Effects on Growth Performance and Meat Quality Parameters by Restricted Diet during Finishing Days

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ABSTRACT : The objective of the present study was to investigate the effects on growth performance, meat quality parameters and fatty acids of meat by restricted diet amount on finishing Berkshires. A total of 180 pigs (Berkshire, initially 52 kg BW) at 100 days of age were allotted in arrangement in a completely randomized design (10 pigs per pen), blocked arrangement of treatments with 3 replications. The variables were market ages (180, 200 and 220 days) and in which was also included sex (gilts and barrow). All the pigs were restrictively fed so that day could be marked at 103 kg. Pork quality was evaluated from 4 pigs of each treatment. Average daily gain (ADG) and average daily feed intake (ADFI) were decreased ($p<0.05$) with age increase. The ratio of feed to gain was increased ($p<0.05$) at 200 and 220 days compared to that of 180 days. Moisture and crude protein of *longissimus dorsi* muscle (LM) at 180 days were increased ($p<0.05$) compared to 200 and 220 days. Crude fat was increased ($p<0.05$) by age and crude ash was lower ($p<0.05$) at 180 days than at 220 days. Red to green meat color scale (CIE a*) increased ($p<0.05$) at 200 and 220 days more than at 180 days. Regarding fatty acid composition in meat, saturated fatty acids (SFA) was increased more ($p<0.05$) at 220 days than at 180 and 200 days. The results indicate that even with a restricted diet of low nutrient supplement, there was an improvement in Berkshire meat quality parameters. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 9 : 1294-1298)***

Key Words : Berkshire, Growth Performance, Chemical Compositions, Meat Quality, Fatty Acids

INTRODUCTION

Recently, in Japan and Korea, pork consumption interests have been changing from the crossbred pigs (L×W×D) to Berkshire. Berkshire meat is more expensive than the crossbred pigs (Suzuki et al., 2003). Berkshire has a longer life span than the crossbred pig (Kawaida, 1993). Age of growing-finishing pigs at slaughter have an influence on growth performance and chemical composition of meat (Berry et al., 1970; Candek-Potokar et al., 1998). The fact that age increase at slaughter results in an improvement of pork quality has widely been recognized (Berry et al., 1970; Candek-Potokar et al., 1998). Age increase alone slowed down growth during restricted feeding (Candek-Potokar et al., 1998). With regards to muscle characteristics, Monin (1983) and Lebret et al. (1996) reported that age and weight of pig influenced slaughter. However, Candek-Potokar et al. (1998) reported that age increase alone has no effect on moisture when pigs were fed either *ad libitum* or restricted diet 30%. In addition, increasing age and weight of pigs at slaughter resulted in a more intense color of meat (Martin et al., 1980). However, the subjective color score and Hunter L measurement were unaffected by age increase at a given weight (Candek-Potokar et al., 1998). French et al. (2000) reported that fatty acid composition of meat could be improved by the diet. Quality of meat relates to fatty acid composition (Cameron and Enser, 1991).

The objective of the present study was to investigate the effects on growth performance, meat quality parameters and fatty acids of meat by restricted diet amounts during finishing days in Berkshire.

MATERIALS AND METHODS

Animals and diets

One hundred eighty pigs were used to determine the effects of age (180, 200, 220 days) and sex (gilt, barrow) on growth performance, chemical compositions, meat quality parameters and fatty acids of meat. They were allotted at 100 days of age and 52 kg live weight to 6 treatments according to 3 days×2 sexes. The pigs were housed at 10 per pen (3.6 m×8.1 m pens with solid concrete flooring) in an open-fronted building. Separated as gilts and barrows and as three replicates per treatment. Diets used in this experiment were made on the basis of crude protein (CP) and digestible crude protein (DCP) as reported by Kawaida (1993). The diet fed to pigs of 52 kg to 70 kg live weight (Step-I) contained 15.92%, 13.05% and 3.31 Mcal/kg on CP, DCP and digestible energy (DE), respectively. The diet fed

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Table 1. Ingredient composition of experimental diet (%)

Items	FEED I	FEED II
Components of diet		
Maize	47.20	52.70
Soybean meal 44%	19.80	10.80
Wheat bran	12.00	14.50
Rice bran	2.00	2.00
Wheat germ		4.00
Bakery product	8.00	0.40
Palm meal	4.00	8.00
Animal fat	0.70	0.70
Molasses	3.00	3.50
TCP (tri-cal-phos)	1.03	0.27
Limestone	1.00	1.79
Salt	0.30	0.30
Vit-comp 1[a]	0.30	
Vit-comp 2[b]		0.30
Min-comp 1[c]		0.20
Min-comp 2[d]	0.20	
Choline 25%		0.10
Lysine 99%		0.12
Meth 99%		0.01
CTC 100	0.05	
Oraquindox50	0.10	
Bio-micro	0.30	0.30
Yucca	0.02	0.01

[a] Premix contains: Vit. A, 3,200,00IU; Vit. D, 600.000 IU; Vit. E, 8.000IU; Vit. K, 500 mg; Vit. B_1, 500; Vit. B_2, 4.000 mg; Vit. B_6, 800 mg; Vit. B_{12}, 15; Ca-pan, 8,000 mg; Niacin, 15.000 mg; Biotin, 30 mg; Folic acid, 250; Ethoxquiene, 6,000 mg.

[b] Premix contains: Vit. A, 3,000,00IU; Vit. D, 600,000IU; Vit. E, 16,000 IU; Vit. K, 500 mg; Vit. B_1, 500; Vit. B_2, 3,000 mg; Vit. B_6, 600 mg; Vit. B_{12}, 10; Ca-pan, 5,000 mg; Niacin, 10,000 mg; Biotin, 55 mg; Folic acid, 1.000; Ethoxquiene, 6.000 mg.

[c] Premix contains: $FeSO_4$, 67.500 mg; $CoSO_4$, 375 mg; $CuSO_4$, 71.500 mg; $MnSO_4$, 19,370 mg; $ZnSO_4$, 51,000 mg; ICa, 375 mg; SeNa, 140 mg.

[d] Premix contains: $FeSO_4$, 59,400 mg; $CoSO_4$, 250 mg; $CuSO_4$, 54,500 mg; $MnSO_4$, 17,500 mg; $ZnSO_4$, 52,500 mg; ICa, 400 mg; SeNa, 135 mg.

to the pigs at 103 kg live weight (Step-II) was 14.01%, 11.03% and 3.18 Mcal/kg on CP, DCP, and DE, separately. All other nutrient requirements met or exceeded that of NRC recommended for 50 to 110 kg finishing pigs (NRC, 1998). A finishing diet of Feed I was given to pigs of 52 kg to 70 kg live weight (Step-I) in restricted amounts (Kawaida, 1993). During this period, the daily feed allowance was increased from 2.2, 2.0 and 1.8 kg/d at 52 kg pigs until 70 kg pigs on all treatments. Pigs were allowed *ad libitum* access to water from nipple waters.

On the other hand, a finishing diet of Feed II in restricted amounts was given to all pigs until 103 kg live weight (Step-II). The daily feed allowance was increased until 103 kg live weight. Pigs were allowed ad libitum access to water from nipple waters. Pigs were allowed access to diets at 08:00 and 15:00. Pig weights were measured at 15-day intervals and feed disappearance was measured everyday. Pig weights and feed disappearance

Table 2. Chemical composition of experimental diets (as-feed basis)

Items	FEED I	FEED II
Crude protein (%)	15.92	14.01
Ethanol extract (%)	4.11	3.74
Crude fiber (%)	4.68	5.12
Crude ash (%)	5.95	6.07
DCP	13.05	11.03
DE (Mcal/kg)	3.31	3.18
Calcium (%)	0.67	0.80
Phosphorus (%)	0.64	0.54

were measured to determine ADG, ADFI. The ratio of feed to gain was calculated from ADG and ADFI.

Chemical composition and meat quality parameters

The pigs weighing 103 kg were collected for slaughter. four pigs were chosen from each treatment. All the pigs were transported for 1 h and kept in lairage for 2 h separately. The pigs were slaughtered 12 h from the time of food withdrawal. They were stunned electrically (300 V for 3 s) with a pair of stunning tongs, shackled by the right leg and exsanguinated while hanging. Carcasses were then placed in a dehairer at 62°C for 5 min and the hair that remained was removed after exit from the dehairer using a knife and flame. Carcasses were then eviscerated and split before being placed in a chiller set at 5°C for 24 h. For the determination of chemical compositions and meat quality parameters, the LM (6^{th} to 13^{th} rib) was cut off and kept at 4°C, and then transported to the laboratory. Among chemical compositions, the concentrations of moisture, crude protein, crude fat and crude ash in samples of LM were determined according to AOAC (1994) about 48 h after slaughter. For measurement of pH, a 2 g sample of LM was homogenized about 48 h postmortem in 10 volumes of distilled water using a polytron homogenizer (MSE, U.S.E). pH was measured using a Hanna HI 9025 pH meter (Woonsocket, RI) with an Orion 8163 glass electrode (Berverly, MA). Meat color of LM was evaluated on a freshly cut surface (3 cm thick slice) using a Minolta chromameter CR-300 (Minolta, Japan) (D65/10°) after placing for 20 min at room temperature. The average of five replicates were expressed as CIE L*, a* and b*.

Determination of fatty acids

For the determination of fatty acids in LM, extracted fat sample was prepared from LM after meat quality parameters were estimated. Meat fat was extracted from the ground muscle using a modification of the Folch wash method as described by Ways and Hanrahan (1964). Fatty acids were quantified as their fatty acid methyl esters (FAME), and prepared by acid catalyzed methanolysis (Stanton et al., 1997). The FAMEs in the hexane layer were analyzed on an Agilent chromatograph (Agilent-6890+, USA) with a mass spectrometry detector (MSD) and split

Table 3. Effects of growth performance in Berkshire by age and sex

Items	Days			SE	Sex		SE
	180	200	220		Gilt	Barrow	
Live body weight (kg)							
Stat	52.50	51.88	52.50	0.55	52.50	52.09	0.45
Step-I	73.59	72.48	72.96	0.45	72.81	73.21	0.37
Step-II	103.17	103.83	104.16	0.62	103.22	104.22	0.37
ADG (g/d)							
Step-I	514.31[a]	429.10[b]	386.01[c]	14.51	434.40	451.88	12.38
Step-II	739.50[a]	591.63[b]	528.90[c]	15.16	614.21	625.81	12.38
Step-total	625.52[a]	514.39[b]	461.28[c]	10.37	526.43	541.03	8.47
ADFI (kg/d)							
Step-I	2.70[a]	2.48[b]	2.40[b]	0.03	2.55	2.48	0.03
Step-II	3.33[a]	2.99[b]	2.79[c]	0.04	3.08	2.99	0.03
Step-total	5.99[a]	5.47[b]	5.19[c]	0.05	5.63	5.47	0.04
Ratio of feed to gain							
Step-I	5.19[b]	5.83[a]	6.24[a]	0.21	5.95	5.56	0.17
Step-II	4.52[b]	5.06[a]	5.27[a]	0.10	5.06	4.84	0.08
Step-total	4.80[b]	5.35[a]	5.65[a]	0.10	5.41	5.12	0.08

[a, b, c] Means with different superscripts in a row differ significantly ($p<0.05$).

Table 4. Effects of chemical composition in *longissimus dorsi* muscle by age and sex

Items	Days			SE	Sex		SE
	180	200	220		Gilt	Barrow	
Moisture (%)	71.94[a]	69.56[b]	69.12[b]	0.45	69.77	70.64	0.37
Crude protein (%)	21.81[a]	19.85[b]	19.16[b]	0.23	19.97	20.58	0.19
Crude fat (%)	2.28[c]	3.04[b]	3.76[a]	0.18	2.77	3.28	0.15
Crude ash (%)	1.25[b]	1.41[ab]	1.60[a]	0.09	1.45	1.38	0.07

[a, b, c] Means with different superscripts in a row differ significantly ($p<0.05$).

(50:1) injector. The samples were methylated in duplicate and were injected twice onto the GLC column. The separation of the FAME was performed on a HP-5MS capillary GLC column (HP. 30 m×0.32 mm i.d; 0.25 mm film thickness) using He as the carrier gas. MS interface and Injector temperature was fixed at 270°C and 260°C respectively. Oven temperature was instituted to 160°C at 2.5 min, 160 to 260°C at 4°C/min and 260 at 5 min. Data were recorded and analyzed on a ChemStation (G1701CA Version C.00, USA).

Statistical analyses

Statistical analyses were performed by the Statistical Analysis Systems Institute software package (SAS, 1995) and using the general linear model procedure (GLM). The data of growth performance, chemical compositions, meat quality parameters and fatty acids of meat was obtained from pigs was subjected to analysis of least square means by completely randomized design. The results were given as means and standard error (SE). The correlation coefficients were calculated on residual values from an analysis of variance including the effect of age.

RESULTS AND DISCUSSION

The results of growth performance are shown in Table 3. The effects on ADG and ADFI significantly decreased ($p<0.05$) with increasing age in Step-I, Step-II and Step-total but were unaffected between gilts and barrows. Hsia and Lu (2004) reported that daily weight gain increased when protein and energy content of diet increased. In studies by Ekstrom (1991) and Friesen et al. (1994), ADFI was increased in barrows compared to gilts, however contrary results were reported by Kawaida (1993). Our result may be due to the difference of feeding system, diet intake ratio and nutrient levels. The results of feed to gain ratio was significantly increased ($p<0.05$) in 200 and 220 days than 180 days of the phases of Step-I, Step-II and Step-total but were unaffected between gilts and barrows. The age×sex interaction was not significant on growth performance in the Step-I, Step-II and Step-total. Friesen et al. (1994) reported that the ratio of feed to gain was not significantly improved between barrows and gilts. There was no significant improvement of feed to gain ratio between gilts and barrows and the increase of this ratio with result to age may be related to the fact that ADFI increased with increasing age than ADG.

The results of chemical composition are presented in Table 4. The moisture concentration of LM was significantly decreased ($p<0.05$) in 200 and 220 days than 180 days. This result is in agreement with the findings of Elson et al. (1963). However, Kawaida (1993) and Candek-

Table 5. Effects of pH and meat color in *longissimus dorsi* muscle by age and sex

Items	Days			SE	Sex		SE
	180	200	220		Gilt	Barrow	
PH	5.41	5.49	5.56	0.06	5.47	5.50	0.05
Meat color[1]							
CIE L*	46.01	45.63	44.95	0.77	44.87	46.19	0.63
CIE a*	3.58[b]	4.40[a]	4.66[a]	0.26	4.16	4.27	0.21
CIE b*	7.18	6.79	6.77	0.17	6.97	6.87	0.14

[a, b, c] Means with different superscripts in a row differ significantly ($p<0.05$).
[1] CIE L* = Black (0) to white (100) scale, CIE a* = red (−) to green (-) color scale, CIE b* = yellow (−) to blue (-) color scule.

Table 6. Effects of fatty acids in *longissimus dorsi* muscle by age and sex

Items	Days			SE	Sex		SE
	180	200	220		Gilt	Barrow	
Myristic	2.11[a]	1.96[b]	1.72[c]	0.04	1.88	1.98	0.03
Palmitate	23.85[c]	24.80[b]	25.77[a]	0.21	24.98	24.63	0.03
Stearic	11.07[b]	11.31[ab]	11.67[a]	0.17	11.57[a]	11.13[b]	0.14
Palmitoleic	3.01	3.26	3.28	0.08	3.07	3.30	0.07
Oleic	42.30	41.85	41.39	0.21	42.60[a]	41.09[b]	0.17
Linoleic	16.89[a]	15.71[ab]	15.06[b]	0.34	14.91[b]	16.87[a]	0.28
Linolenic	0.41	0.49	0.40	0.04	0.45	0.41	0.04
Arachidonic	0.37[b]	0.63[a]	0.71[a]	0.05	0.54	0.60	0.04
SFA[1]	37.04[b]	38.06[b]	39.16[a]	0.36	38.44	37.73	0.29
USFA[2]	62.96[a]	61.94[a]	60.84[b]	0.36	61.56	62.27	0.29

[a, b, c] Means with different superscripts in a row differ significantly ($p<0.05$).
[1] Saturated fatty acids. [2] Unsaturated fatty acids.

potokar et al. (1998) reported that increasing age alone did not significantly affect moisture concentrations. Differences in moisture concentration of LM were not seen between gilts and barrows (Table 4). However, Friesen et al. (1994) reported that carcass moisture concentration was higher in gilts carcasses than barrows. The difference between our study and previous studies may be due to the differential factor of increasing age, restricting weight and experimental pigs. Crude protein was significantly decreased ($p<0.05$) in 200 days and 220 days than 180 days but crude fat was significantly increased ($p<0.05$) by age. Crude ash was significantly increased ($p<0.05$) in 220 days than 180 days. However, chemical compositions in LM were not affected by sex and age×sex interaction. Elson et al. (1963) reported that moisture concentration was decreased in meat by increasing age, and crude protein and crude ash were less reduced but crude fat concentration was significantly increased. Moreover, Ramsey et al. (1990) and Hodgson et al. (1991) reported that the concentration of crude fat was increased when moisture and crude protein were decreased in meat. Our results of chemical composition in this study also agreed with previous studies.

Table 5 shows the results of pH and meat color. The pH was not significantly affected by age and sex. After 24 h from slaughter, no difference in pH was found in gilts and barrows (Langlois and Minvielle, 1989). The age×sex interaction was not significant in moisture concentration and pH of LM. As for meat color, CIE L* was not significantly affected by age and sex (Table 5). In previous studies also, CIE L* measurement was found to be unaffected by increased age at a given weight (Judge et al., 1959; Simpson et al., 1987; Candek-Potokar et al., 1998). However, Kawaida (1993) reported that CIE L* was significantly lower ($p<0.05$) in gilts than barrows. Our results show that CIE L* was lower in gilts than barrows but was not significantly affected. In our study, CIE a* was significantly increased ($p<0.05$) in 200 and 220 days than 180 days but remained affected between gilts and barrows. This result is in agreement with a study by Fernandez and Tornberg (1991). CIE b* was not significantly affected by age and sex.

Table 6 shows the results of fatty acids in LM. Myristic acid (C14:0) was significantly decreased ($p<0.05$) by increasing age but palmitic acid (C16:0) was significantly increased ($p<0.05$). Whereas between gilts and barrows, myristic acid and palmitic acid were not affected. The level of stearic acid (C18:0) was significantly increased ($p<0.05$) in 220 days than 180 days and was significantly higher ($p<0.05$) in gilts than barrows. Palmitoleic acid (C16:1) was not affected by age and sex. The level of oleic acid (C18:1) was not affected by increasing age but was significantly higher ($p<0.05$) in gilts than barrows. Linoleic acid (C18:2) was significantly increased ($p<0.05$) in 180 days than 220 days and was significantly higher ($p<0.05$) in barrows than gilts. Linolenic acid (C18:3) was not significantly affected by sex and age. The level of arachidonic acid (C20:4) was significantly increased ($p<0.05$) in 200 and 220 days than 180 days but was not different between gilts and barrows. The SFA was significantly increased ($p<0.05$) but the SFA was significantly decreased ($p<0.05$) in 180 and 200 days than 220 days and the SFA were not affected between gilts and barrows. Suzuki et al. (2003) reported that in general, saturated fatty acids of meat are palmitic acid and stearic acid in Berkshire, and unsaturated fatty acids are oleic and linoleic acid. The same results were found in our study. French et al. (2000) and Hsia and Lu (2004) reported that fatty acid composition of meat could be improved by the diet. Consequently, this result may have been due to difference of SFA and USFA by increasing age, which was affected by consumed feed volume and composition of fatty acids in diet by increasing age.

IMPLICATIONS

Growth performance, chemical compositions of LM, meat quality parameters and fatty acids were influenced by restricted diets during finishing days. Even with supplement of low nutrients Berkshire improved over crossed pigs.

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