Effects of the Low-Crude Protein and Lysine (Low CP/lys) Diet and a Yeast Culture Supplemented to the Low CP/lys Diet on Growth and Carcass Characteristics in Growing-finishing Pigs

Seung-Ho Ha^{1*}, Byung-Chul Park^{2*}, Seung Won Son¹, Duck-Min Ha³ and C. Young Lee^{3**}

¹Pusan and Kyungnam Cooperative Swine Farms Feed Mill, ²Sunjin Co., Ltd, 517-3 Doonchon-dong, Kangdong-gu, Seoul 134-060, Korea, ³Regional Animal Industry Center, Gyeongnam National University of Science and Technology, Jinju 660-758, Korea

ABSTRACT

The present study was performed to investigate long-term effects of the low-crude protein and lysine (low CP/lys) diet and a yeast culture supplemented to the low CP/lys diet on growth and carcass characteristics in growing-finishing pigs. Forty-five gilts and 45 barrows weighing approximately 25 kg born to Yorkshire × Landrace dams and Duroc sires were allocated to nine pens, with five gilts and five barrows assigned per pen. Every three pens received CP/lys-rich grower and finisher diets (control), low CP/lys grower and finisher (basal), or the low CP/lys grower and finisher supplemented (2%) with a yeast culture providing 3.2×10^8 *Saccharomyces cerevisiae* cells/kg diet (yeast) for 31 and 79 days, respectively. The ADG was less in the low CP/lys (basal + yeast) group than in the control group ($P < 0.01$) during both grower (0.59 vs. 0.70 kg) and finisher (0.75 vs. 0.89 kg) phases. However, marbling score was greater ($P < 0.05$) in the low CP/lys group vs. control (3.86 vs. 3.12) at slaughter, which resulted in a twice percentage of the 1⁺-quality grade carcasses in the former compared with that for the latter. Supplementation of the yeast culture to the basal diet caused a decrease in ADG during the grower phase ($P < 0.01$), but not during the finisher phase (0.64 vs. 0.53 kg and 0.73 vs. 0.77 kg for the basal vs. yeast group during the grower and finisher phases, respectively), without influencing the marbling score or percentage of the 1⁺-quality grade carcasses. In conclusion, results indicate that long-term provision of the low CP/lys diet has a beneficial effect on marbling and carcass quality grade as well as a negative effect on weight gain and that the yeast culture supplemented to the low CP/lys diet has no beneficial effect on weight gain or carcass quality.

(**Key words** : Pig, Lysine, Yeast culture, Growth, Meat quality)

INTRODUCTION

Marbling is a most important carcass characteristic which is a primary determinant of the carcass quality grades of the pig and beef cattle in Korea (Park et al., 2009; Ha et al., 2010; MFAFF, 2007, 2011). Numerous studies have demonstrated that intramuscular fat (IMF) content (Essen-Gustavsson et al., 1994; Witte et al., 2000; Binder et al., 2004) or marbling score (Moon et al., 2008 RDA, 2010) of the pig carcass could be increased by feeding finishing pigs with a low-lysine and/or low lysine-low protein (low CP/lys) diet for four to seven weeks [see also reviews by Pettigrew and Esnaola (2001) and Apple (2010)]. The ADG and gain:feed is usually unaffected and backfat thickness either unaffected or decreased by the low CP/lys treatment during a relatively

short period of the finisher phase.

Effects of the low CP/lys diet for a prolonged period from the nursery or grower through finisher phase on pig growth and carcass characteristics are less than clear. The ADG and gain:feed of the pigs decreased and IMF increased in response to the long-term low CP/lys treatment in the studies of Castell et al. (1994) and Kerr et al. (1995). However, in D'Souza et al. (2003), ADG and backfat thickness were not affected by a 15% or 30% reduction in dietary protein and lysine concentrations whereas IMF was increased owing to the dietary treatment.

Probiotic yeast cultures provided as feed additives, which contain the *Saccharomyces* or other yeast cells and their metabolites produced during fermentation, are known to promote intestinal immune and digestive function (van Heugten et al.,

* Equally contributed to this work.

** Corresponding author : C. Young Lee, Regional Animal Industry Center, Gyeongnam National University of Science and Technology, Jinju 660-758, Korea. Tel: +82-55-751-3285, Fax: +82-55-753-4422, E-mail: cylee@gntech.ac.kr

2003; Shen et al., 2009; Jung et al., 2010; Price et al., 2010). The in-feed yeast culture, alone or in combination with probiotic bacteria, also suppresses the emission of noxious gases (Hong et al., 2002; Jung et al., 2010), but it has a slightly positive or no effect on growth performance in nursery as well as growing-finishing pigs (Kil et al., 2004; Kim et al., 2007; Jang et al., 2009). Interestingly, the yeast-rich bakery by-product, which is used as a supplementary diet for the 'Kagoshima' Berkshire pigs in Japan, is said to partly contribute to the superior pork quality including marbling of the Kagoshima brand (personal communication with Dr. Y. M. Song, Gyeongnam National University of Science and Technology, Korea). No published

data are available, however, as to the effects of the bakery by-product or yeast culture on marbling and other carcass quality traits. The present study was therefore performed to investigate the long-term effects of the low CP/lys diet as well as a yeast culture supplemented to the low CP/lys diet on growth and carcass characteristics, especially marbling and the quality grade, in growing-finishing pigs.

MATERIALS AND METHODS

1. Animals

Forty-five gilts and 45 barrows weighing approximately 25

Table 1. Composition of the experimental diets (as-fed basis)

Item	Grower			Finisher		
	Control	Low CP/lys		Control	Low CP/lys	
		Basal	Yeast		Basal	Yeast
Ingredient, %						
Corn, ground	54.05	57.28	55.66	54.44	57.20	53.06
Wheat	3.00	3.00	3.00	3.00	3.00	3.00
Wheat bran	1.50	3.50	3.50	1.00	2.00	4.00
Soybean meal (44% CP)	23.38	19.44	19.44	16.36	14.30	14.30
Rapeseed meal	3.50	3.50	3.50	3.00	3.00	3.00
Palm kernel meal	4.00	4.00	4.00	4.00	4.00	4.00
DDGS				6.00	6.00	6.00
Limestone	1.24	1.24	1.24	1.49	1.05	1.10
Dicalcium phosphate	0.77	0.61	0.63	0.68	0.84	0.84
Salt	0.25	0.25	0.25	0.30	0.30	0.30
Vitamin premix ^{1,2)}	0.11	0.11	0.11	0.11	0.11	0.11
Mineral premix ^{3,4)}	0.10	0.10	0.10	0.10	0.10	0.10
Animal fat	5.58	4.82	4.42	5.09	4.10	4.19
Molasses	2.00	2.00	2.00	4.00	4.00	4.00
Glucose	0.15	0.15	0.15			
L-lysine-HCl	0.27			0.33		
DL-methionine	0.10			0.10		
Yeast culture ⁵⁾			2.00			2.00
Total	100.00	100.00	100.00	100.00	100.00	100.00
Chemical composition						
DE, Mcal/kg	3.60	3.45	3.45	3.60	3.45	3.45
Crude protein, %	19.50	16.00	16.00	17.50	14.40	14.40
Lysine, %	1.20	0.80	0.80	1.00	0.60	0.60
Crude fat, %	8.30	7.50	7.50	8.25	7.20	7.20

¹⁾ Provided per kg of grower diet: 10,000 IU vitamin A, 1,500 IU vitamin D₃, 60 IU vitamin E, 3.0 mg vitamin K, 2.0 mg thiamin, 1.0 mg riboflavin, 3.0 mg pyridoxine, 0.04 mg vitamin B₁₂, 20 mg pantothenic acid, 45 mg niacin, 0.12 mg biotin, and 1.0 mg folic acid.

²⁾ Provided per kg of finisher diet: 8,100 IU vitamin A, 1,200 IU vitamin D₃, 45 IU vitamin E, 2.55 mg vitamin K, 1.5 mg thiamin, 0.6 mg riboflavin, 2.55 mg pyridoxine, 0.03 mg vitamin B₁₂, 19.5 mg pantothenic acid, 39 mg niacin, 0.09 mg biotin, and 0.75 mg folic acid.

³⁾ Provided per kg of grower diet: 110.0 mg FeSO₄, 0.500 mg CoSO₄, 70 mg CuSO₄, 60 mg MnSO₄, 80 mg ZnSO₄, 0.60 mg Ca(IO₃)₂ and 0.450 mg Na₂SeO₃.

⁴⁾ Provided per kg of finisher diet: 102.7 mg FeSO₄, 0.442 mg CoSO₄, 67 mg CuSO₄, 54.18 mg MnSO₄, 69 mg ZnSO₄, 0.546 mg Ca(IO₃)₂, and 0.338 mg Na₂SeO₃.

⁵⁾ Contained 1.6×10^{10} *Saccharomyces cerevisiae* cells/kg and their metabolites.

kg, which were progenies of (Landrace × Yorkshire) dams and Duroc sires, were allocated randomly by sex to nine pens, with five gilts and five barrows housed in each pen. Every three pens received crude protein (CP) and lysine-rich control grower and finisher diets, low-CP and lysine (low CP/lys) grower and finisher, or the low CP/lys grower and finisher supplemented (2%) with a yeast culture providing 3.2×10^8 *Saccharomyces cerevisiae* cells/kg diet for 31 and 79 days, respectively (Table 1). The control diets were formulated to meet or exceed the nutrients densities recommended by NRC (1998) and National Swine nutrition Guide (NSNG 2010). Body weight of the individual animal was measured at the beginning and end of each of the grower and finisher phases. As for feed intake, only the total consumption of each diet during each phase was measured.

2. Carcasses

Ten animals out of each dietary group weighing 107 to 129 kg were selected for slaughter and subsequent carcass analysis so that predicted carcass weights of the selected animals would fall within the range eligible for the yield grade A or B (MFAFF, 2007) at the time this study was performed. Selected animals were slaughtered at a local

abattoir following the feeding trial and their carcasses were chilled overnight at 4°C. Backfat thickness, intramuscular fat (marbling) score, and the yield and quality grades of the cold carcass were measured or judged by the carcass grading official (MFAFF, 2007).

3. Statistical analysis

The experimental unit was the individual animal or carcass. All data were analyzed using MIXED procedure of SAS (1996), with the variance associated with the sex partitioned into the random error. Orthogonal contrasts were used to test the significance of the effects of the low CP/lys diet and the yeast culture supplemented to the low CP/lys diet.

RESULTS

1. Growth performance

Final body weight at the end of the 31-day grower phase was less ($P < 0.01$) in pigs fed the low-CP and lysine diet (LOW CP/LYS) than in those fed the CP/lys-rich control diet (CONTROL; Table 2). Moreover, this variable was less

Table 2. Effects of the low-crude protein and lysine (low CP/lys) diet and a yeast culture supplemented to the low CP/lys diet on growth performance of growing-finishing pigs

Item	Control ¹⁾	Low CP/lys		SEM	<i>P</i> -value in Contrast	
		Basal ²⁾	Yeast ³⁾		Low CP/lys ⁴⁾	Yeast ⁵⁾
Grower phase ⁶⁾						
Initial wt, kg	25.7	25.4	25.5	0.5	0.69	0.89
Days on feed	31	31	31	–	–	–
Final wt, kg	47.3	45.4	41.9	1.0	<0.01	0.02
ADG, kg	0.70	0.64	0.53	0.02	<0.01	<0.01
Finisher phase ⁶⁾						
Days on feed	79	79	79	–	–	–
Final wt, kg	117.7	103.0	102.8	1.6	<0.01	0.94
ADG, kg	0.89	0.73	0.77	0.02	<0.01	0.21
Overall						
Days on feed	110	110	110	–	–	–
ADG	0.84	0.71	0.70	0.02	<0.01	0.91

¹⁾ Fed the high CP/lys control grower and finisher (Table 1).

²⁾ Fed the low CP/lys grower and finisher.

³⁾ Fed the low CP/lys grower and finisher supplemented with a yeast culture.

^{4),5)} Compared between 'Control' and 'Low CP/lys' and between 'Basal' and 'Yeast' within Low CP/lys, respectively, by the orthogonal contrast.

⁶⁾ ADFI for 'Control,' 'Basal' and 'Yeast' within Low CP/lys were 1.13, 1.23, and 1.01 kg during the grower phase and 2.52, 2.35, and 2.41 kg during the finisher phase, respectively.

($P < 0.05$) in the group fed the low CP/lys diet supplemented with the yeast culture (YEAST) than in the low CP/lys basal group (BASAL). Similarly, ADG during the grower phase was less ($P < 0.01$) in LOW CP/LYS (BASAL + YEAST) than in CONTROL as well as in YEAST than in BASAL. The reduced final weight and ADG in YEAST vs. BASAL was apparently associated with a reduced ADFI in the former (1.01 vs. 1.23 kg on an average) due to supplementation of the yeast culture.

As in the grower phase, average final weight and ADG of the animals for the 79-day finisher phase were less ($P < 0.01$) in LOW CP/LYS than in CONTROL. However, unlike the result of the grower phase, ADG during the finisher phase was not influenced by supplementation of the yeast culture to the low CP/lys diet, which was apparently related to similar ADFI of these two groups (2.35 and 2.41 kg on an average for BASAL and YEAST, respectively). Overall, ADG was reduced by feeding the low CP/lys diet ($P < 0.01$), but not by supplementing the yeast culture to the low CP/lys diet, during the entire growing-finishing period.

2. Carcass characteristics

Carcass weight was greater in CONTROL than in LOW CP/LYS ($P < 0.05$). Backfat thickness tended to be reduced by feeding the low CP/lys vs. control diet ($P = 0.07$) whereas it was not influenced by supplementation of the yeast culture. Marbling score was increased by feeding the low CP/lys diet ($P < 0.05$). However, supplementation of the yeast culture to the low CP/lys diet exerted no effect on marbling score.

Out of 10 carcasses per group which were graded, both BASAL and YEAST exhibited six quality grade 1⁺ and four grade 1 carcasses whereas CONTROL had three grade 1⁺ and six grade 1. In the yield grade, CONTROL, BASAL, and YEAST had five, ten, and eight A, respectively. The rest of the carcasses, which exceeded the upper limit of carcass weight and/or backfat thickness required for the eligibility for grade A, received B or C.

DISCUSSION

Apart from the experimental design of the present study, ADG of the pigs fed the low-crude protein and lysine (low CP/lys) basal diet during the 31-day grower phase (0.64 kg) was only insignificantly reduced compared with when fed the

control diet (0.70 kg). In contrast, during the 79-day finisher phase, ADG was visibly reduced by feeding the low CP/lys basal (0.73 kg) vs. control diet (0.89 kg). These were similar to published results in which growth performance of growing-finishing pigs was mostly uninfluenced by the low CP/lys diet during a short period (Witte et al., 2000; Binder et al., 2004; Moon et al., 2008) whereas prolonged provision of the low CP/lys diet usually resulted in reduced growth (Castell et al., 1994; Kerr et al., 1995). It thus seems that the negative effect of the low CP/lys diet on pig growth becomes apparent with increasing days on the diet. One might raise a possibility that the difference in growth performance between the control and low CP/lys diet groups could be partly attributable to a 150 kcal DE/kg greater dietary energy density in the former. However, this possibility was not considered in the present study, because growth performance is barely influenced by a change of dietary energy density less than 200 or 300 kcal DE/kg in growing-finishing pigs (Apple et al., 2004; Lee et al., 2007).

It was evident in the present study that consistent with known effects of the low CP/lys diet (Moon et al., 2008; Apple, 2010; RDA, 2010), marbling of the pig carcass was enhanced by the low CP/lys treatment, although a limited number of carcasses were examined due to a limited availability of the carcasses meeting the criteria required for the yield grade A or B at termination of the feeding trial. Moreover, the percentage of the 1⁺ carcass quality grade, which is determined primarily by the marbling score in Korea (Park et al., 2009; Ha et al., 2010), was also increased by feeding the low CP/lys diets. However, whether or not the low CP/lys diet is useful is likely to depend on the market situation. In case the pig carcass is sold by auction in which the price difference per kilogram carcass between 1⁺A and 1A grades or between 1B and 2B due to a difference in marbling (MIFAFF, 2011) is rather small, the beneficial effect of the low CP/lys diet on the quality grade may be far offset by the negative effect of the diet on weight gain. On the other hand, if the extra cost for producing the high-marbled pork is paid back through an incentive program of an integrative pork production and distribution system, it may be worthwhile to use the low CP/lys diet to enhance marbling.

Supplementation of the *Saccharomyces cerevisiae* yeast culture to the low CP/lys diet apparently had no additive effect on marbling or carcass quality grade. Instead, the supplementary yeast culture caused a decrease in ADG

Table 3. Effects of the low-crude protein and lysine (low CP/lys) diet and a yeast culture supplemented to the low CP/lys diet on carcass characteristics and grades

Item	Control ¹⁾	Low CP/lys		<i>P</i> value in Contrast	
		Basal ²⁾	Yeast ³⁾	Low CP/lys ⁴⁾	Yeast ⁵⁾
Carcass wt, kg ⁶⁾	91.0 ± 1.2	86.8 ± 1.2	88.9 ± 1.2	0.04	0.22
Backfat thickness ^{6,7)} , mm	24.9 ± 0.9	22.6 ± 0.8	22.6 ± 0.8	0.07	0.99
Marbling ^{6,8)}	3.12 ± 0.27	4.04 ± 0.28	3.68 ± 0.27	0.03	0.37
Quality grade					
1 ⁺	3	6	6	–	–
1	6	4	4	–	–
2	1	0	0	–	–
Yield grade					
A	5	10	8	–	–
B	4	0	1	–	–
C	1	0	1	–	–

¹⁾ Fed the high CP/lys control grower and finisher (Table 1).

²⁾ Fed the low CP/lys grower and finisher.

³⁾ Fed the low CP/lys grower and finisher supplemented with a yeast culture.

^{1),2),3)} Data were obtained from 10 carcasses.

^{4),5)} Compared between 'Control' and 'Low CP/lys' and between 'Basal' and 'Yeast' within Low CP/lys, respectively, by the orthogonal contrast.

⁶⁾ Data are means ± SEM.

⁷⁾ Live weight was included in the model as a covariate.

⁸⁾ Scored by the carcass grading official according to a 5-point whole number scale.

during the grower phase seemingly by suppressing feed intake. However, the yeast culture did not influence growth performance during the finisher phase, suggesting that the animals adapted to the negative effect of the supplementary ingredient after a prolonged exposure to it. The present result regarding the effect of the supplementary yeast culture on long-term growth was similar to the reported lack of effect of dietary supplementation of *Saccharomyces cerevisiae* cells plus probiotic bacteria on growth rate in growing-finishing pigs (Kil et al., 2004; Kim et al., 2007).

Besides using the low-lysine diet, there are some other strategies which have been attempted to enhance marbling of the pig carcass. Addition of 1 to 3% leucine to the low-lysine or normal diet, which causes an exaggerated amino acid imbalance resulting in a lesser lysine intake (Apple, 2010), has been reported to increase (Hyun et al., 2003; RDA, 2010) or not influence (Cisneros et al., 1996; Park et al., 2006; Hyun et al., 2007) marbling or intramuscular fat content. However, this doesn't appear to be practical at the present because the expected benefit of this is not as great as to meet a high cost of supplementary leucine. Provision of a low-energy diet to finishing pigs for several weeks

before slaughter has been reported to enhance marbling (Park et al., 2009). This approach is thought to be practically feasible especially when the dietary energy cost is high, although its expected effect on enhancing marbling is not as great as that of the low-lysine diet. Above all, genetic selection for marbling, which is known to be inheritable to a medium level (Suzuki et al., 2005; van Wijk et al., 2005), may be the most fundamental and probably most efficient way of improving marbling as long as lean gain is not compromised for this quality trait.

In summary, long-term provision of the low CP/lys diet resulted in a decrease in weight gain as well as an improvement in the marbling score and grade of the carcass. Supplementation of the yeast culture to the low CP/lys diet had no positive effect on either weight gain or carcass quality.

ACKNOWLEDGMENT

We authors owed Dr. Jin Hee Lee for invaluable advice and assistance, without which implementation of this study would have been impossible. We are also grateful to Mr.

Choon Shik Kim for his assistance with the feeding trial.

REFERENCES

- Apple, J. K. 2010. Nutritional effects on pork quality in swine production. In: National Swine Nutrition Guide, pp. 288-299. U.S. Pork Center of Excellence (USPCE), Iowa State University, Ames, IA, USA.
- Apple, J. K., Maxwell, C. V., Brown, D. C., Friesen, K. G., Musser, R. E., Johnson, Z. B. and Armstrong, T. A. 2004. Effects of dietary lysine and energy density on performance and carcass characteristics of finishing pigs fed ractopamine. *J. Anim. Sci.* 82:3277-3287.
- Binder, B. S., Ellis, M., Witte, D. P., Carr, S. N. and McKeith, F. K. 2004. Influence of dietary lysine level, pre-slaughter fasting, and rendement napole genotype on fresh pork quality. *Meat Sci.* 68:53-60.
- Castell, A. G., Cliplef, R. L., Poste-Flynn, L. M. and Butler, G. 1994. Performance, carcass and pork characteristics of castrates and gilts self-fed diets differing in protein content and lysine: energy ratio. *Can. J. Anim. Sci.* 74:519-528.
- Cisneros, F., Ellis, M., Baker, D. H., Easter, R. A. and McKeith, F. K. 1996. The influence of short-term feeding of amino acid-deficient diets and high dietary leucine levels on the intramuscular fat content of pig muscle. *Anim. Sci.* 63:517-522.
- D'Souza, D. N., Pethick, D. W., Dunshea, F. R., Pluske, J. R. and Mullan, B. P. 2003. Nutritional manipulation increases intramuscular fat levels in the *Longissimus* muscle of female finisher pigs. *Aust. J. Agr. Res.* 54:745-749.
- Essen-Gustavsson, B., Karlsson, A., Lundstrom, K. and Enfalt, A.-C. 1994. Intramuscular fat and muscle fibre lipid contents in halothane-gene-free pigs fed high or low protein diets and its relation to meat quality. *Meat Sci.* 38:269-277.
- Ha, D.-M., Kim, G. D., Han, J.-C., Jeong, J. Y., Park, M.-J., Park, B.-C., Joo, S. T. and Lee, C. Y. 2010. Effects of dietary energy level on growth efficiency and carcass quality traits of finishing pigs. *J. Anim. Sci. Technol. (Kor.)* 52:191-198.
- Hong, J. W., Kim, I. H., Kwon, O. S., Kim, J. H., Min, B. J. and Lee, W. B. 2002. Effects of dietary probiotics supplementation on growth performance and fecal gas emission in nursing and finishing pigs. *J. Anim. Sci. Technol. (Kor.)* 44:305-314.
- Hyun, Y., Ellis, M., McKeith, F. K. and Baker, D. H. 2003. Effect of dietary leucine level on growth performance, and carcass and meat quality in finishing pigs. *Can. J. Anim. Sci.* 83:315-318.
- Hyun, Y., Kim, J. D., Ellis, M., Peterson, B. A., Baker, D. H. and McKeith, F. K. 2007. Effect of dietary leucine and lysine levels on intramuscular fat content in finishing pigs. *Can. J. Anim. Sci.* 87:303-306.
- Jang, Y. D., Oh, H. K., Piao, L. G., Choi, H. B., Yun, J. H. and Kim, Y. Y. 2009. Evaluation of probiotics as an alternative to antibiotic on growth performance, nutrient digestibility, occurrence of diarrhea and immune response in weaning pigs. *J. Anim. Sci. Technol. (Kor.)* 51:25-32.
- Jung, J. H., Hong, S. M., Kim, H. J., Meng, Q. W. and Kim, I. H. 2010. Effect of probiotics in diet on growth performance, nutrient digestibility, fecal microbial count, noxious gases emission from the feces, and blood profile in early-finishing pigs. *J. Anim. Sci. Technol. (Kor.)* 52:23-28.
- Kerr, B. J., McKeith, F. K. and Easter, R. A. 1995. Effect on performance and carcass characteristics of nursery to finisher pigs fed reduced crude protein, amino acid-supplemented diets. *J. Anim. Sci.* 73:433-440.
- Kil, D. Y., Lim, J. S., Tian, J. Z., Kim, B. G., Kim, K. S. and Kim, Y. Y. 2004. Effect of continuous feeding of probiotics on growth performance, nutrient digestibility, blood urea nitrogen and immune responses in pigs. *J. Anim. Sci. Technol. (Kor.)* 46:39-48.
- Kim, H. -Y., Kim, Y. -J. and Park, G.-B. 2007. The effect of feeding probiotics, illite, active carbon and hardwood vinegar on the performance and fatty acid composition of finished pigs. *Kor. J. Food Sci. Anim. Resour.* 27:60-66.
- Lee, C. Y., Kim, M. H., Ha, D. M., Park, J. W., Oh, G. Y., Lee, J. R., Ha, Y. J. and Park, B. C. 2007. Effects of the energy level of the finisher diet on growth efficiency and carcass traits of 'high'-market weight pigs. *J. Anim. Sci. Technol. (Kor.)* 49:471-480.
- MIFAFF. 2007. "Grading Standards for Livestock Products" (published in Korean; translated into English). Notification No. 2007-40 of the Ministry of Food, Agriculture, Forestry and Fisheries, Republic of Korea.
- MIFAFF. 2011. "Grading Standards for Livestock Products" (published in Korean). Notification No. 2011-46 of the Ministry of Agriculture, Forestry and Fisheries, Republic of Korea.
- Moon, H. K., Lee, S. D., Jung, H. J., Kim, Y. H., Park, J. C., Ji, S. Y., Kwon, O. S. and Kim, I. C. 2008. Effects of dietary lysine and leucine levels on growth performance and meat quality parameters in finishing pigs. *J. Anim. Sci. Technol. (Kor.)* 50:687-694.

- NRC. 1998. Nutrient Requirements of Swine. 10th ed. National Academy Press, Washington, D.C.
- NSNG. 2010. National Swine Nutrition Guide. U.S. Pork Center of Excellence (USPCE), Iowa State University, Ames, IA, U.S.A.
- Park, J. C., Kim, Y. H., Jung, H. J., Lee, S. D., Cho, K. H., Kim, I. C., Lee, S. J. and Moon, H. K. 2006. Effects of dietary L-leucine levels in low-lysine diets on growth performance and meat quality parameters in finishing Duroc pigs. J. Anim. Sci. Technol. (Kor.) 48:813-818.
- Park, M. J., Jeong, J. Y., Ha, D. M., Han, J. C., Sim, T. G., Park, B. C., Park, G. B., Joo, S. T. and Lee, C. Y. 2009. Effects of dietary energy level and slaughter weight on growth performance and grades and quality traits of the carcass in finishing pigs. J. Anim. Sci. Technol. (Kor.) 51:143-154.
- Pettigrew, J. E. and Esnaola, M. A. 2001. Swine nutrition and pork quality: a review. J. Anim. Sci. 79 (Suppl.):E316-E342.
- Price, K. L., Totty, H. R., Lee, H. B., Utt, M. D., Fitzner, G. E., Yoon, I., Ponder, M. A. and Escobar, J. 2010. Use of *Saccharomyces cerevisiae* fermentation product on growth performance and microbiota of weaned pigs during *Salmonella* infection. J. Anim. Sci. 88:3896-3908.
- RDA. 2010. Pork Quality and Sanitation Guide. Rural Development Administration, Republic of Korea.
- SAS. 1996. SAS User's Guide: Statistics. SAS Inst., Inc., Cary, NC, USA.
- Shen, Y. B., Piao, X. S., Kim, S. W., Wang, L., Liu, P., Yoon, I. and Zhen, Y. G. 2009. Effects of yeast culture supplementation on growth performance, intestinal health, and immune response of nursery pigs. J. Anim. Sci. 87:2614-2624.
- Suzuki, K., Irie, M., Kadowaki, H., Shibata, T., Kumagai, M. and Nishida, A. 2005. Genetic parameter estimates of meat quality traits in Duroc pigs selected for average daily gain, longissimus muscle area, backfat thickness, and intramuscular fat content. J. Anim. Sci. 83:2058-2065.
- van Heugten, E., Funderburke, D. W. and Dorton, K. L. 2003. Growth performance, nutrient digestibility, and fecal microflora in weanling pigs fed live yeast. J. Anim. Sci. 81:1004-1012.
- van Wijk, H. J., Arts, D. J. G., Matthews, J. O., Webster, M., Ducro, B. J. and Knol, E. F. 2005. Genetic parameters for carcass composition and pork quality estimated in a commercial production chain. J. Anim. Sci. 83:324-333.
- Witte, D. P., Ellis, M., McKeith, F. K. and Wilson, E. R. 2000. Effect of dietary lysine level and environmental temperature during the finishing phase on the intramuscular fat content of pork. J. Anim. Sci. 78:1272-1276.

(Received Nov. 6, 2012; Revised Dec. 13, 2012; Accepted Dec. 15, 2012)