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Effects of Restricted Feeding on Performance, Carcass Quality and Hormone Profiles in Finishing Barrows

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ABSTRACT : To investigate the effects of feeding restricted on growth, carcass characteristics and plasma profiles in an attempt for optimum responses, a total of 108 cross-bred finishing barrows [(Landrace×Yorkshire)×Duroc]weighing an average of 46.88±0.52 kg were assigned in a randomized complete block (RCB) design to one of four treatments with three replicates and nine pigs per pen. Feeding regimens were, 1) *ad libitum* from 50 kg to market weight (Ad 3/3), 2) restricted feeding from 90 kg to market weight (Ad 2/3), 3) restricted feeding from 70 kg to market weight (Ad 1/3), and 4) restricted feeding from 50 kg to market weight (Ad 0/3). During the experimental period, average daily feed intake (ADFI) was decreased from 2.53 kg (AD 3/3) to 2.09 kg (AD 0/3) with increasing restricted feeding duration of ($p<0.05$). Average daily gain (ADG) of AD 3/3 (0.79 kg) was significantly higher ($p<0.05$) than those of AD 1/3 (0.74 kg) or AD 0/3 (0.72 kg). Feed efficiency was not influenced by restriction regimens. Blood IGF-I concentrations were increased from 74.14 to 134.25 (167.36-115.66) ng/ml as body weight increased. Blood leptin concentrations were affected by feed intake level and coincided with blood IGF-I concentrations. Most of carcass characteristics were not significantly affected by restricted feeding, however cooking losses in AD 1/3 and Ad 0/3 treatment diet were higher than those in Ad 3/3 and Ad 2/3. In addition, there was a trend that backfat thickness was lowered in proportional to decreasing feed intake ($p>0.05$). In conclusion, restricted feeding improved feed efficiency after 50 kg body weight without deteriorating the pork quality of barrows. (**Key Words :** Barrows, Restricted Feeding, Growth Performance, Carcass Characteristics, IGF-I, Leptin)

INTRODUCTION

Improvement of growth rate and efficiency of nutrient utilization as well as improving net income are ultimate goals of swine producers and animal nutritionists. Due to lower capacity for protein deposition, barrows generally require less dietary protein and amino acids to support maximum growth than boars and gilts (Tullis, 1981; Williams et al., 1984; Yen et al., 1986a, b; Hahn et al., 1995). Barrows also consume more feed than boars and gilts, consequently their carcass leanness and feed efficiency are reduced compared to boars and gilts (Langlois and Minvielle, 1989; Hammell et al., 1993; Clapper and Clark, 1999). Certainly, animals should be fed to more closely match the nutrient requirements of the genders and growth phases (Ko et al., 2004). Campbell and Taverner (1988) observed that boars and barrows fed diets containing higher daily DE during 45 to 90 kg body weight periods showed improved growth performance due to increasing energy intake. Bikker et al. (1996) demonstrated similar results during the 45 kg to 85 kg stage of growth, when gilts were fed increased energy (1.7 to 3.7×maintenance and *ad libitum*).

Intramuscular fat could be an important indicator to evaluate meat quality, because high levels of intramuscular fat caused a significant decrease in shear force (DeVol et al., 1988; Hodgson et al., 1991). It is well established that boars generally grow faster and more efficiently than barrows and gilts (Langlois and Minvielle, 1989; Clapper and Clark, 1999; Owens et al., 1999). Serum IGF-I concentration was positively correlated with growth rate in pigs (Blair et al., 1987; Buonomo et al., 1987; Dammacco et al., 1993), and its level was changed as pigs grew (Clapper and Clark, 1999; Owens et al., 1999). Ocak and Erener (2005) also demonstrated that feed restriction resulted in a better feed conversion without reduction in carcass weight in the Japanese quail.

Therefore, the objectives of this study were 1) to assess the impact of restricted feeding on growth performance,

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Table 1. Experimental design

	Ad 3/3	Ad 2/3	Ad 1/3	Ad 0/3
Day 0-28	*ad libitum*	*ad libitum*	*ad libitum*	Restricted feeding
Day 29-56	*ad libitum*	*ad libitum*	Restricted feeding	Restricted feeding
Day 57-84	*ad libitum*	Restricted feeding	Restricted feeding	Restricted feeding

Table 2. Formula and chemical composition of the experimental diets

Ingredients (%)	Body weight	
	50-75 kg	75-110 kg
Corn (yellow)	39.47	40.31
Wheat	15.00	20.00
Barley	2.00	4.00
Lupin	4.00	4.00
Rice bran	2.50	-
Wheat bran	-	0.34
Lupin seed coats	2.50	3.00
Corn gluten meal	2.50	2.50
Rapseed meal	4.00	5.00
Soybean meal (44.5%)	15.64	10.22
Corn germ meal	2.50	2.50
Limestone	0.61	0.98
DCP	1.17	1.22
Salt	0.30	0.30
Tallow	2.72	1.00
Molasses	4.00	4.00
Mineral Mix.[1]	0.25	0.18
Vitamin Mix.[2]	0.25	0.19
Choline chloride	0.05	0.02
L-lysine . HCl	0.52	0.24
DL-methionine	0.02	-
Total	100.00	100.00
Chemical composition[3]		
DE (kcal/kg)	3,600	3,500
CP (%)	17.35	15.87
Lysine (%)	1.00	0.80
Calcium (%)	0.67	0.80
Phosphorus (%)	0.66	0.62

[1] Provided the following amounts per kilogram of diet: Selenium 0.15 mg; Manganese 0.03 g; Zinc 0.1 g; Iron 0.1 g; Iodine 0.5 mg; Magnesium 0.1 g.

[2] Provided the following amounts per kilogram of diet: Vitamin A 5,500 IU; Vitamin D_3 550 IU; Vitamin E 27 IU; Menadione sodium bisulfate 2.5 mg; Pantothenic acid 27 mg; Niacin 33 mg; Riboflavin 5.5 mg; Vitamin B_{12} 0.04 mg; Thiamin 5 mg; Pyridoxine 3 mg; Biotin 0.24 mg; Folic acid 1.5 mg; Choline chloride 700 mg.

[3] Calculated value.

carcass characteristics and plasma profiles and 2) to determine a suitable feed restriction strategy to use with barrows during the growing-finishing period.

MATERIALS AND METHODS

One hundred eight cross-bred finishing barrows [(Landrace×Yorkshire)×Duroc] weighing an average of 46.88±0.52 kg of body weight were randomly assigned to one of four treatments on the basis of body weight. This experiment was a randomized complete block (RCB) design using three replicates with nine pigs per pen. Feeding regimens for each treatment were 1) *ad libitum* from 50 kg to market weight (Ad 3/3), 2) restricted feeding from 90 kg to market weight (Ad 2/3), 3) restricted feeding from 70 kg to market weight (Ad 1/3), and 4) restricted feeding from 50 kg to market weight (Ad 0/3) (Table 1).

Experimental diets were formulated to contain 17.35% crude protein for 50 to 75 kg BW, 15.87% crude protein for 75 to 110 kg BW, respectively. The formula and chemical composition of experimental diets were presented in Table 2. Pigs were housed in a concrete floored pen, equipped with a feeder and nipple waterer, and allowed free access to water throughout the whole experiment.

The pigs were fed twice daily at 08:00 and 16:00. Body weight was measured at two week intervals and body weight gain was calculated by the difference between the initial body weight and final body weight. Feed efficiency was calculated with the corresponding body weight gain by dividing the amount of feed consumed. The amounts of feed offered during the next 2 week were calculated by 90% of the average amounts of feed consumed during the previous 2 weeks.

Blood samples were drawn via jugular vein puncture of fifteen animals per treatment at two weeks interval. Collected samples were centrifuged for 15 min at 3,000 rpm in a cold chamber (4°C). The serum was saved and carefully transferred to plastic vials and stored at -20°C for further analysis. Leptin and IGF-I concentrations in serum were analyzed using RIA kit (Diagnostic Systems Laboratories, Inc. USA). During the growing period, backfat thickness was measured at 5 to 8 cm off midline between the 10th and 11th rib using ultrasonic Lean-Meater (Renco Corp., Minneapolis, MN) on the day of weighing. All pigs were slaughtered when they reached an average body weight of 110 kg. After slaughtering, backfat depth was measured again at the 10-11th rib, the thoracic and lumbar vertebrae. The loin eye areas were measured between the 5-6th rib of each carcass. After 24 h of postmortem, loin muscles between the 10th and 11th ribs were taken, vacuum packed and kept at 5°C until needed for proximate analysis. Meat samples were mixed with distilled water at a 1:10(w/v), homogenized and pH measured using an Orion Research 601A Ionalyzer (Orion Research Inc., USA). Color values were measured by a Chromameter

Table 3. Effects of different feeding regimens on the growth performance of finishing barrows

	Ad 3/3[1]	Ad 2/3	Ad 1/3	Ad 0/3	MSE[2]
Body wt (kg)					
Initial	46.59	47.52	46.13	47.24	
2 wk	56.08	56.84	55.55	56.46	
4 wk	67.26	68.20	66.63	66.15	
6 wk	79.97	81.26	75.63	74.22	
8 wk	90.63	92.41	86.77	86.14	
10 wk	101.45	102.26	97.91	96.65	
Overall (0-10 wk)	113.56	111.66	108.74	107.76	
ADG (kg/day)					
0 -14 d	0.67	0.66	0.67	0.65	0.02
15-28 d	0.79[a]	0.81[a]	0.79[a]	0.69[b]	0.01
29-42 d	0.90[a]	0.93[a]	0.64[b]	0.57[b]	0.02
43-56 d	0.76	0.79	0.74	0.85	0.02
57-70 d	0.77	0.70	0.79	0.75	0.02
71-84 d	0.86[a]	0.67[b]	0.77[a]	0.79[a]	0.01
0 -84 d	0.79[a]	0.76[ab]	0.74[b]	0.72[b]	0.01
ADFI (kg/day)					
0 -14 d	1.96[a]	1.94[a]	1.95[a]	1.65[b]	0.01
15-28 d	2.14[a]	2.12[a]	2.12[a]	1.77[b]	0.02
29-42 d	2.62[a]	2.59[a]	1.97[b]	1.97[b]	0.03
43-56 d	2.57[a]	2.44[b]	2.34[c]	2.34[c]	0.01
57-70 d	2.95[a]	2.16[b]	2.16[b]	2.16[b]	0.03
71-84 d	2.96[a]	2.66[b]	2.66[b]	2.66[b]	0.01
0 -84 d	2.53[a]	2.32[b]	2.20[c]	2.09[a]	0.01
Gain/feed					
0 -14 d	0.34[b]	0.34[b]	0.35[b]	0.39[a]	0.01
15-28 d	0.37	0.38	0.37	0.39	0.01
29-42 d	0.34[a]	0.35[a]	0.32[b]	0.29[b]	0.01
43-56 d	0.29[b]	0.32[ab]	0.31[b]	0.36[a]	0.01
57-70 d	0.26[b]	0.32[a]	0.36[a]	0.34[a]	0.01
71-84 d	0.29[a]	0.25[b]	0.29[a]	0.29[a]	0.01
0 -84 d	0.32	0.33	0.34	0.34	0.01

[1] Refer to Table 1. [2] Mean Standard Error.
[a, b, c] Means in the same row with different superscripts differ (p<0.05).

(Minolta Co. CR 301) for lightness (L), redness (a) and yellowness (b) of CIE and Hunter color. The purge loss was measured based upon the amounts of drip loss during vacuum packing. Filter papers (diameter 150 mm; Whatman NO. 1., Japan) were used to absorb water on the meat surface. Proximate principles of collected carcass samples were analyzed according to the methods of the AOAC (1995). The data obtained from the experiment were analyzed by comparing means using Duncan's multiple range test by GLM procedure of SAS (1985) program. The pen was considered as the experimental unit for performance data.

RESULTS AND DISCUSSION

Performance

Table 3 summarized the effects of various feeding regimens on the performance of finishing barrows. Feed intake was the lowest for pigs with totally restricted feeding in Ad 0/3 treatment (p<0.05), while decreased feed intake resulted in improved gain/feed. Furthermore, ADG of pigs reared in Ad 0/3 treatment was the lowest (p<0.05) and gain/feed was not affected by treatment after 2 weeks. Average daily gain of AD 1/3 treatment was lower than that of Ad 3/3 treatment (p<0.05). From 43 to 70 d, ADG of Ad 0/3 treatment was similar to the others. This result demonstrated that a compensatory growth started to occur in the restricted feeding treatments. From 57 to 70 d, ADG of AD 2/3 treatment which was restricted to feeding at 57 d was similar to those of other treatments. Throughout the whole experimental period, the difference between total feed intake and body weight gain of Ad 3/3 treatment and Ad 0/3 treatment was 37 kg and 5.9 kg, respectively. Gain to feed ratio in finishing pigs was not affected by restriction regimens. It was interesting that the growth retardation of pigs due to restricted feeding during the early fattening period could be recovered during the late fattening period. This result could be explained by the pattern of protein deposition in finishing pigs. It would be decreased as body weight increased, even though feed intake was maintained constant. When feed intake was not enough to support maximal growth during the growing or early finishing periods, less protein deposition would occur. However, compensatory growth took place during the late finishing period if nutrients were available at that time.

Throughout the whole experimental period from 47 to 110 kg, the ADFI within various feeding regimens decreased approximately 0.44 kg/d from 2.53 (Ad 3/3) to 2.09 kg/d (Ad 0/3). Average daily gain in AD 3/3 (0.79 kg) treatment was much higher (p<0.05) than those of AD 1/3 (0.74 kg) or AD 0/3 (0.72 kg) treatment. These results demonstrated that restricted feeding during early fattening period for barrows could be possible, because carcass grade was improved although ADG was significantly reduced when restricted feed was provided.

Lee et al. (2002) reported that ADG was reduced up to 18% (0.86 and 0.70 kg for *ad libitum* and restricted feeding, respectively) when fed 80% *ad libitum* to barrows from 59 to 105 kg and without any changes in G/F ratio.

Quiniou et al. (1996) reported linear responses of increased ADG with dietary energy levels of 70, 80, 90 and 100% ME when evaluated effect of dietary energy level on barrows of 45 to 100 kg body weight. Bikker et al. (1996), using 1.7, 2.2, 2.7, 3.2 and 3.7 times of maintenance energy levels and *ad libitum* feeding, observed progressive linear increases in growth of pigs from 20 to 45 kg BW. Klindt et al. (2001) indicated that the greatest efficiencies of gain were obtained approximately from 62.5-75% of *ad libitum* level. Final body weight ranged from 78 to 113 kg and backfat thickness ranged from 12 to 23 mm in developing gilts from 13 to 25 wk of age which were assigned to from 50 to 87.5% *ad libitum*. During the whole experimental

Table 4. Effects of different feeding regimens on carcass characteristics of finishing barrows

	Ad 3/3[1]	Ad 2/3	Ad 1/3	Ad 0/3	MSE[2]
Carcass body weight (kg)	89.71	85.70	86.01	83.97	0.91
Carcass grade[3]	2.20	2.20	1.93	1.53	0.13
Carcass backfat depth (mm)	25.20	24.33	24.26	22.93	0.63
Shear value (kg)	3.05	3.09	3.17	3.13	0.04
Cooking loss (%)	29.77[b]	30.38[b]	32.48[a]	31.96[a]	0.36
Water holding capacity (%)	58.95	57.62	58.58	57.63	0.40
pH	5.65	5.68	5.62	5.68	0.01
Loin eye area (cm^2)	43.79	43.51	45.03	42.42	0.90
Chemical analysis (%)					
Moisture	72.93	73.13	73.62	73.35	0.14
Crude fat	2.13	2.40	1.80	1.99	0.14
Crude protein	22.82	22.25	22.45	22.59	0.11
Crude ash	1.05	1.04	1.06	1.04	0.01

[1] Refer to Table 1. [2] Mean standard error.
[3] Based on a scale with 1 = grade A, 2 = grade B, 3 = grade C, 4 = grade D.
[a, b] Means with different superscripts in the same column differ (p<0.05).

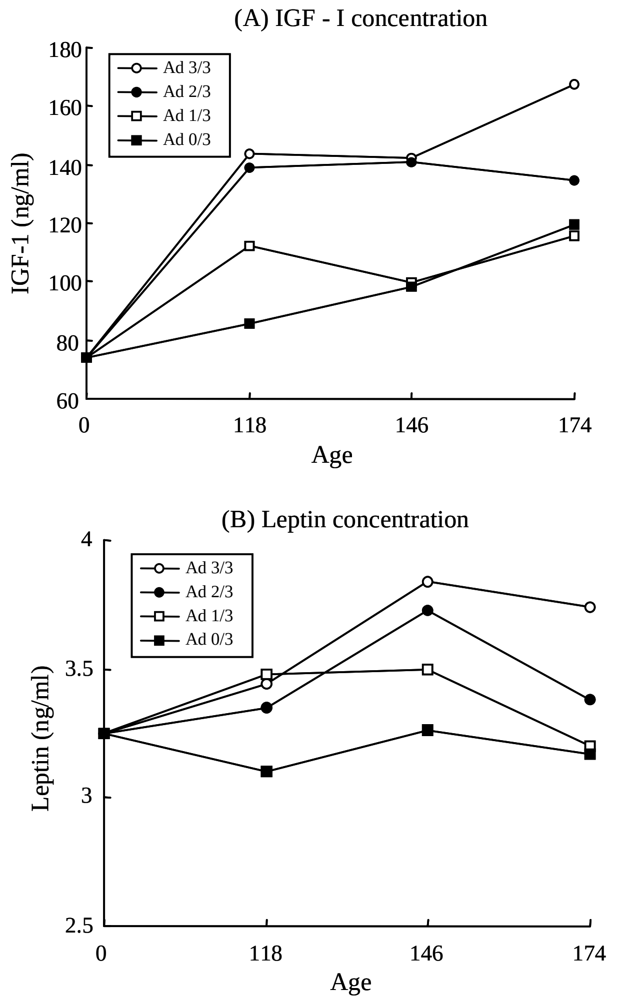

Figure 1. Relationship between (A) IGF-I or (B) leptin concentration and age.

period, the difference of body weight gain and feed intake between Ad 3/3 and Ad 0/3 was 5.8 kg and 36.7 kg, respectively. This result demonstrated that additional feed intake above the amounts of optimum restricted feeding affected fat deposition rather than protein accumulation in finishing barrows. Due to the fact that backfat thickness tended to decrease as restricted feeding was applied while protein percentage was not affected by feed restriction (Table 4).

Therefore, the present study represented that restricted feeding strategy from 50 kg BW to market weight can be a very effective method for improving feed efficacy.

IGF-I and leptin concentration

The concentrations of blood IGF-I and leptin undergone different feeding regimens during the 84-day experiment were shown in Figure 1.

Overall, blood IGF-I concentration tended to increase from 74.14 to 134.25 (167.36-115.66) ng/ml as body weight increased. This tendency was in agreement with the results of other researchers who reported that serum concentrations of IGF-I were positively correlated with growth rate in pigs and other animals (Blair et al., 1987; Buonomo et al., 1987; Dammacco et al., 1993; Clapper and Clark, 1999; Owens et al., 1999). On the contrary, several researches demonstrated that circulating IGF-I concentration was reduced under conditions of restricted energy or feed intake (Smith et al., 1995; Booth et al., 1996; Ketelslegers et al., 1996; Hall et al., 1999). Almeida et al. (2001) and Lee et al. (2002) reported that the restriction of feed intake did not affect plasma IGF-I concentrations because low restriction level of feed intake in their study might not enough to cause changes in blood concentrations of IGF-I. Presumably, blood IGF-I concentration was influenced by restriction of feed during experimental period.

Restricted feeding significantly affected blood IGF-I concentration of Ad 2/3 and Ad 1/3 treatment (p<0.05), but did not affect Ad 0/3 treatment (p>0.05). The changes of blood leptin concentrations were similar to those of blood

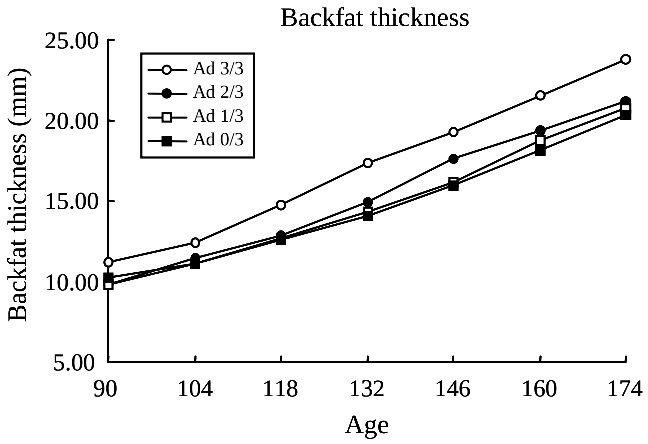

Figure 2. Relationship between backfat thickness and age.

IGF-I concentrations. This finding were agreement with previous demonstrated by Barb et al. (2001) demonstrated that fasting caused a reduction of serum leptin concentration in ovariectomized gilts within 20 h of feed deprivation. In addition, Mao et al. (1999) reported that 50% feed reduction to lactating sows for 7 days resulted in lower serum leptin concentrations.

Carcass characteristics

Pig's ability to consume feed usually exceeds its capacity to deposit protein during the finishing period (Whittemore, 1987). A relatively large portion of the energy and protein ingested during this period might be deposited as carcass fat, and lower the protein and fat ratio of the carcass. Therefore, it is very important that swine producers should feed pigs the diets with adequate nutrient contents according to their physiological requirements.

Table 4 showed the results of carcass quality of pigs reared in different restricted feeding regimens. Barrows assigned to Ad 3/3, Ad 2/3, Ad 1/3 and Ad 0/3 treatment showed carcass body weights of 89.71, 85.70, 86.01, 83.97 kg, respectively. Carcass body weight was slightly reduced according to the degree of restricted feeding. Similar results on carcass characteristics were reported by van de Ligt et al. (2002) who demonstrated animals reached a common slaughter weight earlier due to increased energy available for growth and external fat deposition when a higher energy diet was provided. Feeding regimens of Ad 0/3 treatment was highest carcass grade among treatments, although there were no significant differences (p>0.05). There was a trend that backfat thickness was decreased along with lower feed intake decreased (p>0.05, Table 4 and Figure 2). Han et al. (1998) investigated the effects of phase feeding on carcass characteristics of finishing pigs and demonstrated that the backfat thickness was significantly reduced about 7% in lighter pigs averaging 104 kg of slaughter weight when fed low nutrient density diets. Bikker et al. (1996) also reported that backfat thickness was increased linearly with increased feeding level from 1.7 times maintenance level to *ad libitum*. It was observed that all carcass characteristics except cooking loss measured in this study, all treatments were not significantly different (p>0.05). Cooking losses of Ad 1/3 or Ad 0/3 treatment were higher than those of Ad 3/3 and Ad 2/3 treatment (p<0.05). There was a trend that shear value was increased as feed intake decreased (p>0.05). Meat color was not influenced by treatments (Table 5). According to the present results, it was concluded that the degree of restricted feeding did not affect the pork quality of barrows. Thus, restrict feeding regimen for finishing pigs seemed to be one of the alternative methods in finishing period for improvement of pork quality.

Table 5. Effects of different feeding regimens on carcass meat color of finishing barrows

	Ad 3/3[1]	Ad 2/3	Ad 1/3	Ad 0/3	MSE[2]
Color L	53.43	53.19	53.09	54.09	0.40
a	7.56	7.80	7.49	7.60	0.19
b	5.87	5.73	5.33	5.99	0.18
Hunter L	46.34	46.09	48.98	46.98	0.90
a	6.32	6.59	6.22	6.35	0.17
b	4.53	4.48	4.13	4.65	0.15

[1] Refer to Table 1. [2] Mean standard error.

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