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Original Research Article

Effects of dynamic segmentation of nutrient supply on growth performance and intestinal development of broilers

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ABSTRACT

This experiment was to investigate the effects of dynamic segmentation of interval nutrient supply phase feeding on the growth performance, carcass characteristics, immune organs indexes and intestinal morphology of broilers. A total of 320 one-day-old broilers were randomly assigned into 4 feeding treatments, which included 4 interval nutrient supply phases as follows. Treatment A: a nutrient supply standard was used for every 14 d. Treatment B: a nutrient supply standard was used for every 7 d. Treatment C: a nutrient supply standard was used for every 3.5 d except that one nutrient supply standard was used for d 1 to 7. Treatment D: a nutrient supply standard was used for every 3.5 d including d 1 to 7. Each treatment was represented by 8 replicates with 10 broilers per replicate. The trial lasted for 42 days. Throughout the 42 d trial period, treatment A showed significantly higher average daily gain than treatments B and C ($P < 0.05$). The feed:gain ratio of treatment A was significantly lower than those of treatments C and D ($P < 0.05$). On d 28 and 42, body weight of broilers in treatment A was much higher than those of treatments B and C ($P < 0.05$). The slaughter rate of treatment A was significantly higher than that of treatment B ($P < 0.05$). Eviscerated percentage of treatment A was significantly higher than those of treatment B and D ($P < 0.05$). There were no significant differences among 4 treatments in immune organs indexes ($P > 0.05$). The crypt depth of duodenum was significantly greater in treatments A and B than in treatment C on day 42 ($P < 0.05$). Meanwhile, the ratio of villus height to crypt depth (V:C ratio) of treatment D was significantly higher than that of treatment A ($P < 0.05$). No significant differences were found between treatments C and D in growth performance, carcass performance, immune organs indexes and intestinal structure ($P > 0.05$). In conclusion, this study revealed that the growth and carcass performance of broilers is the best for 14 days segmentation phase feeding, and 3.5 days segmentation interval phase feeding can promote small intestinal development of broilers. Dynamic segmentation of dietary supply fails to affect the immune function of broilers.

1. Introduction

Modern animal nutrition research has mainly described the conversion of nutrients from static rules to dynamic nutrition, and dynamic precision nutrition has become the inevitable trend in the development of animal nutrition and feed science (Ji, 2008). Dynamic precision nutrition is to meet the nutritional needs of animals in different growth stages, environment and production purposes by the precise feed formulation and feeding technology. Application of precision farming can maximize animal performance, improve feed efficiency and reduce environmental pollution (D'Alfonso et al., 1996; Brewer et al., 2012; Kebreab et al., 2012). Currently, the nutrient specifications for Arbor Acres (AA) are 0–10 d, 1124 d, and 25 d to slaughter. According to report by Wang et al. (1994), the first week after the broiler hatching is the most special period because that the nutrients requirements are provided by both exogenous nutrition (diet) and endogenous nutrition

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(yolk sac). It is confirmed that in the early age of birds, physiological development is under a very unstable state, particularly digestive physiology (Guo and Zhan, 2015). The implementation of dynamic farming will not only affect the growth performance of broilers, further more it can reduce the feed costs and improve the feeding efficiency (Roush et al., 2004; Warren and Emmert, 2000; Qiu et al., 2013).

Growth process of broiler is complex as the nutrition requirements change with age. Broilers get stressed if dietary supply of nutrients is inconsistent with the requirements. However, if we change the diets of broilers every day according to its daily nutrition requirement, it will also led to the occurrence of stress due to frequent changes of nutrient levels. Stress may affect the immune function and the development of intestine, thereby affecting the growth and carcass performance of broilers. There must be a balance point of dynamic segmentation where the broilers can reach the best growth potential. Few studies have determined the effects of dynamic segmentation of dietary nutrient supply on production and physicochemical properties of broilers, thus a reasonable dynamic segmentation phase feeding program needs to be evaluated.

2. Materials and methods

2.1. Animals and diets

A total of 320 newly hatched healthy AA broilers from a commercial hatchery (Hua Du Broiler Company, Beijing, China) were randomly assigned into four treatments with 8 replicates (half male and half female). Treatments A to D were 4 interval nutrient supply phase feeding programs. Treatment A: to change nutrient supply standard for every 14 days. Treatment B: to change nutrient supply standard for every 7 days. Treatment C: to change nutrient supply standard for every 3.5 days except that one nutrient supply standard was used from d 1 to 7. Treatment D: to change nutrient supply standard for every 3.5 days and including d 1 to 7. Treatments C and D were set to test the effects of early (d 1 to 7) dynamic segmentation on broilers. Twelve types of diets were formulated according to the dynamic nutrition requirements and performance prediction model designed by the software of Feed Research Institution, Chinese Academy of Agricultural Sciences. Formulated diets were from the same batch of raw materials. Ingredients and nutrient composition of experimental diets are shown in Table 1.

The experiment lasted for 42 days. Broilers in treatment A were successively fed diets 1, 5, 9 every 2 weeks, and broilers in treatment B were successively fed diets 1, 3, 5, 7, 9 and 11 every week, broilers in treatment D were successively fed diets 1 to 12 every 3.5 days, and broilers in treatment C were fed diet 1 in the first week, and then the same diets as treatment D for the following 5 weeks. Birds were given water and feed ad libitum and vaccinated according to the normal immunization program. Experimental procedures followed the pertinent laws of animal protection approved by the Animal Care Advisory Committee of Feed Research Institute, Chinese Academy of Agricultural Sciences.

2.2. Sampling

On d 14, 28 and 42 of the trial, one bird with average body weight was taken from each replicate, weighed and slaughtered by bleeding the left jugular vein. Tissue samples (about 1.5 cm in length) were taken from duodenum, jejunum and ileum, flushed, and fixed in 4% neutral buffered formalin for histological analysis. Thymus, spleen and bursa were collected and weighed after excluding the fat. Besides, 2 birds from each replicate were weighed and slaughtered by bleeding the left jugular vein on day 42 of the trial.

2.3. Growth performance

Fasting of broilers began at 24:00 on d 13, 27 and 41 with free access to water. The feed intake, ADFI, ADG and F:G ratio were determined at 08:00 on d 14, 28 and 42 for each replicate.

2.4. Carcasses performance

On d 42 of the trial, live weight, carcass weight, eviscerated weight, breast muscle, leg muscle and abdominal fat of 2 birds were weighed to calculate slaughter rate, eviscerated percentage, percentage of breast muscle, percentage of leg muscle and abdominal fat rate. Carcass weight means the weight of poultry body after bleeding and plucking. Eviscerated weight is the weight of half-eviscerated, which refers to the removal of the weight of the heart, liver, gizzard, proventriculus, lungs, abdominal fat, head and feet.

2.5. Immune organs indexes

Thymus, spleen and bursa index were derived by the following equation. Immune organs indexes (%) = 100 × Immune organ weight/Body weight.

2.6. Intestinal morphology examination

Morphological analysis was performed on formalin-fixed intestinal samples. The samples were embedded in paraffin, sectioned and stained with hematoxylin and eosin. The sections were visualized using a light microscope. Villus height and crypts depth were measured and analyzed using Image-ProPlus 7.0 software, and 5 well-oriented villi and crypts from each sample were selected for measuring villus height and crypt depth. The ratio of villus height to crypt depth (V:C ratio) was also calculated.

2.7. Statistical analysis

Growth performance data, carcasses performance data, immune organs indexes and intestinal morphology data were analyzed with one-way ANOVA using SPSS 19.0. If the effects of dynamic segmentation of nutrient supply were significant, the means among the treatments were further compared using the Duncan test. Data were presented as means ± SD, and $P < 0.05$ was considered as significant.

3. Results

3.1. Growth performance

Broiler growth performance is presented in Table 2. No differences in ADG, ADFI and F:G ratio of broilers were observed among the 4 treatments ($P > 0.05$) from both d 1 to 14 and d 29 to 42. However, the ADG of broilers in treatment A was higher than those of treatment B and C for d 15 to 28, and d 1 to 42 periods ($P < 0.05$). Throughout the entire trial, the F:G ratio was significantly lower of treatment A than of treatments C and D ($P < 0.05$). Moreover, there were no significant differences appeared in growth performance between treatments C and D ($P > 0.05$).

Body weight data of broilers on d 1, 14, 28 and 42 are shown in Table 3. On d 1 and 14, there were no significant differences in BW

Table 1
Composition and nutrient levels of diets (air-dry basis).

Item	Diets[1]											
	1	2	3	4	5	6	7	8	9	10	11	12
Ingredients, %												
Corn	51.59	52.80	54.00	55.29	56.60	58.29	60.10	61.74	63.62	64.37	65.10	65.97
Soybean meal	38.90	37.60	36.20	34.90	33.50	31.80	30.00	28.40	26.60	25.90	25.20	24.50
Soybean oil	5.39	5.58	5.85	6.00	6.18	6.18	6.17	6.16	6.10	6.09	6.09	6.01
$CaHPO_4$	1.57	1.57	1.53	1.44	1.40	1.37	1.37	1.34	1.31	1.26	1.20	1.11
DL-Met	0.23	0.21	0.21	0.19	0.18	0.18	0.18	0.17	0.17	0.17	0.18	0.18
L-LysHCl	0.19	0.18	0.18	0.16	0.15	0.17	0.18	0.19	0.20	0.21	0.22	0.21
Thr	0.06	0.04	0.04	0.03	0.02	0.04	0.04	0.06	0.06	0.07	0.08	0.08
NaCl	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Limestone	1.11	1.07	1.04	1.04	1.02	1.02	1.01	1.00	1.00	0.99	1.00	1.01
Choline chloride	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.13
Premix[2]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nutrient levels[3], %												
ME, MJ/kg	12.73	12.83	12.94	13.04	13.14	13.20	13.26	13.31	13.37	13.39	13.42	13.44
CP	23.79	23.39	23.34	23.27	23.19	21.77	20.52	20.01	19.29	18.86	18.52	18.48
Ca	1.95	1.92	1.91	1.89	1.86	1.85	1.83	1.81	1.77	1.74	1.66	1.64
Phosphorus	3.38	3.37	3.30	3.29	3.27	3.26	3.25	3.23	3.22	3.21	3.14	2.92
Lys	1.73	1.59	1.59	1.56	1.58	1.56	1.59	1.48	1.37	1.27	1.39	1.30
Met	0.59	0.59	0.58	0.55	0.51	0.63	0.54	0.38	0.49	0.49	0.57	0.57
Met + Cys	0.90	0.89	0.90	0.85	0.82	0.94	0.82	0.65	0.76	0.78	0.83	0.84
Thr	1.05	0.94	0.95	0.89	0.93	0.91	0.89	0.89	0.83	0.82	0.81	0.78

ME = metabolic energy; CP = crude protein.
[1] Diets were numbered from 1 to 12.
[2] The premix provided the following per kg of diets: vitamin A 10,000 IU, vitamin D_3 2,000 IU, vitamin E 20 IU, vitamin B_1 2.0 mg, vitamin K_3 2.5 mg, vitamin B_2 4.0 mg, vitamin B_6 5.0 mg, vitamin B_{12} 0.02 mg, *D*-pantothenic acid 11.0 mg, nicotinic acid 35 mg, folic acid 0.5 mg, biotin 0.12 mg, Fe (as ferrous sulfate) 80 mg, Cu (as copper sulfate) 8 mg, Zn (as zinc sulfate) 78 mg, Mn (as manganese sulfate) 100 mg, I (as potassium iodide) 0.34 mg, Se (as sodium selenite) 0.15 mg.
[3] Except that the value of ME was calculated, other values were measured.

Table 2
Effects of dynamic segmentation of nutrient supply on performance of broilers.

Treatment	ADG, g	ADFI, g	F:G ratio
d 1 to 14			
A	27.37 ± 1.34	32.91 ± 1.38	1.24 ± 0.08
B	26.63 ± 1.30	33.20 ± 0.99	1.24 ± 0.53
C	26.49 ± 0.49	33.23 ± 1.52	1.24 ± 0.42
D	27.25 ± 1.22	33.51 ± 1.20	1.24 ± 0.05
d 15 to 28			
A	70.09 ± 8.88[a]	103.00 ± 7.41	1.54 ± 0.19
B	61.42 ± 5.36[b]	97.69 ± 5.84	1.59 ± 0.19
C	62.60 ± 4.76[b]	98.16 ± 5.87	1.52 ± 0.11
D	65.67 ± 4.85[ab]	101.47 ± 9.67	1.66 ± 0.14
d 29 to 42			
A	73.93 ± 5.57	150.47 ± 12.83	2.05 ± 0.14
B	69.20 ± 7.49	145.29 ± 12.26	2.12 ± 0.04
C	69.03 ± 8.24	143.10 ± 14.83	2.09 ± 0.12
D	68.31 ± 8.92	149.63 ± 13.43	2.21 ± 0.15
d 1 to 42			
A	58.32 ± 2.32[a]	91.26 ± 3.74	1.66 ± 0.05[b]
B	53.66 ± 3.57[b]	87.99 ± 4.60	1.71 ± 0.02[ab]
C	53.52 ± 4.05[b]	89.06 ± 4.43	1.72 ± 0.07[a]
D	54.67 ± 3.05[ab]	92.17 ± 4.73	1.75 ± 0.04[a]

ADG = average daily gain; ADFI = average daily feed intake; F:G ratio = feed intake: gain.
[a,b] Within a column, means with different superscripts differ significantly ($P < 0.05$).

among the 4 treatments ($P > 0.05$). However, BW of treatment A was higher than those of treatments B and C on both d 28 and 42 ($P < 0.05$). Meanwhile, no differences were observed in BW between treatments C and D ($P > 0.05$).

3.2. Carcass performance

The broiler carcass performance was presented in Table 4. Broilers slaughter rate was higher of treatment A than of treatment B ($P < 0.05$). Furthermore, eviscerated percentage was higher of treatment A than of treatments B and D ($P < 0.05$). However, there were no significant differences in percentage of breast muscle, percentage of leg muscle and abdominal fat rate among 4 treatments ($P > 0.05$). Besides, no significant differences appeared in carcass performance between treatments C and D ($P > 0.05$).

3.3. Immune organs indexes

There were no significant differences in the thymus index, spleen index, bursa index among 4 treatments ($P > 0.05$, Table 5).

Table 3
Effects of dynamic segmentation of nutrient supply on BW of broilers.

Treatment	BW, g			
	d 1	d 14	d 28	d 42
A	43.95 ± 0.71	427.17 ± 19.09	1,408.42 ± 130.88[a]	2,493.18 ± 98.14[a]
B	44.20 ± 0.93	417.00 ± 18.59	1,276.91 ± 86.80[b]	2,297.80 ± 149.68[b]
C	43.93 ± 0.85	414.80 ± 7.40	1,291.25 ± 69.64[b]	2,291.67 ± 170.69[b]
D	44.43 ± 1.06	425.86 ± 16.86	1,345.21 ± 78.01[ab]	2,340.49 ± 128.42[ab]

BW = body weight.
[a,b] Within a column, means with different superscripts differ significantly ($P < 0.05$).

Table 4
Effects of dynamic segmentation of nutrient supply on the carcass performance of broilers.

Treatment	Slaughter rate, %	Eviscerated percentage, %	Percentage of breast muscle, %	Percentage of leg muscle, %	Abdominal fat rate, %
A	85.36 ± 1.06[a]	74.26 ± 1.35[a]	13.69 ± 0.58	10.22 ± 0.39	2.59 ± 0.70
B	83.93 ± 0.88[b]	71.77 ± 0.88[c]	14.12 ± 0.82	10.31 ± 0.99	2.66 ± 0.75
C	84.91 ± 0.99[ab]	73.35 ± 0.52[ab]	13.90 ± 0.31	9.87 ± 0.51	2.96 ± 0.72
D	84.91 ± 0.79[ab]	72.93 ± 0.78[b]	14.06 ± 0.79	9.89 ± 0.59	2.45 ± 0.47

[a,b] Within a column, means with different superscripts differ significantly ($P < 0.05$).

Table 5
Effects of dynamic segmentation of nutrient supply on immune organ index of broilers.

Treatment	Thymus index, %	Spleen index, %	Bursa index, %
d 14			
A	0.32 ± 0.12	0.08 ± 0.03	0.21 ± 0.06
B	0.39 ± 0.08	0.08 ± 0.02	0.21 ± 0.04
C	0.33 ± 0.08	0.09 ± 0.02	0.19 ± 0.04
D	0.37 ± 0.06	0.09 ± 0.02	0.21 ± 0.04
d 28			
A	0.19 ± 0.04	0.09 ± 0.02	0.14 ± 0.03
B	0.20 ± 0.04	0.08 ± 0.02	0.15 ± 0.04
C	0.27 ± 0.13	0.09 ± 0.03	0.16 ± 0.05
D	0.24 ± 0.06	0.09 ± 0.02	0.16 ± 0.03
d 42			
A	0.13 ± 0.04	0.13 ± 0.06	0.05 ± 0.01
B	0.14 ± 0.04	0.12 ± 0.03	0.06 ± 0.01
C	0.16 ± 0.03	0.08 ± 0.03	0.06 ± 0.02
D	0.13 ± 0.01	0.14 ± 0.04	0.07 ± 0.02

3.4. Intestinal morphology

Morphological data of duodenum are presented in Table 6. There were no significant differences in the villus height, crypt depth and V:C ratio in the duodenum on d 14 and 28 ($P > 0.05$). However, the crypt depth of broilers was higher in treatments A and B than in treatment C on d 42 ($P < 0.05$). The V:C ratio was significantly higher in treatment D than in treatment A on d 42 ($P < 0.05$). Furthermore, no significant differences appeared in villus height, crypt depth and V:C ratio between treatments C and D ($P > 0.05$). No significant differences appeared in villus height, crypt depth and V:C ratio in the jejunum among all groups ($P > 0.05$, Table 7). Similarly, there were no significant differences in villus height, crypt depth and V:C ratio in the ileum ($P > 0.05$, Table 8).

Table 6
Effects of dynamic segmentation of nutrient supply on villous height, crypt depth and V:C ratio in duodenum of broilers.

Treatment	Duodenum		
	Villous height, μm	Crypt depth, μm	V:C ratio
d 14			
A	666.01 ± 35.04	126.87 ± 18.60	5.33 ± 0.70
B	655.11 ± 42.21	124.50 ± 17.49	5.36 ± 0.89
C	664.22 ± 34.37	121.83 ± 13.44	5.50 ± 0.61
D	640.67 ± 27.51	118.73 ± 13.31	5.45 ± 0.58
d 28			
A	828.27 ± 77.17	149.06 ± 8.07	5.57 ± 0.57
B	843.11 ± 114.26	156.13 ± 13.61	5.41 ± 0.73
C	850.94 ± 95.13	153.78 ± 7.63	5.54 ± 0.60
D	829.00 ± 98.63	154.45 ± 14.00	5.42 ± 0.91
d 42			
A	827.66 ± 127.92	184.99 ± 11.16[a]	4.28 ± 0.64[b]
B	853.34 ± 60.12	184.25 ± 13.31[a]	4.60 ± 0.45[ab]
C	796.24 ± 69.77	173.18 ± 4.50[b]	4.60 ± 0.33[ab]
D	846.79 ± 81.43	174.89 ± 8.65[ab]	4.86 ± 0.40[a]

V:C = the ratio of villus height to crypt depth.
[a,b] Within a column, means with different superscripts differ significantly ($P < 0.05$).

Table 7
Effects of dynamic segmentation of nutrient supply on villous height, crypt depth and V:C ratio in jejunum of broilers.

Treatment	Jejunum		
	Villous height, μm	Crypt depth, μm	V:C ratio
d 14			
A	402.12 ± 55.70	88.85 ± 15.82	4.61 ± 0.81
B	364.32 ± 34.04	89.57 ± 9.05	4.09 ± 0.46
C	386.55 ± 42.79	90.98 ± 9.65	4.26 ± 0.25
D	381.35 ± 31.21	87.61 ± 16.48	4.50 ± 1.01
d 28			
A	799.97 ± 113.99	150.30 ± 15.09	5.34 ± 0.80
B	762.58 ± 111.69	155.14 ± 25.72	4.99 ± 0.85
C	774.02 ± 105.94	150.37 ± 12.53	5.17 ± 0.73
D	780.89 ± 111.18	156.17 ± 17.07	5.05 ± 0.88
d 42			
A	795.06 ± 96.83	145.49 ± 12.11	5.52 ± 0.62
B	737.37 ± 59.71	149.76 ± 15.41	4.81 ± 0.64
C	763.98 ± 76.99	152.63 ± 8.78	5.02 ± 0.52
D	748.41 ± 101.10	141.60 ± 28.24	5.01 ± 0.87

V:C = the ratio of villus height to crypt depth.

Table 8
Effects of dynamic segmentation of nutrient supply on villous height, crypt depth and V:C ratio in ileum of broilers.

Treatment	Ileum		
	Villous height, μm	Crypt depth, μm	V:C ratio
d 14			
A	347.88 ± 11.00	112.12 ± 19.21	3.17 ± 0.47
B	358.00 ± 30.03	116.69 ± 30.04	3.21 ± 0.71
C	349.99 ± 29.27	113.57 ± 18.22	3.15 ± 0.55
D	358.76 ± 30.86	116.60 ± 33.16	3.26 ± 0.83
d 28			
A	507.74 ± 100.01	115.76 ± 24.01	4.40 ± 0.39
B	517.62 ± 65.35	119.97 ± 22.69	4.40 ± 0.69
C	522.51 ± 86.24	119.96 ± 15.24	4.34 ± 0.25
D	518.56 ± 56.74	127.75 ± 16.90	4.11 ± 0.61
d 42			
A	513.89 ± 54.90	122.60 ± 11.27	4.30 ± 0.24
B	497.78 ± 61.85	118.57 ± 12.99	4.13 ± 0.41
C	520.53 ± 48.63	125.80 ± 10.57	4.28 ± 0.52
D	545.87 ± 25.08	124.18 ± 8.09	4.47 ± 0.30

V:C = villus height: crypt depth.

4. Discussion

4.1. Growth performance

Qiu et al. (2013) found that 14 days' dynamic segmentation diet can significantly improve the ADG and feed conversion ratio of Rose broilers over d 1 to 42 feeding period. It was reported that dynamic segmentation diet can improve BW of broilers on day 42 (Saki et al., 2010). In this trial, changing diets every 14 days significantly improved the BW of broilers on d 28 and 42 compared with changing diets every 3.5 days (except d 1 to 7) and every 7 days. Furthermore, ADG of birds with 14 d diet segmentation was significantly higher than that of birds with 3.5 d diet segmentation (except d 1 to 7) and birds with 7 d diet segmentation (d 15 to 28, and d 1 to 42). Moreover, F:G ratio of 14 d segmentation group was significantly lower than 3.5 d segmentation groups (including Treatment C and D) throughout the 42 d trial period, which was in agreement with the above studies. The reason was that the nutrients levels of 3.5 d and 7 d segmentation groups changed more frequently than those of 14 d segmentation, resulting relatively larger stress. Besides, 14 d segmentation basically meet the dynamic nutritional needs of broilers.

4.2. Carcasses performance

Slaughter rate and eviscerated percentage are 2 important indices of the carcass performance of broilers. Min et al. (2005) indicated that the level of energy have significant effects on eviscerated percentage and abdominal fat rate of geese, and crude protein levels significantly affected breast muscle rate and leg muscle rate. The interaction of dietary energy and protein levels had a significant effect on leg muscle rate. Moreover, we found that the birds with 14 d diet segmentation had the best slaughter rate and eviscerated rate, which was inconsistent with the result of Sun (2013) who suggested that there were no significant differences in carcass performance between different combinations of protein and energy levels. The reasons are unclear. Perhaps, not only the levels of energy and protein changed, but also other dietary nutrients levels, such as amino acid, calcium, phosphorus, changed with days, thus it had big impact on carcass performance. Furthermore, the constantly changing in the levels of diets energy and protein might also have a cumulative effect on carcass performance.

4.3. Immune organs indexes

It has been confirmed that immune organs indexes is a preliminary measure of immune function, and the development status of immune organs directly reflects the levels of the body's immune response (Wu et al., 2015). Fast maturation of immune organs can improve the immune function of broilers, which increased the capacity to resist all kinds of pathogenic microorganism infection and resistance to various stress (Xing et al., 2015). In the present study, we found that dynamic segmentation diet had no significant effects on the immune organs indexes, which were consistent with the results of Cui (2010), in which immune organs indexes of broilers had no significant differences compared with the control group when 1.5% dietary crude protein level was reduced. The reason was that the 2 major changing factors were the levels of energy and protein, which had no significant effects on immune organs indexes according to the above study.

4.4. Intestinal morphology

Xiao et al. (2013) found that Villus height and crypt depth are main factors that affect animal's ability to absorb nutrients in the intestine. The V:C ratio can substantially reflect the intestinal function. It has been confirmed that an increase in the villus height and V:C ratio and an decrease in crypt depth meant improved development of the intestine (Caspary, 1992). Our data showed that 3.5 d diet segmentation could significantly decrease the crypt depth (Treatment C) and increase the V:C ratio (Treatment D), indicating the improvement in the development of small intestine. The findings were in agreement with the result of Zhao and Qin (2008) who suggested that dietary protein levels and protein sources would affect intestinal morphology of pigs. The reason maybe that the levels of dietary protein in 3.5 d segmentation group meet the needs of intestinal development better compared with those in 7 d or 14 d segmentation groups.

4.5. Early (d 1 to 7) dynamic segmentation diet

Mo et al. (1994) found that from d 1 to 3, the nutrient requirements of broilers were satisfied entirely from the yolk sac. However, from d 5 to 7, the nutritional source was transferred from the yolk sac to diets. Our data showed that 3.5 d diet segmentation (except d 1 to 7) and 3.5 d diet segmentation (including d 1 to 7) had no significant differences in growth performance, carcass performance, immune organs indexes and intestinal morphology, indicating that early (d 1 to 7) dynamic diet segmentation had no adverse effects on broilers. We speculated that it was the yolk sac but not the diet mainly provides the nutrition of broilers from d 1 to 7. Thus, the nutrition levels of diet cannot significantly affect the growth of broilers.

5. Conclusions

Broilers with 14 d diet segmentation can obtain the best growth performance and carcass performance. However, 3.5 d diet segmentation can promote the development of small intestine. Moreover, dynamic diet has no significant effects on the immune organs indexes of broilers.

In the actual production, to achieve good growth performance and carcasses performance, changing diet every 14 days is a better choice, because the frequency is appropriate and operable.

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