# Effects of Early Feed Restriction on the Occurrence of Compensatory Growth, Feed Conversion Efficiency, Leg Abnormality and Mortality in Unsexed Broiler Chickens Reared in Cages

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**ABSTRACT :** Two experiments were conducted to evaluate the effect of early feed restriction on growth, feed conversion ratio (FCR) and mortality in unsexed broiler chickens. In Experiment 1, 350 one-day-old broiler chickens were divided into 7 groups. Each treatment group was represented by five replicates of ten broilers each. One group was fed *ad libitum* as the control group and the other six groups were fed 25% *ad libitum* (25% multiplied by amount of feed intake of *ad libitum* chickens at the previous day) for 4 or 6 days, 50% *ad libitum* for 4 or 6 days, and 75% *ad libitum* for 4 or 6 days. In experiment 2, 500 broiler chickens were divided into 10 groups. Each treatment group was represented by five replicates of ten broilers each. One group was fed *ad libitum* as the control group. Three ages of feed restriction initial timing (2, 4 or 6 days of age) and three types of feed restriction (physical restriction, meal feeding and diet dilution) were used (3×3) in both experiments. They were feed-restricted for 6 days. Results showed that restricted broilers exhibited compensatory growth in both experiments except for diet dilution groups. In both experiments, FCR of restricted broilers was higher, whereas feed intake of them was lower during restriction period. FCR of restricted broilers was lower upon refeeding. Mortality was inconsistently affected by early feed restriction. Leg abnormality was lower in restricted broilers in both experiments. Level of feed restriction significantly influenced body weight, FCR and feed intake of restricted broilers ($p<0.05$), but duration of feed restriction had no effect. Type of restriction significantly affected body weight, feed intake and FCR ($p<0.05$). It appeared that to achieve the best result (complete compensatory growth and better FCR), broilers should be restricted at 25% *ad libitum* for 6 days (Experiment 1). Meal feeding started at 2 days of age would show the best performance (Experiment 2). ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 9 : 1319-1325)***

**Key Words** : Early Feed Restriction, Compensatory Growth, Leg Abnormality, Mortality

## INTRODUCTION

Compensatory growth can occur after broiler chickens are feed-restricted at an early age (Santoso, 2001b; Santoso et al., 1993b, 1995ab). Body weights of restricted chickens can exceed those of *ad libitum* chickens (Plavnik and Hurwitz, 1990; Santoso, 2001a; Santoso et al., 1993b). However, most studies of early feed restriction used sexed chickens. Because female and male chickens have different responses to early feed restriction (Plavnik and Hurwitz, 1988; Santoso et al., 1993ab), it is of interest to know whether this program could be applied in unsexed chickens. Santoso (2001a) showed that unsexed chickens reared on-floor showed compensatory growth when they were restricted-refed at an early ages and this phenomenon was affected by the duration and severity of feed restriction.

It was known that poultry reared on-floor had different responses to nutritional planes as compared to those reared in cages (Anderson and Adams, 1994), leading to the assumption that the different rearing types may result in different responses to early feed restriction. In addition, the success of a restriction in separated sexes was affected by initial ages at which broilers were restricted (Ballay et al., 1992; Plavnik and Hurwitz, 1988; Su et al., 1999), and types of feed restriction (Su et al., 1999). However, no study has been conducted to evaluate these factors in unsexed chickens. Therefore, two studies have been conducted to evaluate the response of broiler chickens reared in cages to early feed restriction, and to determine the effects of duration and severity of feed restriction, initial age and type of feed restriction on the performance of unsexed broilers.

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## MATERIALS AND METHODS

### Experiment 1

Three hundred and fifty 1-day-old broiler chickens (Arbor Acres strain, unsexed, ratio of males to females 1:1) obtained from a commercial hatchery were used in this study. From 1 to 14 days 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 to room temperature at the second week. The broiler chickens were maintained in the cages in a house under continuous fluorescent lighting with feed and water available *ad libitum* during the early dry season. At 7 days of age, broiler chickens were divided into 7 groups. Each

treatment group was represented by five replicates of ten broilers each. One group was fed *ad libitum* as the control group and other six groups were fed 25% *ad libitum* (25% multiplied by amount of feed intake of *ad libitum* chickens at the previous day) for 4 or 6 days, 50% *ad libitum* for 4 or 6 days, and 75% *ad libitum* for 4 or 6 days. 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 a commercial starter diet from 1 to 28 days of age, and a commercial finisher diet from 29 to 56 days of age. The nutrient composition of the commercial feed is published elsewhere (Santoso, 2001a). Broilers were weighed individually on a weekly basis except during feed restriction period, and feed intake was recorded daily. Recovery index during refeeding period was calculated using the following equation: (A-B)/A×100%, where A was the difference of body weight between control group and restricted broilers at the end of feed restriction and B was the difference of body weight between control group and restricted broilers at 56 days of age (Brody, 1964). Mortality was also determined. Individual broilers were assigned leg scores of 1 (no visible disorders); 2 (mild), given to broilers able to walk but with a light limp; 3 (moderate), given to broilers with a more distinct limp; or 4 (severe) given to broilers who have great difficulty in walking and would likely be culled under commercial practice (Hester et al., 1990).

All data were statistically analyzed using analysis of variance. Significant difference between treatments was determined by single d.f. orthogonal contrasts. Factorial design (2×3) 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 (Duncan, 1955).

**Experiment 2**

Five hundred 1-day-old broiler chickens (Arbor Acres strain, unsexed, ratio of males and females=1:1) obtained from a commercial hatchery were used in this study. From 1 to 14 days 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 to room temperature at the second week. The broiler chickens were maintained in the cages in a house under continuous fluorescent lighting with feed and water available *ad libitum* during the early dry season. At 7 days of age, broiler chickens were divided into 10 groups. Each treatment group was represented by five replicates of ten broilers each. One group was fed *ad libitum* as the control group. Three ages of feed restriction initial timing (2, 4 or 6 days of age) and three types of feed restriction (physical restriction, meal feeding and diet dilution) were examined in a 3×3 factorial. Physical restriction was conducted by feeding broiler chickens at 25% *ad libitum* (the best result in Experiment 1); meal feeding was conducted by feeding broiler chickens for 6 h from 08:00 to 14:00; diet dilution was conducted by feeding broiler chickens with a diet diluted with sawdust (25:75). They were feed restricted for 6 days. Thereafter, they were fed *ad libitum* to 56 days of age. Water was provided *ad libitum* and recommended husbandry practices and variables measured were similar to Experiment 1.

All data were statistically analyzed as in Experiment 1.

## RESULTS

**Experiment 1**

Table 1 shows the effects of early feed restriction on body weight gain, feed intake and feed conversion ratio (FCR) during feed restriction. Body weight gain and feed intake of restricted broilers were significantly lower as compared to the control ($p<0.01$) at the end of the restriction period. FCR was significantly higher in broilers fed 25% *ad libitum* for 4 ($p<0.001$) or 6 days ($p<0.01$), 50 % ($p<0.05$) and 75% ($p<0.05$) *ad libitum* for 4 days. No mortality was observed during this period.

Table 2 shows the effects of early feed restriction on

**Table 1.** Effect of early feed restriction on growth, feed intake and feed conversion ratio during feed restriction[1] (Experiment 1)

| Variables | Control | 4 d of restriction | | | 6 d of restriction | | | SD |
|---|---|---|---|---|---|---|---|---|
| | | 25% | 50% | 75% | 25% | 50% | 75% | |
| Body weight, g/chick | | | | | | | | |
| 7 d | 113 | 109 | 108 | 109 | 109 | 108 | 111 | 3.7 |
| 11 d | 220 | 110** | 137** | 158** | | | | 44.4 |
| 13 d | 305 | | | | 134** | 189** | 234** | 67.3 |
| Feed intake, g/chick | | | | | | | | |
| 7-11 d | 136 | 29** | 58 ** | 88 * | | | | 13.3 |
| 7-13 d | 263 | | | | 57 *** | 115** | 171* | 24.3 |
| Feed conversion ratio | | | | | | | | |
| 7-11 d | 1.25 | 29.3*** | 2.0* | 1.79* | | | | 1.70 |
| 7-13 d | 1.37 | | | | 2.29** | 1.41 | 1.39 | 0.45 |

[1] Values reported represent means for 5 pens of 10 broilers each.

*, ** or *** Significantly different from the control group at level $p<0.05$; $p<0.01$ or $p<0.001$, respectively.

**Table 2.** Effect of early feed restriction on growth, feed intake and feed conversion ratio during refeeding[1] (Experiment 1)

| Variables | Control | 4 d of restriction | | | 6 d of restriction | | | SD |
|---|---|---|---|---|---|---|---|---|
| | | 25% | 50% | 75% | 25% | 50% | 75% | |
| BWG, g/chick | | | | | | | | |
| 12-56 d | 2,114 | 2,230 | 2,211* | 2,235* | | | | 72 |
| 14-56 d | 2,031 | | | | 2,201* | 2,070 | 2,142* | 123 |
| Feed intake, g/chick | | | | | | | | |
| 12-56 d | 4,564 | 4,575 | 4,619 | 4,803* | | | | 152 |
| 14-56 d | 4,438 | | | | 4,403 | 4,432 | 4,636 | 178 |
| Feed conversion | | | | | | | | |
| 12-56 d | 2.16 | 2.05* | 2.09* | 2.15 | | | | 0.06 |
| 14-56 d | 2.19 | | | | 2.00* | 2.14 | 2.16 | 0.05 |

[1]Values reported represent means for 5 pens of 10 broilers each.

* Significantly different from the control group at level $p<0.05$ or $p<0.01$ respectively.

body weight gain, feed intake and FCR during refeeding.

Body weight gain was significantly higher in broilers fed 50-75% *ad libitum* for 4 days ($p<0.05$) and 25% or 75% ($p<0.05$) *ad libitum* for 6 days ($p<0.05$). Feed intake was higher in restricted chickens fed 75% *ad libitum* for 4 days ($p<0.05$). FCR was significantly lower in broilers fed 25-50% *ad libitum* for 4 days, and 25% *ad libitum* for 6 days ($p<0.05$).

Table 3 shows the effects of early feed restriction on body weight, feed intake, FCR, mortality, leg abnormalities and recovery index at 56 days of age. Body weight was not significantly different, whereas feed intake of chickens fed 25-50% *ad libitum* for 6 days was lower compared to the control ($p<0.05$). Feed conversion ratio of chickens fed 25% *ad libitum* for 6 days was significantly lower as compared with the control ($p<0.05$). Complete compensatory growth was observed in restricted chickens as indicated by recovery index ≥ 100% except for chickens fed 50% *ad libitum* ($p<0.01$). Mortality was lower in chickens fed 25, 50% or 75% *ad libitum* for 4 days and 25% *ad libitum* for 6 days as compared to the control. Leg abnormalities of restricted broilers were significantly lower ($p<0.05$) as compared to the control except for broilers fed 75% *ad libitum* for 6 days.

Table 4 shows the effects of duration and level of feed restriction on body weight, feed intake and FCR. It was shown that the level of feed restriction affected body weight, FCR ($p<0.05$) and feed intake ($p<0.01$) of chickens at 56 days of age. Recovery index of restricted chickens was significantly affected by duration ($p<0.01$) and level of feed restriction ($p<0.01$).

**Experiment 2**

Table 5 shows the effects of early feed restriction on body weight, feed intake and FCR during feed restriction. Body weight and feed intake of restricted broilers were significantly lower compared to the control ($p<0.001$) at the end of restriction period. FCR was significantly higher in restricted broilers ($p<0.01$).

Table 6 shows the effects of early feed restriction on body weight gain, feed intake and FCR during refeeding. Body weight gain was significantly higher in broilers subjected to physical restriction started at 2 or 4 days of age, meal feeding started at 2 days of age ($p<0.05$). Feed intake was significantly higher in meal feeding started at 2 days of age ($p<0.05$), but it was significantly lower in diet dilution started at 2, 4 or 6 days of age ($p<0.05$). FCR was significantly lower in broilers subjected to physical restriction started at 2 or 4 days of age, meal feeding started at 4 or 6 days of age, and diet dilution started at 6 days of age.

Table 7 shows the effects of early feed restriction on body weight, body weight gain, feed intake and FCR, recovery index, mortality and leg abnormalities at 56 days

**Table 3.** Effect of early feed restriction on body weight, feed intake and feed conversion ratio, recovery index, mortality and leg abnormalities in broiler chickens at 56 days of age[1] (Experiment 1)

| Variables | Control | 4 days of restriction | | | 6 days of restriction | | | SD |
|---|---|---|---|---|---|---|---|---|
| | | 25% | 50% | 75% | 25% | 50% | 75% | |
| BWG, g/chick | 2,221 | 2,231 | 2,240 | 2,284 | 2,226 | 2,151 | 2,265 | 80 |
| Body weight | 2,336 | 2,340 | 2,348 | 2,393 | 2,336 | 2,259 | 2,376 | 95 |
| Feed intake | 4,710 | 4,604 | 4,677 | 4,891 | 4,460 | 4,547* | 4,807 | 150 |
| FCR | 2.12 | 2.06 | 2.09 | 2.14 | 2.00* | 2.11 | 2.12 | 0.04 |
| Recovery index[2] | - | 104 [b] | 114 [b] | 192 [d] | 100 [b] | 34 [a] | 156 [c] | 20 |
| Mortality, % | 6 | 4 | 2 | 4 | 2 | 6 | 6 | |
| Leg abnormality | 1.3 | 1.08* | 1.04* | 1.04* | 1.02* | 1.06* | 1.24 | 0.03 |

[1] Values reported represent means for 5 pens of 10 broilers each.

* Significantly different from the control group at level $p<0.05$; $p<0.01$ or $p<0.001$, respectively.

[2] Means within a row not followed by the same superscripts are significantly different.

**Table 4.** Effect of duration and level of feed restriction on body weight, feed intake and feed conversion ratio in broiler chickens at 56 days of age[1] (Experiment 1)

| Variables | Duration of restriction | | Level of restriction | | | SD | ANOVA | | |
|---|---|---|---|---|---|---|---|---|---|
| | 4 d | 6 d | 25% | 50% | 75% | | L | D | L×D |
| Body weight | 2,360 | 2,332 | 2,318[a] | 2,303[a] | 2,417[b] | 96 | <0.05 | NS | NS |
| Feed intake | 4,717 | 4,611 | 4,541[a] | 4,602[a] | 4,849[b] | 145 | <0.01 | NS | NS |
| FCR | 2.10 | 2.07 | 2.02[a] | 2.10[b] | 2.13[b] | 0.06 | <0.05 | NS | NS |
| Recovery index | 137[B] | 97[A] | 102[b] | 74[a] | 174[c] | 21 | <0.01 | <0.01 | <0.05 |

[1] Values reported represent means for 5 pens of 10 broilers.
L=Level of restriction, D=Duration of restriction, L×D=Interaction.
Means within a row not followed by the same superscripts are significantly different.

**Table 5.** Effect of early feed restriction on body weight, feed intake and FCR during feed restriction[1] (Experiment 2)

| Variables | Control | Physical feed restriction | | | Meal feeding | | | Diet dilution | | | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 d | 4 d | 6 d | 2 d | 4 d | 6 d | 2 d | 4 d | 6 d | |
| BWG, g/chick | | | | | | | | | | | |
| 2-8 | 128 | 15*** | | | 55*** | | | 3[2]*** | | | 4.5 |
| 4-10 | 150 | | 32*** | | | 61*** | | | 15[2]*** | | 14.5 |
| 6-12 | 199 | | | 28*** | | | 82*** | | | 27[2]*** | 20.6 |
| Feed intake, g/chick | | | | | | | | | | | |
| 2-8 | 174 | 36*** | | | 84*** | | | 36*** | | | 20.0 |
| 4-10 | 286 | | 59*** | | | 129** | | | 46*** | | 15.4 |
| 6-12 | 358 | | | 82*** | | | 197** | | | 64*** | 21.5 |
| FCR | | | | | | | | | | | |
| 2-8 | 1.36 | 2.36** | | | 1.53 | | | 11.54[2]*** | | | 0.08 |
| 4-10 | 1.90 | | 1.84 | | | 2.13* | | | 3.09[2]*** | | 0.07 |
| 6-12 | 1.81 | | | 2.92** | | | 2.40* | | | 2.36[2]*** | 0.3 |

[1] Values reported represent means for 5 pens of 10 broilers each.
[2] The significance of the negative values.
*, ** or *** Significantly different from the control group at level $p<0.05$; $p<0.01$ or $p<0.001$, respectively.

**Table 6.** Effect of early feed restriction on body weight, feed intake and FCR during refeeding[1] (Experiment 2)

| Variables | Control | Physical feed restriction | | | Meal feeding | | | Diet dilution | | | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 d | 4 d | 6 d | 2 d | 4 d | 6 d | 2 d | 4 d | 6 d | |
| BWG, g/chick | | | | | | | | | | | |
| 8-56 | 2,190 | 2,272* | | | 2,364* | | | 2,104 | | | 75 |
| 10-56 | 2,135 | | 2,294* | | | 2,187 | | | 2,084 | | 91 |
| 12-56 | 2,048 | | | 2,115 | | | 2,169 | | | 2,130 | 92 |
| Feed intake, g | | | | | | | | | | | |
| 8-56 | 5,172 | 4841 | | | 5,327* | | | 4,827* | | | 120 |
| 10-56 | 5,035 | | 5048 | | | 5,073 | | | 4,785* | | 115 |
| 12-56 | 4,902 | | | 4794 | | | 4,781 | | | 4,556* | 122 |
| FCR | | | | | | | | | | | |
| 8-56 | 2.36 | 2.13* | | | 2.25 | | | 2.29 | | | 0.06 |
| 10-56 | 2.36 | | 2.20* | | | 2.02* | | | 2.29 | | 0.07 |
| 12-56 | 2.39 | | | 2.27 | | | 2.20* | | | 2.14* | 0.05 |

[1] Values reported represent means for 5 pens of 10 broilers each.
* Significantly different from the control group at level $p<0.05$.

of age. Body weight of broilers subjected to physical restriction and meal feeding were not significantly different, whereas in those subjected to diet dilution it was significantly lower ($p<0.05$). Feed intake was significantly lower in broilers subjected to physical restriction, meal feeding and diet dilution ($p<0.01$). FCR was significantly lower in broilers subjected to physical restriction, meal feeding, and diet dilution started at 6 days of age ($p<0.05$). Recovery index was significantly different ($p<0.01$) among the restricted broilers. Complete compensatory growth as indicated by recovery index ≥100% occurred with physical feed restriction started at 4 days of age, and meal feeding started at 2, 4 or 6 days of age. Diet dilution started at 2 or 4 days of age showed negative recovery index. Mortality of restricted broilers was similar to the control group. Leg abnormalities of restricted broilers were significantly lower

**Table 7.** Effect of early feed restriction on body weight, feed intake and FCR, recovery index and mortality at 56 days of age[1] (Experiment 2)

| Variables | Control | Physical feed restriction | | | Meal feeding | | | Diet dilution | | | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 d | 4 d | 6 d | 2 d | 4 d | 6 d | 2 d | 4 d | 6 d | |
| Body weight | 2,380 | 2,349 | 2,420 | 2277 | 2,482 | 2,381 | 2,384 | 2,163* | 2,164* | 2,224* | 120 |
| BWG, g/chick | | | | | | | | | | | |
| 2-56 | 2,318 | 2,287 | | | 2,418* | | | 2,100* | | | 76 |
| 4-56 | 2,285 | | 2,326 | | | 2,287 | | | 2,070* | | 89 |
| 6-56 | 2,246 | | | 2,143 | | | 2,251 | | | 2,087* | 91 |
| Feed intake, g | | | | | | | | | | | |
| 2-56 | 5,393 | 4,907** | | | 5176* | | | 4,834** | | | 137 |
| 4-56 | 5,403 | | 5099** | | | 5116** | | | 4,859** | | 112 |
| 6-56 | 5,460 | | | 4,810** | | | 4,974* | | | 4,724** | 189 |
| FCR | | | | | | | | | | | |
| 2-56 | 2.33 | 2.15* | | | 2.14* | | | 2.30 | | | 0.07 |
| 4-56 | 2.37 | | 2.19* | | | 2.24* | | | 2.35 | | 0.05 |
| 6-56 | 2.43 | | | 2.24* | | | 2.21* | | | 2.26* | 0.06 |
| Recovery index[2] | - | 72.6$^{d}$ | 133.9$^{f}$ | 39.8$^{c}$ | 241.5$^{g}$ | 101.1$^{e}$ | 103$^{e}$ | -65.4$^{b}$ | -30.7$^{a}$ | 29.7$^{c}$ | 25.5 |
| Mortality (%) | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | |
| Leg abnormality | 1.21 | 1.08* | 1.09* | 1.10* | 1.11* | 1.12* | 1.21 | 1.11* | 1.14* | 1.11* | 0.04 |

[1]Values reported represent means for 5 pens of 10 broilers each.

* or ** Significantly different from the control group at level $p<0.05$ or $p<0.01$, respectively.

[2]Means within a row not followed by the same superscripts are significantly different.

as compared to the control group ($p<0.05$) except for broilers subjected to meal feeding started at 6 days of age.

Table 8 shows the effects of initial age and type of restriction on body weight gain, body weight, feed intake and FCR. Initial age did not affect body weight gain, body weight, and FCR. Restricting broilers started at 6 days of age had lower feed intake than those started at 4 days of age ($p<0.05$). Type of restriction significantly affected body weight gain, body weight, feed intake and FCR ($p<0.01$). There was interaction between initial age and type of restriction on feed intake and recovery index ($p<0.05$).

## DISCUSSION

The amount of feed allocated to the restricted chickens during the restriction period was at least sufficient to provide for basic maintenance and body functions (except for diet dilution group) as these broilers gained body weight during the restriction period. Feed intake was lower during feed restriction. There was a significant positive correlation between duration and feed intake ($r=0.57$; $p<0.05$), and between level of feed restriction and feed intake (0.82; $p<0.01$). It seemed that longer duration and more severe feed restriction would significantly reduce feed intake (Experiment 1).

Less severe feed restriction might be less stressful to broilers so that broilers adapted more quickly to feed restriction. This might explain better FCR during feed restriction in less severe groups. Longer duration resulted in greater body weight gain (g/day) with better FCR. It is possible that longer duration of feed restriction allows broilers to adapt to feed restriction as far as temperature is maintained at an accurate level. Average daily temperature was 29.13°C. This temperature is far from suitable for birds in subtropics but it might be a proper temperature in tropic zones. Types of restriction (Experiment 2) also influenced growth, feed intake and FCR. Diet dilution resulted in negative growths indicating that diet dilution applied was too severe to meet the nutrient requirement for maintenance. The inclusion of sawdust may affect the ME content of the

**Table 8.** Effect of initial age and type of restriction on body weight gain, body weight, feed intake, FCR and recovery index at 56 days of age[1] (Experiment 2)

| Variable | Initial age | | | Type of restriction | | | SD | ANOVA | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 4 | 6 | Physical | Meal | Dilution | | IA | TR | IA×TR |
| Body weight | 2,268 | 2,228 | 2,160 | 2,252$^{ab}$ | 2,319$^{b}$ | 2,086$^{a}$ | 130 | NS | <0.05 | NS |
| BWG | 2,331 | 2,308 | 2,295 | 2,349$^{b}$ | 2,402$^{b}$ | 2,184$^{a}$ | 125 | NS | <0.05 | NS |
| Feed intake | 4,972$^{AB}$ | 5,025$^{B}$ | 4,836$^{A}$ | 4,939$^{ab}$ | 5,089$^{b}$ | 4,806$^{a}$ | 140 | <0.05 | <0.05 | <0.05 |
| FCR | 2.19 | 2.26 | 2.24 | 2.19$^{a}$ | 2.19$^{a}$ | 2.30$^{b}$ | 0.07 | NS | <0.05 | NS |
| Recovery index, % | 84.6$^{B}$ | 68.1$^{A}$ | 57.5$^{A}$ | 82.1$^{b}$ | 148.5$^{c}$ | -20.5$^{a}$ | 10.6 | <0.05 | <0.01 | <0.05 |

[1]Values reported represent means for 5 pens of 10 broilers each.

IA=Initial age, TR=Type of restriction, IA×TR=Interaction.

Means within a row not followed by the same superscripts are significantly different.

feed, having a depressive effect on energy balance.

Initial age might be also correlated to body weight gain (r=0.69), feed intake (r=0.51), FCR (r=0.38) during feed restriction. Older initial age would result in better growth and FCR with higher feed intake. Nitsan et al. (1991) found that at 5-10 days of age, relative growth reached its peak and relative weight of the pancreas and small intestine were also maximal in broiler chickens. At this age, broilers might be more adaptable to nutritional planes compared to younger ages. This might be true for diet dilution, because the present study showed earlier initial age (less than 5 days of age) should be applied for physical restriction and meal feeding in order to achieve optimal results.

Feed restriction has been shown to reduce the metabolic energy loss (Mitchell, 1962), leading to reduced requirement for maintenance and thus improved FCR during feed restriction. The present study, however, showed that feed restriction increased FCR. The increment of FCR might partly be explained by higher requirement for maintenance due to smaller body weight during feed restriction.

The present study confirmed previous results (Santoso, 2001a), which showed that unsexed restricted-broilers showed compensatory growth when they were refed. However, the present study showed that early feed restriction did not result in heavier body weight as shown in the previous study (Santoso, 2001a). This difference might be due to the different types of rearing. In the previous study broilers were raised on-floor, whereas in the present study they were raised in cages. It was shown that broilers raised on-floor had higher body weights than those raised in cages (Anderson and Adams, 1994; Sinurat et al., 1995). Finally, animals raised on the floor are losing less energy than the caged animals because thermal insulation conditions are better than in cages. This factor might influence the response of broilers to early feed restriction.

The present study showed that initial age of feed restriction had no effect on the occurrence of compensatory growth. Plavnik and Hurwitz (1988) also found that various initial ages had no effect on the occurrence of compensatory growth in male birds. However, in females, restriction at the earlier age of 7 days minimized the loss of body weight observed when restriction was applied at 9 or 11 days. Ballay et al. (1992) also found that initial age from 1 to 12 days of age resulted in compensatory growth with comparable FCR in males. Plavnik and Hurwitz (1988) suggested that with mixed populations, the earlier restriction, starting at the age of 5 to 7 days, should be preferred over later age. The present study showed that initial age of 2 to 6 days could be applied to mixed populations.

Types of restriction also influenced the occurrence of compensatory growth. Meal feeding showed higher compensatory growth than the other types. Su et al. (1999) found that meal feeding allows broilers to compensate with better growth and FCR than with physical feed restriction. Furthermore, it was found that more frequent meal feeding might bring about better compensatory growth. This result indicates that in order to exhibit compensatory growth with better FCR, chickens do not require to be restricted at maintenance requirement as suggested by Plavnik and Hurwitz (1985). Diet dilution failed to induce any compensatory growth. This did not agree with the observation of Leeson et al. (1991) who found complete compensatory growth when broilers were fed diluted diet. This difference might be partly caused by more severe effect of diet dilution in the present study.

The present study showed that feed restriction level affected the degree of compensatory growth and duration of feed restriction tended to exert an effect on it. Santoso (2001a) also found that duration and level of feed restriction influenced the degree of compensatory growth. Less severe and shorter duration of feed restriction resulted in higher degree of compensatory growth.

Early feed restriction did not consistently improve FCR in restricted broilers at 56 days of age. To produce complete compensatory growth with better FCR, chickens reared in cages should be fed 25% *ad libitum* for 6 days. Santoso (2001a) found that broilers reared on-floor could be fed 25% *ad libitum* for 9 days, indicating that rearing type might influence the response of broilers to early feed restriction. It was known that broilers reared on-floor had better insulation, and thus they could be restricted longer. It seemed that more severe feed restriction would result in better FCR. The present study found that broilers receiving meal feeding or physical restriction showed better FCR as compared with diet dilution. This result was contrary to the observation of Su et al. (1999) who found that meal feeding resulted in better FCR ratio than physical feed restriction in broilers. Although it was not significantly different, it appears that early feed restriction started at 2 days of age had better FCR than the others.

As pointed out by Ballay et al. (1992) *ad libitum* feeding of broilers might be detrimental because of higher mortality. Results of the present study confirmed that observation (Experiment 1). However, the present study proved that early feed restriction did not consistently reduce mortality. The present study also confirms that early feed restriction could reduce leg abnormalities as observed in other investigations (Hester et al., 1990; Robinson et al., 1992). Lower protein intake in restricted broilers during restriction period might contribute to lower leg abnormality in restricted broilers. Hulan et al. (1980) found that lower protein intake would reduce leg abnormalities.

In order to achieve the best results from the early feed restriction, it was concluded from Experiment 1 that

broilers should be restrict-fed at 25% *ad libitum* for 6 days. Meal feeding started at 2 days of age showed the best performance (Experiment 2).

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