pellet in broiler chickens and reported that birds receiving the mash treatment had the highest feed consumption in the first and second weeks of rearing. They attributed the increased feed consumption in the mash treatment to excessive feed spillage, which is consistent with the findings of previous study in early ages of rearing (Moradi *et al*. 2018). However, the finding of Massuquetto *et al*. (2019) demonstrated that the use of pellet diet significantly improved feed intake, daily weight gain and feed conversion ratio, consistent with the results of our study. Quantitative research using extruded feed, processed as a complete diet, has been conducted. Most studies have focused on feed ingredients such as corn, soybean mash and other oilseed mash (Chae *et al*. 1997; Veum *et al*. 2017). In a study by Subuh *et al*. (2002) on extruded soybeans in broiler chickens, it was found that extruded soybeans can partially or completely replace raw soybean mash and have significant effects on body weight, FCR, mortality, and abdominal fat percentage (Janocha *et al*. 2022).

The effect of a diet containing extruded flaxseed on the growth performance of broiler chickens, oxidative stability, and organoleptic properties of meat and meat products was investigated. Studies have shown that the supplementation of extruded flaxseed in the diet reduces body weight gain, and feed consumption, and increases FCR in broiler chickens. Feeding extruded flaxseed to chickens through feed significantly improves the quality and functional properties, fatty acid content, and reduces the oxidative stability of meat and meat products (Anjum *et al*. 2013). The effect of experimental treatments on weight gain in different feeding periods is presented in Table 2. The results showed that the feed form had a significant effect on weight gain (P<0.05). From day 1 to 10, the highest weight gain value was observed in birds fed with extruded feed, while the lowest level was in birds fed with mash feed (P<0.01). From day 11 to 24, birds fed with pellets had the highest weight gain, but the difference compared to other treatments was not significant (P>0.05).

From day 25 to 42, the highest weight gain was observed in birds fed with crumbled feed in the starter diet and extruded form in the grower and finisher diets, while the lowest weight gain was in birds fed with mash feed throughout the rearing period (P<0.01). For the entire rearing period (1 to 42 days), the highest weight gain was observed in birds fed with extruded feed throughout the rearing period, but no significant difference was observed between treatments that consumed extruded feed throughout the entire rearing period and treatments that used crumbled feed in the starter diet and extruded and pellet forms in the grower and finisher diets (P>0.05). Results of the present study indicated that birds fed with pellet and extruded diets had significantly higher weight gain compared to other treatments. It seems that increasing the density of the feed in pellet and extruded diets accelerates growth and increases daily weight gain, average body weight of broiler chickens throughout the rearing period, and improves FCR, consistent with the findings of (Azizian and Saki, 2020).

Studies demonstrated that when birds initially consume crumbled feed form followed by pellet or extruded form, their digestive system adapts better to the particle size of the feed, resulting in an improved performance compared to birds that receive a mash diet at starter (Garcia *et al*. 2006; Amerah *et al*. 2009).

On the other hand, pelleting and extrusion increase the density of feed particles, requiring birds to exert less effort to consume the required feed. This allows them to allocate more energy towards growth and production, which was reported by other studies (Salari *et al*. 2006; Jafarnejad *et al*. 2010). In a study, the effect of feed form and grain type on performance and some hematological parameters of broiler chickens was investigated.

The results of this study showed that during the feeding period, birds fed with pellet diets had higher daily weight gain compared to birds fed with mash diets (Zhang *et al*. 2021), it is consistent with the results of the present study. The results indicated that the feed form significantly influenced the FCR in different feeding periods (P<0.01). Throughout the rearing period, the lowest FCR was related to treatments using crumbled feed in the starter diet and extruded feed in the grower and finisher diets, but no significant difference was observed compared to birds that consumed extruded feed throughout the entire period and those that used crumbled feed in the starter diet and pellet in the grower and finisher diets. The highest FCR was obtained in mashed form throughout the rearing period (Table 2).

FCR is the most important economic criterion in evaluating the profitability of broilers. The results of this study demonstrated that feeding with extruded and pellet forms improves growth performance and FCR compared to feeding with mashed feed in broiler chickens. These findings are comparable with other studies (Amerah *et al*. 2009; Abdollahi *et al*. 2013b; Shabani *et al*. 2015). In a study, the effects of pellet and mash diets on the performance of broiler chickens performed under similar to our management conditions indicated that the difference observed in the FCR of the pellet-consuming group was correlated with the quality difference of pellets (Amerah *et al*. 2009; Shabani *et al*. 2015).

In other studies, it was reported that birds fed with mash diets spend more time feeding and consume more energy compared to birds fed with pellet diets. In addition, it was reported that the feed conversion efficiency in birds fed with pellet diets is better than those fed with mash diets (Moradi *et al*. 2018), which is consistent with the results of our study and other research (Jahan *et al*. 2006; Jiménez-Moreno *et al*. 2016).

The results showed that the feed form had a significant effect on live weight and thigh weight (P<0.05), but no significant difference was observed for carcass weight and breast weight (P>0.05). Moreover, chicks fed with extruded feed throughout the rearing period had a higher mean live weight compared to other treatments (P<0.05), while chicks fed with crumble feed in the starter and extruded feed in the grower and finisher had the highest thigh weight (P<0.05).

Azizian and Saki (2020) demonstrated that chicks fed by pellet and extruded feeds had the highest live weight and the maximum FCR at the end of the rearing period. Another study showed the pellet feed had more improved efficiency and FCR levels compared to mash feed, (Jahan *et al*. 2006), which is consistent with our data. In another study, it was reported that the use of extruded and pelleted feeds throughout the rearing period improved the FCR and economic performance index (EPI) due to the reduced energy consumption during FI and reduced feed wastage (Nir *et al*. 1994), this is consistent with the results of the present study.

In another study, it was also reported that the use of extruded and pellet feeds improved the FCR and EPI due to reduced energy consumption during FI and reduced feed wastage, which is consistent with the results of the current research (Li *et al*. 2018). Massuquetto *et al*. (2019) compared pellet and mash diets in broiler chicken and found that chickens fed with pellet had the best FCR, the highest live weight, and the highest breast weight at the end of the rearing period. Their management conditions were comparable to ours and their results are consistent with the results of this study. They also showed that the differences observed in FCR and the performance of broiler chickens were correlated with differences in pellet quality. Mingbin *et al*. (2015) investigated the effects of feed form on the performance and some hematological parameters of broiler chickens and showed that the relative weights of carcass, breast, thigh, heart, spleen, bursa of Fabricius, liver, and abdominal fat were not affected by the feed form, which is consistent with our results regarding carcass weight and breast weight. The results showed that the feed form did not have a significant effect on the relative weight of heart components (P>0.05).

Bölükbasi *et al*. (2005) demonstrated that the form of the consumed feed affects hematocrit and the right ventricle to total ventricle ratio (RV:TV). They found that the hematocrit levels and the RV:TV in treatments receiving pellet feed were significantly higher than in other treatments. Sarvestani *et al*. (2006) reported that the RV:TV is not affected by the feed form of the diet, which is consistent with the results of this study.

The obtained data showed a significant effect of the feed form on the relative weight of gizzard and abdominal fat (P<0.01), however, no significant effect was observed on the relative weight of liver and proventriculus (P>0.05). Chicks fed with mash feed throughout the rearing period had the highest gizzard weight, while those fed with pellet or crumble feed throughout the rearing period had the lowest gizzard weight. However, no significant difference was found between treatments fed with pellet, crumble, and extruded feed throughout the rearing period. The chicks fed with crumble feed in the starter and extruded feed in the grower and finisher phases showed the highest amount of abdominal fat, while the lowest amount of abdominal fat was observed in the treatment with mash feed throughout the rearing period.

The gizzard is a muscular organ whose function leads to the reduction of feed particle size, thus improving feed digestion and absorption. It has been shown that pellet feed reduces gizzard weight and volume.

Table 2 Effects of feed treatments on the growth performance of broiler chickens at different rearing period

Experimental treatments	Feed intake				Body weight gain				Feed conversion ratio			
	1-10 days	11-24 days	25-42 days	1-42 days	1-10 days	11-24 days	25-42 days	1-42 days	1-10 days	11-24 days	25-42 days	1-42 days
Mash throughout rearing period	259.56^{b}	1321.63^{a}	2821.00^{b}	4402.19^{c}	164.42^{c}	825.74	1232.84^{d}	2223.00^{d}	1.34^{a}	1.54^{a}	2.1^{a}	1.98^{a}
Crumble throughout rearing period	275.24^{a}	1300.9^{a}	2980.03^{ab}	4555.88^{b}	210.11^{ab}	887.76	1565.22^{c}	2663.09^{b}	1.31^{b}	1.47^{a}	1.83^{b}	1.74^{bc}
Extruded throughout rearing period	26928^{b}	1184.97^{c}	3070.00^{a}	4524.81^{b}	217.80^{a}	881.98	1852.78^{a}	2810.44^{a}	1.19^{c}	1.25^{b}	1.63^{c}	1.61^{c}
Pellet throughout the rearing period	245.22^{c}	1268.13^{ab}	2987.48^{ab}	4501.23^{b}	199.28^{b}	891.43	1700.74^{b}	2663.45^{b}	1.08^{c}	1.34^{b}	1.74b^{c}	1.69^{bc}
Crumble (starter) and pellet (grower and finisher)	-	1075.01^{c}	3197.16^{a}	4560.49^{b}	-	721.18	1842.80^{a}	2781.40^{a}	-	1.37^{b}	1.63^{c}	1.64^{c}
Crumble (starter) and extruded (grower and finisher)	-	1079.77^{c}	3002.00^{a}	4403.88^{c}	-	777.66	1865.42^{a}	2751.88^{a}	-	1.26^{b}	1.56^{c}	1.60^{c}
Pellet (starter and grower) and mash (finisher)	-	-	3116.5^{a}	4696.1^{a}	-	-	1475.00^{c}	2563.72^{bc}	-	-	1.94^{a}	1.83^{b}
Extruded (starter and grower) and mash (finisher)	-	-	3184.07^{a}	4717.65^{a}	-	-	1538.20^{c}	2592.12^{bc}	-	-	2.07^{a}	1.82^{b}
SEM	2.11	16.2	27.80	37.04	3.15	15.71	28.13	36.75	0.018	0.025	0.029	0.035
P-value	0.001	0.0001	0.0001	0.013	0.0001	0.159	0.0001	0.0001	0.0001	0.0138	0.0001	0.0001

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Gizzard development as a nutritional strategy can be achieved by manipulating feed particle size. There is a positive relationship between gizzard weight and decreased feed particle size. Researchers have shown that feeding birds by pellet and extruded diets leads to a reduction in the weight and volume of the proventriculus, gizzard, and small intestine due to a decrease in the total length of the small intestine. In pellet feed, gizzard performance is practically decreased, and food passes through it more quickly, which has a reducing effect on proventriculus and gizzard development (Engberg *et al*. 2002); our obtained results is consistent with these data. In the pelleting process, the reduction in particle size causes feed to remain at a less time in the gizzard, leading to a decreased mechanical stimulation of the gizzard and subsequently reducing its size. The effect of the feed form on the average relative weight of carcass components, the relative weight of heart component traits, including heart weight, total ventricle weight, right ventricle weight, left ventricle weight, and the relative weight of internal organs, is presented in Table 3. The levels of two indicators of liver injury, ALT and AST enzymes were measured (Table 4). They are primarily present inside the cells and enter the bloodstream in case of cellular damage. The results indicated that all experimental feed forms did not have significant effects on ALT (P>0.05).

However, the level of AST was influenced by the experimental treatments (P<0.05). The highest level of AST was observed in the treatment group fed with pellet in the starter and grower phases and mash in the finisher phase, while the lowest level was observed in the chickens fed with crumbled feed throughout the rearing period. Furthermore, broiler chickens fed with pellet and extruded feeds had higher levels of AST compared to those fed with mash feed (Table 4).

These results are consistent with the findings of Azizian and Saki, (2020). Numerous studies have shown an increase in AST and ALT levels due to the consumption of extruded and pellet feeds compared to mash feed, which is consistent with the current findings. Massuquetto *et al*. (2019), changes in enzymatic activity and lipid metabolism are results of abnormal metabolism in the liver, leading to hepatocellular damage and liver injury.

The results of this study indicated that the feed form significantly affected the cholesterol, hemoglobin, hematocrit, glucose, uric acid, HDL, and LDL levels (P<0.01), but this effect was not significant regarding hematocrit (P>0.05). The highest level of cholesterol was observed in chickens fed with extruded or pellet feeds throughout the rearing period, while the lowest level was found in chickens fed with mash feed throughout the rearing period.

Table 3 Effect of experimental treatments on relative weight of carcass components, heart components, and internal organs of broiler chickens at the end of experimental periods

Experimental treatments	Live weight	Carcass[1] weight	Breast weight[2]	Thigh weight[2]	Heart weight[1]	Right ventricle/total ventricle ratio	Liver[1]	Proventriculus[1]	Gizzard[1]	Abdominal fat[1]
Mash throughout rearing period	2259.8^{c}	62.20	35.42	30.24^{ab}	0.514	0.202	2.08	89.1^{a}	0.378	0.649^{c}
Crumbled throughout rearing period	2705.2^{ab}	62.81	36.66	30.73^{ab}	0.487	0.259	2.13	0.91^{c}	0.338	1.381^{a}
Extruded throughout rearing period	2844.8^{a}	65.28	35.84	31.12^{ab}	0.490	0.176	2.23	0.92^{c}	0.350	1.385^{a}
Pellet throughout rearing period	2630.6^{ab}	62.76	35.08	31.92^{ab}	0.537	0.236	2.29	0.91^{c}	0.393	1.415^{a}
Crumbled (starter) and pellet (grower and finisher)	2827.7^{a}	63.10	35.04	31.22^{ab}	0.524	0.241	2.31	1.02^{c}	0.384	1.154^{a}
Crumbled (starter) and extruded (grower and finisher)	2797.1^{a}	63.92	34.81	32.19^{a}	0.488	0.260	2.28	0.94^{c}	0.343	1.464^{a}
Pellet (starter and grower) and mash (Finisher)	26.5.3^{bc}	63.28	34.91	31.45^{ab}	0.514	0.247	2.09	1.35^{b}	0.366	1.289^{a}
Extruded (starter and grower) and mash (finisher)	2634.5^{bc}	64.79	35.31	29.84^{b}	0.473	0.234	2.16	1.50^{b}	0.349	0.917^{bc}
SEM	31.54	0.346	0.283	0.256	0.01	0.017	0.026	0.044	0.009	0.045
P-value	0.0005	0.312	0.786	0.029	0.80	0.94	0.199	0.0001	0.801	0.0001

[1] % of live weight.
[2] % of carcass weight.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 4 Effect of the experimental treatments on liver enzymes levels of aspartate aminotransferase (AST) and alanine aminotransferase (ALT)

Experimental treatments	AST	ALT
Mash the rearing period	281.80^{ab}	20.50
Crumble throughout rearing period	266.00^{b}	18.10
Extruded throughout rearing period	301.80^{ab}	21.20
Pellet throughout rearing period	326.20^{ab}	21.10
Crumble (starter) and pellet (grower and finisher)	292.50^{ab}	22.50
Crumble (starter) and extruded (grower and finisher)	297.30^{ab}	18.90
Pellet (starter and grower) and mash (finisher)	337.80^{a}	21.30
Extruded (starter and grower) and mash (finisher)	286.20^{ab}	18.90
SEM	0.52	6.98
P-value	0.019	0.317

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 5 Effect of experimental treatments on hematological parameters

Experimental treatments	Cholesterol (mg/dL)	Hemoglobin (g/dL)	Hematocrit (%)	Glucose (mg/dL)	Uric acid (mg/dL)	HDL (mg/dL)	LDL (mg/dL)
Mash throughout rearing period	122.6^{c}	10.40^{c}	31.38	219.40^{c}	4.77^{a}	58.22^{ab}	57.26^{e}
Crumble throughout rearing period	150.60^{a}	10.71^{c}	30.33	255.50^{a}	4.59^{ab}	60.87^{ab}	74.67^{ab}
Extruded throughout rearing period	151.40^{a}	12.14^{a}	35.37	257.70^{a}	4.60^{ab}	32.88^{a}	72.75^{abc}
Pellet throughout rearing period	143.50^{b}	11.37^{b}	33.18	241.90^{ab}	4.54^{ab}	60.80^{ab}	62.62^{ed}
Crumble (starter) and pellet (grower and finisher)	135.80^{ab}	11.35^{b}	33.41	242.40^{ab}	4.42^{b}	61.44^{ab}	66.39^{bdec}
Crumble (starter) and extruded (grower and finisher)	141.30^{ab}	11.87^{ab}	34.39	237.30^{abc}	4.76^{a}	63.94^{a}	64.17^{edc}
Pellet (starter and grower) and mash (finisher)	148.20^{ab}	11.44^{b}	33.37	228.50^{bc}	4.79^{a}	51.51^{c}	78.34^{a}
Extruded (starter and grower) and mash (finisher)	137.80^{b}	11.87^{ab}	34.67	220.7	4.87^{a}	55.85^{bc}	68.58^{bdc}
SEM	1.69	0.088	4.04	2.74	0.038	0.47	1.31
P-value	0.0001	0.0001	0.3801	0.0003	0.046	0.0001	0.0001

HDL: high density lipoprotein and LDL: low density lipoprotein.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Additionally, chickens fed with mash or crumbled feeds throughout the rearing period had the minimum hemoglobin levels, while those fed with extruded feed showed the maximum hemoglobin level.

Chickens fed with extruded feed throughout the rearing period and those fed with mash feed had the highest and lowest blood glucose levels, respectively. The level of uric acid was lowest in the treatments including crumbled feed in the starter diets and pellet feed in the grower and finisher diets. The level of HDL was lowest in the treatments including pellet feed in the starter and grower diets and mash feed in the finisher diet, while chickens fed with crumbled feed in the starter diet and extruded feed in the grower and finisher diets exhibited the highest levels. Moreover, treatments including pellet feed in the starter and grower diets and mash feed in the finisher diet had the lowest levels of LDL, while chickens fed with mash feed throughout the rearing period had the lowest levels of LDL (Table 5).

Blood parameters are well-established indicators of the physiological, pathological, and nutritional status of animals, and changes in these are considered to find the effects of nutritional factors and feed additives used in animal diets. These parameters are influenced by genetic and environmental factors. Researchers have shown that in treatments where animals consumed feed in pellet form, plasma glucose levels, alanine aminotransferase, cholesterol, and red blood cells were higher compared to treatments in mash form. However, hematocrit and hemoglobin were higher in the mash form (Attia *et al*. 2014), which is not consistent with the results of this study.

CONCLUSION

Based on the obtained data, it can be concluded that different forms of feed during the rearing period had different effects on bird performance. Throughout the rearing period, the greatest BWG was observed in birds fed with extruded feed, while the lowest FCR was related to treatments where crumbled feed was used in the starter diet and extruded feed in the grower and finisher diets, however, no significant difference was observed compared to birds fed with extruded feed throughout the entire rearing period. Examination of some blood parameters also indicated the effect of feed form on some of them. Overall, the results of this study demonstrated that the performance of broiler chickens is influenced by the feed form, and using extruded and pellet feed, especially when used throughout the entire rearing period or in the finishing diet will have positive outcomes with improved broiler performance.

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REFERENCES

Abdollahi M.R., Ravindran V. and Svihus B. (2013a). Influence of grain type and feed form on performance, apparent metabolisable energy and ileal digestibility of nitrogen, starch, fat, calcium and phosphorus in broiler starters. *Anim. Feed Sci. Technol.* **186,** 193-203.

Abdollahi M.R., Ravindran V. and Svihus B. (2013b). Pelleting of broiler diets: An overview with emphasis on pellet quality and nutritional value. *Anim. Feed Sci. Technol.* **179,** 1-23.

Amerah A.M., Ravindran V. and Lentle R.G. (2009). Influence of wheat hardness and xylanase supplementation on the performance, energy utilisation, digestive tract development and digesta parameters of broiler starters. *Anim. Prod. Sci.* **49(1),** 71-78.

Amornthewaphat N., Lerdsuwan S. and Attamangkune S. (2005). Effect of extrusion of corn and feed form on feed quality and growth performance of poultry in a tropical environment. *Poult. Sci.* **84(10),** 1640-1647.

Anjum F.M., Haider M.F., Issa Khan M.M.F., Sohaib M. and Arshad M.S. (2013). Impact of extruded flaxseed meal supplemented diet on growth performance, oxidative stability and quality of broiler meat and meat products. *Lipids Health Dis.* **12(13),** 1-12.

Attia Y.A., El-Tahawy W.S., Abd El-Hamid A.E.H.E., Nizza A., Al-Harthi M.A., El-Kelway M.I. and Bovera F. (2014). Effect of feed form, pellet diameter and enzymes supplementation on carcass characteristics, meat quality, blood plasma constituents and stress indicators of broilers. *Arch. Anim. Breed.* **57(1),** 30-42.

Aviagen. (2019). Ross 308: Broiler Performance Objectives and Nutrition Specifications. Aviagen Ltd., Newbridge, UK.

Azizian M. and Saki A.A. (2020). Effects of the physical form of diet on growth performance, ascites and sudden death syndrome incidences in broiler chickens. *J. Hell. Vet. Med. Soc.* **71(2),** 2087-2094.

Bölükbasi S.C., Aktas M.S. and Güzel M. (2005). The effect of feed regimen on ascites induced by cold temperatures. *Int. J. Poult. Sci.* **4(5),** 326-329.

Brenes A., Viveros A., Centeno C., Arija I. and Marzo F. (2008). Nutritional value of raw and extruded chickpeas (*Cicer arietinum* L.) for growing chickens. *Span. J. Agric. Res*. **6(4),** 537-545.

Chae B.J., Han I.K., Kim J.H., Yang C.J., Chung Y.K., Rhee Y.C. and Ryu K.H. (1997). Effects of extrusion conditions of corn and soybean meal on the physico-chemical properties, ileal digestibility and growth of weaned pigs. *Asian-Australasian J. Anim. Sci.* **10(2),** 170-177.

Chewning C.G., Stark C.R. and Brake J. (2012). Effects of particle size and feed form on broiler performance. *J. Appl. Poult. Res.* **21(4),** 830-837.

Engberg R.M., Hedemann M.S. and Jensen B.B. (2002). The influence of grinding and pelleting of feed on the microbial composition and activity in the digestive tract of broiler chickens. *Br. Poult. Sci.* **43(4),** 569-579.

Garcia A.R., Batal A.B. and Baker D.H. (2006). Variations in the digestible lysine requirement of broiler chickens due to sex, performance parameters, rearing environment, and processing yield characteristics. *Poult. Sci.* **85(3),** 498-504.

Jafarnejad S., Farkhoy M., Sadegh M. and Bahonar A.R. (2010). Effect of crumble-pellet and mash diets with different levels of dietary protein and energy on the performance of broilers at the end of the third week. *Vet. Med. Int*. **4(1),** 328123-328133.

Jahan M.S., Asaduzzaman M. and Sarkar A.K. (2006). Performance of broiler fed on mash, pellet and crumble. *Int. J. Poult. Sci.* **5(3),** 265-270.

Janocha A., Milczarek A., Pietrusiak D., Łaski K. and Saleh M. (2022). Efficiency of soybean products in broiler chicken nutrition. *Animals*. **12(3),** 294-305.

Jiménez-Moreno E., de Coca-Sinova A., González-Alvarado J.M. and Mateos G.G. (2016). Inclusion of insoluble fiber sources in mash or pellet diets for young broilers. 1. Effects on growth performance and water intake. *Poult. Sci*. **95(1),** 41-52.

Li Y., Yang H., Xu L., Wang Z., Zhao Y. and Chen X. (2018). Effects of dietary fiber levels on cecal microbiota composition in geese. *Asian-Australasian J. Anim. Sci.* **31(8),** 1285-1290.

Lv M., Yan L., Wang Z., An S., Wu M. and Lv Z. (2015). Effects of feed form and feed particle size on growth performance, carcass characteristics and digestive tract development of broilers. *Anim. Nutr.* **1(3),** 252-256.

Massuquetto A., Panisson J.C., Marx F.O., Surek D., Krabbe E.L. and Maiorka A. (2019). Effect of pelleting and different feeding programs on growth performance, carcass yield, and nutrient digestibility in broiler chickens. *Poult. Sci.* **98(11),** 5497-5503.

Mingbin L., Zang J. and Piao X. (2015). Effects of feed form and feed particle size on growth performance and gastrointestinal tract development of broilers. *Anim Nutr*. **98(1),** 1-9.

Moradi A., Moradi S. and Abdollahi M.R. (2018). Influence of feed ingredients with pellet-binding properties on physical pellet quality, growth performance, carcass characteristics and nutrient retention in broiler chickens. *Anim. Prod. Sci.* **59(1),** 73-81.

Moritz J.S., Parsons A.S., Buchanan N.P., Calvalcanti W.B., Cramer K.R. and Beyer R.S. (2005). Effect of gelatinizing dietary starch through feed processing on zero-to three-week broiler performance and metabolism. *J. Appl. Poult. Res.* **14(1),** 47-54.

Nir I., Hillel R., Shefet G. and Nitsan Z. (1994). Effect of grain particle size on performance: 2. grain texture interactions. *Poult. Sci.* **73(6),** 781-791.

Rahman M.A.U., Rehman A., Chuanqi X., Long Z.X., Binghai C., Linbao J. and Huawei S. (2015). Extrusion of feed/feed ingredients and its effect on digestibility and performance of poultry: A review. *Int. J. Cur. Microbiol. Appl. Sci*. **4(4),** 48-61.

Reshadi-Nejad S., Tabeidian S.A. and Toghyani M. (2015). The effect of diet type (mash, pellets, extruded and crumble) on some immune responses broiler chicken. *Biol. Forum-An Int. J.* **7(1),** 901-904.

Salari S., Kermanshahi H. and Moghaddam H.N. (2006). Effect of sodium bentonite and comparison of pellet *vs*. mash on performance of broiler chickens. *Int. J. Poult. Sci*. **5(1),** 31-34.

Sarvestani T.S., Dabiri N., Agah M.J. and Norollahi H. (2006). Effect of pellet and mash diets associated with biozyme en-

zyme on broilers performance. *Int. J. Poult. Sci.* **5(5),** 485-490.

SAS Institute. (2003). SAS®/STAT Software, Release 9.1. SAS Institute, Inc., Cary, NC. USA.

Shabani S., Seidavi A., Asadpour L. and Corazzin M. (2015). Effects of physical form of diet and intensity and duration of feed restriction on the growth performance, blood variables, microbial flora, immunity, and carcass and organ characteristics of broiler chickens. *Livest. Sci.* **180,** 150-157.

Subuh A.M.H., Motl M.A., Fritts C.A. and Waldroup P.W. (2002). Use of various ratios of extruded full fat soybean meal and dehulled solvent extracted soybean meal in broiler diets. *Int. J. Poult. Sci.* **1(1),** 9-12.

Veum T.L., Serrano X. and Hsieh F.H. (2017). Twin-or single-screw extrusion of raw soybeans and preconditioned soybean meal and corn as individual ingredients or as corn-soybean product blends in diets for weanling swine. *J. Anim. Sci.* **95(3),** 1288-1300.

Zhang X., Chelliappan B. and Antonysamy M. (2021). Recent advances in applications of bioactive egg compounds in non-food sectors. *Front. Bioeng. Biotechnol*. **9,** 738993-738999.