



Effect of Two-step Time-restricted Feeding on the Fattening Traits in Geese

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ABSTRACT: The present study was conducted to determine whether the two-step time-restricted feeding improves the fattening traits of one-step time-restricted feeding in geese. Thirty-six 8-wk-old geese were allotted into one of three groups. Group R1 (the 1-step restricted feeding group) was allowed access to feed for 2 h in the morning from 8 wk to 14 wk of age. Group R2 (the 2-step restricted feeding group) was treated as Group R1, but was additionally fed for 2 h in the afternoon from 12 wk to 14 wk of age. Group C (the control group) was fed *ad libitum* from 8 wk to 14 wk of age. Feed intake and body weight (BW) were recorded daily and weekly, respectively. At 14 wk of age, the blood samples were collected to determine the fasting plasma levels of glucose, triacylglycerols and uric acid before sacrifice. The results showed that daily feed intake (DFI) was lower, feed efficiency (FE) was higher in both Groups R1 and R2 than in Group C, and daily gain (DG) in Group R2 was higher than in Group R1 during the whole experimental period ($p < 0.05$). Group R1 exhibited lower abdominal and visceral fat weights in carcass than did Group C ($p < 0.05$), and Group R2 was in intermediate. The fasting plasma glucose levels in Group C were higher, and triacylglycerol levels in Group R1 were higher, compared with the other groups ($p < 0.05$). It is concluded that time-restricted feeding in the fattening period not only increases FE but reduces DFI, and the additional meal during the late fattening period improves the DG without the expense of FE in geese. (**Key Words:** Carcass Traits, Fattening, Goose, Restricted Feeding, Time-restricted Feeding)

INTRODUCTION

Geese grow slowly and exhibit a low level of feed efficiency (FE) in the fattening period (Chen et al., 2003). However, geese are not typically sent to market until they reach 12 wk to 14 wk of age. Therefore, increasing the FE or decreasing the daily feed intake (DFI) during the fattening period is a critical topic in the goose farming industry. Restricted feeding offers an opportunity to achieve the aim. Quantity-restricted feeding is commonly practiced in the fattening period of pigs (Whittemore, 2006; Bonneau and Lebret, 2010), as well as in the rearing and laying periods of broiler breeders (Scanen et al., 2004). However, in the large-group feeding situations, quantity-restricted feeding may lead underfeeding in certain inferior animals

and overfeeding in certain superior animals. Time-restricted feeding offers an alternative strategy, allowing all animals to evenly reduce the DFI. Time-restricted feeding has been found to improve FE in broilers (Su et al., 1999; Svihus et al., 2010). Furthermore, broilers experienced a skipping feeding time by 2 d/wk showed a 30% decrease in feed intake; their daily gain (DG) and FE were significantly higher compared with broilers that experienced 30% quantitative feed reduction, and were similar to those of broilers that experienced 15% quantitative feed reduction (Benyi and Habi, 1998). Feeding on alternate days also improved FE (Boa-Amponsem et al., 1991). The benefits of restricted feeding (including time-restricted feeding) may partially result from the reduction of heat production (MacLeod et al., 1979; Lovatto et al., 2006). In mice, meal feeding increased the amplitudes of circadian variations in rectal temperatures (Nelson et al., 1975). In pigeons, restricted feeding or fasting caused high-amplitude diurnal cycles in metabolic rates and body temperatures, primarily

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resulting from nocturnal hypometabolism and hypothermia (Rashotte et al., 1995). The nocturnal hypometabolism and hypothermia indicate that the energy requirement for maintenance is reduced by time-restricted feeding. Therefore, time-restricted feeding can potentially decrease the cost of feed.

Notwithstanding the restricted feeding improves the FE, some authors showed that the feed-restricted birds did not attain the same body weight (BW) as the controls at marketing age (Summers et al., 1990; Yu et al., 1990; Su et al., 1999). In the previous study we also found that the time-restricted feeding in the morning increased the FE of fattening geese, but lowered the DG, compared with *ad libitum* feeding (Ho et al., 2014). Clearly, in the time-restricted feeding situation, the weight gain must be improved in order to increase the marketing BW. In this study, we intended to offer an additional meal in time-restrictedly fed geese during the late fattening period to exceed the previously adjusted energy requirement and increase the weight gain in the last two weeks of the fattening period in geese. Briefly, the aim of this study was to improve the weight gain of the geese subjected to one-step time-restricted feeding without the expense of FE by using two-step time-restricted feeding.

MATERIALS AND METHODS

The experimental protocols used in the present study were approved by the Tunghai University Experimental Animal Care and Use Committee. Eighteen 8-wk-old goslings of each gender, which were exposed to 16 L:8 D photoperiod and fed *ad libitum* before the experiment, were randomly assigned to 9 pens (1.8×1.2 m) each containing 2 male and 2 female goslings. The pens were allotted into Group R1, R2, or C (three replicates per group). During the experimental period, the goslings were fed a fattening diet containing 15% crude protein (CP) and 3,000 kcal ME/kg, and were exposed to natural photoperiod. The day length (from civil dawn to civil dusk) gradually decreased from 13 h to 12.1 h during the experimental period.

The geese in Group R1 were allowed free access to feed for 2 h in the morning (from 07:00 h to 09:00 h) from 8 wk to 14 wk of age; the geese in Group R2 were treated as Group R1, but were additionally allowed free access to feed for 2 h in the afternoon (from 16:00 h to 18:00 h) from 12 wk to 14 wk of age; the geese in Group C were fed *ad libitum* from 8 wk to 14 wk of age. The feed intakes were recorded daily, and the BW at 4 to 6 h after feed withdrawal were recorded weekly. At the end of the experiment (14 wk of age), geese were fasted for more than 8 h followed by the collection of blood samples from one male and one female goslings in each pen to determine the fasting plasma levels of glucose, triacylglycerols, and uric acid using automatic

blood biochemistry analyzer (VITROS DT60 II Chemistry System, Johnson & Johnson Ortho Clinical Diagnostics, Raritan, New Jersey, USA), and then were sacrificed to evaluate the carcass traits. The live weights were recorded immediately before bleeding. The carcass weight was defined as the weight after exsanguination, defeathering, and viscera removal. The samples of breast meat were collected, and their moisture, CP, ether extracts, and ash contents were analyzed using the methods described by AOAC (1984). Data were analyzed with ANOVA of completely randomized design model and the difference between means was determined by Tukey test, using the general linear model of SAS statistical software (SAS Inst. Inc., Cary, NC, USA). In the fattening traits, each pen was considered as the experimental unit; in the carcass traits and plasma levels of metabolites, each individual was considered as the experimental unit. Variability in each trait was expressed as root mean square error (RMSE), and a probability level of $p < 0.05$ was considered as statistically significant, whereas a trend was expressed when $p < 0.10$.

RESULTS

The fattening traits in the three groups are shown in Table 1. The BW at 8 wk, 12 wk and 14 wk of age did not significantly differ among groups ($p > 0.05$). From 8 wk to 12 wk of age, the DG did not significantly differ among groups ($p > 0.05$) because of large variation. From 12 wk to 14 wk of age, the DG in Groups R1 and C were low, but that in Group R2 was high ($p < 0.05$). During the whole experimental period (from 8 wk to 14 wk of age), average DG in Group R1 was significantly lower compared with Group R2 ($p < 0.05$); the average DG in Group R2 was almost the same as that in Group C. From 8 wk to 12 wk of age, the DFI in R1 and R2 groups did not differ each other ($p > 0.05$), but were significantly lower than that in Group C ($p < 0.05$). From 12 wk to 14 wk of age, Group R1 exhibited a lower DFI than Group C ($p < 0.05$), and Group R2 was in intermediate. During the whole experimental period, geese in Group C ingested significantly more feed compared with the other two groups ($p < 0.05$). From 8 wk to 12 wk of age, the FE did not differ among groups ($p > 0.05$). From 12 wk to 14 wk of age, the FE in Group R2 was higher than those in both Groups R1 and C ($p < 0.05$). In terms of the FE during the whole experimental period, both time-restricted feeding groups were superior to the control group ($p < 0.05$).

The carcass traits in three groups are shown in Table 2. The carcass weight in Group R1 was lower compared with both Groups R2 and C ($p < 0.05$). The dressing percentages differed significantly between groups, with the highest in Group C and the lowest in Group R1 ($p < 0.05$). The abdominal and visceral fat absolute weights and relative weights (% BW) in Group R1 were significantly lower

Table 1. The effect of time-restricted feeding on the fattening traits¹ in geese

Item	Group ²			RMSE	p-value
	R1	R2	C		
BW at 8 wk of age (g)	3,995	3,980	3,997	198	0.993
BW at 12 wk of age (g)	4,478	4,489	4,784	277	0.365
BW at 14 wk of age (g)	4,609	4,968	4,940	268	0.266
Daily gain (g/d)					
8-12 wk	17.1	18.2	28.1	6.8	0.169
12-14 wk	9.7 ^b	34.2 ^a	11.1 ^b	6.0	0.004
8-14 wk	14.6 ^b	23.5 ^a	22.5 ^{ab}	3.4	0.035
Daily feed intake (g)					
8-12 wk	99 ^b	118 ^b	249 ^a	22	<0.001
12-14 wk	141 ^b	236 ^{ab}	282 ^a	51	0.036
8-14 wk	113 ^b	157 ^b	260 ^a	30	0.002
Feed efficiency (gain/feed)					
8-12 wk	0.172	0.154	0.112	0.030	0.111
12-14 wk	0.069 ^b	0.145 ^a	0.047 ^b	0.026	0.008
8-14 wk	0.130 ^a	0.149 ^a	0.086 ^b	0.015	0.005

RMSE, root mean square error.

¹ Values represent the means of 3 pens with 4 geese per pen.

² Group R1 was fed one meal during the whole fattening period; Group R2 was fed one meal from 8 wk to 12 wk of age, and was fed two meals from 12 wk to 14 wk of age; Group C was fed *ad libitum* during the fattening period.

^{ab} Means in a same row without a common superscript letter differ significantly ($p < 0.05$).

($p < 0.05$) than those in Group C, and those in Group R2 were in intermediate. Neither liver nor digestive tract absolute weight significantly differed among groups ($p > 0.05$). The relative digestive tract weight tended to differ among groups ($p = 0.079$). None of the contents of components of breast meat differed among groups ($p > 0.05$; data not shown).

The fasting plasma glucose level in Group C was significantly higher than those in both restricted feeding groups ($p < 0.05$; Table 3). By contrast, the fasting plasma

triacylglycerol level in Group R1 was higher than those in Groups R2 and C ($p < 0.05$). The fasting plasma uric acid level was not affected by feeding regimen ($p > 0.05$).

DISCUSSION

During the late fattening period, the DFI in Group R1 was still lower than that in Group C, indicating that either the development of gastrointestinal capacity does not meet the requirement or the nutrient requirements for

Table 2. The effect of time-restricted feeding on carcass traits¹ in geese

Item	Group ²			RMSE	p-value
	R1	R2	C		
Live weight (g)	4,925	5,449	5,555	578	0.164
Carcass weight (g) ³	3,648 ^b	4,476 ^a	4,775 ^a	510	0.005
Dressing percentage	74.1 ^c	82.1 ^b	85.9 ^a	2.3	<0.001
Weight of abdominal fat (g)	73 ^b	118 ^{ab}	159 ^a	31	0.001
% of live weight	1.49 ^b	2.15 ^{ab}	2.89 ^a	0.55	0.002
Weight of visceral fat (g)	44 ^b	77 ^a	102 ^a	21	0.001
% of live weight	0.89 ^b	1.42 ^{ab}	1.83 ^a	0.37	0.002
Weight of liver (g)	83.1	91.7	80.3	13.0	0.319
% of live weight	1.69	1.68	1.44	0.18	0.049
Weight of digestive tract (g)	446	412	429	49	0.500
% of live weight	9.05	7.56	7.88	1.11	0.079

RMSE, root mean square error.

¹ Values represent the means of 6 geese.

² Group R1 was fed one meal during the whole fattening period; Group R2 was fed one meal from 8 wk to 12 wk of age, and was fed two meals from 12 wk to 14 wk of age; Group C was fed *ad libitum* during the fattening period.

³ The carcass weight was defined as the weight after exsanguination, defeathering, and viscera removal.

^{ab,c} Means in a same row without a common superscript letter differ significantly ($p < 0.05$).

Table 3. The Effect of time-restricted feeding on fasting plasma levels of metabolites¹ in geese

Plasma metabolite	Group ²			RMSE	p-value
	R1	R2	C		
Glucose (mg/dL)	160 ^b	157 ^b	189 ^a	17	0.011
Triacylglycerol (mg/dL)	105 ^a	64 ^b	55 ^b	20	0.002
Uric acid (mg/dL)	4.37	2.37	3.22	1.50	0.101

RMSE, root mean square error.

¹ Values represent the means of 6 geese.

² Group R1 was fed one meal during the whole fattening period; Group R2 was fed one meal from 8 wk to 12 wk of age, and was fed two meals from 12 wk to 14 wk of age; Group C was fed *ad libitum* during the fattening period.

^{a,b} Means in a same row without a common superscript letter differ significantly ($p < 0.05$).

maintenance and growth are reduced. Summarizing the data from the 6-wk experimental period, Group R1 exhibited lower feed intake but higher FE compared with the control group. These results were consistent with the results of previous study (Ho et al., 2014). The results also agreed with the earlier reports that described the effects of restricted feeding during the fattening period on the growth rate and FE in broilers (Benyi and Habi, 1998; Svihus et al., 2010) and pigs (Mullan et al., 2009). The reduction of heat production caused by restricted feeding (MacLeod et al., 1979; Lovatto et al., 2006) may partially account for the superior FE. In pigeons, restricted feeding or fasting was also shown to cause nocturnal hypometabolism and hypothermia (Rashotte et al., 1995).

In Group R2, which received an additional meal in the afternoon from 12 wk to 14 wk of age, the DFI was increased, but was lower than twice the intake in Group R1, indicating that the feed intake is regulated by the requirement, and the low feed intake cannot be explained by the limitation of gastrointestinal capacity. Although the feed intake from 12 wk to 14 wk of age in Group R2 was not as much as expected, the DG in Group R2 was significantly higher than those in both Groups R1 and C. Consequently, the BW at 14 wk of age in Group R2 was almost the same as that in the control group. During the late fattening period, the FE in Group R2 was significantly higher than those in the other two groups. The improvement in the FE found in Group R2 indicates that the additional meal in the late fattening period caused a catch-up growth without the expense of FE, and implies that the relatively low basal metabolism of sparing mechanism in the restricted feeding is maintained beyond the severely restricted period. The improvement in feed digestibility may also be implicated in the increased FE. Numerous studies have reported an improvement in digestibility during restriction or the re-feeding period following restriction (Gidenne et al., 2012). Summarizing the data from the whole 6-wk experimental

period (from 8 wk to 14 wk of age), the additional meal in the late fattening period improves the weight gain and reserves the superior FE obtained by time-restricted feeding.

The higher weight gain and superior FE during the last two weeks of the fattening period in Group R2 were somewhat similar to the process of compensatory growth. Compensatory (or catch-up) growth is defined as a physiological process whereby an organism accelerates its growth after a period of restricted development, usually due to reduced feed intake, in order to reach the weight of animals whose growth was never reduced (Hornick et al., 2000). Numerous articles indicated that broilers experienced feed restriction in early life and then *ad libitum* feeding exhibited higher FE (Fontana et al., 1992; Palo et al., 1995a,b; Zhong et al., 1995; Zubair and Leeson, 1996; Urdaneta-Rincon and Leeson, 2002), although whether the final BW of restricted birds attained to the final weight of *ad libitum* birds was inconsistent among articles. The magnitude of compensation is associated with the intensity, duration, and age of the previous growth restriction (Hornick et al., 2000). In the present study, the intensity of restriction in Group R2 from 8 wk to 12 wk of age was severe, especially in the first week of the restriction, and the DFI from 12 wk to 14 wk of age in Group R2 still did not attain the level of *ad libitum* feeding; however, the BW in Group R2 completely caught up. Accordingly, the fattening geese can endure severe feed restriction, and the compensatory growth is not impaired.

Previous study found that the abdominal fat and visceral fat were less in one-step time-restricted feeding group compared with *ad libitum* feeding group in geese (Ho et al., 2014). The result was further confirmed by the results of Group R1 in this study. The leaner carcass was also found in broilers (Benyi and Habi, 1998; Ocak and Sivri, 2008) and pigs (Mullan et al., 2009) that experienced restricted feeding during the fattening period. Both quantity-restricted feeding and time-restricted feeding during the late growing period of broilers increased the relative entire gut and liver weights, compared with the control feeding (Ocak and Sivri, 2008). In geese, a previous study found that time-restricted feeding caused higher liver and digestive tract relative weights compared with *ad libitum* feeding (Ho et al., 2014). The less fat accretion and higher relative liver and digestive tract weights may also contribute to the superior FE in the geese experienced once-a-day feeding.

When an additional afternoon meal was supplied to the geese subjected to one-meal feeding during the late fattening period, the fat accretion, at least in visceral fat, was increased, compared with Group R1. The relative digestive tract weight in Group R2 was close to that in control group. The low relative gastrointestinal weight in Group R2 may result from the voluntarily decreased meal size at each meal. The result also implies that the involution

of digestive tract is quick, and that twice-a-day feeding does not cause digestive tract enlargement in fattening geese. Compared with the *ad libitum* feeding, the 2-step restricted feeding did not influence the abdominal fat accretion of geese. The effects of early nutrient restriction on the fatness of carcass in broilers varied among studies. Some studies showed that early feed restriction led fatter carcass (Lippens et al., 2000; Zhan et al., 2007); some showed the opposite results (Plavnik and Hurwitz, 1988; 1991; Jones and Farrell, 1992a,b; Zhong et al., 1995); and some showed no influence (Yu et al., 1990; Fontana et al., 1993; Palo et al., 1995a,b; Zubair and Leeson, 1996). The discrepancy among reports may partially be attributed to the breed and the duration of the compensatory growth. Hornick et al. (2000) suggested that the growth of different tissues in compensatory growth depends on breed, age of the animal, and the duration of refeeding. In terms of the duration of refeeding, at the initial stage of compensatory growth, deposited tissue is mostly muscle and protein; thereafter, fat deposition takes over and the final body composition depends on refeeding duration. In the present study, 4-wk once-a-day feeding followed by 2-wk twice-a-day feeding improved the FE but did not increase the fat accretion, compared with the *ad libitum* feeding. Therefore, the two-step time-restricted feeding clearly improves the weight gain without the expense of feed efficiency, compared with the one-step time-restricted feeding.

The fasting plasma glucose levels in both restricted groups were lower than that in control group in the present study. This result differed from that in previous study in which the fasting plasma glucose levels did not differ between restricted feeding and *ad libitum* feeding geese (Ho et al., 2014). In broiler breeders, the plasma glucose levels immediately before feeding were lower in the birds that were fed once a day compared with the birds that were fed twice or thrice a day (Moradi et al., 2013). In the present study, the fasting plasma triacylglycerol level in Group R1 was higher than those in Groups R2 and C. The result was contrary to the previous study in which the fasting plasma triacylglycerol level in the restricted geese was lower compared with the *ad libitum* geese (Ho et al., 2014). In quantity-restricted broiler breeders, the plasma triacylglycerol level was not influenced by the feeding frequency (Moradi et al., 2013). Therefore, the effects of restricted feeding on the fasting plasma glucose and triacylglycerol levels are still not conclusive.

In conclusion, both one-step and two-step time-restricted feeding regimens improved FE, and reduced feed intake. One-step time-restricted feeding led less fat accretion and lowered weight gain compared with *ad libitum* feeding. The two-step time-restricted feeding increased the weight gain compared with one-step time-restricted feeding, and obtained the final BW similar to the

ad libitum feeding. It is suggested that time-restricted feeding in the fattening period not only increases FE but also substantially reduces feed intake, and the additional meal during the late fattening period improves the weight gain without the expense of FE in geese. Therefore, the two-step time-restricted feeding will further increase the profits in fattening geese.

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