Effects of Early Feed Restriction on Growth, Fat Accumulation and Meat Composition in Unsexed Broiler Chickens

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ABSTRACT : The present study was conducted to evaluate the effect of early feed restriction on growth, fat accumulation and meat composition in unsexed broiler chickens. Five hundred 7-day old unsexed broiler chickens were distributed into ten treatment groups with 5 pens of 10 broilers each group. One group was fed *ad libitum* as the control group and other nine groups were fed 25% *ad libitum* for 3, 6 or 9 days, 50% *ad libitum* for 3, 6 or 9 days, and 75% *ad libitum* for 3, 6 or 9 days, respectively. Thereafter, they were fed *ad libitum* to 56 days of age. The present results showed that broilers showed compensatory growth when they were restrict-refed. Feed conversion ratio was significantly lower in broilers fed 25% *ad libitum* for 9 days ($p<0.05$). Triglyceride concentration of serum was significantly lower in restricted unsexed broilers ($p<0.01$), whereas cholesterol concentration was not significantly different. Abdominal fat was significantly lower in broilers fed 25% *ad libitum* for 9 days, 50% *ad libitum* for 3 days and 75% *ad libitum* for 6 or 9 days ($p<0.05$). Moisture and protein contents of meats were not significantly affected. Ash content of meat was significantly higher in restricted broilers. Fat content of meat was lower in broilers fed 25% *ad libitum* for 9 days, 75% *ad libitum* for 3 to 9 days. In conclusion, broilers showed compensatory growth when they were restrict-refed at an early age. In order to achieve the success of early feed restriction (namely reduce fat accumulation and improve feed conversion ratio with comparable body weight at market age), unsexed broilers should be fed at level of 25 *ad libitum* for 9 days starting at 7 days of age. ***(Asian-Aust. J. Anim. Sci. 2001. Vol 14, No. 11 : 1585-1591)***

Key Words : Early Feed Restriction, Compensatory Growth, Meat Composition, Unsexed Broilers

INTRODUCTION

There is pressure on the broiler chickens industry to reduce the fat content of its product due to greater consumer awareness of a dietary fat and its perceived adverse effects on human health (Jones and Farrell, 1992). Furthermore, the carcass from current broilers have excessive fat in abdominal and visceral region, which must be removed and reprocessed as component of poultry by product meal at a greatly reduced value when compared to the value of the carcass (Goodwin, 1979).

Nutrition planes are known influencing fat, protein and ash deposition in broiler chickens. Previous research suggested that producers could grow chickens with desired fat and protein contents by regulating the energy:protein ratio of the finishing diet (Mabray and Waldroup, 1981; Summers et al., 1965). Early feed restriction has been proven by many investigators that this program could improve growth characteristics with lower fat accumulation (Plavnik and Hurwitz, 1985, 1988, 1989; Santoso et al., 1993; Santoso et al., 1995a,b). The feed restriction might reduce fat cell hyperplasia and therefore limit the potential for growth of fat. Santoso et al. (1993, 1995) showed that early feed restriction resulted in lower hepatic acetyl-CoA carboxylase activity, a rate-limiting enzyme for fatty acid synthesis. This may limit hepatic triglyceride synthesis causing lower serum triglyceride concentration, and therefore it partly contributes to reduce fat accumulation. In farm, broiler chickens are raised in unsexed condition. Broilers raised in separated sex may have different responses to nutritional planes as compared to those raised in unsexed type. It was known that female and male broilers had different responses to early feed restriction (e.g. Plavnik and Hurwitz, 1988; Santoso et al., 1993) Unfortunately, most published investigations of early feed restriction used separated sex. Therefore, the present study was conducted to evaluate effect of early feed restriction on growth, fat accumulation, serum triglyceride and cholesterol concentration, and meat composition in unsexed broiler chickens.

MATERIALS AND METHODS

Five hundred 1-day-old unsexed broiler chicks (strain Arbor Acres CP 707) obtained from commercial hatchery (P. T. Charoen Phokphand, Indonesia) were used in this study. From 1 to 14 day of age, supplemental heat was provided with a hanging heat lamp. Temperature was maintained at 32.5°C in the first week and gradually decreased at the second week. The broiler chicks were maintained on the floor in a house under continuous fluorescent lighting with feed and water available *ad libitum* during early dry season. At 7 days of age, broiler chicks were divided into 10 groups

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as follows. One group was fed *ad libitum* as the control group and other nine groups were fed 25% *ad libitum* (25% multiplied by amount of feed intake of *ad libitum* chicks at the previous day) for 3, 6 or 9 days, 50% *ad libitum* for 3, 6 or 9 days, and 75% *ad libitum* for 3, 6 or 9 days, respectively. Thereafter, they were fed *ad libitum* to 56 days of age. Water was provided *ad libitum* and recommended husbandry practices were followed in this experiment. Broilers were fed commercial starter diet from 1 to 28 days of age, and commercial finisher diet from 29 to 56 days of age. The nutrient composition of commercial feed is presented in table 1. Broilers were weighed individually on a weekly basis except during feed restriction period, and feed consumption was recorded daily. Recovery index during refeeding period was calculated using the following equation: $(A-B)/A \times 100\%$, where A is the difference of body weight between control group and restricted broilers at the end of feed restriction and B is the difference of body weight between control group and restricted broilers at 56 days of age (Brody, 1964).

At 56 day of age, 6 broilers (male:female = 1:1) were selected from control and restric-refed groups, and blood was taken from wing vein with heparinized syringe and then centrifuged at 3.000 rpm for 10 minutes. Serum obtained was stored and frozen at -30°C until analysis of lipid fraction concentration. Thereafter, broilers were slaughtered by decapitation, and abdominal fat and liver were immediately removed and weighed.

The meat (breast + leg) was then removed and grounded through a 5 mm screen. The ground meat was passed through the mincer five times to obtain uniform mixing. Fat, moisture and protein of meat was determined by the method of AOAC (1980). Ash content was calculated using the following equation: 100% - (% crude protein + % moisture + % fat). The serum were analyzed their total cholesterol and triglyceride concentration using colorimetric method.

Table 1. The nutrient composition of commercial diets used in the present study

Nutrient Composition (%)	BP-11 (starter period)	BP-12 (finisher period)
Moisture (maximum)	13	13
Crude protein (minimum)	21	19
Crude fat (minimum)	5	5
Crude fiber (maximum)	4	4.5
Ash (maximum)	6.5	6.5
Ca (minimum)	0.9	0.9
P (minimum)	0.7	0.7
BETN	50.5	52.0
ME, kcal/kg	3200	3200
Antibiotic	Zinc Bacitrazin	Zinc Bacitrazin

All data were statistically analyzed using analysis of variance (Shinjo, 1990). Significant difference between treatments was determined by single d.f. orthogonal contrasts. Factorial design (3 × 3) was used to evaluate the effect of duration and level of feed restriction and its interaction. Significant difference was determined by Duncan's Multiple Range Test.

RESULTS

Table 2 shows effect of early feed restriction on body weight, feed intake and FCR during feed restriction in broilers. Body weight of restricted broilers was significantly lower as compared to the control group ($p<0.01$) at the end of restriction period. Feed intake of restricted broilers was also significantly lower as compared to the control ($p<0.01$). FCR was significantly higher in broilers fed 25% or 50% *ad libitum* as compared to the control ($p<0.01$).

Table 3 shows effect of early feed restriction on body weight, feed intake, feed conversion ratio and abdominal fat content. Body weight of restricted broilers fed 50% *ad libitum* for 3 days, 75% *ad libitum* for 3 to 9 days had heavier body weight than the control group ($p<0.01$). Feed intake was significantly lower in broilers fed 25% *ad libitum* for 6 or 9 days and fed 50% *ad libitum* for 9 days ($p<0.05$) as compared to the control. However, broilers fed 50% or 75% *ad libitum* for 3 days had higher feed intake ($P<0.05$) as compared to the control. Feed conversion ratio was significantly better in broilers fed 25% *ad libitum* for 9 days. Abdominal fat weight was significantly lower in unsexed broilers fed 25% for 9 days, 50% *ad libitum* for 3 days, 75% *ad libitum* for 6 or 9 days ($p<0.05$). Liver weight was not significantly different ($p>0.05$). Complete compensatory growth was indicated by recovery index ≥ 100%. Complete compensatory growth occurred in broilers fed 25% *ad libitum* for 3 days, 50% *ad libitum* for 3 or 6 days, and 75% *ad libitum* for 3, 6 or 9 days. No mortality was observed through out the experimental period.

As shown in table 4, feeding level, and period of restriction significantly affected body weight and feed intake at 56 days of age. Higher level and longer duration of feed restriction would reduce body weight of broilers. Level or duration of feed restriction had no effect on feed conversion ratio and abdominal fat. Broilers fed 50% or 75% *ad libitum* had higher feed intake ($p<0.05$) than 25% *ad libitum*. Restricting broilers for 3 days had significantly higher feed intake ($p<0.05$) than those for 6 or 9 days. Higher duration of feed restriction would reduce feed intake of broilers. Interaction was observed for body weight and feed intake. No interaction was observed for FCR and abdominal fat.

Table 5 shows effect of early feed restriction on weight gain, feed intake and feed conversion ratio during refeeding.

Table 2. Effects of early feed restriction on body weight and feed intake during feed restriction in unsexed broilers[1]

Variables	Control	25% *ad libitum*			50% *ad libitum*			75% *ad libitum*			Pooled SE
		3 days	6 days	9 days	3 days	6 days	9 days	3 days	6 days	9 days	
Body weight, g											
7 d	113.7	110.5	110.3	113.7	111.5	109.3	110.3	112.1	113.7	107.3	3.6
10 d	182.1	103.3**			123.5**			139.1**			15.2
13 d	295.2		129.7**			169.3**			210.8**		14.7
16 d	415.4			154.3**			216.8**			298.3**	19.5
Feed intake,											
g/chick	89.1	17.2***			34.3**			44.2**			15.1
7-10 d	220.9		49.3***			98.6**			143.2**		14.4
7-13 d	392.5			89.7***			176.4**			265.9**	12.6
7-16 d											
F C R	1.3	-2.4***			2.9***			1.3			0.04
7-10 d	1.2		2.5***			1.6*			1.4		0.05
7-13 d	1.3			2.2***			1.8*			1.4	0.04
7-16 d											

[1] Values are presented as mean ± Pooled SE (n= 5 pens each group).
* Significantly different from the control group at level $p<0.05$.
*** Significantly different from the control group at level $p<0.001$.

Table 3. Effects of early feed restriction on growth performance, abdominal fat weight and liver weight in unsexed broilers

Variables	Control	25% *ad libitum*			50% *ad libitum*			75% *ad libitum*			Pooled SE
		3 days	6 days	9 days	3 days	6 days	9 days	3 days	6 days	9 days	
Body wt. [1], g	2525	2587	2498	2491	2714*	2552	2444	2648*	2574	2653.6*	46.2
Recovery index (%)	100	178.7	83.7	87.0	422.5	121.5	59.2	158.1	158.1	209.1	25.1
Feed intake[1], g	5090	4979	4718*	4476**	5203*	5059	4815*	5210*	4986	4860	46.2
F C R[1]	2.11	2.01	1.98	1.88*	2.0	2.07	2.06	2.05	2.03	1.99	0.05
Abdominal fat (%)[2]	1.9	1.7	1.8	1.6*	1.6*	1.8	1.8	1.7	1.4**	1.6*	0.1
Liver weight (%)[2]	2.3	1.8	1.9	1.8	1.7	2.0	1.9	1.7	1.9	2.1	0.15

[1] Values are presented as mean ± Pooled SE (n=5 pens each group).
[2] Values are presented as mean (male: female =1:1) ±pooled SE (n=6 each group).
* Significantly different from the control group at level $p<0.05$.
** Significantly different from the control group at level $p<0.01$.

Table 4. Effect of duration and level of early feed restriction on growth performance and fat accumulation

Variables	Feeding level			Period			Pooled SE	ANOVA		
	25% *ad libitum*	50% *ad libitum*	75% *ad libitum*	3 days	6 days	9 days		L	P	L×P
Body weight[1], g	2525^{1a}	2570^{ab}	2625^{b}	2695^{B}	2564^{A}	2529^{A}	22.8	<0.01	<0.01	<0.01
Feed intake[1], g	4724^{a}	5026^{b}	5119^{b}	5131^{C}	4921^{B}	4717^{A}	37.6	<0.05	<0.01	<0.05
FCR[1]	1.96	2.04	2.04	1.99	2.01	1.95	0.03	NS	NS	NS
Abdominal fat[2], % BW	2.31	2.52	2.85	2.34	2.76	2.56	0.17	NS	NS	NS

[1] Values are presented as mean ± Pooled SE (n=5 pens each group). L=feeding level; P=Period of restriction; L X P=interaction.
[2] Values are presented as mean (male: female =1:1) ± Pooled SE (n=6 each group).
Mean within a row not followed by the same superscripts are significantly different.

Body weight gain was significantly higher in broilers fed 25% *ad libitum* for 6 or 9 days, 50% *ad libitum* for 3 or 6 days, and 75% *ad libitum* for 3 days. Feed intake was significantly higher in broilers fed 50% *ad libitum* for 3 days and 75% *ad libitum* for 3 days. Feed conversion ratio was significantly lower in broilers fed 25% *ad libitum* for 6 or 9 days, and 75% *ad libitum* for 9 days.

Table 6 shows effect of early feed restriction on meat composition, and triglyceride and cholesterol concentration in serum. Early feed restriction significantly reduced serum triglyceride concentration ($p<0.01$), whereas cholesterol concentration was not affected ($p>0.05$). Early feed

Table 5. Effects of early feed restriction on body weight gain, feed intake and feed conversion ratio during refeeding in unsexed broilers[1]

Variables	Control	25% *ad libitum*			50% *ad libitum*			75% *ad libitum*			Pooled SE
		3 days	6 days	9 days	3 days	6 days	9 days	3 days	6 days	9 days	
Body weight gain											
11-56 d	2342.9[1]	2483.7			2590.5			2509.0			30.1
14-56 d	2229.8		2368.3*			2382.7*			2363.2*		25.1
17-56 d	2109.6			2336.7*			2227.2			2357.7*	23.3
Feed intake											
11-56 d	5001.0	4961.8			5168.7*			5165.8*			36.2
14-56 d	4869.1		4668.7			4960.4			4842.8		30.7
17-56 d	4697.5			4386.3*			4638.6			4594.1	36.1
F C R											
11-56 d	2.14	2.0			1.99			2.06			0.01
14-56 d	2.18		1.97*			2.08			2.05		0.01
17-56 d	2.23			1.88*			2.08			1.95*	0.01

[1] Values reported represent for 5 pens ± SE.
* Significantly different from the control group at level $p<0.05$.
** Significantly different from the control group at level $p<0.01$.

Table 6. Effects of early feed restriction on meat composition and serum lipid fractions in unsexed broilers[1]

Variables	Control	25% *ad libitum*			50% *ad libitum*			75% *ad libitum*			Pooled SE
		3 days	6 days	9 days	3 days	6 days	9 days	3 days	6 days	9 days	
Meat composition											
Moisture, %	56.8	57.0	57.1	57.5	56.9	56.6	57.0	58.2	58.3	58.5	0.7
Protein, %	18.6	18.8	18.9	19.2	18.4	18.3	18.8	19.6	19.7	19.5	0.3
Fat, %	22.5	20.3	20.1	19.0*	21.2	21.8	20.4	18.3*	18.1*	18.1*	0.6
Ash, %	2.1	3.9**	3.9**	3.9**	3.5*	3.3*	3.8**	3.9**	3.9**	3.9**	0.3
Serum lipid fraction, mg/100 ml											
Triglyceride	74.5	37.8**	58.3*	35.8**	42.8*	56.8*	57.3*	56.8*	34.8**	50.3*	8.3
Cholesterol	132	109	129	122	127	122	145	126	137	126	14

[1] Values reported represent for 6 unsexed broilers (male: female =1:1) ± pooled SE.
* Significantly different from the control group at level $p<0.05$.
** Significantly different from the control group at level $p<0.01$.

restriction had no effect on moisture and protein content. Fat content was significantly lower in broiler fed 25% *ad libitum* for 9 days, 75% *ad libitum* for 3 to 9 days ($p<0.05$). Ash content was significantly higher in restricted broilers than the control group ($p<0.01$). Feeding level, and period of restriction did not significantly influence these variables except for ash content of meat (table 7). No interaction was observed for these variables.

DISCUSSION

The present study showed that compensatory growth was occurred when restricted broilers were refed after early feed restriction. The results were in agreement with the observation of Plavnik and Hurwitz (1985, 1988, 1989) and Santoso et al. (1993, 1995). The results indicate that early feed restriction might be able to applied under the farm condition. Santoso et al. (1998) found that early feed restriction could be applied in public farm condition (keeping broiler for 2,000 birds/house), and resulting in heavier body weight and better feed conversion ratio. From these results it could be justified that unsexed broilers may have similar responses to early feed restriction as compared to separated sex. It was suggested that compensatory growth occurred because body had a set point for body size appropriate for age (Mosier, 1986). It is unknown, however, how restricted broilers exceed the body weight. It appeared that higher feed intake during refeeding period might partly cause heavier body weight in restricted unsexed broilers ($r= 0.84$). Newcombe et al. (1992) found that plasma triiodothyronine was elevated in restricted chickens which coincided with a period of compensatory growth. Plasma concentration of this appeared to be positively related to growth rate (Decuypere and Buyse, 1988: McGuiness and

Table 7. Effect of duration and level of early feed restriction on meat composition and serum lipid fractions

Variables	Feeding level			Period			Pooled SE	ANOVA		
	25% *ad libitum*	50% *ad libitum*	75% *ad libitum*	3 days	6 days	9 days		L	P	L×P
Meat composition, %										
Moisture	56.7	56.5	57.5	57.2	57.1	56.5	0.6	NS	NS	NS
Fat	19.8	21.1	18.2	19.9	20.1	19.2	0.5	NS	NS	NS
Protein	18.3	18.3	18.2	18.2	18.3	18.2	0.3	NS	NS	NS
Ash	5.1^{b}	4.1^{a}	5.9^{b}	4.6^{A}	4.7^{A}	5.7^{B}	0.3	<0.05	<0.05	NS
Serum lipid fraction, mg/100 ml										
Triglyceride	56.9	52.3	47.3	45.8	49.7	47.8	6.2	NS	NS	NS
Cholesterol	123.1	131.3	129.3	120.4	129.2	130.6	9.9	NS	NS	NS

[1] Values are presented as mean ± SE (n= 6 broiler each group). L= feeding level; P = Period of restriction; L × P = interaction.
Mean within a row not followed by the same superscripts are significantly different.

Cogburn, 1990). It appeared that severe early feed restriction as well as longer duration may reduce the ability of unsexed broilers to achieve complete compensatory growth. These results were in agreement with the observation of Santoso (1992) when separated sex (females or males) was subjected to various levels and duration of early feed restriction.

Jones and Farrell (1992), Santoso (1995) and Wilson and Osbourn (1960) found that body weights at 56 days of age were heavier for broilers of which the body weight during feed restriction period was lower. The present study, however, failed to prove it. At a given level and duration of feed restriction, better feed conversion ratio during refeeding may also account for the compensatory growth. Furthermore, an increased rate of protein turnover during refeeding period may also have an important role to the occurrence of compensatory growth (Hayashi et al., 1990). Other workers proposed that compensatory growth relate to the reduction in maintenance requirements due to smaller body size during refeeding (Graham and Searle, 1975; Dickerson, 1978; Wilson and Osbourn, 1960).

Higher feed conversion ratio during feed restriction period in broilers fed 25% or 50% *ad libitum* was in agreement with the observation of Alberts et al. (1990). This could be partly explained by higher metabolic rate during feed restriction. At given level and duration, feed restriction resulted in improved feed conversion ratio at 56 days of age. This was in agreement with the observation of Plavnik and Hurwitz (1985).

Serum triglyceride levels are determined by a delicate balance between hepatic triglyceride synthesis and accretion on one hand and serum triglyceride clearance on the other. Therefore, the observed reduction in serum triglyceride level by early feed restriction in broilers could be accomplished by retarded synthesis, reduced hepatic output, enhanced clearance or a combination of these factors. Santoso (1995a,b) found that at 56 days of age, hepatic acetyl-CoA carboxylase activity of restricted broilers, the rate-limiting enzyme in fatty acid synthesis, was decreased as compared with the *ad libitum* group. It appeared that a decrease in this enzyme activity indicated a decrease in fatty acid synthesis, and then reduces triglyceride synthesis in the liver (Skorve et al., 1993), and therefore it reduced serum triglyceride.

The present study showed that lower triglyceride concentration in serum may be not the sole factor lowering abdominal fat weight. It is possible that early feed restriction may also influence the recovery of fat cell number during refeeding. According to Jones and Farrell (1992) restricting the feed intake of broiler chickens to provide only 3.1 kJ/kg $BW^{0.67}$/day during the period 7-13 days of age resulted in lower fat cell number and, as a consequence, decreased total body fat content and abdominal fat content.

The present study showed that unsexed broilers fed 25 % *ad libitum* for 9 days, or 75% *ad libitum* had lower fat content of meat. The present study proved that abdominal fat weight was not a good indicator to estimate meat fat content (r= -0.3169). Considerable changes in the size of adipose tissue are not accompanied by appreciable changes in inter- or intramuscular fat content in chicken body (Grey et al., 1983; Ricard et al., 1983; Becker et al., 1984; Cahaner et al., 1986).

The present study showed that serum cholesterol in broilers fed 25% for 3 days tended to be the lower than the control group. Santoso (1995) showed that decrease in serum cholesterol was accompanied by decrease in liver cholesterol. Ramirez et al. (1984) found that feed restriction produce a decrease in hepatic 3-hydroxy-3-methylglutaryl-CoA reductase activity in chicks, the rate limiting enzyme in cholesterogenesis, and refeeding had little effect on cholesterogenesis. It is possible that feed restriction at this level decreased cholesterogenesis in the liver and refeeding did not recover cholesterogenesis in this group.

In general, feed restriction also increased ash content of meat. During feed restriction, broilers consume less protein than the control. Lower protein consumption may improve mineral metabolism. This assumption was based on the finding of Hulan et al. (1980) who found that lower protein consumption would reduce leg abnormality. From the finding of Robinson et al. (1992) also showed that lowering growth at an early age would allow the bone grow faster at optimum rate. Other investigators (Nir et al., 1987; Katanbaf et al., 1989) found that restricted chicks had heavier digestive tract. Cherry and Siegel (1978) showed that chickens with heavier relative digestive tract weight had slower gastro-intestinal clearance than those with lighter digestive tract. A slower clearance of feed from the intestinal tract allows the nutrients (i.e. minerals) greater exposure to the absorptive cells and consequently influences the efficiency of nutrient utilization.

In conclusion, broilers showed compensatory growth when they were restrict-refed at an early age. In order to achieve the success of early feed restriction (namely reduce fat accumulation and improve feed conversion ratio with comparable body weight at market age), broilers should be fed at level of 25% *ad libitum* for 9 days started at 7 days of age.

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