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Effects of wet feeding and early feed restriction on blood parameters and growth performance of broiler chickens



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ABSTRACT

The aim of the study was to investigate the effects of early feed restriction (FR) with wet feeding on size of small intestine, blood lipids and performance parameters in broilers from d 1 to 42. A total of 160 one-day-old male broiler chickens were randomly allocated to 4 treatments with 4 pens per treatment and 10 chickens per pen, in a fully randomized 2×2 factorial arrangement, two feeding arrangement; providing feed *ad libitum* (Full Fed) or FR by 50% between days 6 to 12, and feed in either wet or dry form (wet form, 1.2 g water per 1 g dry feed). Body weight and feed intake of broiler chickens were determined at d 0, 21, and 42, and feed conversion ratio (FCR) was calculated. At d 42, two birds per replicate were euthanised for determination of carcass weight, organ weight and length, and also for blood parameters, which included high density lipoprotein (HDL), low density lipoprotein (LDL), total cholesterol and triglycerides (TG). The broilers fed wet form irrespective of FR throughout had superior body weight gain and carcass weight compared with birds fed dry diets at d 22 and 42 ($P < 0.05$). The wet form with FR significantly showed lower FCR compared with the wet form and *ad libitum* at d 1 to 21 ($P < 0.05$). The broilers fed wet form had significantly increased HDL, LDL, and total cholesterol and decreased TG ($P < 0.05$). In conclusion, wet form can improve performance growth and blood parameters, and the FR birds were able to attain normal market body weight at d 42, which suggests that growth compensation occurred.

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1. Introduction

The advantages of wet feeding in broilers were recently reviewed by [Yasar and Forbes \(2000\)](#) and wet feeding was suggested by [Scott \(2002\)](#), [Scott and Silversides \(2003\)](#) and [Afsharmanesh et al. \(2006\)](#) as being a valuable tool in increasing our understanding of the limitations in feed intake by broilers fed cereal-based diets. [Yasar and Forbes \(2000\)](#) showed consistent benefits to broiler chickens of feeding conventional feeds mixed with 1.3 parts of water by weight per part of air-dry food. This effect

may be due to changes in the physical properties of the feed, and to allowing more rapid penetration of digestive juices, rather than through improved palatability or pre-digestion between wetting and consumption. In general, broilers more readily accept feed in wet form than dry form ([Mikkelsen and Jensen, 2001](#)). Wet feed can improve daily weight gain and feed intake but can have a variable effect on feed conversion ratio (FCR) ([Afsharmanesh et al., 2006](#); [Scott and Silversides, 2003](#)), because [Scott \(2002\)](#) suggested that adding water to the diet before feeding the hydrated diet allowed digestion to begin immediately and the bird to eat more and grow more quickly, therefore it can be concluded that broilers cannot eat enough dry feed to attain their genetic potential for growth. Fermented wet feed can reduce gastric pH and the number of coliform bacteria in the gastrointestinal tract of broilers ([Afsharmanesh et al., 2010](#)). However, for cereal-based diets, wet feeding resulted in a disproportionately larger increase in feed intake relative to growth rate, and may resulting in a significant increase in FCR ([Yasar and Forbes, 2000](#)). [Washburn \(1991\)](#) demonstrated that slowing the rate of passage of a diet increased nutrient retention.

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Akinola et al. (2015) reported a markedly higher body weight gain for chickens fed wet diets. Wet feeding has been reported to stimulate increased dry matter intake, growth rate and feed conversion efficiency of broilers (Yalda and Forbes, 1995; Awojobi and Meshioye, 2001; Awojobi et al., 2009). It has also been shown to improve broiler performance in the hot tropic as it reduces heat stress and improve feed intake (Dei and Bumbie, 2011). Restricting the excessively high intake of wet-based diets may increase the retention of nutrients.

Physical FR is one of the common procedure was used in controlling feed intake in poultry. Physical FR supply a calculated amount of feed per bird, which is often just enough to meet maintenance requirements (Plavnik and Hurwitz, 1989). Quantitative FR has been observed to reduce mortality and culling (Yu and Robinson, 1992), improve feed conversion ratio (Deaton, 1995; Lee and Lesson, 2001) and allow a complete recovery of body weight if the degree of restriction was not too severe and slaughter ages were extended beyond 6 weeks (Plavnik and Hurwitz, 1988; Deaton, 1995). Plavnik and Hurwitz (1989) reported that broilers subjected to a short period (7 to 14 d) of severe early FR (before 21 d) could show complete catch up in body weight following refeeding. Some studies shows that feed restriction (FR) for short periods during the early growth phases show improvement of feed efficiency and reach a weight equal to that of birds fed *ad libitum* (Hornick et al., 2000; Pinheiro et al., 2004).

However, the aims of this study were to investigate three items as follows: 1) Examine the phenomenon of compensatory growth due to short-term FR with wet feeding method; 2) Determine if feeding wet diets with early FR can be manipulated to overcome the marked loss in FCR of wet-fed cereal-based diets; 3) Effects of limiting feed intake from d 6 to 12 with wet feeding method on growth performance in restricted-*ad lib* fed broilers.

2. Material and methods

2.1. Birds and treatments

One hundred and sixty 1-day-old male broiler chickens (Ross 308) were housed in floor pens covered with wood shavings and were fed experimental treatments from d 1 to 42. At d 1, chickens were individually weighed and assigned to 16 floor pens (100 cm × 120 cm, 10 birds per pen) in an environmentally controlled room with 23-h light and 1-h dark cycle. Room temperature was maintained at 32°C during the first week and gradually decreased to 24°C by the end of the third week. Experimental procedures were approved by the Kerman University Animal Ethics Committee and complied with the animal welfare guidelines at the Veterinary Control and Research Institute of Kerman, Iran.

The starter (d 1 to 21) and finisher (d 22 to 42) basal diets were based on corn-wheat and soybean meal (Table 1). The four dietary treatments tested were based on a 2 × 2 factorial arrangement, two feeding arrangement (full fed, *ad libitum*; FR, restricted to 50% of *ad libitum* from d 6 to 12), and feed in either wet or dry form (wet form, 1.2 g water per 1 g dry feed). Each treatment was fed to four replicate cages of ten chickens each.

The experimental treatments were as follows:

- Treatment 1, *ad libitum* + dry form;
- Treatment 2, *ad libitum* + wet form;
- Treatment 3, FR + dry form;
- Treatment 4, FR + wet form.

Birds in the full-fed groups (Treatments 1, 2) consumed diet (Table 1) on an *ad libitum* basis throughout the experimental period of d 1 to 42. In the other two treatments (3 and 4), birds were

Table 1
Ingredient composition and calculated values of the basal diets (as fed basis).

Item	Starter diet (d 1 to 21)	Grower diet (d 22 to 42)
Ingredients, %		
Corn	45.85	43.74
Wheat	8.00	18.84
Soybean meal, 48%	37.40	29.06
Soybean oil	4.64	4.50
Limestone	1.70	1.74
Dicalcium phosphate ¹	1.20	1.00
NaCl	0.29	0.29
Vitamin-mineral premix ²	0.75	0.75
D, L-Methionine	0.17	0.09
Calculated analysis, %		
Dry matter	92	91
AMEn, kcal/kg	3,076	3,140
Crude protein	22.00	20.20
Calcium	1.00	0.94
Available phosphorus	0.45	0.40
Methionine + cysteine	0.90	0.73
Total lysine	1.25	1.11
Arginine	1.51	1.32
Arginine:lysine	1.21	1.19

AMEn = nitrogen corrected apparent metabolizable energy.

¹ Contained 23% Ca and 20% P.

² Supplied per kilogram of diet: vitamin A, 8,800 IU (retinyl palmitate); vitamin D₃, 3,300 IU; vitamin E, 11.0 IU (dl- α -tocopheryl acetate); riboflavin, 9.0 mg; biotin, 0.25 mg; thiamin, 4 mg; pantothenic acid, 11.0 mg; vitamin B₁₂, 13 μ g; niacin, 26 mg; choline, 900 mg; vitamin K, 1.5 mg; folic acid, 1.5 mg; ethoxyquin, 125 mg; manganese, 55 mg; zinc, 50 mg; copper, 5 mg; iron, 30 mg; selenium, 0.1 mg.

limited in quantity of feed through physical FR. Feed intake of FR chickens during the period d 6 to 12 was restricted to 50% of the voluntary feed intake of their full-fed counterparts in Treatments 1, 2. This amount was calculated by averaging the daily feed intake for all four replicates of the control birds and then providing 50% of this as the feed allocation for the FR birds for the following days.

Dry diets were ground with a hammer mill (P-241 DTF Pulverator, Jacobson Machine Works, Minneapolis, MN) with 3-mm screen, to give grind sizes classified as fine meal. The basal diets were isonitrogenic at 225.0 and 200.0 g/kg crude protein and isocaloric at 12.9 and 13.2 nitrogen corrected apparent metabolizable energy (AMEn) MJ/kg in starter and grower phases, respectively. The diets met or exceeded the nutrient requirements of chickens (National Research Council, 1994). Provision of each of the two wet-diets was as described by Scott (2002). Briefly, an ample allotment of daily dry feed was mixed by hand with 1.2 parts water (this amount of water was sufficient to give the consistency of sloppy porridge), allowed to stabilize for 15 min and then divided into plastic-lined feeders identical to those used for feeding dry diets. The wet feed and feeder were weighed, presented to the broilers for a 24 h period and reweighed, with the difference used to determine intake expressed on a dry weight basis. Any feed remaining after 24 h was discarded. No correction was made for evaporation of water from the wet diet.

2.2. Performance and digestive tract measurements

Daily feed intake for each pen was recorded. The average body weight gain (BWG) and feed intake was adjusted for mortality to d 22 and 42 and was used to calculate FCR. When the broilers were 42 days of age, 8 birds per treatment (two birds closest to the mean weight of each replicate pen) were randomly selected, BW was recorded and the birds were euthanised by cervical dislocation. The gastrointestinal tract and organs were carefully excised. The empty weight and length of duodenum, proximal ileum (from the pancreatic loop to Meckel's diverticulum), and distal ileum (from Meckel's diverticulum to the ileocaecal junction) were recorded.

Empty weight of the gizzard and the weights of the pancreas, heart, spleen, bursa and liver were also recorded. The relative organ weights (g/kg BW) and relative length (cm/kg BW) were calculated.

2.3. Blood sample collection

Before euthanization at d 42, a blood sample was collected from the brachial vein into heparinized syringes from eight birds per treatment for digestive tract measurements. Blood samples were stored in ice following collection and then centrifuged, and plasma was stored at -20°C until analysis. The concentrations of plasma lipids (high density lipoprotein (HDL), low density lipoprotein (LDL), total cholesterol and triglycerides (TG)) were measured using standard commercial kits (Sigma Chemical Co., St. Louis, MO 63178-9916).

2.4. Statistical analyses

Data were subjected to ANOVA using the general linear model procedure of SAS (SAS Institute, 1999, Cary, NC, USA) to determine the main effects and the interactions for feeding arrangement and feed form (FF). Means were separated using Duncan's post hoc test and were considered to be significantly different at $P < 0.05$. Interaction between the treatments was excluded from the model when not significant ($P > 0.05$).

3. Results

3.1. Chicken performance

The effects of feeding arrangement and FF on growth performance are summarized in Table 2. Birds on the wet treatment weighed more ($P < 0.01$) than those on the dry treatment at d 22 and 42. From d 1 to 21, 22 to 42, and 1 to 42, the feed intake of birds fed the wet form was higher ($P < 0.01$) than that of birds fed the dry form, but there were no differences ($P > 0.05$) between treatments in the FCR. Over the entire trial period (d 1 to 42), there were no difference ($P > 0.05$) in the BWG, feed intake, and FCR of broilers fed diets with or without FR. However, the average feed intake and FCR from d 1 to 21 were lower ($P < 0.05$) for birds with restricted feed

compared with the control birds, but no difference in BWG was observed. The birds fed wet form had higher BWG and feed intake ($P < 0.01$) from d 1 to 21, 1 to 42 and 22 to 42. The birds fed wet form and restricted feed have significantly lower FCR compared with those fed wet form and the feed was available *ad libitum* at d 1 to 21. There were no significant effects of feeding level on FCR at d 42 for either the wet form or dry form.

3.2. Carcass and digestive tract measurements

Relative carcass weight was significantly ($P < 0.05$) higher for the broilers fed wet form than dry diets by 3.6% (Table 3). Relative duodenum weight and ileum length of broilers fed wet form were significantly ($P < 0.05$) lower than those fed dry form. A significant interaction ($P < 0.05$) was observed between FF and FR (restricted, *ad libitum*) for the relative ileum weight, indicating a positive effect of wet feeding on producing the lowest relative ileum weight in compared with dry feeding especially in *ad libitum*. The relative weights of gizzard, pancreas, liver, bursa and spleen were not significantly affected by either feed form or FR or the interaction between them (results not shown).

3.3. Plasma analysis

The main effects and interactions between feeding arrangement and FF on plasma lipids contents are summarized in Table 4. Statistical analysis of the data showed that changing in feed form as wet caused a significant increase in the plasma HDL, LDL and total cholesterol ($P < 0.05$) concentrations, and a decrease in plasma TG ($P < 0.05$) content. However, in wet feeding with restricted, the plasma TG was significantly lower ($P < 0.01$) than that with dry feeding. Total cholesterol in birds receiving wet feeding as *ad libitum* was significantly higher compared with dry feeding as restricted ($P < 0.05$). However, LDL in chickens fed wet form as *ad libitum* or restricted diets were higher compared with those fed dry form as restricted ($P < 0.01$).

Table 2
Effects of feed form (wet and dry) and feeding arrangement (feed restricted and *ad libitum*) on daily weight gain, feed intake and FCR of male broilers on d 1 to 21, d 22 to 42 and d 1 to 42.¹

Item	Body weight gain, g/(bird · d)			Daily feed intake, g/(bird · d)			FCR, g/g		
	(d 1 to 21)	(d 22 to 42)	(d 1 to 42)	(d 1 to 21)	(d 22 to 42)	(d 1 to 42)	(d 1 to 21)	(d 22 to 42)	(d 1 to 42)
Feeding arrangement									
FR	33.04	80.15	55.56	44.42 ^b	160.17	99.77	1.34 ^b	2.00	1.79
<i>Ad libitum</i>	33.65	80.46	56.05	46.73 ^a	157.3	99.58	1.38 ^a	1.95	1.77
Feed form (FF)									
Dry	31.27 ^b	77.23 ^b	53.52 ^b	42.64 ^b	150.91 ^b	95.0 ^b	1.36	1.95	1.77
Wet	35.41 ^a	83.38 ^a	58.09 ^a	48.51 ^a	166.56 ^a	104.3 ^a	1.37	2.00	1.79
SEM	0.96	5.10	5.54	3.52	8.26	4.50	0.04	0.04	0.06
Feeding arrangement × FF									
FR × Dry	31.03	76.31	52.99	42.13 ^c	151.37	95.12	1.35 ^b	1.98	1.79
FR × Wet	35.04	83.99	58.13	46.71 ^b	168.96	104.42	1.33 ^b	2.01	1.79
<i>Ad libitum</i> × Dry	31.52	77.54	53.75	43.14 ^c	150.45	94.97	1.36 ^{ab}	1.93	1.76
<i>Ad libitum</i> × Wet	35.78	82.77	58.05	50.31 ^a	164.15	104.19	1.40 ^a	1.98	1.79
SEM	0.5	2.75	1.44	0.66	4.51	2.34	0.01	0.03	0.02
Source of variation	Significance of treatment effect								
Feeding arrangement	NS	NS	NS	*	NS	NS	*	NS	NS
FF	*	*	*	*	*	*	NS	NS	NS
Feeding arrangement × FF	NS	*	NS	**	NS	NS	**	NS	NS

FCR = feed conversion ratio; FR = feed restricted, 50% FR from d 6 to 12; Dry = dry form; Wet = wet form, 1.2 g water per 1 g dry feed; SEM = standard error of mean. NS = non significant, * $P < 0.05$, ** $P < 0.01$.

^{a, b} Within a column, means without a common superscript differ significantly ($P < 0.05$).

¹ Data are means of 4 replicate pens of 10 birds each.

Table 3Effects of feed form (wet and dry) and feeding arrangement (feed restricted and ad libitum) on relative weight and length of gastrointestinal segments of male broilers at d 42.¹

Item	Relative carcass weight, % BW		Small intestine weight, % BW			Small intestine length, cm		
	Carcass	Heart	Duodenum	Proximal ileum	Distal ileum	Duodenum	Proximal ileum	Distal ileum
Feeding arrangement								
FR	60.93	0.60	0.60	1.42	1.24	1.37	3.02	2.93
Ad libitum	62.00	0.61	0.63	1.46	1.14	1.34	2.99	2.99
Feed form (FF)								
Dry	60.37 ^b	0.63	0.65 ^a	1.50	1.20	1.40	3.28 ^a	3.28 ^a
Wet	62.55 ^a	0.58	0.57 ^b	1.38	1.17	1.32	2.73 ^b	2.64 ^b
SEM	2.02	0.06	0.06	0.14	0.16	0.12	0.26	0.26
Feeding arrangement × FF								
FR × Dry	60.35	0.58	0.59	1.46 ^{ab}	1.20 ^{ab}	1.40	3.28	3.21
FR × Wet	61.50	0.61	0.61	1.38 ^b	1.20 ^{ab}	1.35	2.76	2.65
Ad libitum × Dry	60.38	0.58	0.60	1.55 ^a	1.27 ^a	1.40	3.28	3.35
Ad libitum × Wet	63.59	0.63	0.66	1.37 ^b	1.07 ^b	1.29	2.70	2.63
SEM	1.07	0.03	0.03	0.07	0.07	0.06	0.14	0.13
Source of variation			Significance of treatment effect					
Feeding arrangement	NS	NS	NS	NS	NS	NS	NS	NS
FF	*	NS	*	NS	NS	NS	*	*
Feeding arrangement × FF	NS	NS	NS	*	*	NS	NS	NS

FR = feed restricted, 50% FR from d 6 to 12; Dry = dry form; Wet = wet form, 1.2 g water per 1 g dry feed; SEM = standard error of mean.

NS = non significant, * $P < 0.05$, ** $P < 0.01$.^{a, b} Within a column, means without a common superscript differ significantly ($P < 0.05$).¹ Data are means of 4 replicate pens of 2 birds each.**Table 4**Effects of feed form (wet and dry) and feeding arrangement (feed restricted and ad libitum) on blood cholesterol, HDL, LDL and TG in male broilers at d 42.¹

Item	Blood fat parameters			
	Total cholesterol, mg/dL	HDL, mg/dL	LDL, mg/dL	TG, mg/dL
Feeding arrangement				
FR	124.42	74.66	29.78	99.92
Ad libitum	133.08	75.08	35.15	135.08
Feed form (FF)				
Dry	123.00 ^b	69.50 ^b	27.85 ^b	153.25 ^a
Wet	134.50 ^a	80.28 ^a	37.90 ^a	81.75 ^b
SEM	13.24	7.90	6.34	45.14
Feeding arrangement × FF				
FR × Dry	118.16 ^b	68.66	21.76 ^b	138.66 ^{ab}
FR × Wet	130.66 ^{ab}	80.66	37.76 ^a	61.16 ^c
Ad libitum × Dry	127.83 ^{ab}	70.33	32.28 ^a	167.83 ^a
Ad libitum × Wet	138.33 ^a	79.83	38.03 ^a	102.33 ^{bc}
SEM	7.20	3.89	2.45	21.64
Source of variation	Significance of treatment effect			
Feeding arrangement	NS	NS	NS	NS
FF	*	*	*	*
Feeding arrangement × FF	*	NS	**	**

HDL = high density lipoprotein; LDL = low density lipoprotein; TG = triglycerides; FR = feed restricted, 50% FR from d 6 to 12; Dry = dry form; Wet = wet form, 1.2 g water per 1 g dry feed; SEM = standard error of mean.

NS = non significant, * $P < 0.05$, ** $P < 0.01$.^{a-c} Within a column, means without a common superscript differ significantly ($P < 0.05$).¹ Data are means of 4 replicate pens of 2 birds each.

4. Discussion

One of the main aim of this study was to determine if feeding wet diets with early FR can be manipulated to overcome the marked loss in FCR of wet-fed cereal-based diets. Changing FF in this experiment significantly influenced BW, FI, blood parameters, and most carcass characteristics. The birds fed wet form throughout had superior performance and carcass weight compared with birds fed dry feed at any time, which is in agreement with previous results (Afsharmanesh et al., 2006, 2010; Scott, 2002; Scott and Silversides, 2003). Increased body weights of birds fed wet form may be linked, to some extent, to increased feed consumption. In the current experiment, feed-restricted birds were able to attain normal market body weight at d 42, suggesting that growth compensation occurred. The duration and severity of the FR used in

this experiment allowed birds to attain market body weight for age. The energy to support accelerated growth may come from a reduction in the overall maintenance energy needs (Yu and Robinson, 1992) or from a decrease in needs for basal metabolic rate as previously observed in feed-restricted birds (Zubair and Leeson, 1994). However, fast initial growth rate can lead to management problems, such as increased incidence of metabolic disorders. Also, if early growth rate can be tempered without loss in weight-for-age at 42 to 56 d, then there should be potential for improved feed efficiency due to reduced maintenance needs. This concept is often termed compensatory gain. If growth rate is to be reduced, then based on needs to optimize feed usage, nutrient restriction must occur early in the growth out period. As the bird gets older, a greater proportion of nutrients are used for maintenance and less is used for growth. Therefore, reducing nutrient intake in,

say the first 7 d, will have little effect on feed efficiency, because so little feed is going towards maintenance. At 8 weeks of age, a FR program would be more costly, because with say a 20% restriction there would likely be no growth, because 80% of nutrients must go towards maintenance. Early FR programs therefore make sense from an energetic efficiency point of view, and are the most advantageous in programs aimed at reducing the incidence of metabolic disorders (Leeson and Summers, 1997).

Washburn (1991) demonstrated that slowing the rate of passage of a diet increased nutrient retention. Therefore, in this experiment restricting the excessively high intake of wet based diets may increase the retention of nutrients and positively affect BWG. This finding may result from the fact that proportionally more nutrients are used for growth rather than for maintenance (Leeson and Summers, 1997). Results of this experiment generally show significance of diet form manipulation (wet form vs. dry form) as a means of accelerating growth rate during after restriction.

This study showed that wet corn-wheat-based diets lowered relative ileum weight and length of broilers throughout the trial period, which may impact the retention of nutrients and maintenance requirements associated with decreased gut size (Washburn, 1991). The decrease in the relative weight and length of ileum was probably caused by a decrease in the thickness of the small intestine and a reduction in the crypt cell proliferation rate (Yasar and Forbes, 2000). The greater feed intake and decreased gut length with wet feeding indicate a faster rate of passage of digesta. The reduction in ileum length and weight in wet-fed birds may be associated with a decrease in the viscosity of gut contents and the concentration of volatile fatty acids in the ceca (Yasar and Forbes, 2000) and a faster digesta passage rate and its greater dilution with water. The reduction in gut size represents a considerable reduction in the nutrient cost of maintaining the integrity of the gut and a potential to increase the efficiency of utilization of nutrients for growth (Yasar and Forbes, 2000).

Scott (2002) suggested that adding water to the diet before feeding the hydrated diet allowed digestion to begin immediately and the bird to eat more and grow more quickly. The current study showed an increased feed transit rate of birds offered wet diets, and this may have enabled the birds to eat more and grow more quickly (Afsharmanesh et al., 2010). Further, wet feeding reduced digesta viscosity and crypt cell proliferation and increased intestinal villus height, all factors that improve nutrient digestibility (Yasar and Forbes, 2000).

Nutritional factors (diet quantity, form and composition) also affect intermediary metabolism, resulting in changes in plasma metabolite levels in poultry (Buyse et al., 2002; Swennen et al., 2005). Interestingly, this study showed that wet form with restricted diets resulted in decreased TG. The addition of water could have enhanced the digestion of feed and absorption of nutrients, which in turn which may have been responsible for an enhanced rate of lipid metabolism and it could have affected blood metabolite concentrations. However, the mechanism(s) of action still need to be elucidated (Swennen et al., 2005).

5. Conclusions

It is concluded that the wet feeding increased BWG irrespective if feed was available ad libitum or restricted, and caused a proportional increase in feed intake relative to growth rate, but wet feeding with FR improved FCR compared with wet feeding and ad

libitum at 1 to 21 d. These results show that wet form with restricted feed not only didn't have any harmful effects on BW and FCR in whole of study periods. Broilers fed wet form with restriction decreased TG and LDL.

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