Effect of feeding frequency on the growth performance, carcass traits, and apparent nutrient digestibility in geese

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ABSTRACT This study was conducted to determine the effect of feeding frequency on growth performance, carcass traits, and apparent nutrient digestibility in geese from 28 to 70 D of age. In experiment 1, a total of 240 geese were distributed in a completely randomized design into 4 treatments and 6 replicates of 10 birds each. The treatments were free access to the feeder (ad libitum) and access to the feeder 3, 4, and 5 times daily. Geese fed 3 times daily had a lower ($P < 0.05$) BW, ADG, and ADFI and a higher ($P = 0.064$) feed conversion ratio (**FCR**) from 28 to 41 D of age compared with the other groups. Geese fed 4 times daily had a higher ($P < 0.05$) ADG and ADFI and a lower ($P < 0.05$) FCR from 42 to 55 D of age compared with ad libitum fed geese. Geese fed 3 times daily had a higher ($P < 0.05$) ADG from 56 to 69 D of age than geese fed ad libitum and 4 times daily. No differences ($P > 0.05$) in BW, ADFI, ADG, and FCR were observed between ad libitum and feeding frequency groups from 28 to 69 D of age. Carcass traits and gastrointestinal development were not affected ($P > 0.05$) by feeding frequency. In experiment 2, the apparent nutrient digestibility in geese from 71 to 77 D of age fed using different feeding frequencies was determined using the total fecal collection method. Feeding frequency did not affect ($P > 0.05$) the apparent digestibility of DM, CP, crude ash, calcium, phosphorous, or ether extract in geese. Our study demonstrates for the first time that compensatory growth can be gained by enhancing feed intake when a lower feeding frequency is imposed on geese. Both ad libitum feeding and fixed feeding frequency for 3 to 5 times daily are suitable for geese from 28 to 70 D of age to achieve optimum production.

Key words: feeding frequency, growth performance, carcass traits, apparent nutrient digestibility, geese

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INTRODUCTION

In poultry production, ad libitum feeding is widely used for maximizing bird growth. However, ad libitum feeding may result in consumption that exceeds the requirements for bird maintenance and production as well as the excessive deposition of body fat that reduces meat quality (Butzen et al., 2013) and increases the incidence of sudden death syndrome, ascites, and skeletal problems (Khurshid et al., 2019). One management strategy to reduce fat deposition and prevent metabolic disturbances is feed restriction (Adeyemi et al., 2015; Mohammadalipour et al., 2017). Limited feeding frequency is one of the feed restriction method. In sucking piglets, 6 times daily feedings led to a higher ADG and lower feed conversion ratio (**FCR**) than those in pigs fed 12 times daily (Liu et al., 2019a). Growing pigs fed twice daily had an accelerated weight gain and exhibited a greater gain/feed than pigs fed 12 times daily (Le Naou et al., 2014). Finished pigs fed twice daily showed a deteriorated ADG and gain/feed compared with feeding 6 times daily in limit-feeding situations (Schneider et al., 2011). In broiler chickens, limited feeding frequency has been used to restrict feed consumption and improve feed efficiency (Farghly and Hassanien, 2012; Farghly and Makled, 2015); intermittent feeding regimes (intermittent daily feeding periods of 4 h of feeding and 4 h of non-feeding) had higher ADG and lower FCR values than restricted feeding regimes and did not produce any adverse effects on performance or physiological parameters (Farghly et al., 2019).

Goose meat is rich in unsaturated fatty acids and essential fatty acids and low in cholesterol, providing a high-quality protein source for humans (Schmid, 2011). As such, there is a growing interest in increasing worldwide goose production. In 2018, more than 630 million geese were used globally for meat production (Hou, 2019). Given the effect of feeding frequency on pig and chicken performance, it was speculated that increasing

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feeding frequency could improve growth, feed utilization efficiency, and carcass traits in geese. However, minimal literature on the effect of feeding frequency in geese is currently available.

Our previous study indicated that dry pellet is more suitable for geese from 28 to 70 D of age (Liu et al., 2019b). Thus, the aim of this study was to investigate the effect of feeding frequency on growth performance, carcass traits, and apparent nutrient digestibility in geese from 28 to 70 D of age.

MATERIALS AND METHODS

Animal and Experimental Design

This study was approved by the Animal Care and Welfare Committee of the Chongqing Academy of Animal Science, China. All geese used in this study were obtained from the Chongqing Academy of Animal Science goose-breeding center.

Experiment 1 studied the effect of feeding frequency on the growth performance, carcass traits, and gastrointestinal development of geese. A total of 240 mixed-sex 28-day-old Sichuan White geese were allocated to 24 plastic wire-floor pens with a 1:1 female/male ratio (each pen housed 5 male and 5 female geese) and fed according to the following frequencies: ad libitum (free access to the feeder; control group), 3 times daily (730, 1,330, and 1,930 h), 4 times daily (730, 1,130, 1,530, and 1,930 h), and 5 times daily (730, 1,030, 1,330, 1,630, and 1,930 h). Each feeding frequency treatment had 6 replicates with 10 birds per pen and were balanced for average initial body weight. Geese in the feeding frequency groups were allowed 30 min feed access at every feeding time. The experiment lasted 42 D, until the geese reached 70 D of age.

Experiment 2 studied the effect of feeding frequency on apparent nutrient digestibility in geese. Once the geese reached 70 D of age, 2 geese with an average body weight of 3.2 kg were selected from each replicate (n = 12 per treatment) and moved to clean, disinfected steel frame metabolic cages (56 cm × 36 cm × 60 cm) equipped with a grid floor and collector tray. Geese were administered 1 of 4 different feeding frequency treatments (ad libitum, 3 times daily, 4 times daily, 5 times daily; feed times and duration were the same as in experiment 1), whereas feed intake and dropping weight per bird were recorded on a daily basis using the total collection method. The experiment lasted 7 D. Three days of adjustment were allowed before the 4-D collection period.

Animal Housing and Diet

Ingredient composition and nutrient content of the basal diet is shown in Table 1. The experimental diet was formulated based on the analyzed value of the ingredients, except for the AME and tryptophan. The basal diet consisted of dry pellets. All geese had full access to drinking water throughout the entire experimental period. Birds were housed under a 16:8 h light: dark cycle, and the daily average temperature ranged between 13°C and 25°C (50∼70%).

Table 1. Basal diet composition and nutrient levels.

Ingredient	Content (%)
Corn	65.20
Soybean meal	20.93
Alfalfa meal	10.00
L-Lysine HCl	0.15
DL-Methionine	0.22
L-Tryptophan	0.08
L-Arginine HCl	0.12
Salt	0.30
Limestone	1.30
Hydrophosphate	1.30
Choline chloride	0.10
Mineral and vitamin premix[1]	0.30
Total	100.00
Calculated nutrient content	
Metabolizable energy (MJ/kg)	11.50
Tryptophan	0.25
Determined nutrient content	
Crude protein	15.93
Crude fiber	4.90
Calcium	1.05
Total phosphorus	0.53
Lysine	0.85
Methionine	0.45
Threonine	0.60
Arginine	1.00

[1]Premix provided the following per kg of basal diet: Cu ($CuSO_4 \cdot 5H_2O$) 8 mg; Fe ($FeSO_4 \cdot H_2O$) 85 mg; Zn ($ZnSO_4 \cdot H_2O$) 80 mg; Mn ($MnSO_4 \cdot H_2O$) 85 mg; Se (Na_2SeO_3) 0.3 mg; I (KI) 0.4 mg; Vitamin A 20,000 IU; Vitamin D_3 5,000 IU; Vitamin E 7.4 IU; Vitamin K_3 9.6 mg; Vitamin B_1 3 mg; Vitamin B_2 6 mg; Vitamin B_6 2 mg; Vitamin B_{12} 0.02 mg; Pantothenic acid 10 mg; Nicotinic acid 40 mg; Folic acid 1 mg; Biotin 0.04 mg.

Parameters Measured

Live BW and feed intake for all geese were measured every 2 wk and recorded following 12 h of fasting. The ADG, ADFI, and FCR of geese from each treatment group were measured. Feed intake and FCR were all corrected for mortality.

Two geese were selected according to average body weight from corresponding pens, killed by cervical dislocation, then bled, and dissected to determine carcass parameters. Birds were immersed in 60°C water for 2 min, then plucked and eviscerated manually. Breast meat (pectoralis major and pectoralis minor), leg meat (thigh and drumstick), abdominal fat, and skin and subcutaneous fat were removed from the carcasses and weighed. Breast meat, leg meat, abdominal fat, and skin and subcutaneous fat yield were expressed as weight relative to live body weight processing. The gastrointestinal tract and organs were carefully excised. The empty weight and length of the duodenum, jejunum (from the pancreatic loop to Meckel's diverticulum), ileum (from Meckel's diverticulum to the ileocecal junction), and cecum were recorded. Empty weight of the gizzard, proventriculus, and the weights of the heart and liver were also recorded. The relative organ weights were calculated. Heart, liver, gastro (gizzard and proventriculus), and intestine were expressed as weight relative to live body weight.

The collected droppings were weighed, then oven dried at 70°C to a constant weight. The dried fecal samples and feed samples were ground and taken to the laboratory for determination of DM, CP, crude ash (**CA**), calcium, phosphorous, and ether extract (EE) according to the Association of Official Analytical Chemists (AOAC, 2000). Apparent nutrient digestibility was calculated as follows:

$$\text{Nutrient digestibility} = \frac{\text{nutrient intake} - \text{nutrient voided}}{\text{nutrient intake}} \times 100$$

$$\text{Nutrient intake} = \text{nutrient in diet} \times \text{feed intake}$$

$$\text{Nutrient voided} = \text{nutrient in feces} \times \text{amount of feces voided}$$

Statistical Analysis

Data were analyzed by one-way ANOVA using SPSS software (ver. 19, SPSS Inc., Chicago, IL) using pen as the experimental unit for analysis. The significance of differences among treatments was tested using Duncan's multiple-range test. Statistical significance was established at $P < 0.05$.

RESULTS

Growth Performance

Feeding frequency affected the growth performance of geese from 28 to 41 D of age (Table 2). Geese fed 3 times daily had a lower BW ($P < 0.001$), ADG ($P < 0.001$), and ADFI ($P < 0.001$) and a higher FCR ($P = 0.064$) from 28 to 41 D of age compared with those of the other groups. Geese fed 3 times daily also had lower BW ($P = 0.015$) than geese fed 4 times daily by the time geese reached 56 D of age. Geese fed 4 times daily had a higher ADG ($P = 0.003$) and ADFI ($P = 0.005$) and a lower FCR ($P = 0.014$) from 42 to 55 D of age compared with those of the ad libitum group. Geese fed 3 times daily had a higher ADG ($P = 0.005$) from 56 to 69 D of age than those of the ad libitum group and those fed 4 times daily. There was no significant difference in the ADFI ($P = 0.067$) of geese between the ad libitum and feeding frequency groups from 56 to 69 D of age. Geese fed 3 times daily had a lower FCR ($P = 0.003$) than geese fed 4 times daily from 56 to 69 D of age. Nonsignificant differences in BW ($P = 0.845$), ADFI ($P = 0.596$), ADG ($P = 0.850$), and FCR ($P = 0.956$) were observed between the ad libitum and feeding frequency groups from 28 to 69 D of age.

Carcass Traits

Feeding frequency did not affect the percentage of dressed animal ($P = 0.325$), breast meat ($P = 0.999$), leg meat ($P = 0.314$), skin and subcutaneous fat ($P = 0.191$), abdominal fat ($P = 0.217$), heart ($P = 0.126$), or liver ($P = 0.321$) of geese (Table 3). The weights of the gizzard ($P = 0.602$) and proventriculus ($P = 0.543$) and weight ($P = 0.230$, $P = 0.484$, $P = 0.751$, $P = 0.943$, $P = 0.569$, respectively) and length ($P = 0.141$, $P = 0.564$, $P = 0.767$, $P = 0.811$, $P = 0.696$, respectively) of the duodenum, jejunum, ileum, cecum, and intestine were not affected by feeding frequency (Table 4). The percentages of gastro ($P = 0.638$) and intestine ($P = 0.445$) were not affected by feeding frequency (Table 4).

Nutrient Digestibility

Feeding frequency did not affect the apparent digestibility of DM ($P = 0.299$), CP ($P = 0.186$), EE ($P = 0.959$), CA ($P = 0.591$), calcium ($P = 0.971$), or phosphorous ($P = 0.718$) in geese from 71 to 77 D of age (Table 5).

Table 2. Effect of feeding frequency on growth performance in geese.[1]

		Feeding schedule					
Parameter	Day	Ad libitum	3 times daily	4 times daily	5 times daily	SEM	P-value
Initial body weight (g)	28	1,116.67	1,117.50	1,116.67	1,117.50	1.53	0.996
Final body weight (g)	42	2,189.17^{a}	1,945.83^{b}	2,078.33^{a}	2,096.67^{a}	22.39	<0.001
	56	2,799.44^{a,b}	2,696.11^{b}	2,901.48^{a}	2,850.09^{a,b}	25.61	0.020
	70	3,151.30	3,156.46	3,155.83	3,214.31	27.32	0.845
Average daily gain (g)	28–41	76.61^{a}	59.23^{b}	68.69^{a}	70.00^{a}	1.60	<0.001
	42–55	43.59^{b}	52.19^{a,b}	58.80^{a}	53.86^{a}	1.66	0.004
	56–69	25.13^{b}	32.88^{a}	21.48^{b}	26.02^{a,b}	1.25	0.005
	28–69	48.44	48.57	48.55	49.94	0.66	0.850
Average daily feed intake (g)	28–41	191.73^{a}	155.36^{c}	175.42^{b}	176.55^{b}	3.22	<0.001
	42–55	186.28^{b}	196.81^{a,b}	208.55^{a}	207.08^{a}	2.67	0.003
	56–69	179.30	198.24	185.15	191.23	2.70	0.067
	28–69	193.41	193.46	196.18	201.11	2.20	0.596
Feed conversion ratio (feed/gain)	28–41	2.50	2.63	2.56	2.53	0.02	0.064
	42–55	4.34^{a}	3.78^{a,b}	3.59^{b}	3.86^{a,b}	0.09	0.019
	56–69	7.19^{a,b}	6.18^{b}	8.56^{a}	7.54^{a,b}	0.26	0.006
	28–69	4.00	3.99	4.06	4.03	0.05	0.956

[a–c]In the same row, values with different superscripted lowercase letters indicate a significant difference ($P < 0.05$).
[1]Data are the mean of 6 replicates (10 birds per replicate).

Table 3. Effect of feeding frequency on carcass traits (%) in 70-day-old geese.[1,2]

Parameter	Feeding schedule				SEM	P-value
	Ad libitum	3 times daily	4 times daily	5 times daily		
Average live weight of slaughtered geese (g)	3,300.00	3,358.33	3,291.67	3,325.00	28.41	0.801
Dressed weight (g)	2,847.83	2,879.83	2,824.17	2,892.67	28.10	0.778
Dressed[3]	86.30	85.75	85.77	86.99	0.27	0.325
Breast meat	8.15	8.05	8.12	8.06	0.25	0.999
Leg meat	10.24	10.12	9.65	10.46	0.15	0.314
Skin and subcutaneous fat	13.75	12.37	12.61	12.15	0.27	0.191
Abdominal fat	1.91	1.15	1.30	1.47	0.13	0.217
Heart	0.67	0.74	0.74	0.74	0.01	0.126
Liver	2.08	1.94	2.18	2.28	0.06	0.321

[1]Data are the mean of 6 replicates (2 birds per replicate).
[2]The percentage yield is calculated using the following equation: Yield = measured parameter/processed live BW × 100.
[3]Dressed is defined as the weight after exsanguination and plucking.

DISCUSSION

Growth Performance

In the first 2 wk, geese fed 3 times daily had a lower ADFI and ADG compared with those of the other 3 treatment groups, indicating that lower feeding frequency decreased feed intake in this phase. This was similar to findings in chickens (Farghly and Hassanien, 2012). Furthermore, the ADFI and ADG in birds fed 4 and 5 times daily from 42 to 55 D of age were higher than those of birds fed ad libitum. It may be that geese have an adaptation as they become capable of increasing feed intake per time to meet the growth required. The ADFI and ADG in birds fed 3 times daily from 56 to 69 D of age were higher than those of birds fed ad libitum, indicating that a lower feeding frequency resulted in an increased ADFI of geese, and thus, full compensatory growth occurred in birds from 42 to 69 D of age. In birds, a reduction in the amount of available feed causes an adaptative response enabling the consumption of greater amounts of food in a shorter space of time (Peter and Gernat, 2006); this partly explains the increased ADFI in birds fed less often in the present study. In chickens, compensatory growth occurs in the finishing period so that the average weight is reached by feed restricted individuals (Zhan et al., 2007; Svihus et al., 2013; Jayasiri et al., 2019), and feed-restricted broilers gain more body weight than ad-libitum fed broilers during their re-alimentation period (Dozier et al., 2002). In geese, time-restricted feeding in the morning greatly reduces feed intake and weight gain but substantially improves feed efficiency in geese compared with ad libitum feeding (Ho et al., 2014). Our study demonstrates for the first time that compensatory growth can be gained by enhancing feed intake when a lower feeding frequency is imposed on geese. Therefore, both ad libitum and fixed feeding frequency for 3 to 5 times daily are suitable for goose production.

Carcass Traits

In the present experiment, carcass traits and gastrointestinal development of geese at 70 D of age were not affected by feeding frequency. Similar results were also observed in broiler chicks (Farghly and Hassanien, 2012), which showed that feeding frequency had no significant effect on dressed carcass, drumsticks, femurs, breast, heart, gizzard, and giblets percentages, intestine

Table 4. Effect of feeding frequency on gastrointestinal development of geese at 70 D of age.[1,2]

Parameter	Feeding schedule				SEM	P-value
	Ad libitum	3 times daily	4 times daily	5 times daily		
Gizzard weight (g)	92.58	88.92	93.83	99.75	2.76	0.602
Proventriculus weight (g)	11.58	12.00	10.58	11.75	0.36	0.543
Duodenum weight (g)	9.07	9.68	10.83	10.01	0.31	0.230
Jejunum weight (g)	19.39	18.73	21.27	21.35	0.71	0.484
Ileum weight (g)	14.79	15.37	16.60	15.39	0.59	0.751
Cecum weight (g)	4.65	4.36	4.63	4.61	0.18	0.943
Intestine weight (g)	47.89	48.16	53.32	51.35	1.56	0.569
Gastro percentage (%)	3.16	3.04	3.18	3.36	0.08	0.638
Intestine percentage (%)	1.45	1.43	1.63	1.55	0.05	0.445
Duodenum length (cm)	31.00	34.83	34.08	31.40	0.72	0.141
Jejunum length (cm)	68.67	70.58	64.92	68.00	1.41	0.564
Ileum length (cm)	63.67	64.42	60.33	62.00	1.44	0.767
Cecum length (cm)	41.83	41.25	38.92	40.30	1.09	0.811
Intestine length (cm)	205.17	211.08	198.25	201.70	3.84	0.696

[1]Data are the mean of 6 replicates (2 birds per replicate).
[2]The percentage yield is calculated using the following equation: Yield = (gastro or intestine weight)/processing live BW × 100.

Table 5. Effect of feeding frequency on apparent total tract nutrient digestibility (%) of geese.[1]

	Feeding schedule					
Parameter	Ad libitum	3 times daily	4 times daily	5 times daily	SEM	*P*-value
Dry matter	69.93	72.83	71.57	70.34	0.62	0.299
Crude protein	45.77	52.91	50.16	42.91	1.73	0.186
Crude ash	19.11	24.98	21.69	19.90	1.59	0.591
Calcium	21.14	22.14	21.23	19.66	1.45	0.971
Phosphorous	22.38	26.41	25.19	20.22	1.79	0.718
Ether extract	88.24	87.97	87.18	88.02	0.69	0.959

[1]Data are mean of 12 replicates (1 bird per replicate).

weight or length, cecum weight or length, or proventriculus and spleen percentages. Some researchers have also studied the effect of feeding frequency on birds by intermittent feeding. Farghly and Makled (2015) indicated that intermittent feeding (a different number of cycles daily, each consisting of a feeding period followed by a fasting period) did not affect the carcass characteristics of broilers. Farghly et al. (2019) reported that organ weights were not significantly changed by intermittent feeding (3 cycles daily for 4 h of feeding and 4 h of nonfeeding) except for the heart. However, Aliakbarpour et al. (2013) observed a significant decrease in carcass percentage when raising broiler chickens under intermittent feeding programs (5 times daily). The main reason for this discrepancy might be the differences in feeding frequency between studies.

Nutrient Digestibility

In our study, no difference was observed in the apparent digestibility of DM, CP, EE, CA, calcium, or phosphorous among all treatments, which was similar to findings in pigs by Cao et al. (2019). Liu et al. (2018) reported that feeding frequency did not influence the ileal apparent digestibility coefficients of CA, DM, EE, and CP in pigs. However, it has also been reported that feeding frequency influences nutrient digestibility. Increasing feeding frequency improves nutrient digestibility in pigs by stimulating pancreatic secretions and the flow of digestive enzyme production in the small intestine (de Haer and de Vries, 1993a, b). Decreasing feeding frequency enhances the total tract apparent digestibility coefficients for DM compared with pigs given free access to feed (Chastanet et al., 2007). This discrepancy is presumably because of the differences in type of animal, experimental diet, feeding regime, and rearing environment.

CONCLUSION

Fed 3 times daily decreased ADFI and ADG in geese between 28 and 41 D of age, whereas compensatory growth occurs in geese by increasing feed intake per time between 42 and 70 D of age. Fixed feeding frequency did not have any adverse effects on growth performance and carcass traits compared with ad libitum fed geese. Under the present experimental conditions, both ad libitum feeding and fixed feeding frequency for 3 to 5 times daily are suitable for geese from 28 to 70 D of age to achieve optimum production.

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