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for the Degree of Doctor of Philosophy

Effects of Dietary Energy and Amino Acid Levels on Growth Performance, Physiological Responses and Reproductive Performance in Swine

사료내 에너지와 아미노산 수준이 돼지의 성장성적,
생리학적 반응 및 번식성적에 미치는 영향

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By

Chung, Woo Lim

School of Agricultural Biotechnology
Graduate School, Seoul National University

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지도교수 김 유 용

이 논문을 농학박사 학위논문으로 제출함
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Overall Summary

Effects of Dietary Energy and Amino Acid Levels on Growth Performance, Physiological Responses and Reproductive Performance in Swine

The objectives of this research described were 1) to evaluate the effect of dietary energy and amino acid levels on growth performance, blood profiles, meat quality and economic analysis in grower - finisher pigs, 2) to determine the effect of dietary amino acid levels on body changes, reproductive performance, blood profiles and milk composition in gestating to lactating sows, and 3) to investigate the effect of dietary valine:lysine ratios on body changes, reproductive performance, blood profiles and milk composition in lactating sows.

Experiment I. Effect of Dietary Energy and Amino Acid Levels on Growth Performance, Blood Profiles, Meat Quality and Economic Analysis in Grower - finisher Pigs

This experiment was conducted to evaluate the effect of dietary energy and amino acid levels on growth performance, blood profiles, meat quality and economic analysis in grower - finisher pigs. A total of 180 cross-bred pigs ([Yorkshire × Landrace] × Duroc) with an initial mean body weight of 29.5 ± 4.04 kg were allotted to one of six treatments based on 2 × 3 factorial arrangement with 3 replicates. The first factor is two levels of metabolizable energy (ME) and the second factor is three different levels of amino acid (AA), and treatments were 1) LL: 3,200 kcal of ME/kg, NRC (1998) AA requirement; 2) LM: 3,200 kcal of ME/kg, NRC (median value between 1998 and 2012) AA requirement; 3) LH: 3,200 kcal of ME/kg, NRC (2012) AA requirement; 4) HL: 3,300 kcal of ME/kg, NRC

(1998) AA requirement; 5) HM: 3,300 kcal of ME/kg, NRC (median value between 1998 and 2012) AA requirement; or 6) HH: 3,300 kcal of ME/kg, NRC (2012) AA requirement. Experiment diets were provided *ad libitum* during the entire experimental period. Higher body weight was observed when pigs were fed high dietary energy treatment ($P<0.01$) during the whole experimental period. The average daily gain tended to be higher as dietary energy and AA level increased during 0 to 3 weeks ($P=0.08$ and $P=0.07$, respectively). During 0 to 3 weeks, dietary energy and amino acid levels improved gain to feed ratio ($P<0.01$ and $P=0.02$, respectively) which is higher than that of low energy treatment. The BUN, albumin, globulin, total protein, IgG and IgA concentration in blood had no difference among dietary treatments. However, creatinine concentration in low energy treatment tended to be higher in 10 week ($P=0.06$). Moisture content in carcass was increased as dietary energy level higher ($P<0.01$). Moreover, water holding capacity (WHC) of physiochemical property was also increased in proportion to dietary energy level increased ($P=0.04$) There was no difference on meat color after slaughter by dietary energy and amino acid levels. However, the feed cost per kg of weight gain was higher as dietary amino acid level increased ($P=0.03$). Consequently, this research recommended the energy requirement for grower - finisher pigs should be 3,300 kcal of ME/kg with AA requirement of NRC (1998).

Key words: Energy, Amino acid, Growth performance, Blood profiles, Meat quality, Economic analysis, Grower - finisher pig.

Experiment II. Effect of Dietary Amino Acid Levels on Body Changes, Reproductive Performance, Blood Profiles and Milk Composition in Gestating to Lactating Sows

This study was conducted to investigate the effect of dietary amino acid levels on body changes, reproductive performance, blood profiles and milk

composition in gestating to lactating sows. A total of 60 (1 to 3 mixed-parity; 1.7) sows (F1, Yorkshire × Landrace; Darby, Korea) with an initial mean body weight of 194.4 ± 2.84 kg were allotted to one of four treatments by a completely randomized design (CRD) with 15 replicates. Each experimental diet contained different amino acid (AA) levels, and treatments were 1) AA110: 110% of the NRC (2012) AA requirement; 2) AA100: 100% of the NRC (2012) AA requirement; 3) AA90: 90% of the NRC (2012) AA requirement; or 4) AA80: 80% of the NRC (2012) AA requirement. The experimental diet was provided to each treatment from 35 to 110 days of gestation and fed at 2.0, 2.2 and 2.4 kg/d to gestating sows of first, second and third parities, respectively. Lactating sows were fed the same diet regardless of treatments during lactation period. There were no significant differences in the change of body weight and backfat thickness among treatments during gestation to lactation. In addition, the different dietary amino acid levels did not influence on reproductive performance in lactation. However, there was a quadratic effects on litter weight at 21 day of lactation (quadratic, P=0.03), and on litter weight gain (quadratic, P=0.02) in AA90 treatment. Also, the piglet weight at 21 day of lactation (quadratic, P=0.03) and the piglet weight gain (quadratic, P=0.02) during lactation were higher in AA90 treatment than other treatments. Analysis based on quadratic response in growth performance of piglets, 93.7% of NRC (2012) AA requirement showed the highest litter size. There was no significant differences in IgG, BUN and creatinine concentrations of blood profiles in sows and their progeny. However, lysine (linear, P=0.08), methionine (linear, P=0.05) and threonine (linear, P=0.02) concentrations in blood AA at 110 day of gestation tended to be higher as the dietary amino acid level increased. Dietary amino acid level was not affected on milk composition during lactation. Consequently, this research demonstrated that the level of amino acid in diet should be 93.7% AA requirement of NRC (2012) both in gestating and lactating sows.

Key words: Amino acid, Body changes, Reproductive performance, Blood profiles, Milk composition, Gestating to lactating sow.

Experiment III. Effect of Dietary Valine:Lysine Ratios on Body Changes, Reproductive Performance, Blood Profiles and Milk Composition in Lactating Sows

This study was conducted to evaluate the effect of dietary valine:lysine ratios on body changes, reproductive performance, blood profiles and milk composition in lactating sows. A total of 40 (2 to 4 mixed-parity; 3.0) sows (F1, Yorkshire × Landrace; Darby, Korea) with an initial mean body weight of 236.0 ± 3.06 kg were allotted to one of four treatments in a completely randomized design (CRD) with 10 replicates. Each experimental diet contained different total valine (Val) : lysine (Lys) ratios, and treatments were 1) V100: Val(0.90%) : Lys(0.90%) ratio; 2) V110: Val (0.99%) : Lys (0.90%) ratio; 3) V120: Val (1.08%) : Lys (0.90%) ratio; or 4) V130: Val (1.17%) : Lys (0.90%) ratio. The dietary Val:Lys ratios had no significant differences in body weight, backfat thickness or their changes during lactation period. The number of total born, stillbirth, mummy and born alive of reproductive performance were not affected by the dietary Val:Lys ratios in lactation. However, the number of weaning pigs tended to be higher as the dietary Val:Lys ratios increased (linear, P=0.07). Average daily feed intake of lactating sows was not affected by dietary Val:Lys ratios. The IgG, BUN, creatinine, blood AA concentrations and milk composition in lactating sows and their progeny, were not affected by the dietary Val:Lys ratios. Consequently, these results demonstrated that the optimum valine to lysine ratio should be valine (1.17%) : lysine (0.90%) for higher reproductive performance of lactating sows.

Key words: Valine:lysine ratio, Body changes, Reproductive performance, Blood profiles, Milk composition, Lactating sow.

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List of Abbreviation

AA	:	Amino acid
ADG	:	Average daily gain
ADFI	:	Average daily feed intake
ATP	:	Adenosine triphosphate
BCAA	:	Branched chain amino acid
BF	:	Back-fat
BUN	:	Blood urea nitrogen
BW	:	Body weight
CP	:	Crude protein
FTA	:	Free Trade Agreement
GF	:	Gain to feed
KLSS	:	Korea Livestock Specification Standard
IgA	:	Immunoglobulin A
IgG	:	Immunoglobulin G
LH	:	Luteal hormone
LM	:	Longissimus muscle
MAFRA	:	Ministry of Agriculture, Food and Rural Affairs
ME	:	Metabolizable energy
NO	:	Nitric oxide
NRC	:	National Research Council
PD	:	Protein deposition
SAS	:	Statistical Analysis System
SBM	:	Soybean meal
SID	:	Standardized ileal digestibility
WEI	:	Weaning to estrus interval
WHC	:	Water holding capacity

Chapter I. General Introduction

In the agricultural industry in Korea, livestock industry accounts for more than 50%, and swine industry takes position for 30% (MAFRA, 2017). Especially, the pork consumption exceeded the rice consumption, for the first time in 2016, swine industry became the prominent business among agricultural industry. More specifically, the consumption of pork per capita in Korea increased from 20.9 kg in 2013 to 24.1 kg in 2016 (MAFRA, 2017). However, Korea's pork self-sufficiency rate has been falling from 84% in 2013 to 73.7% in 2016 due to increased import of pork since Free Trade Agreement (FTA) declared with E.U, U.S.A and several other countries. In order to preserve domestic swine industry, it is necessary to enhance competitiveness by improvement of productivity as well as reduction of cost of production. There are several ways to increase productivity of domestic swine industry, nutritional management is regarded one of the most important factor for improvement animal growth as well as retrenchment of feed cost in swine production. The nutrient requirement is revised frequently, because genetic potential of pig is being improved as times goes by. Among dietary nutrients, the energy and protein (amino acid) levels of the feed should be balanced and formulated precisely due to the fact that approximately 50% of feed cost is determined by these two nutrients. Moreover, excessive amino acids in diet did not show positive response on animal growth, but it causes an environmental problems (Jeong et al., 2010).

Voluntary feed intake of growing pigs are affected by the dietary energy and protein contents. Therefore, it seems logical that the amino acid levels in diet should be related to its energy concentration (Chiba et al., 1991). NRC (2012) suggested that higher energy intake in sows had positive effect on fetus growth, development and corresponding tissues (placenta, uterus and mammary tissue) as well as deposition of maternal lipid and protein in sows. The dietary energy of the gestating sows should be required between 6,678 and 8,182 kcal of ME/d, which is 1,650 kcal higher than its previous edition (NRC, 1998). Thus, dietary adequate

energy supply could be one of the effective methods for improving swine productivity.

The importance of amino acids to swine has been well known. In the past decades, effects of dietary protein have been widely studied. However, recent researches have demonstrated that adjusting amino acid balance even for low protein feeds is more important (Liao et al., 2015; Boessen et al., 2018). Some amino acids that are not synthesized in the body or deficient, those problem can be resolved by adding synthetic amino acids in the feed. Especially in swine nutrition, lysine is one of the most important amino acid as the first limiting amino acid, because lysine is a main component of muscle protein. Consequently, livestock prefer to use amino acids for body protein synthesis, and amino acids should be supplied more than the required amount of livestock to synthesize body proteins or other nitrogen compounds are digested and used as energy sources in critical situation. The residual protein or amino acid in the body that is used and left is discharged into the urine and feces, which led to serious environmental pollution. Subsequently, appropriate level of dietary amino acids should be established (Wu and Meininger, 2002).

In case of valine, it is well known as the fourth or fifth essential amino acid in swine body. However, it is classified as a second limiting amino acid especially in lactation period (Richert et al., 1997b). Moreover, valine is an indispensable branched chain amino acid (BCAA) which cannot be synthesized by the animal, therefore it must be supplied through the feed (Soumeh et al., 2015). Also, the valine has a positive effect on the litter size, milk composition and body protein synthesis in pig (Richert et al., 1997a). Thus, the importance of dietary valine has been re-evaluated, especially for hyper-prolific sows.

Swine industry in the world is being rapidly changed, and the dietary energy and amino acid requirements are getting more important. Consequently, higher swine productivity and longevity of sows are great concerns in domestic swine producers. Improved productivity is essential for them to be a sustainable

swine business under FTA. Therefore, this dissertation prepared the three different experiments;

1) to evaluate the effect of dietary energy and amino acid levels on growth performance, blood profiles, meat quality and economic analysis in grower - finisher pigs, 2) to determine the effect of dietary amino acid levels on body changes, reproductive performance, blood profiles and milk composition in gestating to lactating sows, and 3) to investigate the effect of dietary valine:lysine ratios on body changes, reproductive performance, blood profiles and milk composition in lactating sows.

Chapter II. Review of Literature

1. Importance of Nutritional Factors in Swine

1.1. Energy

Energy is expected to become an increasingly expensive nutrient as competition with bio-fuel industries grows for ingredients rich in starch or fat. Understanding how energy is utilized by the pig, and how the pig responds to changes in dietary energy concentration, is essential information in determining the optimal concentration of dietary energy under farm conditions.

It has generally been assumed that over a wide range of dietary energy concentrations, growing pigs will adjust feed intake to maintain a constant or nearly constant daily energy intake (Ellis and Augspurger, 2001). King (1999) suggested that performance in growing pigs showed negative effect at dietary concentrations above 3,325 kcal of ME/kg, whereas the NRC (1998) concluded that daily energy intake would be constant, provided pigs had access to feed *ad libitum*. Campbell and Dunkin (1983) reported that the capacity of the pigs for growth exceeded its ability to consume sufficient energy between 20 and 50 kg, but this limitation in energy intake was removed in heavier animals. Black (1995) suggested that the

critical lower limits would be 3,608, 3,157 and 2,255 kcal of ME/kg for pigs weighing less than 20 kg, between 20 to 50 kg, and greater than 50 kg, respectively. Clearly, there is little agreement in the literature on the capacity of the pig to optimized or maximize daily energy intake when offered feed *ad libitum*. Also, intake of energy is the most important factor in determining growth rate, and many concepts that control feed intake have been studied extensively in previous studies (Ellis and Augspurger, 2001; Torrallardona and Roura, 2009).

Changes in energy concentration certainly lead to changes in ingredients. Previous studies investigating that the dietary energy was also influenced feed intake, which is affected by genotype, health status, the physical environment, diet palatability and prior nutritional history (Nyachoti et al., 2004).

1.2. Protein and Amino Acids

Protein (Greek: proteios, primary) is an essential nutrient that has an important role in biological processes. Proteins are the structural components of amino acid mediate almost all molecular transformations and biochemical re-actions.

Amino acids are precursors for syntheses of proteins as well as peptides, hormones, neurotransmitters, purine and pyrimidine nucleotides, creatine, camitine, porphyrines, polyamines, and nitric oxide in animal body (Wu and Morris, 1998). All natural proteins are composed of 20 α-amino acids, which have a primary amino group and a carboxylic acid group in a carbon. Amino acids differ in the structures of their side chains. Animal cells cannot use inorganic N such as urea or ammonia to synthesize amino acids when carbon skeletons are not available; therefore, essential amino acids must be provided from the animal diets. It has been previously observed that when fed a diet containing crystalline amino acids as the sole source of nitrogen, young pigs gained weight (Chung and Baker, 1991) and sows were able to maintain a normal pregnancy during the last 84 d of gestation (Easter and Baker, 1976). Amino acids are not only the building blocks of proteins in cells, but are also precursors for syntheses of nitrogenous substances [e.g., nitric oxide (NO), polyamines, creatine, dopamine, and catecholamines] essential for whole-body

homeostasis (Wu and Meininger, 2002; Odenlund et al., 2009; Suryawan et al., 2009).

2. Amino Acids Metabolism in Swine

2.1. Lysine Metabolism

2.1.1. Catabolism and Energy Source

It has been known for decades that the growth and development of muscle of pigs essentially required dietary supply of protein, or its components, amino acids (AAs). There are about 20 AAs in nature (referred to as standard proteinogenic AAs) that serve as building blocks for protein bio-synthesis, but not all AAs are indispensable dietary components because swine can de novo synthesize about 10 of them. Consequently, the essential dietary AAs are defined as those that need to be supplied exogenously because pigs cannot de novo synthesize them or cannot synthesize enough for their metabolic needs (Fuller et al., 1987). Among these essential AAs, lysine is the first limiting one in swine nutrition because it is the most deficient AA in nearly all typical swine diets based on cereal grains (Lewis, 2001; NRC, 2012). For this reason, lysine holds a very special, if not the paramount, significance in swine nutritional management practices (Fig. 1).

The primary pathway of lysine catabolism is thought to be the saccharopine pathway in liver (Papes et al., 1999; Gatrell et al., 2013). In this pathway lysine first combines with α-ketoglutarate (α-KG) to form an adduct, saccharopine, by the catalysis of lysine-ketoglutarate reductase (LKR). Then saccharopine is converted to α-aminoadipic-6-semialdehyde and glutamate by saccharopine dehydrogenase (SDH), which is a part of a single polypeptide, bifunctional aminoadipate δ-semialdehyde synthase (AASS) as LKR is (Gatrell et al., 2013). The α-aminoadipate-6-semialdehyde is subsequently converted into Acetyl-CoA via a few more steps (Wu, 2013). This pathway is unusual in the way that the ε-amino group is transferred to α-KG and then into the general nitrogen pool. The further oxidation of Acetyl-CoA produces CO_2 and energy via TCA cycle.

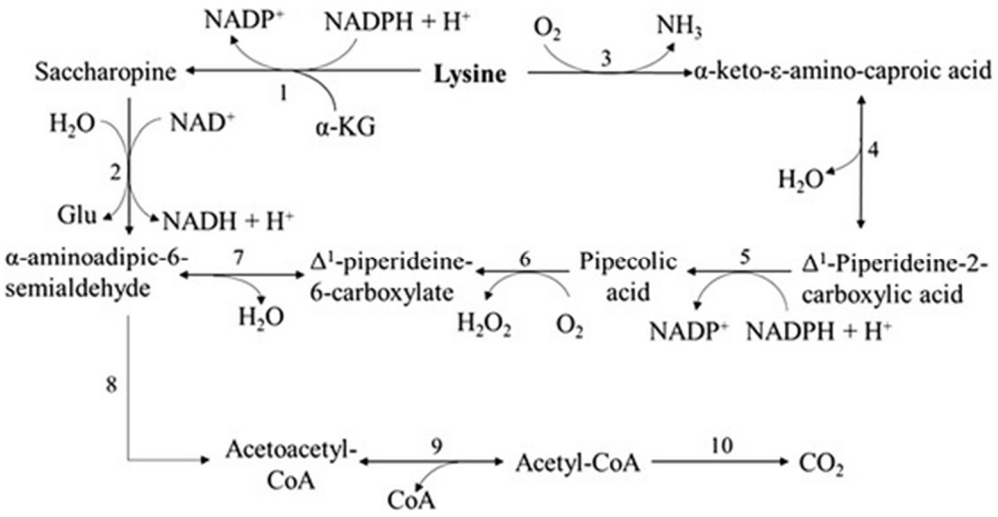

Figure 1. Lysine catabolism in monogastric animals

2.1.2. Physiological Functions of Lysine

Beyond the metabolic functions described above, lysine also exerts many physiological functions for monogastric animals. Lysine can affect animal metabolism of other nutrients, hormone production, and immunity (Wu, 2010a; Wu, 2013). More remarkably, peptide bound lysine is a potential active site of post-translational modification (PTM) and epigenetic regulation of gene expression. Understanding these physiological functions of lysine within the animal body is requisite for animal scientists and producers to better use lysine for promoting animal health and production (Wu, 2010a).

2.1.3. Lysine Mechanism and Perspectives

Commercial feed-grade crystalline lysine was introduced to animal feed industry in the late 1980s (Wittmann and Becker, 2007). Because lysine deficiency has negative impact on animal health and growth performance, and lysine appears to be non-toxic even at a high rate of dietary supplementation, animal nutritionists

should put more emphasis on dietary lysine supplementation to avoid lysine deficiency rather than lysine toxicity.

Previous investigations have shown that dietary supplementation of crystalline lysine can improve muscle protein accretion and whole-body growth of pigs. In experiments with growing and finishing pigs, lysine supplementation increased the nitrogen retention and protein accretion, and improved the growth performance of the animals (Sharda et al., 1976; Fuller et al., 1987; Salter et al., 1990; Shelton et al., 2011). Furthermore, it has been suggested that the increase in muscle protein accretion was due to a greater increase in the rate of protein synthesis, rather than a greater decrease in the rate of protein degradation (Salter et al., 1990). Nevertheless, the underlying metabolic and molecular mechanisms by which dietary lysine regulates muscle mass accumulation of pigs is not clear (Wu, 2010b; Rezaei et al., 2013). Thus, the up-to-date knowledge of lysine metabolic and physiological functions related to muscle growth and development of pigs is summarized (Liao et al., 2015). It needs to be pointed out that a large portion of the knowledge was appropriated from the research on other monogastric animals including humans because the swine-related research in this regard is very limited in the literature.

2.2. Methionine Metabolism

2.2.1. Methionine and Cysteine

The metabolic relationships between methionine and cysteine are well established (Fig. 2). Methionine can be activated by adenosine triphosphate (ATP) to S-adenosylmethionine. This compound readily donates its methyl group to a wide variety of acceptors (Finkelstein, 1990). The resulting compound, S-adenosyl-homo-cysteine, is then hydrolyzed to homo-cysteine and adenosine. Homocysteine is a key intermediate because it can be re-methylated to methionine or can condense with serine to form cystathionine and then cysteine. An important feature of these conversions is that the conversion of homocysteine into cysteine is not reversible

(Bauchart-Thevret et al., 2009). The net effect of these metabolic pathways is that methionine can be converted into cysteine, but cysteine cannot be converted into methionine. Several of the steps in the activated methyl cycle (in which methionine is de-methylated to homocysteine and homocysteine is then re-methylated to methionine) require B-vitamin coenzymes (Finkelstein, 1998).

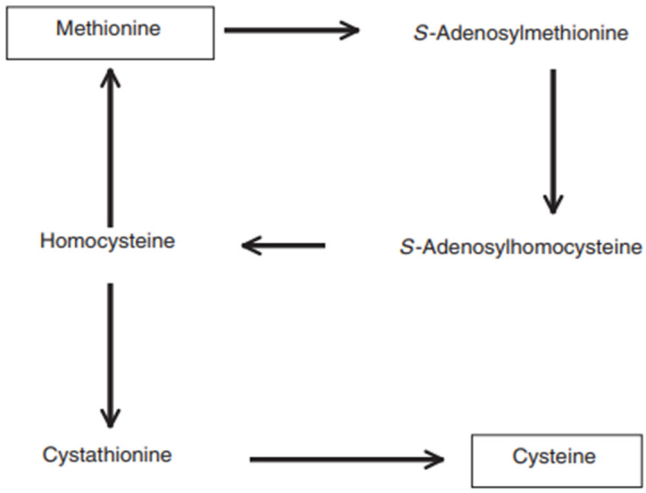

Figure 2. Metabolic pathways of sulfur amino acids

2.3. Tryptophan Metabolism

Tryptophan is an essential amino acid. Apart from its incorporation into body proteins, tryptophan is known to play important biological roles, most of them being associated to metabolic pathways involved in tryptophan catabolism. Tryptophan is the precursor for the synthesis of serotonin, an important neuromediator associated to mood, stress response, sleep and appetite regulation. From a quantitative point of view, the proportion of tryptophan used for the production of serotonin is very low that is degraded would be into serotonin. Tryptophan transport and availability in the brain seems to be one of the limiting steps for the synthesis of brain serotonin. Low tryptophan diets are known to depress feed intake. The relationship between tryptophan and serotonin is usually

considered as the mechanism involved in the depressive effect of low tryptophan diet on appetite. Furthermore, tryptophan is an essential amino acid that has to be supplied through the feed, since its synthesis cannot be achieved by the animal. This means that when tryptophan supply is low compared to the other essential amino acids, this will limit protein synthesis and accretion and, finally, growth rate.

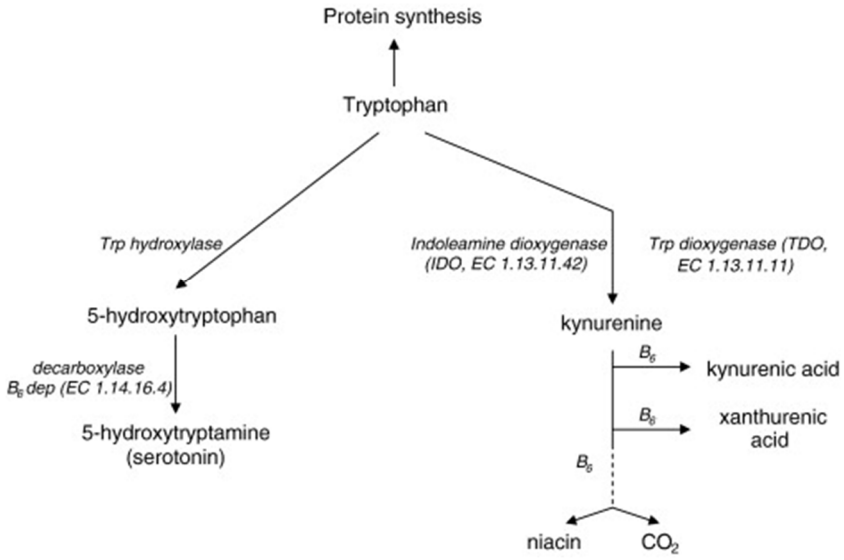

Figure 3. Metabolic pathways of tryptophan

2.4. Threonine Metabolism

Although some essential amino acids are known to be oxidized by the portal-drained viscera (PDV) (van Goudoever et al., 2000; Riedijk et al., 2007), catabolism of essential amino acids does not seem to be their major fate within the intestinal tissues. Threonine catabolism through L-threonine 3-dehydrogenase pathway is a minor component within the splanchnic tissues with no contribution from the intestine (Le Floc'h and Sève, 2005, Schaart et al., 2005). However, intestinal oxidation measured by $^{13}CO_2$ production from 13C-labeled threonine accounts for 2% of intestinal threonine utilization and 13% of whole-body threonine oxidation (Schaart et al., 2005).

These findings suggest that dietary threonine utilization by the intestinal mucosa of pigs is dominated by protein synthesis (Le Floc'h and Sève, 2005, Schaart et al., 2005), most likely through incorporation into mucins. Mucins (Montagne et al., 2004) are polymeric glycoproteins representing an important component of the mucus layer that covers the epithelium of the gastrointestinal tract, as well as all epithelia of mammals. Mucins can be membrane bound or secreted. The secretory mucins play a key role in the innate immune defense of the mucosa, and the core protein of the major intestinal mucins contains a large amount of threonine. In rats, the fractional synthesis rate of mucin glycoproteins was demonstrated to be relatively constant along the length of the intestine (range 112 - 138 %/d), but substantially higher than the total mucosal protein synthesis rate, especially in the ileum (77 %/d) and colon (44 %/d) (Faure et al., 2002).

Mucins account for approximately 11% of endogenous protein in ileal digesta of pigs with threonine contributing 30% to mucin protein (Lien et al., 1997). Amino acids from endogenously secreted proteins, reaching the large intestine, are lost by the animal. Likewise, secretion of mucins, erosion of the mucus, and subsequent recovery of mucins in endogenous ileal losses is dependent on many dietary factors including fiber, protein, and anti-nutritional factors (Montagne et al., 2004). Thus, the secretion, recycling, and loss of intestinal mucins most likely have a substantial impact on the requirement for threonine, and this perhaps contributes to the energy needs of the organism. Van der Schoor et al (2002) reported that involving a 12-h-feeding and a 12-h-fasting period, intestinal recycling of amino acids from secretory proteins was proposed to be an important regulatory mechanism for the systemic availability of dietary amino acids. However, no significant threonine recycling from mucosal protein in the portal circulation could be detected, suggesting that these proteins could be very resistant to digestion, or that recycled threonine might be immediately reincorporated into mucosal protein.

2.5. Valine Metabolism

The valine has the highest oxidation rate of any AA in the mammary gland (Kim et al., 2001). Its role in milk synthesis is not well understood, but studies by Richert et al (1997a) and Moser et al (2000) have found significant litter gains (2 to 3 kg heavier litter weight at weaning) when Val:Lys ratios were increased. Val:Lys ratios in the lactation diets did not improve performance at a litter level in this previous studies. However, the intake of valine ranged from 47.6 to 92 g/d in the current study and was much higher than that of Richert et al (1997a; 29.9 to 64.9 g/d) and Moser et al (2000; 46.1 to 66.2 g/d). This may indicate that valine was oversupplied.

Several lines of evidence support the notion that supplementing valine to the diets of lactating sows enhances milk yield and neonatal growth. First, Richert et al (1997a) found that litter weaning weight and litter weight gain in high-producing lactating sows increased as dietary valine increased from 0.85 to 1.15%. Subsequently, these authors reported that increasing dietary valine (0.64-1.44%) to the lactating sow nursing 10 or more piglets increased litter weaning weights and litter weight gain (Richert et al., 1997b). This effect of dietary valine on lactation was confirmed by Moser et al (2000). Furthermore, Paulicks et al (2003) observed that dietary supplementation of valine (0.85-1.45%) to the lactating sow increased milk production and milk protein content, in comparison with the control group (0.55% of valine). Similarly, increasing dietary intake of valine, isoleucine, or total branched-chain amino acids by lactating sows resulted in an improvement of milk synthesis and litter weight gain (Richert et al., 1996).

Emerging evidence from animal studies indicates that dietary supplementation with valine or a mixture of BCAA stimulates milk synthesis and lactation in sows (Richert et al., 1997a; 1997b). Because dietary supplementation with valine increases milk protein synthesis (Richert et al., 1997a; 1997b), but this amino acid has no effect on the mTOR signaling pathway (Suryawan and Davis, 2011), increases in substrate provision may contribute to enhanced lactation performance in sows.

2.6. Ideal Amino Acid Balance

2.6.1. Gestating Sows

Fetal and mammary tissue growth is rapid during late gestation, the AA needs are greater, particularly in primiparous sows. Muscle tissue growth must be accounted for in younger sows as part of their reproductive needs. In our recent studies with modern breeds of sows, particular attention was paid to the growth pattern of fetuses (McPherson et al., 2004), mammary glands, and maternal tissues (Ji et al., 2005). The findings indicate that the growth of fetus and mammary gland occurred mostly during late gestation.

However, with new information about the dynamic metabolism of AA in the porcine conceptus (Self et al., 2004; Wu et al., 2008), AA requirements of gestating sows are expected to vary greatly with gestational stage. Considering that N accretion rate in maternal tissues (including the placenta) increases (McPherson et al., 2004) and AA composition in fetal pigs changes (Wu et al., 1999) with gestation, a constant AA ratio in the diet for pregnant pigs seems unreasonable. Thus, based on recent result (McPherson et al., 2004), we have determined an ideal dietary AA pattern for pregnant gilts, as described in the following paragraph. However, contributions of AA from hair, skeleton, head, and feet were not obtained and, thus, were excluded from this calculation. The ideal AA ratios for the diets of pregnant gilts were formulated on the basis of the following data and steps: 1) the weights and contents of CP and AA in carcass soft tissue, remaining viscera, gastrointestinal tract, liver, uterus, mammary gland, and fetuses in gilts at d 0, 60 and 114 of gestation were obtained from Wu et al (1999), Kim et al (2001), McPherson et al (2004), and Ji et al (2005); 2) the contents of individual AA in these tissues on each day of gestation were summed to obtain the total amounts of individual AA at d 0, 60 and 114 of gestation; 3) the accretions of individual AA between d 0 and 60 (early gestation) and between d 60 and 114 of gestation (late gestation) were calculated from the differences in AA contents between the first and the last day of each period; 4) the Lys-based AA ratios for protein accretion were

obtained; 5) the adjusted BW of gilts at d 60 and 114 of gestation was obtained by subtracting the weights of mammary gland and reproductive tract from the entire BW, representing the BW of the gilts that are not pregnant but of the same age at the first and the last days of each period; 6) the true ileal digestible Lys needs for maintenance in the early and late gestation were calculated using 36 mg/$BW^{0.75}$ kg (NRC, 1998) where BW was the average adjusted BW of each phase; 7) the needs of other essential AA for maintenance were calculated from the true ileal digestible Lys need and the Lys-based AA ratios for maintenance suggested by NRC (1998); and 8) the amounts of AA required for protein accretion and maintenance were summed to obtain the AA needs for pregnant gilts and were used to calculate the Lys-based AA ratios.

2.6.2. Lactating Sows

Milk production and growth of lactating mammary parenchymal tissues contribute to AA needs for sows during lactation. In the case of limited voluntary feed intake, maternal tissue mobilization, mainly composed of protein and fat, contributes to the AA needs for milk production and mammary tissue growth (Trottier and Johnston, 2001; Kim and Easter, 2001). Protein synthesis can be improved when the ratio of AA from both dietary protein and body tissue mobilization matches the needs for whole body protein synthesis (Richert et al., 1997a), thereby minimizing excess AA oxidation. Currently available recommended ratios for dietary AA for lactating sows (NRC, 1998) indicate a fixed ratio regardless of body condition score (BCS) of sows during lactation. However, our research shows that most common corn and soybean meal-based lactation diets do not provide an AA pattern that is ideal for lactating sows (Kim et al., 2001). We obtained the ideal dietary AA pattern by comparing differences in amounts of individual AA between those from maternal tissue mobilization during lactation and those used for mammary parenchymal tissue gain and for milk production. Thus, our ideal dietary AA pattern can be varied when the balance between these

components is altered (Kim et al., 2001). To understand AA needs and ideal ratios for mammary parenchymal tissues and milk production, as well as AA contributions from maternal tissue mobilization, we have conducted a series of studies as described subsequently. These results provided convincing empirical evidence that the AA profile in a typical corn-soybean meal lactation diet has Lys, Thr, and Val as its first, second and third limiting AAs, that is, under conditions in which substantial BW loss and protein depletion are occurring during lactation. The implications of the results of Soltwedel et al (2006) are that the ideal ratio of Thr:Lys does not exceed 0.63, and the ideal ratio of Val:Lys is less than 0.81 for lactating sows losing 25 kg of BW during a 21-d lactation. These ratios support the results from Kim et al (2001) for sows with similar BW loss during lactation.

3. Importance of Milk

3.1. Yield of Colostrum and Milk

It is not possible to regularly milk the sow in the same condition as can be done with dairy cows. This is because the fact that the porcine mammary gland does not contain cisterns for storage of milk, secreted by the epithelial cells of the alveoli. Due to the lack of cisterns milk removal, from the alveoli and milk ducts, can only be performed after inducing the milk ejection reflex. Stimulation by the piglets, for at least one minute, is necessary to induce the milk ejection reflex in order to obtain a release of oxytocin and milk ejection (Fraser, 1980; Hartmann and Holmes, 1989). Besides this the sow nurses her piglets around 20 times per day for several weeks after parturition and the duration of milk flow is only ten to 20 seconds (Fraser, 1980; Hartmann and Holmes, 1989). The yield of sow colostrum and milk is therefore difficult to measure. However, there are several methods used to estimate yield in sows. The first method is called weigh – suckle – weigh (WSW). This method is performed by weighing the piglets before and after they nurse in order to measure the weight difference. The increase in weight should correspond to the intake of milk. However, this method can cause stress, as the piglets must be

separated from their mother, which can lead to a decreased milk intake. Another aspect is that defecation, urination, metabolic processes and salivation must be considered, since the piglet also loses weight due to these factors. The second method is called the isotope dilution technique. This method aims to measure the rate of total water turnover in the piglets. The difficulty of this method is that it must be ensured that the piglets does not eat or drink anything other than sow milk (Pettigrew et al., 1985; Theil et al., 2002). According to Theil et al (2002) the WSW method resulted in 12.7% lower milk yield than the dilution method, which indicates that WSW underestimates the sows' milk yield. A third method is based on weight gain of piglets. The piglets are weighed at birth and again at another age, for example 24 h after birth (to estimate colostrum yield) or three weeks after birth (to estimate milk yield). A feed conversion ratio is thereafter used in order to recalculate the weight gain into milk yield (Devillers et al., 2004; Devillers et al., 2007; Bergsma et al., 2008; Aguinaga et al., 2011).

3.2. Composition of Colostrum and Milk

Colostrum has a higher DM, a higher content of CP and a higher content of whey protein than milk, but lower levels of lactose, fat and caseins (Klobasa et al., 1987; Le Dividich et al., 2005). The high DM and protein content in colostrum is due to the presence of immunoglobulins, such as immunoglobulin G (IgG), immunoglobulin A (IgA) and immunoglobulin M (IgM), and albumins (Klobasa et al., 1987). However, immunoglobulins are also present in milk but in lower concentrations. In colostrum IgG accounts for most of the protein content whereas in milk IgA is more common (Klobasa et al., 1987; Rooke and Bland, 2002). There is a positive correlation between yield and protein content in colostrum. There is also a positive correlation between yield and IgG content in colostrum. This means that when the yield increases the protein content and IgG content also increases (Devillers et al., 2007). Protein is an important factor in colostrum as well as in milk. Especially arginine deficiency in milk is a limiting factor for piglet growth (Kim

and Wu, 2009). The sow prioritizes protein content in colostrum and milk if the protein content in the feed is scarce, by metabolizing body reserves, which indicates that protein is extremely important to the piglets (King et al., 1996). The amount of essential amino acids in sow milk is 1.2 g/d at day five of lactation and 7.0 g/d at 21 day (Kim et al., 1999). The fat in colostrum and milk mostly consists of long chain fatty acids (Le Dividich et al., 2005) and can be affected by the composition of the feed during gestation and lactation (Farmer and Quesnel, 2009). The lactose content in colostrum is lower than in milk and nearly doubles during the first 14 days of lactation. Since lactose is osmotic and drives water into the alveoli, this affects the milk yield. Milk yield is therefore higher than colostrum yield (Klobasa et al., 1987; Hartmann and Holmes, 1989).

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Chapter III: Effect of Dietary Energy and Amino Acid Levels on Growth Performance, Blood Profiles, Meat Quality and Economic Analysis in Grower - finisher Pigs

ABSTRACT: This experiment was conducted to evaluate the effect of dietary energy and amino acid levels on growth performance, blood profiles, meat quality and economic analysis in grower - finisher pigs. A total of 180 cross-bred pigs ([Yorkshire × Landrace] × Duroc) with an initial mean body weight of 29.5 ± 4.04 kg were allotted to one of six treatments based on 2 × 3 factorial arrangement with 3 replicates. The first factor is two levels of metabolizable energy (ME) and the second factor is three different levels of amino acid (AA), and treatments were 1) LL: 3,200 kcal of ME/kg, NRC (1998) AA requirement; 2) LM: 3,200 kcal of ME/kg, NRC (median value between 1998 and 2012) AA requirement; 3) LH: 3,200 kcal of ME/kg, NRC (2012) AA requirement; 4) HL: 3,300 kcal of ME/kg, NRC (1998) AA requirement; 5) HM: 3,300 kcal of ME/kg, NRC (median value between 1998 and 2012) AA requirement; or 6) HH: 3,300 kcal of ME/kg, NRC (2012) AA requirement. Experiment diets were provided *ad libitum* during the entire experimental period. Higher body weight was observed when pigs were fed high dietary energy treatment ($P<0.01$) during the whole experimental period. The average daily gain tended to be higher as dietary energy and AA level increased during 0 to 3 weeks ($P=0.08$ and $P=0.07$, respectively). During 0 to 3 weeks, dietary energy and amino acid levels improved gain to feed ratio ($P<0.01$ and $P=0.02$, respectively) which is higher than that of low energy treatment. The BUN, albumin, globulin, total protein, IgG and IgA concentration in blood had no difference among dietary treatments. However, creatinine concentration in low energy treatment tended to be higher in 10 week ($P=0.06$). Moisture content in carcass was increased as dietary energy level higher ($P<0.01$). Moreover, water holding capacity (WHC) of physiochemical property was also increased in proportion to dietary energy level increased ($P=0.04$) There was no difference on meat color after slaughter by dietary

energy and amino acid levels. However, the feed cost per kg of weight gain was higher as dietary amino acid level increased (P=0.03). Consequently, this research recommended the energy requirement for grower - finisher pigs should be 3,300 kcal of ME/kg with AA requirement of NRC (1998).

Key words: Energy, Amino acid, Growth performance, Blood profiles, Meat quality, Economic analysis, Grower - finisher pig.

INTRODUCTION

Recently, swine genotypes are different from the past, and nutrient requirements also demand higher energy and amino acid levels. However, feeding with excessive nutrients in the diet is not economical, because of it lowers the efficiency of feed use, and it also causes dangerous pollutants such as nitrogen and phosphorus, which may cause environmental pollution (Jeong et al., 2010). Voluntary feed intake of growing pigs given *ad libitum* access to feed is affected by the energy content of the diet. Therefore, it seems logical that the amino acid levels of a diet should be related to its energy concentration (Chiba et al., 1991). Feeding strategy and phsae of growth activated viscera and body composition, and it may result in variation in the energy requirement for maintenance (Noblet et al., 1999). However, investigations of the need to adjust amino acids according to changes in energy have yielded conflicting result (Prince, 1987). Despite of the extensive research, the demand for energy and essential amino acids that of lysine, methionine, tryptophan and threonine is still not established (NRC, 2012). The major feedstock is cereals such as corn, soybean, barley and wheat. Furthermore, that cereals are provides only 30~60% of the total amino acid requirement. It should be formulated taking into account the appropriate energy and amino acid ratio in the feed to meet the nutrient requirement. Previous study have shown that crystalline amino acids are absorbed well in the small intestine and most have a 100% bio-availability (Lewis

and Bayley, 1995). Thus, these essential amino acids must be supplied with appropriate additions in feed (NRC, 2012).

Future research needs to formulate energy and amino acid content accurately. If the concept of intake requirements is used in corn-soybean meal based diets, the amino acid requirement should be changed as the energy content in the feed. According to the specification standards (NRC 1998 and 2012), dietary energy and amino acid requirements are different because of the pig's genetic capabilities, growth stages and environmental factors affect the pig's energy and amino acid requirements.

Therefore, this experiment was conducted to investigate the effect of energy and amino acid levels on growth performance, blood profiles, meat quality and economic analysis in grower - finisher pigs.

MATERIALS AND METHODS

Animals and housing

All experimental procedures involving animals were conducted in accordance with the Animal Experimental Guidelines provided by the Seoul National University Institutional Animal Care and Use Committee (SNUIACUC; SNU-160819-9).

A total of 180 crossbred ([Yorkshire x Landrace]) x Duroc) growing pigs with an average initial mean body weight (BW) of 29.52 ± 4.04 kg were used. This experiment was designed as a 2 x 3 factorial arrangement of treatments, 30 pigs per treatment in a randomized complete block design (RCBD) with 3 replicates using the experimental animal allotment program (Kim and Stein, 2009). The pen was a fully concrete floor facility (2.60 x 2.84 m) in the experimental period, equipped with a feeder and water nipple, and was in an environmentally controlled facility in Seoul National University Farm (Eumseong-gun, Chungcheongbuk-do, Korea).

Experimental diets and treatments

The experimental period lasted 14 weeks and consisted of 4 phases; phase 1 was weeks 0 to 3, phase 2 was weeks 4 to 6, phase 3 was weeks 7 to 10, and phase 4 was weeks 11 to 14. Body weight and feed intake were collected at the end of each phase in order to calculate the average daily gain, average daily feed intake, and gain to feed ratio. An allotment of feed to all of the pigs was recorded each day, and waste feed left in the feeder was recorded at the end of each phase.

The experimental treatments were divided by energy and amino acids levels; 1) LL: 3,200 kcal of ME/kg, NRC (1998) AA requirement; 2) LM: 3,200 kcal of ME/kg, NRC (median value between 1998 and 2012) AA requirement; 3) LH: 3,200 kcal of ME/kg, NRC (2012) AA requirement; 4) HL: 3,300 kcal of ME/kg, NRC (1998) AA requirement; 5) HM: 3,300 kcal of ME/kg, NRC (median value between 1998 and 2012) AA requirement; or 6) HH: 3,300 kcal of ME/kg, NRC (2012) AA requirement. All nutrients met or exceeded the requirement of NRC (1998) and NRC (2012), respectively. The formula and chemical composition of experimental diets for each phase are presented in Tables 1, 2, 3 and 4, respectively.

Blood sampling and analysis

The body weight of pigs and feed intake of each pen were measured on 3, 6, 10 and 14 weeks of grower - finisher phase. Body weight and residual feed intake were measured on an electric scale (CAS Co. Ltd., Yangju-si, Gyeonggi-do, Korea). The voluntary feed intake of the grower - finisher pigs was determined from records of the feed supply and wastage during the whole experimental period.

Blood sample (n = 4, for each treatment; based on the nearest of mean BW) were taken from the jugular vein for measuring BUN, creatinine, IgG, IgA, albumin, globulin and total protein when the body weights were recorded. Collected blood samples were centrifuged for 15 min at 3,000 rpm on 4℃ (Eppendorf centrifuge 5810R, Germany). The sera were carefully transferred to 1.5 ml plastic tubes and

stored at -20℃ until later analysis. All the blood concentrations were analyzed using a blood analyzer (Modular analytics, P, Roche, Germany).

Carcass traits

At the end of the experiment, 4 pigs from each treatment were selected and slaughter for the carcass analysis. After slaughtering, longissimus muscle (LM) was procured from the interface of 10^{th} and 11^{th} rib of the carcass. Because of the chilling procedure, 30 minutes after slaughter was regarded as the initial time. Meat colors of the LM procured from the interface of 10^{th} and 11^{th} rib were measured at 24 hours after slaughter. Meat color were determined by Commission Internationale de I Echairege (CIE) color values using a CR-300 (Minolta Camera Co., Japan). Chemical analysis of the pork samples was conducted using the method of AOAC International (2005).

Pork quality

The water holding capacity (WHC) of the pork was measured by centrifuge method. Three longissimus muscle (LM) samples were ground and sampled in a filter tube, then heated in a water bath at 80℃ for 20 min, and centrifuged for 10 min at 2,000 rpm at 10℃ (Eppendorf centrifuge 5810R, Germany). To calculate the cooking loss, the longissimus muscle (LM) samples were packed with a polyethylene bag, heated in a water bath until the core temperature reached 72℃, and weighed before and after cooking. After heating, the samples were cored (1.27 cm in diameter) parallel to the muscle fiber and the cores were used to measure the shear force using a salter (Warner Barzler Shear, U.S.A). The amino acid content of the loin meat was determined by ion-exchange chromatography (Amino Acid Analyzer L-8900, Hitachi, Tokyo, Japan) with post-column derivatization with ninhydrin. Performic acid was used in oxidizing the amino acids and was neutralized with sodium citrate dihydrate and then hydrolyzed with 6 N HCl for 22 hours at 110℃ to be liberated from the protein. Amino acids were quantified with the internal standard method (amino acid mixture standard

solution Type H, Wako Chemical, Osaka, Japan; L-cysteic acid, Tokyo Chemical Industry, Tokyo, Japan; DL-methionine sulfone, Sigma, Missouri, US) by measuring the absorption of the reaction products with ninhydrin at 570 nm.

Chemical analysis

Diets were ground by a Cyclotec 1093 Sample Mill (Foss Tecator, Hillerod, Denmark) and ground diets were analyzed. All analyses were performed in duplicate samples and repeated if the results from the duplicate samples varied more than 5% from the mean. The dry matter of the diet samples was determined by oven drying at 135℃ for 2 hours (method 930.15) (AOAC International, 2005). Aspartic acid was used as a calibration standard, crude protein was calculated as N × 6.25, and the diets were also analyzed for ash (method 942.05) (AOAC International, 2005). The collected diets were pooled and dried in an air-forced drying oven at 60℃ for 72 hours, and then ground into 1 mm particles in a Wiley mill for chemical analysis, including moisture, protein, fat and ash contents (AOAC International, 2005).

Statistical analysis

All of collected data were carried out by least squares mean comparisons and were evaluated with the General Linear Model (GLM) procedure of SAS (SAS Institute, 2004). Individual growing pig was used as the experimental unit and were analyzed as 2 x 3 factorial arrangements in a split-plot design and the differences were declared significant at $P<0.05$ or highly significant at $P<0.01$ and the determination of tendency for all analysis was $P>0.05$ and $P<0.10$. The main-plot was the dietary energy levels and the sub-plot was dietary amino acid levels of the grower - finisher pigs. The effect of dietary energy and amino acid levels were also analyzed as linear and quadratic components by orthogonal polynomial contrasts.

RESULTS

Effect of dietary energy and AA levels on growth performance in grower - finisher pigs was presented in Table 5. Body weight was affected by dietary energy levels ($P<0.01$), resulting in higher body weight when dietary energy level was increased during total period. Furthermore, HH treatment showed the highest BW, ADG and G:F ratio of growth performance at 3 week ($P<0.05$, $P<0.05$ and $P<0.01$, respectively). However, there was no significant differences on average daily feed intake (ADFI). The effect of dietary energy and AA levels on blood profiles and immune responses were presented in Tables 6 and 7, respectively. Dietary energy and AA levels did not affect BUN, albumin, globulin and total protein. However, creatinine concentrations in blood tended to be higher as dietary energy increased at 10 week ($P=0.06$). There was no significant differences on IgG and IgA concentrations on immune response by dietary energy and AA levels. The effect of dietary energy and AA levels on carcass traits is summarized in Table 8. Moisture content of carcass was higher when fed the high energy treatments than low energy treatments ($P<0.01$). There were no differences in crude protein, crude fat and ash. The water holding capacity (WHC) of the physiochemical property were increased as dietary energy level increased ($P=0.04$). There was no significant differences detected by energy and AA levels on cooking loss and shear force among treatments. Table 9 shows the effect of dietary energy and AA levels on meat color. There were no significant differences on CIE values of meat color by dietary energy and AA levels. Table 10 shows the guideline of Korea's pork grading system. Pork grade score in this study is recorded in Table 11. HL treatment recorded the highest pork grade of total experimental treatments. The effect of dietary energy and AA levels on economic analysis is presented in Table 12. Total feed cost per kg of weight gain ($P=0.03$) was lower when fed the high energy with low AA levels.

DISCUSSION

Supplementation of energy in pig diet has been studied for a lengthy period of time. Dietary energy levels had effects on feed intake, reproductive performance, feed efficiency, and immunity in pigs (Quiniou et al., 1995). Especially, metabolizable energy (ME) intake is the most important factor in determining growth rate, and many concepts that control feed intake have been studied extensively in many studies (Myer et al., 1992; Torrallardona and Roura, 2009; Yan et al., 2010). In present study, the effect of dietary energy level increased growth performance throughout the whole experimental period, indicating that the dietary energy is exerted beneficial effect on the grower - finisher pigs. This results suggested that a low energy density could decrease BW. Similarly, other study reported that increased nutrient density improved ADG and G:F ratio in grower - finisher pigs (Yan et al., 2010). The present study showed that the dietary 3,300 kcal of ME/kg increased the growth performance in grower - finisher pigs.

Previous study reported that dietary supplementation with deficient essential amino acid (EAA) such as lysine, methionine, threonine and tryptophan were ineffective in restoring protein synthesis or whole-body growth in pigs (Deng et al., 2009). Furthermore, crystalline amino acids are absorbed well in the small intestine and most have a 100% bio-availability (Lewis and Bayley, 1995). Thus, the livestock industry needed to add the deficient EAA in diets. Past study reported that as the EAA level increased, daily gain and feed conversion ratio improved, and the higher energy and lysine levels, improved the body weight gain and feed to gain ratio (Noblet et al., 1987). Other studies demonstrated that increasing feed intakes in pigs fed same CP with different AA-supplemented diets were reported no differences (Knowles et al., 1998; Smith et al., 1999). These findings are in accordance with our study. In this results, indicated that feed intake had no difference as supplementation of dietary AA levels. However, dietary different energy levels had effect on that of growth performance in grower - finisher pigs.

Blood urea nitrogen (BUN) is in accordance with varies based on nitrogen retention in the body (Whang and Easter, 2000) and protein availability decreased (Hong et al., 2016) and with increased the excretion of the nitrogen as urea form (Han et al., 2001). Thus, increase of BUN concentration indicates excessive amino acid levels, metabolized inefficiently and circulating in blood before excretion (Hong et al., 2016). Blood creatinine concentration is widely used to calculate body muscle content, and it has a positive correlation with the total muscles in the body (Baxmann et al., 2008). Low energy diet resulted in tended to increased percent yield of lean cuts and high energy diet increased carcass fatness (Myer et al., 1992). Previous study showed similarly results with present study. Albumin is an indicators of protein reserves in animals and can be specifically influenced by dietary protein shortages indicated by alterations in the albumin content (Adesehinwa and Ogunmodede, 1995). This result showed that the amino acid levels in the diets were able to support normal protein reserves in the pigs resulting from efficient protein utilization. Globulins are in plasma inflammation and immunology parameters (Adesehinwa, 2009). In our experiment the concentration of plasma globulin was unaffected by the dietary energy and amino acid levels. AA intake had no effect on the serum levels of albumin and globulin. Suggesting that production of acute-phase proteins has a high priority during immune system stimulation (ISS), even when AA intake is below the requirements for maximum protein deposition (PD). Also, albumin and globulin is the main plasma proteins. Both plasma protein sources are the most part of total protein (TP) deposition. A greater serum TP levels indicated that the protein status improved in pigs. Moreover, concentrations of TP reflect the health and nutritional status of pigs (Etim et al., 2014). Increased TP concentration suggests that more protein is available for utilization and the decrease in urea suggests sufficient protein consumption. Moreover, the normal serum total protein level range was 5.41 to 6.80 mg/dL (Hlatini and Chimonyo, 2016). Except with phase 4 period, numerically higher than normal value of total protein level range, because of lower feed intake. In this study as the total protein, albumin, globulin parameters were not significantly ($P>0.05$) influenced by the dietary treatments. It is

indicating that the nutrient profile of the diets was adequate to support the performance of the pigs. Therefore, these results have concluded that the both energy and amino acid levels had no negative effect on blood profiles in grower - finisher pigs.

Plasma IgG and IgA, widely used as an indexes of hormonal immune parameters, are the major immunoglobulin that the extra vascular compartment against pathogenic viruses and microorganisms. IgG is generally considered as the most common type of antibody in blood circulation, which plays important role to control bacterial infection in the body. IgA is the major antibody which presents in mucosal secretions and has many functional roles such as preservation of bacteria or viruses from breaching the mucosal barrier. Recent study have concluded that where is limited antigen, IgA is able to trigger effect or functions that have the potential to destroy micro-organisms and mammalian cells by inhibiting complement activation (Taranu et al., 2005). Moreover, the plasmatic contents of both IgG and IgA increased with the age of the animals (Taranu et al., 2005). The results of present study are partially agreement with previous study. Considering our experimental condition, during phase 4, their feed intake is lower than growing phase. However, serum IgG and IgA levels were not affected by dietary energy and amino acid levels.

Generally, carcass traits of pork are directly related to crude fat contents and leaner pork resulted in lower water holding capacity, higher shear force as well as cooking loss. Leaner pork resulted in lower water holding capacity, higher shear force as well as cooking loss. Moreover, intramuscular fat of the LM was correlated with juiciness, flavor and tenderness. There was significant difference in moisture content of carcass ($P<0.01$). Moisture proportion showed higher as dietary energy level increased. Also, WHC was increased by dietary energy level increased ($P=0.04$). Past study demonstrated that increasing energy level influenced to increasing moisture and it may improve the WHC (Deng et al., 2009). However, shear force of loin was not affected by dietary energy and AA levels. Cooking loss

can be an indirect index of WHC because cooking loss had numerically decreased when water holding capacity had increased.

Generally, meat color can be affected by several factors such as temperature, pH, micro-organism and metal ion of pork. However, there was no difference among treatments, that because in our study within a same experimental conditions with same body weight when the experiment was ended. These results was accordance with previous study which was found no significant difference of dietray amino acid or lysine levels on meat color (Deng et al., 2009).

Net profit of pork production from HL [3,300 kcal of ME/kg with NRC (1998) AA requirement] was the highest among treatments, because of similar days of slaughter and lower feed cost per kg weight gain and improved pork grade compared with other treatments.

CONCLUSION

This study recommended that the levels of requirement is dietary 3,300 kcal of ME/kg with amino acid requirement of NRC (1998) in grower - finisher pigs.

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Table 1. Formulas and chemical compositions of the experimental diets during 0 - 3 weeks

Ingredients, (%)	Treatment[1)]					
	LL	LM	LH	HL	HM	HH
Ground corn	59.37	59.54	59.73	56.96	57.14	57.34
SBM, 45%	19.08	18.55	18.07	19.48	18.95	18.43
Wheat	10.00	10.00	10.00	10.00	10.00	10.00
Wheat bran	4.00	4.00	4.00	4.00	4.00	4.00
Palm kernel meal	4.00	4.00	4.00	4.00	4.00	4.00
Tallow	0.70	0.66	0.62	2.70	2.66	2.62
MDCP	1.00	1.01	1.01	1.02	1.02	1.03
Limestone	1.07	1.07	1.07	1.07	1.07	1.07
Vit. Mix[2)]	0.10	0.10	0.10	0.10	0.10	0.10
Min. Mix[3)]	0.10	0.10	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.30	0.30	0.30
DL-methionine, 80%	0.00	0.05	0.09	0.00	0.05	0.09
L-tryptophan, 10%	0.00	0.15	0.25	0.00	0.15	0.25
L-threonine, 99%	0.02	0.08	0.15	0.02	0.08	0.15
L-lysine-HCl, 78%	0.26	0.39	0.51	0.25	0.38	0.51
Total	100.00	100.00	100.00	100.00	100.00	100.00
Chemical composition						
ME, kcal/kg[4)]	3,200.47	3,200.08	3,200.08	3,300.14	3,300.09	3,300.09
Crude protein, %[5)]	15.99	15.05	14.59	15.47	15.35	15.12
Crude fat, %[5)]	4.07	4.72	3.56	5.51	5.75	5.31
Crude ash, %[5)]	4.34	3.91	4.21	4.52	4.26	4.64
Lysine, %[4)]	0.95	1.04	1.12	0.95	1.04	1.12
Methionine, %[4)]	0.25	0.29	0.32	0.25	0.29	0.32
Threonine, %[4)]	0.61	0.67	0.72	0.61	0.67	0.72
Tryptophan, %[4)]	0.17	0.18	0.19	0.17	0.18	0.19
Ca, %[4)]	0.66	0.66	0.66	0.66	0.66	0.66
Total P, %[4)]	0.56	0.56	0.56	0.56	0.56	0.56

[1)]LL: 3,200 kcal of ME/kg + NRC (1998) AA requirement; LM: 3,200 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; LH: 3,200 kcal of ME/kg + NRC (2012) AA requirement; HL: 3,300 kcal of ME/kg + NRC (1998) AA requirement; HM: 3,300 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; HH: 3,300 kcal of ME/kg + NRC (2012) AA requirement.

[2)]Provided vitamins per kg of complete diets: vitamin A, 8,000 IU; vitamin D_3, 1,600 IU; vitamin E, 32 IU; d-biotin, 64g; riboflavin, 3.2mg; calcium pantothenic acid, 8mg; niacin, 16mg; vitamin B_{12}, 12μg; vitamin K, 2.4mg.

[3)]Provided minerals per kg of complete diets: Se, 0.1mg; I, 0.3mg; Mn, 24.8mg; CU, 54.1mg; Fe, 127.3mg; Zn, 84.7mg; Co, 0.3mg.

[4)]Calculated value.

[5)]Analyzed value.

Table 2. Formulas and chemical compositions of the experimental diets during 4 - 6 weeks

Ingredients, (%)	Treatment[1)]					
	LL	LM	LH	HL	HM	HH
Ground corn	64.85	64.97	65.12	62.48	62.64	62.76
SBM, 45%	13.95	13.51	13.10	14.34	13.92	13.47
Wheat	10.00	10.00	10.00	10.00	10.00	10.00
Wheat bran	4.00	4.00	4.00	4.00	4.00	4.00
Palm kernel meal	4.00	4.00	4.00	4.00	4.00	4.00
Tallow	0.47	0.45	0.42	2.46	2.43	2.41
MDCP	0.90	0.91	0.92	0.91	0.91	0.92
Limestone	0.96	0.96	0.96	0.96	0.96	0.96
Vit. Mix[2)]	0.10	0.10	0.10	0.10	0.10	0.10
Min. Mix[3)]	0.10	0.10	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.30	0.30	0.30
DL-methionine, 80%	0.00	0.03	0.07	0.00	0.03	0.07
L-tryptophan, 10%	0.07	0.20	0.28	0.05	0.15	0.28
L-threonine, 99%	0.04	0.10	0.15	0.04	0.10	0.15
L-lysine-HCl, 78%	0.27	0.38	0.48	0.26	0.37	0.48
Total	100.00	100.00	100.00	100.00	100.00	100.00
Chemical composition						
ME, kcal/kg[4)]	3,200.38	3,200.49	3,200.48	3,300.09	3,300.17	3,300.44
Crude protein, %[5)]	14.13	13.78	14.01	14.94	14.36	15.18
Crude fat, %[5)]	3.71	5.02	4.30	5.31	6.10	4.52
Crude ash, %[5)]	4.35	3.77	3.62	4.55	3.85	4.26
Lysine, %[4)]	0.82	0.90	0.97	0.82	0.90	0.97
Methionine, %[4)]	0.22	0.25	0.28	0.22	0.25	0.28
Threonine, %[4)]	0.55	0.60	0.64	0.55	0.60	0.64
Tryptophan, %[4)]	0.15	0.16	0.17	0.15	0.16	0.17
Ca, %[4)]	0.59	0.59	0.59	0.59	0.59	0.59
Total P, %[4)]	0.52	0.52	0.52	0.52	0.52	0.52

[1)]LL: 3,200 kcal of ME/kg + NRC (1998) AA requirement; LM: 3,200 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; LH: 3,200 kcal of ME/kg + NRC (2012) AA requirement; HL: 3,300 kcal of ME/kg + NRC (1998) AA requirement; HM: 3,300 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; HH: 3,300 kcal of ME/kg + NRC (2012) AA requirement.

[2)]Provided vitamins per kg of complete diets: vitamin A, 8,000 IU; vitamin D_3, 1,600 IU; vitamin E, 32 IU; d-biotin, 64g; riboflavin, 3.2mg; calcium pantothenic acid, 8mg; niacin, 16mg; vitamin B_{12}, 12μg; vitamin K, 2.4mg.

[3)]Provided minerals per kg of complete diets: Se, 0.1mg; I, 0.3mg; Mn, 24.8mg; CU, 54.1mg; Fe, 127.3mg; Zn, 84.7mg; Co, 0.3mg.

[4)]Calculated value.

[5)]Analyzed value.

Table 3. Formulas and chemical compositions of the experimental diets during 7 - 10 weeks

Ingredients, (%)	Treatment[1)]					
	LL	LM	LH	HL	HM	HH
Ground corn	69.67	69.74	69.83	67.29	67.35	67.46
SBM, 45%	9.47	9.22	8.95	9.85	9.59	9.33
Wheat	10.00	10.00	10.00	10.00	10.00	10.00
Wheat bran	4.00	4.00	4.00	4.00	4.00	4.00
Palm kernel meal	4.00	4.00	4.00	4.00	4.00	4.00
Tallow	0.21	0.20	0.18	2.21	2.20	2.17
MDCP	0.72	0.72	0.73	0.73	0.75	0.75
Limestone	0.89	0.89	0.89	0.88	0.88	0.88
Vit. Mix[2)]	0.10	0.10	0.10	0.10	0.10	0.10
Min. Mix[3)]	0.10	0.10	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.30	0.30	0.30
DL-methionine, 80%	0.00	0.02	0.06	0.00	0.03	0.06
L-tryptophan, 10%	0.15	0.22	0.28	0.15	0.22	0.27
L-threonine, 99%	0.07	0.10	0.13	0.07	0.10	0.13
L-lysine-HCl, 78%	0.33	0.39	0.45	0.32	0.39	0.45
Total	100.00	100.00	100.00	100.00	100.00	100.00
Chemical composition						
ME, kcal/kg[4)]	3,200.03	3,200.43	3,200.43	3,300.44	3,300.38	3,300.12
Crude protein, %[5)]	12.30	12.08	11.53	12.80	12.78	12.54
Crude fat, %[5)]	3.82	3.61	4.18	5.81	4.95	5.14
Crude ash, %[5)]	3.90	2.92	3.13	4.05	3.12	3.40
Lysine, %[4)]	0.75	0.80	0.84	0.75	0.80	0.84
Methionine, %[4)]	0.20	0.23	0.25	0.20	0.23	0.25
Threonine, %[4)]	0.51	0.54	0.56	0.51	0.54	0.56
Tryptophan, %[4)]	0.14	0.15	0.15	0.14	0.15	0.15
Ca, %[4)]	0.52	0.52	0.52	0.52	0.52	0.52
Total P, %[4)]	0.47	0.47	0.47	0.47	0.47	0.47

[1)]LL: 3,200 kcal of ME/kg + NRC (1998) AA requirement; LM: 3,200 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; LH: 3,200 kcal of ME/kg + NRC (2012) AA requirement; HL: 3,300 kcal of ME/kg + NRC (1998) AA requirement; HM: 3,300 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; HH: 3,300 kcal of ME/kg + NRC (2012) AA requirement.

[2)]Provided vitamins per kg of complete diets: vitamin A, 8,000 IU; vitamin D_3, 1,600 IU; vitamin E, 32 IU; d-biotin, 64g; riboflavin, 3.2mg; calcium pantothenic acid, 8mg; niacin, 16mg; vitamin B_{12}, 12μg; vitamin K, 2.4mg.

[3)]Provided minerals per kg of complete diets: Se, 0.1mg; I, 0.3mg; Mn, 24.8mg; CU, 54.1mg; Fe, 127.3mg; Zn, 84.7mg; Co, 0.3mg.

[4)]Calculated value.

[5)]Analyzed value.

Table 4. Formulas and chemical compositions of the experimental diets during 11 - 14 weeks

Ingredients, (%)	Treatment[1)]					
	LL	LM	LH	HL	HM	HH
Ground corn	69.89	69.98	70.03	67.48	67.60	67.66
SBM, 45%	4.66	4.32	4.03	5.07	4.72	4.42
Wheat	15.00	15.00	15.00	15.00	15.00	15.00
Wheat bran	4.00	4.00	4.00	4.00	4.00	4.00
Palm kernel meal	4.00	4.00	4.00	4.00	4.00	4.00
Tallow	0.14	0.12	0.12	2.14	2.12	2.11
MDCP	0.58	0.58	0.59	0.59	0.60	0.60
Limestone	0.82	0.82	0.82	0.82	0.81	0.81
Vit. Mix[2)]	0.10	0.10	0.10	0.10	0.10	0.10
Min. Mix[3)]	0.10	0.10	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.30	0.30	0.30
DL-methionine, 80%	0.00	0.02	0.03	0.00	0.02	0.03
L-tryptophan, 10%	0.08	0.20	0.30	0.08	0.18	0.29
L-threonine, 99%	0.05	0.09	0.14	0.04	0.09	0.14
L-lysine-HCl, 78%	0.29	0.38	0.45	0.28	0.37	0.45
Total	100.00	100.00	100.00	100.00	100.00	100.00
Chemical composition						
ME, kcal/kg[4)]	3,200.18	3,200.01	3,200.41	3,300.15	3,300.16	3,300.38
Crude protein, %[5)]	11.07	10.72	10.98	10.69	11.25	11.13
Crude fat, %[5)]	4.15	4.20	4.18	5.22	5.92	4.39
Crude ash, %[5)]	3.30	3.32	3.43	3.47	3.52	3.27
Lysine, %[4)]	0.60	0.66	0.71	0.60	0.66	0.71
Methionine, %[4)]	0.19	0.20	0.21	0.19	0.20	0.21
Threonine, %[4)]	0.41	0.45	0.49	0.41	0.45	0.49
Tryptophan, %[4)]	0.11	0.12	0.13	0.11	0.12	0.13
Ca, %[4)]	0.46	0.46	0.46	0.46	0.46	0.46
Total P, %[4)]	0.43	0.43	0.43	0.43	0.43	0.43

[1)]LL: 3,200 kcal of ME/kg + NRC (1998) AA requirement; LM: 3,200 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; LH: 3,200 kcal of ME/kg + NRC (2012) AA requirement; HL: 3,300 kcal of ME/kg + NRC (1998) AA requirement; HM: 3,300 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; HH: 3,300 kcal of ME/kg + NRC (2012) AA requirement.

[2)]Provided vitamins per kg of complete diets: vitamin A, 8,000 IU; vitamin D_3, 1,600 IU; vitamin E, 32 IU; d-biotin, 64g; riboflavin, 3.2mg; calcium pantothenic acid, 8mg; niacin, 16mg; vitamin B_{12}, 12μg; vitamin K, 2.4mg.

[3)]Provided minerals per kg of complete diets: Se, 0.1mg; I, 0.3mg; Mn, 24.8mg; CU, 54.1mg; Fe, 127.3mg; Zn, 84.7mg; Co, 0.3mg.

[4)]Calculated value.

[5)]Analyzed value.

Table 5. Effect of dietary energy and amino acid levels on growth performance in grower - finisher pigs[1)]

Criteria	Treatment[2)]						SEM[3)]	P-value		
	LL	LM	LH	HL	HM	HH		ME[4)]	AA[5)]	ME×AA
Body weight, kg										
Initial	29.52	29.52	29.55	29.50	29.53	29.52	0.904	-	-	-
3 week*	45.13^{c}	46.22^{bc}	47.30^{ab}	46.12^{bc}	47.12^{ab}	48.02^{a}	1.181	<0.01	0.65	0.96
6 week	63.38	65.17	65.65	64.57	65.53	66.45	1.379	<0.01	0.70	0.88
10 week	84.23	84.70	85.63	85.08	86.48	88.09	1.339	<0.01	0.69	0.75
14 week	101.45	100.23	100.92	101.73	101.25	103.89	1.283	<0.01	0.46	0.72
ADG, g										
0 to 3 week*	742^{c}	795^{bc}	845^{ab}	791^{bc}	837^{ab}	881^{a}	17.7	0.08	0.07	0.69
4 to 6 week	871	902	874	879	877	878	14.1	0.31	0.85	0.37
7 to 10 week	745	698	714	732	748	773	10.7	0.33	0.76	0.65
11 to 14 week	615	555	546	595	528	564	18.5	0.21	0.67	0.82
0 to 14 week	752	753	761	762	763	789	7.5	0.71	0.21	0.49
ADFI, g										
0 to 3 week	1,974	1,951	1,973	1,934	1,935	1,999	44.2	0.92	0.94	0.97
4 to 6 week	2,500	2,456	2,447	2,435	2,410	2,456	37.6	0.71	0.95	0.94
7 to 10 week	2,579	2,446	2,460	2,387	2,426	2,470	28.0	0.26	0.80	0.33
11 to 14 week	1,548	1,637	1,593	1,604	1,518	1,630	20.6	0.84	0.74	0.22
0 to 14 week	2,163	2,134	2,131	2,104	2,087	2,151	18.2	0.45	0.81	0.66
G:F Ratio										
0 to 3 week**	0.38^{C}	0.41^{BC}	0.43^{AB}	0.41^{BC}	0.43^{AB}	0.44^{A}	0.007	<0.01	0.02	0.83
4 to 6 week	0.35	0.37	0.36	0.36	0.36	0.36	0.004	0.90	0.45	0.89
7 to 10 week	0.29	0.29	0.29	0.31	0.31	0.31	0.005	0.49	0.83	0.29
11 to 14 week	0.40	0.34	0.34	0.37	0.35	0.35	0.011	0.35	0.78	0.82
0 to 14 week	0.35	0.35	0.36	0.36	0.37	0.37	0.005	0.93	0.74	0.86

[1)]A total of 180 cross-bred pigs with an initial mean body weight of 29.52 kg, and a final mean body weight of 101.58 kg.
[2)]LL: 3,200 kcal of ME/kg + NRC (1998) AA requirement; LM: 3,200 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; LH: 3,200 kcal of ME/kg + NRC (2012) AA requirement; HL: 3,300 kcal of ME/kg + NRC (1998) AA requirement; HM: 3,300 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; HH: 3,300 kcal of ME/kg + NRC (2012) AA requirement.
[3)]Standard error of the mean.
[4)]ME: metabolizable energy.
[5)]AA: amino acid.
[abc]Means in a same row with different superscript letters significantly differ (P<0.05).
[ABC]Means in a same row with different superscript letters significantly differ (P<0.01).

Table 6. Effect of dietary energy and amino acid levels on blood profiles in grower - finisher pigs[1)]

Criteria	Treatment[2)]						SEM[3)]	P-value		
	LL	LM	LH	HL	HM	HH		ME[4)]	AA[5)]	ME×AA
BUN, mg/dL										
Initial	---------- 7.86 ----------						0.523	-	-	-
3 week	8.70	8.00	7.00	8.50	8.30	8.35	0.460	0.70	0.84	0.88
6 week	8.05	8.53	8.30	8.80	6.60	8.77	0.220	0.61	0.21	0.19
10 week	10.43	9.70	9.70	8.25	8.40	7.90	0.550	0.26	0.95	0.97
14 week	10.90	8.90	9.37	9.93	5.00	8.15	0.740	0.32	0.43	0.81
Creatinine, mg/dL										
Initial	---------- 0.82 ----------						0.043	-	-	-
3 week	0.91	0.89	0.94	0.88	0.79	0.86	0.022	0.16	0.49	0.81
6 week	0.94	1.00	1.00	0.91	1.05	1.00	0.036	0.10	0.55	0.93
10 week	1.58	1.63	1.53	1.27	1.59	1.40	0.043	0.06	0.15	0.37
14 week	1.78	1.72	2.01	1.57	1.45	1.85	0.066	0.11	0.10	0.94
Albumin, g/dL										
Initial	---------- 3.60 ----------						0.056	-	-	-
3 week	3.83	3.95	4.00	3.70	3.97	3.85	0.063	0.57	0.47	0.89
6 week	3.67	4.03	3.93	3.73	3.83	4.10	0.057	0.93	0.14	0.43
10 week	4.00	3.80	4.00	3.80	3.88	3.77	0.046	0.30	0.86	0.45
14 week	3.85	3.88	3.85	3.50	3.53	4.15	0.080	0.41	0.25	0.23
Globulin, g/dL										
Initial	---------- 2.50 ----------						0.032	-	-	-
3 week	2.53	2.68	2.33	2.55	2.53	2.20	0.059	0.53	0.14	0.84
6 week	2.70	2.25	2.73	2.73	2.25	2.13	0.088	0.26	0.10	0.22
10 week	2.70	2.90	2.45	2.88	2.85	2.60	0.079	0.62	0.35	0.85
14 week	3.58	3.65	3.63	3.80	3.25	3.45	0.109	0.62	0.70	0.55
Total protein, g/dL										
Initial	---------- 6.10 ----------						0.360	-	-	-
3 week	6.53	6.28	6.43	6.43	6.50	6.13	0.250	0.33	0.39	0.39
6 week	6.50	6.40	6.65	6.65	6.08	6.40	0.075	0.88	0.74	0.56
10 week	6.70	6.90	6.53	6.68	6.73	6.70	0.073	0.34	0.12	0.35
14 week	7.43	7.53	7.48	7.30	6.93	7.80	0.089	0.53	0.83	0.26

[1)]A total of 180 cross-bred pigs with an initial mean body weight of 29.52 kg, and a final mean body weight of 101.58 kg.

[2)]LL: 3,200 kcal of ME/kg + NRC (1998) AA requirement; LM: 3,200 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; LH: 3,200 kcal of ME/kg + NRC (2012) AA requirement; HL: 3,300 kcal of ME/kg + NRC (1998) AA requirement; HM: 3,300 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; HH: 3,300 kcal of ME/kg + NRC (2012) AA requirement.

[3)]Standard error of the mean.

[4)]ME: metabolizable energy.

[5)]AA: amino acid.

Table 7. Effect of dietary energy and amino acid levels on immune response in grower - finisher pigs[1)]

Criteria, (mg/dL)	Treatment[2)]						SEM[3)]	P-value		
	LL	LM	LH	HL	HM	HH		ME[4)]	AA[5)]	ME×AA
IgG										
Initial	---------- 4.47 ----------						0.466	-	-	-
3 week	8.26	8.60	8.69	8.37	8.62	9.19	0.493	0.88	0.94	0.99
6 week	9.91	9.18	9.95	10.19	9.78	8.58	0.272	0.81	0.66	0.36
10 week	5.23	5.40	5.06	5.19	4.51	4.68	0.121	0.15	0.48	0.52
14 week	4.71	4.95	4.82	4.90	4.97	5.03	0.124	0.65	0.88	0.96
IgA										
Initial	---------- 0.53 ----------						0.072	-	-	-
3 week	1.05	0.94	0.91	1.06	0.92	0.73	0.081	0.88	0.87	0.97
6 week	1.08	1.33	1.25	1.30	0.90	1.12	0.093	0.70	0.97	0.62
10 week	0.99	0.98	0.99	0.85	0.97	0.96	0.034	0.57	0.89	0.87
14 week	0.93	0.85	1.04	1.05	0.89	0.64	0.045	0.34	0.34	0.11

[1)]A total of 180 cross-bred pigs with an initial mean body weight of 29.52 kg, and a final mean body weight of 101.58 kg.
[2)]LL: 3,200 kcal of ME/kg + NRC (1998) AA requirement; LM: 3,200 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; LH: 3,200 kcal of ME/kg + NRC (2012) AA requirement; HL: 3,300 kcal of ME/kg + NRC (1998) AA requirement; HM: 3,300 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; HH: 3,300 kcal of ME/kg + NRC (2012) AA requirement.
[3)]Standard error of the mean.
[4)]ME: metabolizable energy.
[5)]AA: amino acid.

Table 8. Effect of dietary energy and amino acid levels on carcass traits of the longissimus muscle[1)]

Criteria	Treatment[2)]						SEM[3)]	P-value		
	LL	LM	LH	HL	HM	HH		ME[4)]	AA[5)]	ME×AA
Analyzed analysis, %										
Moisture	72.40	72.28	71.03	73.51	73.19	73.35	0.241	<0.01	0.24	0.26
Crude protein	23.28	24.01	24.66	23.67	23.71	23.71	0.138	0.30	0.15	0.19
Crude fat	1.61	1.29	1.03	1.26	1.38	1.48	0.098	0.76	0.79	0.31
Crude ash	1.20	1.23	1.21	1.16	1.21	1.19	0.010	0.37	0.44	0.91
Physiochemical property										
WHC[6)], (%)	68.63	69.23	70.63	72.40	71.03	73.71	0.629	0.04	0.39	0.78
Cooking loss, (kg/in)	29.64	28.84	27.27	27.67	28.92	26.63	0.395	0.29	0.43	0.87
Shear force, (N)	70.07	80.44	86.52	70.64	86.23	86.92	2.477	0.92	0.323	0.97

[1)]Least squares means for 4 pigs per treatment.
[2)]LL: 3,200 kcal of ME/kg + NRC (1998) AA requirement; LM: 3,200 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; LH: 3,200 kcal of ME/kg + NRC (2012) AA requirement; HL: 3,300 kcal of ME/kg + NRC (1998) AA requirement; HM: 3,300 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; HH: 3,300 kcal of ME/kg + NRC (2012) AA requirement.
[3)]Standard error of the mean.
[4)]ME: metabolizable energy.
[5)]AA: amino acid.
[6)]WHC: water holding capacity.

Table 9. Effect of dietary energy and amino acid levels on meat color[1)]

Criteria	Treatment[2)]						SEM[3)]	P-value		
	LL	LM	LH	HL	HM	HH		ME[4)]	AA[5)]	ME×AA
Hunter value[6)], L*										
0 hour	40.0	43.4	39.2	42.3	39.1	38.8	0.55	0.66	0.21	0.12
24 hour	44.2	45.4	43.7	46.5	43.8	43.2	0.42	0.90	0.18	0.17
Hunter value, a**										
0 hour	4.0	5.2	3.3	4.6	4.0	3.9	0.22	0.98	0.15	0.17
24 hour	6.0	6.9	5.6	6.5	6.2	5.7	0.16	0.81	0.13	0.52
Hunter value, b***										
0 hour	2.8	3.2	2.7	2.9	2.9	2.7	0.09	0.86	0.25	0.60
24 hour	4.9	5.4	4.6	5.2	4.7	4.4	0.11	0.59	0.10	0.27

[1)]Least squares means for 4 pigs per treatment.
[2)]LL: 3,200 kcal of ME/kg + NRC (1998) AA requirement; LM: 3,200 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; LH: 3,200 kcal of ME/kg + NRC (2012) AA requirement; HL: 3,300 kcal of ME/kg + NRC (1998) AA requirement; HM: 3,300 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; HH: 3,300 kcal of ME/kg + NRC (2012) AA requirement.
[3)]Standard error of the mean.
[4)]ME: metabolizable energy.
[5)]AA: amino acid.
[6)]Hunter values: L*: luminance or brightness (varies from black to white), a**: red and green component (+a: red, -a: green), b***: yellow and blue component (+bellow, -a: blue).

Table 10. Carcass grading system for pigs in Korea[1)]

Grade	Carcass weight, kg	Backfat thickness, mm	Score used in this study
+1	83 – 93	17 – 25	3
1	80 – 98	15 - 28	2
Total score	Neither +1 nor 1 grade		1

[1)]Least squares means for 4 pigs per treatment.

Table 11. Pork grade score in this research[1)]

Criteria	Treatment[2)]					
	LL	LM	LH	HL	HM	HH
1+ grade	1	-	1	2	1	-
1 grade	3	4	3	2	3	4
Total score	9	8	9	10	9	8

[1)]Least squares means for 4 pigs per treatment.
[2)]LL: 3,200 kcal of ME/kg + NRC (1998) AA requirement; LM: 3,200 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; LH: 3,200 kcal of ME/kg + NRC (2012) AA requirement; HL: 3,300 kcal of ME/kg + NRC (1998) AA requirement; HM: 3,300 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; HH: 3,300 kcal of ME/kg + NRC (2012) AA requirement.
[3)]Standard error of the mean.

Table 12. Effect of dietary energy and amino acid levels on economic analysis in finishing pigs[1)]

Criteria	Treatment[2)]						SEM[3)]	P-value		
	LL	LM	LH	HL	HM	HH		ME[4)]	AA[5)]	ME×AA
Feed cost, (won/kg, BW)										
	848[b]	876[a]	878[a]	854[b]	870[ab]	880[a]	13.5	0.77	0.03	0.54
Net proceeds, (won/pig)										
	- 2,000	- 4,000	- 2,000	0	- 2,000	- 4,000	1,505.5	0.44	0.65	0.32

[1)]Least squares means for 4 pigs per treatment.
[2)]LL: 3,200 kcal of ME/kg + NRC (1998) AA requirement; LM: 3,200 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; LH: 3,200 kcal of ME/kg + NRC (2012) AA requirement; HL: 3,300 kcal of ME/kg + NRC (1998) AA requirement; HM: 3,300 kcal of ME/kg + NRC (median value between 1998 and 2012) AA requirement; HH: 3,300 kcal of ME/kg + NRC (2012) AA requirement.
[3)]Standard error of the mean.
[4)]ME: metabolizable energy.
[5)]AA: amino acid.
[ab] Mean with different superscripts in the same row significantly differ ($P<0.05$).

Chapter IV: Effect of Dietary Amino Acid Levels on Body Changes, Reproductive Performance, Blood Profiles and Milk Composition in Gestating to Lactating Sows

ABSTRACT: This study was conducted to investigate the effect of dietary amino acid levels on body changes, reproductive performance, blood profiles and milk composition in gestating to lactating sows. A total of 60 (1 to 3 mixed-parity; 1.7) sows (F1, Yorkshire × Landrace; Darby, Korea) with an initial mean body weight of 194.4 ± 2.84 kg were allotted to one of four treatments by a completely randomized design (CRD) with 15 replicates. Each experimental diet contained different amino acid (AA) levels, and treatments were 1) AA110: 110% of the NRC (2012) AA requirement; 2) AA100: 100% of the NRC (2012) AA requirement; 3) AA90: 90% of the NRC (2012) AA requirement; or 4) AA80: 80% of the NRC (2012) AA requirement. The experimental diet was provided to each treatment from 35 to 110 days of gestation and fed at 2.0, 2.2 and 2.4 kg/d to gestating sows of first, second and third parities, respectively. All the sows were provided *ad libitum* during gestation but lactating sows were fed the same diet regardless of treatments during lactation period. There were no significant differences in the change of body weight and backfat thickness among treatments during gestation and lactation. However, there was a quadratic effects on litter weight at 21 day of lactation (quadratic, P=0.03), and on litter weight gain (quadratic, P=0.02) in AA90 treatment. Also, the piglet weight at 21 day of lactation (quadratic, P=0.03) and the piglet weight gain (quadratic, P=0.02) during lactation were higher in AA90 treatment than other treatments. Analysis based on quadratic response in growth performance of piglets, 93.7% of NRC (2012) AA requirement showed the highest litter size. There was no significant differences in IgG, BUN and creatinine of blood profiles in sows and their progeny. However, lysine (linear, P=0.08), methionine (linear, P=0.05) and threonine (linear, P=0.02) concentrations in blood AA at 110 day of gestation tended to be higher as the dietary amino acid level increased. Dietary amino acid level was

not affected on milk composition during lactation. Consequently, this research demonstrated that the level of amino acid in diet should be 93.7% AA requirement of NRC (2012) both in gestating and lactating sows.

Key words: Amino acid, Body changes, Reproductive performance, Blood profiles, Milk composition, Gestating-lactating sow.

INTRODUCTION

In recent years, higher protein and amino acid (AA) levels have become required in feed due to the improved hereditary capacity of pigs and the increased protein accumulation per day as the pig nutritional physiology field has developed. Nevertheless, feeding with excessive nutrients is not economical, because it lowers the feed efficiency and pollutes the environment with undigested nutrients such as excess nitrogen and phosphorus (Jongbloed and Lenis, 1992). Inefficient use of AAs affects AA metabolism and it may reduce animal growth performance (Pomar et al., 2003).

There have been many studies on the requirement for each essential AA, but few studies were conducted about dietary AA balance for pigs. The major feed industry for most animal diets are cereals such as corn, barley and wheat, which generally provide only 30~60% of the total AA requirement. The raw materials of cereals contain a limited number of essential amino acids (EAAs) such as lysine and threonine, which are not synthesized in the animal body due to differences in AA transfer reactions. Essential AAs are defined as either those whose carbon skeletons cannot be synthesized or those that are inadequately synthesized de novo by the body relative to the need, and which must be provided in the diet to meet the requirements (Chen et al., 2009; Wu, 2009). Non-essential AAs are those that can be synthesized de novo in adequate amounts by the body to protein its requirements

(Baker and Stein, 2009). It is important to prevent excesses or deficiencies of dietary amino acids balance in pigs.

There are several standard requirement in each country, such as; Korea Livestock Specification Standard (KLSS) in Korea or National Research Council (NRC) in U.S.A. The KLSS (2017) suggested that total lysine requirements of 12.35, 11.81 and 9.95 g/d for gestating sows of parity 1, 2 and 3, respectively. The NRC (2012) recommended that total lysine requirements of 12.4/19.3, 11.0/17.5 and 9.4/15.4 g/d (<90d / >90d of gestation) for gestating sows of parity 1, 2 and 3, respectively. Between the difference of NRC (2012) and KLSS (2017) requirements, the AA requirement for gestating sows must be defined.

Consequently, this study was carried out to investigate the effect of different AA levels on body changes, reproductive performance, blood profiles and milk composition in gestating to lactating sows.

MATERIALS AND METHODS

Animals and housing

All experimental procedures involving animals were conducted in accordance with the Animal Experimental Guidelines provided by the Seoul National University Institutional Animal Care and Use Committee (SNUIACUC; SNU-160819-9).

A total of 60 (1 to 3 mixed-parity; 1.7) sows (F1, Yorkshire × Landrace) with an initial mean body weight of 194.43 ± 2.84 kg were used for a trial at a research farm at Seoul National University (Eumseong-gun, Chungcheongbuk-do, Korea). Sows were allotted to each treatment based on body weight, backfat thickness and parity at 35 days of gestation in a completely randomized design (CRD) with 15 replicates. Gestating sows were housed in individual gestation stalls (2.20 × 0.65 m) until 110 days of gestation. Each gestation stall was equipped with a feeder and a water nipple. On the 110 day of gestation, the sows were moved into a

farrowing barn and placed in individual farrowing crates (2.40 × 1.80 m). Each farrowing crate was equipped with a feeder, a water cup, a baby house with a heating lamp and a water nipple for the piglets. The room temperature was maintained at an average of 20 ± 3.2℃ before parturition and at 28 ± 2.4℃ postpartum for the lactating sows. The baby house was kept at 32 ± 2.4℃ under the heating lamp.

Experimental diets and treatments

Four experimental diets for the gestating sows contained the following amino acid levels: 1) AA110: 110% of NRC (2012) AA requirement, 2) AA100: 100% of NRC (2012) AA requirement, 3) AA90: 90% of NRC (2012) requirement, and 4) AA80: 80% of NRC (2012) AA requirement. All sows were fed 2.0, 2.2 and 2.4 kg/d in parity 1, 2 and 3, respectively. Sows were fed once a day (08:00), and the feed was reduced by 0.2 kg/d for 5 days before the due date of parturition. After farrowing, the lactation diet was increased gradually from 1.0 to 5.0 kg/d over 5 days postpartum, and the sows were fed the diet *ad libitum* until weaning. The formulas and chemical compositions of the experimental diets are presented in Table 1.

Sample collection and analysis

The body weight and backfat thickness (P_2 position) of each sow was measured on 35, 70, 110 day of gestation and at 24 hours postpartum, on 21 day of lactation. Body weight was measured on an electric scale (CAS Co. Ltd., Yangju-si, Gyeonggi-do, Korea) and backfat thickness was measured with an ultrasound lean meter (Anyscan BF, Songkang GLC Co. LTD, Seongnam-si, Gyeonggi-do, Korea). The weaning-to-estrus interval (WEI) of the sows was calculated from weaning to first estrus period. The voluntary feed intake of the lactating sows was determined from records of the feed supply and wastage during the lactation period. Within 24 hours postpartum, the numbers of total born, live born, stillbirth and mummy were

recorded, along with the weight of the piglets (CAS Co. Ltd., Yangju-si, Gyeonggi-do, Korea). Individual litter size and piglet weight of lactating sows were recorded at 24 hour postpartum and on 21 day of lactation.

Blood sample (n = 4, for each treatment; based on the nearest of mean BW) were taken from the jugular vein for measuring BUN, IgG and creatinine concentrations when the body weights were recorded. Collected blood samples were centrifuged for 15 min at 3,000 rpm on 4℃ (Eppendorf centrifuge 5810R, Germany). The sera were carefully transferred to 1.5 ml plastic tubes and stored at -20℃ until later analysis. All the blood concentrations were analyzed using a blood analyzer (Modular analytics, P, Roche, Germany).

Amino acid analysis

Amino acid analysis of blood concentration was measured on 35, 70, 110 day of gestation and 24 hours postpartum, 21 day of lactation. Blood samples (n = 4, for each treatment; based on the nearest of mean BW) were collected and stored as described above. Green Cross Lab Cell (Sungnam-si, Gyeonggi-do, Korea) analyzed the blood samples. Physiological samples were analyzed with a TRAQ™ Reagents Application Kit for Use with LC/MS/MS Systems. A 3200 Q TRAP (AB SCIEX, U.S.A) analyzer was used for liquid chromatography tandem mass spectrometry.

Milk composition

Colostrum at 24 hours postpartum and milk on 21 day of lactation were collected from the 2nd and 3rd teats of all experimental sows (n = 4, for each treatment; based on the nearest of mean BW) that had been injected with 5 IU of oxytocin (Komi oxytocin inj., Komipharm International Co., Ltd., Siheung-si, Gyeonggi-do, Korea) in the ear vein. The collected milk samples were stored at -20℃ in a freezer until later analysis. Proximate analysis of the colostrum and milk was conducted at the National Institute of Animal Science (NIAS) (Wanju-gun, Jeollanbuk-do, Korea) by means of Milkoscan FT 120 (FOSS, Hillerod, Denmark).

Statistical Analysis

All the collected data were subjected to least squares mean comparisons and evaluated with the General Linear Model (GLM) procedure of SAS (SAS Institute, 2004). Individual sows and their litters were used as the experimental unit and were analyzed by two-way ANOVA. Orthogonal polynomial contrasts were used to detect linear and quadratic responses to amino acid levels when a significant amino acid effect was detected. Differences were declared significant at $P<0.05$ or highly significant at $P<0.01$, and tendencies were determined at $0.05 \geq P<0.10$.

RESULTS

The effect of dietary amino acid levels on body weight, backfat thickness or their changes in gestating to lactating sows were presented in Tables 2 and 3, respectively. There were no significant differences on body changes and backfat thickness or their changes in gestating to lactating sows. Also, the average daily feed intake (ADFI) and reproductive performance of sows were not affected by dietary treatment during lactation period (Table 4). As shown in Table 5, there were differences in litter weight and litter weight changes on 21 day of lactation among the treatments (quadratic, P=0.03 and P=0.02, respectively). The piglet weight and piglet weight changes were also affected by the dietary amino acid levels (quadratic, P=0.03 P=0.02, respectively). Analyzing the quadratic response, 93.7% of NRC (2012) AA requirement recorded the higher reproductive performance. Although, there were no negative effect on the number of total born, stillbirth, mummy and live born. IgG, BUN and creatinine concentrations of blood profiles were not significantly influenced by the dietary amino acid levels in gestating sows (Table 6) or in lactating sows and their progeny (Table 7). Table 8 showed that the blood AA concentrations by dietary amino acid levels in gestating to lactating sows. Lysine, methionine and threonine concentraions of blood AA were linearly decreased as the dietary amino acid levels decreased (linear, P=0.08, P=0.05 and P=0.04,

respectively). Although the milk composition was not changed by dietary amino acid levels during lactation (Table 9).

DISCUSSION

In the current study, diets containing 110, 100, 90 and 80% of the NRC (2012) dietary amino acid requirement did not affect the body weight, backfat thickness or their changes in gestating to lactating sows. If the sows consuming small amounts of amino acids, the body weight loss is substantial, litter weight gain is reduced and subsequently reproductive function is compromised (King and Williams, 1984; King and Dunkin, 1986). In this study, there was no differences by experimental treatments in body changes and backfat thickness or their changes during the gestation and lactation period. These results indicated that 80% of the NRC (2012) dietary amino acid requirement is a considerable level to feed during gestation. The average daily feed intake (ADFI) in the present study was similar to those observed by Apple et al (2004) and Westermeier et al (1998), they reported that the supply of lysine, methionine, cysteine and threonine had no effect on the ADFI during lactation.

In the present study, the dietary amino acid levels in gestating sows did not significantly influence on reproductive performance during lactation. Some studies have resulted that intrauterine growth retardation (IUGR) is associated with impaired transport of basic, neutral and acidic AAs by the placenta (Regnault et al., 2005; Wu et al., 2008). Thus, maternal protein nutrition, which determines the AA availability to the conceptus (Wu et al., 1998a; 1998b), greatly affects embryonic and fetal survival in pigs (Pond et al., 1969; 1981). In our experiment, there was no difference in maternal protein intake among treatments, because the gestational diets were formulated with the same protein level. A number of studies have demonstrated that low dietary lysine intake during gestation affects the metabolic state, the secretion of LH and the weaning-to-estrus interval (King and Martin, 1989;

Tokach et al., 1992; Jones and Stahly, 1999a) and increases the mobilization of body protein (Jones and Stahly, 1999b) during lactation. Increasing the dietary lysine concentration above that required for maximal lactation performance in primiparous sows was found to shorten the weaning-to-estrus interval (Wilson et al., 1996). However, in this study, the WEI did not differ significantly among the treatments, indicating that the dietary amino acid was sufficient level.

Litter weight gain is an essential factor to consider when nutrient requirements are established, and correlates strongly with litter size (Auldist et al., 1998). As the litter size increases, the nutrient needs for the lactating mammary glands (Kim et al., 1999) and milk production increased, and tissue mobilization occurs if the dietary supply does not meet these nutrient needs (Kim and Easter, 2001). In the present study, the different dietary amino acid levels in gestating sows had effects on litter weight (quadratic, P=0.03), piglet weight (quadratic, P=0.02) and their changes (quadratic, P=0.03, P=0.02, respectively) during lactation. Analyzing the quadratic response, 93.7% of NRC (2012) AA requirement recorded the higher reproductive performance. Kim et al (2001) reported that ideal amino acid intake by primiparous sows during lactation improved litter and piglet weight gain. Zhang et al (2011) evaluated the effects of different lysine intake levels (0.46, 0.56, 0.65 or 0.74% lysine) from gestation until farrowing, and found that increasing dietary lysine concentrations improved the body condition of the sows at farrowing and increased the litter weight, in agreement with our results. However, Ji et al (2005) demonstrated that ideal amino acid intake by second and third parity sows did not affect the litter weight gain. More detailed studies are needed, because our study was designed with sows of parity 1 to 3.

It is well known that IgG offers newborn pigs an extended systemic protection, while IgA and IgM offer transient luminal protection (Curtis and Bourne, 1973). Furthermore, plasma IgG and IgA, which are widely used as indexes of hormonal immune parameters, are the major immunoglobulins protecting against pathogens in the extravascular compartment (Li et al., 2007). Different dietary amino acid levels did not affect the immune response in the gestation to lactating

sows or their progeny. In general, plasma urea N and creatinine are indicators of the dietary amino acid balance and muscle catabolism, respectively (Hanigan et al., 1991). Reduced blood urea nitrogen (BUN) level reflects more efficient use of dietary N (Figueroa et al., 2002; Owusu-Asiedu et al., 2003) and probably depends more on the amount and balance of AAs available systemically than on the feed intake. BUN varies based on the retention of nitrogen in the body (Whang and Easter, 2000), the availability of protein (Hong et al., 2016) and the excretion of nitrogen as urea (Han et al., 2001). Thus, an increase in the BUN concentration indicates that there are excessive levels of amino acids that have been metabolized inefficiently and are circulating in the blood before excretion (Hong et al., 2016). In our study, there were no differences on blood profiles according to the dietary amino acid levels during the whole experimental period in the sows or their piglets.

In this study, linear effects of different dietary amino acid levels on the serum concentrations of amino acids were detected on 110 day of gestation. The concentrations of amino acids in blood significantly decreased as the dietary amino acid levels was decreased. However, there were no significant differences during lactation, because all the sows were fed the same lactation diet. Amino acid utilization in the mammary gland is affected by the amino acid concentration in the blood and the efficiency of amino acid uptake into mammary cells (Hurley et al., 2000). Thus, amino acid excesses or imbalances during lactation could reduce the availability of amino acids for the mammary gland (Guan et al., 2004). Our results demonstrated that the experimental diet in the gestation period did not affect the lactating sows.

A recent study demonstrated that an improved dietary AA balance increased the N utilization efficiency for milk protein production (Huber et al., 2015). Grandhi (2002) demonstrated that modern genotype sows could produce higher amounts of milk than conventional sows and required higher dietary energy and amino acid levels. King (1987) and Yang et al (1989) indicated that sows mobilized fat and protein derived from body reserves to produce milk when dietary nutrients were insufficient, resulting in reduced rates of conception and embryo

survival. Jones and Stahly (1999a) reported that dietary amino acid restriction (0.34% vs 1.20% of lysine) during lactation increased the maternal mobilization of proteinaceous tissue and reduced the milk nutrient output. Some researchers have reported that litter weight gain correlated with the production and nutrient concentration of milk (Noblet and Etienne, 1987; King et al., 1993). The composition of milk may change to some degree during the lactation period, and it appears that a crude protein value of 14.5% is appropriate (Elliott et al., 1971). In this study, the dietary amino acid levels did not affect the milk composition in lactating sows because of the same crude protein level in experimental diets.

CONCLUSION

Consequently, this research recommended that the level of diet were 93.7% of NRC (2012) total AA requirement (lysine: 0.75%, methionine: 0.22% and threonine: 0.54%, respectively) in gestation diet.

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Table 1. Formulas and chemical compositions of the experimental diets in gestation and lactation

Ingredients, %	Treatment[1)]				Lactation
	Gestation				
	AA110	AA100	AA90	AA80	
Ground corn	71.12	71.03	70.80	70.56	67.77
SBM-46	10.75	11.14	11.57	11.94	13.66
Wheat	6.00	6.00	6.00	6.00	6.00
Wheat bran	6.00	6.00	6.00	6.00	6.00
Tallow	2.32	2.22	2.25	2.29	2.96
L-lysine-HCL, 78%	0.46	0.34	0.22	0.11	0.43
DL-methionine, 99%	0.04	0.02	0.00	0.00	0.03
L-threonine, 99%	0.19	0.13	0.06	0.00	0.13
MDCP	1.35	1.35	1.32	1.30	1.38
Limestone	1.17	1.17	1.18	1.20	1.04
Vit. Mix[2)]	0.10	0.10	0.10	0.10	0.10
Min. Mix[3)]	0.10	0.10	0.10	0.10	0.10
Choline chloride-50	0.10	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.30	0.30
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition					
ME, kcal/kg[4)]	3,265.21	3,265.11	3,265.01	3,265.35	3,300.12
Crude protein, %[5)]	12.73	13.11	12.89	13.11	13.52
Crude fat, %[5)]	3.82	3.94	4.11	4.03	4.01
Crude ash, %[5)]	3.43	4.01	4.28	4.19	3.02
Lysine, %[4)]	0.88	0.80	0.72	0.64	0.93
Methionine, %[4)]	0.25	0.23	0.21	0.18	0.25
Threonine, %[4)]	0.64	0.58	0.52	0.46	0.62
Ca, %[4)]	0.75	0.75	0.75	0.75	0.71
Total P, %[4)]	0.60	0.60	0.60	0.60	0.62

[1)]AA110: 110% of the NRC (2012) AA requirement, AA100: 100% of the NRC (2012) AA requirement, AA90: 90% of the NRC (2012) AA requirement, AA80: 80% of the NRC (2012) AA requirement.

[2)]Provided vitamins per kg of complete diets: vitamin A, 8,000 IU; vitamin D_3, 1,600 IU; vitamin E, 32 IU; d-biotin, 64g; riboflavin, 3.2mg; calcium pantothenic acid, 8mg; niacin, 16mg; vitamin B12, 12μg; vitamin K, 2.4mg.

[3)]Provided minerals per kg of complete diets: Se, 0.1mg; I, 0.3mg; Mn, 24.8mg; CU, 54.1mg; Fe, 127.3mg; Zn, 84.7mg; Co, 0.3mg.

[4)]Calculated value.

[3)]Analyzed value.

Table 2. Effect of dietary amino acid levels on body changes in gestating sows

Criteria	Treatment[1)]				SEM[2)]	P-value[3)]	
	AA110	AA100	AA90	AA80		Lin.	Quad.
No. of sows	15	15	15	15	-	-	-
Body weight, kg							
35 days	194.3	194.4	194.4	194.3	2.87	0.71	0.80
70 days	206.5	205.6	205.9	205.1	2.61	0.82	0.75
110 days	231.5	224.0	228.5	226.6	2.85	0.93	0.54
BW gain (35 – 110 days)	37.2	29.6	34.1	32.3	2.18	0.34	0.46
Backfat thickness, mm							
35 days	22.6	22.3	22.5	22.1	0.76	0.86	0.98
70 days	22.1	24.9	23.9	24.4	0.86	0.48	0.43
110 days	24.0	26.0	23.8	24.4	0.74	0.92	0.57
BF gain (35 – 110 days)	1.4	3.7	1.3	2.3	0.64	0.67	0.51

[1)]AA110: 110% of the NRC (2012) AA requirement, AA100: 100% of the NRC (2012) AA requirement, AA90: 90% of the NRC (2012) AA requirement, AA80: 80% of the NRC (2012) AA requirement.
[2)]Standard error of the mean.
[3)]Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 3. Effect of dietary amino acid levels on body changes in lactating sows

Criteria	Treatment[1)]				SEM[2)]	P-value[3)]	
	AA110	AA100	AA90	AA80		Lin.	Quad.
No. of sows	15	15	15	15	-	-	-
Body weight, kg							
24 hrs postpartum	206.5	207.7	208.7	204.7	2.43	0.87	0.28
21 d of lactation	198.3	199.1	195.9	196.6	3.16	0.76	0.83
BW change (1 - 21 days)	-8.2	-8.6	-12.8	-8.1	1.73	0.74	0.32
Back fat thickness, mm							
24 hrs postpartum	23.3	24.3	23.9	23.1	0.75	0.86	0.29
21 d of lactation	20.3	23.0	19.8	19.6	0.68	0.35	0.13
BF change (1 - 21 days)	-3.0	-1.3	-4.1	-3.5	0.51	0.32	0.61
WEI, days	5.2	5.1	5.6	5.7	0.13	0.14	0.92

[1)]AA110: 110% of the NRC (2012) AA requirement, AA100: 100% of the NRC (2012) AA requirement, AA90: 90% of the NRC (2012) AA requirement, AA80: 80% of the NRC (2012) AA requirement.
[2)]Standard error of the mean.
[3)]Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 4. Effect of dietary amino acid levels on reproductive performance in lactating sows

Criteria	Treatment[1)]				SEM[2)]	P-value[3)]	
	AA110	AA100	AA90	AA80		Lin.	Quad.
Reproductive performance							
Total born	12.7	11.8	12.5	13.2	0.37	0.51	0.25
No. of stillbirth	0.3	0.2	0.1	0.1	0.05	0.13	0.73
No. of mummy	0.2	0.3	0.3	0.0	0.08	0.38	0.27
No. born alive	12.0	11.3	12.1	13.1	0.36	0.19	0.21
After cross-fostering	12.0	12.0	12.0	12.0	-	-	-
No. of weaning pig	11.5	11.4	11.7	11.4	0.12	0.91	0.64
ADFI, g	5,298	5,212	5,413	5,657	179.9	0.48	0.85

[1)]AA110: 110% of the NRC (2012) AA requirement, AA100: 100% of the NRC (2012) AA requirement, AA90: 90% of the NRC (2012) AA requirement, AA80: 80% of the NRC (2012) AA requirement.
[2)]Standard error of the mean.
[3)]Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 5. Effect of dietary amino acid levels on litter performance in lactating sows

Criteria, g	Treatment[1)]				SEM[2)]	P-value[3)]	
	AA110	AA100	AA90	AA80		Lin.	Quad.
Litter weight							
Total litter weight	17,273	17,004	17,897	18,532	416.9	0.23	0.62
Litter birth weight	17,224	17,001	17,300	17,861	387.7	0.33	0.90
After cross-fostering	17,243	17,656	17,817	17,793	362.4	0.65	0.69
21 day of lactation	62,623	66,702	68,199	63,881	1,384.7	0.44	0.03
Litter weight gain	45,381	49,046	50,382	46,088	1,163.2	0.54	0.02
Piglet weight							
Birth weight	1,348	1,438	1,398	1,350	27.7	0.94	0.14
After cross-fostering	1,442	1,471	1,484	1,483	29.1	0.65	0.69
21 day of lactation	5,484	5,788	5,819	5,581	95.3	0.34	0.03
Piglet weight gain	4,042	4,316	4,334	4,098	76.9	0.50	0.02

[1)]AA110: 110% of the NRC (2012) AA requirement, AA100: 100% of the NRC (2012) AA requirement, AA90: 90% of the NRC (2012) AA requirement, AA80: 80% of the NRC (2012) AA requirement.
[2)]Standard error of the mean.
[3)]Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 6. Effect of dietary amino acid levels on blood profiles in gestating sows

Criteria, mg/dL	Treatment[1)]				SEM[2)]	P-value[3)]	
	AA110	AA100	AA90	AA80		Lin.	Quad.
Gestating sows	4	4	4	4	-	-	-
IgG							
35 days	---------- 419.7 ----------				66.73	-	-
70 days	467.8	412.3	432.5	410.0	12.37	0.14	0.38
110 days	350.8	317.0	331.3	308.0	12.24	0.40	0.86
BUN							
35 days	---------- 8.7 ----------				1.71	-	-
70 days	9.6	7.1	11.1	7.6	0.47	0.31	0.37
110 days	6.9	7.0	7.5	7.9	0.41	0.26	0.22
Creatinine							
35 days	---------- 1.7 ----------				0.39	-	-
70 days	1.7	1.5	1.6	1.5	0.04	0.30	0.67
110 days	2.3	2.0	2.2	2.3	0.08	0.79	0.41

[1)]AA110: 110% of the NRC (2012) AA requirement, AA100: 100% of the NRC (2012) AA requirement, AA90: 90% of the NRC (2012) AA requirement, AA80: 80% of the NRC (2012) AA requirement.
[2)]Standard error of the mean.
[3)]Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 7. Effect of dietary amino acid levels on blood profiles in lactating sows and their progeny

Criteria, mg/dL	Treatment[1)]				SEM[2)]	P-value[3)]	
	AA110	AA100	AA90	AA80		Lin.	Quad.
Lactating sows	4	4	4	4	-	-	-
IgG							
24 hrs postpartum	344.3	298.7	313.0	317.0	10.18	0.54	0.33
21 d of lactation	390.0	354.0	356.7	386.0	9.94	0.89	0.30
BUN							
24 hrs postpartum	7.0	7.3	7.9	7.2	0.56	0.97	0.66
21 d of lactation	10.0	8.3	8.8	8.6	0.77	0.67	0.69
Creatinine							
24 hrs postpartum	2.3	2.2	2.3	2.1	0.13	0.72	0.99
21 d of lactation	1.8	1.9	2.0	1.6	0.10	0.77	0.28
Piglets	4	4	4	4	-	-	-
IgG							
24 hrs postpartum	503.7	593.7	553.3	568.0	50.00	0.80	0.78
21 d of lactation	219.7	228.0	202.0	240.3	7.79	0.58	0.32
BUN							
24 hrs postpartum	11.2	10.9	12.5	10.9	1.08	0.97	0.82
21 d of lactation	6.9	8.8	6.6	6.4	0.84	0.67	0.49
Creatinine							
24 hrs postpartum	0.6	0.6	0.8	0.6	0.05	0.60	0.68
21 d of lactation	0.8	0.7	0.7	0.6	0.07	0.61	0.91

[1)]AA110: 110% of the NRC (2012) AA requirement, AA100: 100% of the NRC (2012) AA requirement, AA90: 90% of the NRC
(2012) AA requirement, AA80: 80% of the NRC (2012) AA requirement.
[2)]Standard error of the mean.
[3)]Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 8. Effect of dietary amino acid levels on blood amino acid concentrations in sows

Criteria, μmol/L	Treatment[1)]				SEM[2)]	P-value[3)]	
	AA110	AA100	AA90	AA80		Lin.	Quad.
Gestating sows	4	4	4	4	-	-	-
35 days							
Lysine	---------- 466.5----------				45.18	-	-
Methionine	---------- 59.0 ----------				12.68	-	-
Threonine	---------- 146.8 ----------				36.21	-	-
110 days							
Lysine	349.5	267.7	243.0	247.0	16.47	0.08	0.27
Methionine	62.0	43.0	42.0	42.7	2.52	0.05	0.12
Threonine	226.0	187.0	170.0	158.7	9.65	0.04	0.40
Lactating sows	4	4	4	4	-	-	-
24 hrs postpartum							
Lysine	419.0	379.0	237.0	275.5	34.55	0.60	0.81
Methionine	54.7	64.7	47.7	51.7	4.34	0.56	0.76
Threonine	295.7	315.3	232.0	275.5	14.90	0.26	0.72
21 d of lactation							
Lysine	436.3	296.0	191.0	208.5	57.75	0.29	0.45
Methionine	58.0	51.5	35.5	31.0	5.50	0.32	0.95
Threonine	239.5	165.5	136.5	164.7	20.31	0.32	0.38

[1)]AA110: 110% of the NRC (2012) AA requirement, AA100: 100% of the NRC (2012) AA requirement, AA90: 90% of the NRC
(2012) AA requirement, AA80: 80% of the NRC (2012) AA requirement.
[2)]Standard error of the mean.
[3)]Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 9. Effect of dietary amino acid levels on milk composition during lactation

Criteria, %	Treatment[1)]				SEM[2)]	P-value[3)]	
	AA110	AA100	AA90	AA80		Lin.	Quad.
Fat							
24 hrs postpartum	5.47	6.31	8.09	8.06	0.64	0.17	0.76
21 d of lactation	7.19	11.94	6.76	6.11	1.17	0.42	0.26
Lactose							
24 hrs postpartum	4.63	4.61	4.49	4.54	0.11	0.77	0.91
21 d of lactation	6.35	5.41	6.44	6.40	0.24	0.59	0.38
Protein							
24 hrs postpartum	7.63	7.21	7.05	8.03	0.50	0.86	0.61
21 d of lactation	4.55	6.77	4.52	4.59	0.48	0.60	0.26
Solid not fat							
24 hrs postpartum	12.58	12.12	11.75	12.80	0.44	0.95	0.51
21 d of lactation	10.87	12.12	10.89	11.11	0.24	0.79	0.26
Total solid							
24 hrs postpartum	19.94	20.26	21.97	23.16	0.78	0.18	0.80
21 d of lactation	19.33	26.82	18.83	18.39	1.77	0.49	0.27
Casein							
24 hrs postpartum	5.92	5.60	5.47	6.25	0.36	0.84	0.57
21 d of lactation	4.22	5.73	4.29	4.23	0.30	0.57	0.19

[1)]AA110: 110% of the NRC (2012) AA requirement, AA100: 100% of the NRC (2012) AA requirement, AA90: 90% of the NRC
(2012) AA requirement, AA80: 80% of the NRC (2012) AA requirement.
[2)]Standard error of the mean.
[3)]Abbreviation: Lin. (linear) and Quad. (quadratic).

Chapter V: Effect of Dietary Valine:Lysine Ratios on Body Changes, Reproductive Performance, Blood Profiles and Milk Composition in Lactating Sows

ABSTRACT: This study was conducted to evaluate the effect of dietary valine:lysine ratios on body changes, reproductive performance, blood profiles and milk composition in lactating sows. A total of 40 (2 to 4 mixed-parity; 3.0) sows (F1, Yorkshire × Landrace; Darby, Korea) with an initial mean body weight of 236.0 ± 3.06 kg were allotted to one of four treatments in a completely randomized design (CRD) with 10 replicates. Each experimental diet contained different total valine (Val) : lysine (Lys) ratios, and treatments were 1) V100: Val(0.90%) : Lys(0.90%) ratio; 2) V110: Val (0.99%) : Lys (0.90%) ratio; 3) V120: Val (1.08%) : Lys (0.90%) ratio; or 4) V130: Val (1.17%) : Lys (0.90%) ratio. The different dietary Val:Lys ratios had no significant differences in body weight, backfat thickness or their changes during lactation period. The number of total born, stillbirth, mummy and born alive of reproductive performance were not affected by the dietary Val:Lys ratios in lactating sows. However, the number of weaning pigs tended to be higher as the dietary Val:Lys ratios increased (linear, P=0.07). V130 treatment showed the highest number of weaning pigs (11.6) among the treatments. Average daily feed intake of lactating sows was not affected by dietary Val:Lys ratios. The IgG, BUN, creatinine, blood AA concentrations and milk composition in lactating sows and their progeny, were not affected by the dietary Val:Lys ratios. Consequently, these results demonstrated that the optimum total valine to lysine ratio should be Valine(1.17%):Lysine(0.90%) for higher reproductive performance of lactating sows.

Key words: Valine:lysine, Body changes, Reproductive performance, Blood profiles, Milk composition, Lactating sow.

INTRODUCTION

Recently, dietary valine has been recognized as more important for hyper-prolific sows. Valine is well known as the fourth or fifth essential amino acid in swine body. It is classified as a second limiting amino acid especially in lactation period (Richert et al., 1997b). Moreover, valine is an indispensable branched chain amino acid (BCAA) which cannot be synthesized by the animal, therefore it must be supplied through the feed (Soumeh et al., 2015). Also, the valine has a positive effect on the litter size, milk composition and body protein synthesis in pig (Richert et al., 1997a). In the EU, the average number of live piglets per litter is more than 13 (BPEX, 2014). Accordingly, dietary valine has been increasing rapidly as the improving average litter size. Therefore, the importance of dietary valine has been re-evaluated especially for hyper-prolific sows.

The standard requirements for dietary each lysine and valine in the lactating sow diet are 0.90 and 0.78%, respectively. This recommendation is equivalent to a standard ileal digestible (SID) in Val:Lys ratios of 0.85:1 (NRC, 2012). Richert et al (1996) reported a linear increase in litter growth as the Val:Lys ratios was raised from 0.83 to 1.28:1 in a 0.90% lysine diet. However, Southern et al (2000) reported no improvement in sow productivity when the Val:Lys ratios was increased from 0.85 to 0.94:1. Kim et al (2009) reported that the valine content of the mammary gland increased by 91.3% when the number of pigs in sucking sow doubled from 6 to 12. Carter et al (2000) indicated that there was no benefit of elevated dietary valine for lactating sows nursing more than 10 piglets and consuming a corn-soybean meal diet containing 0.90% lysine and 0.80% valine. Lowering the dietary Val:Lys ratios from 72% to 59% reduced the daily gain from 457 to 361 g per day in weaning pigs. In a recent study, dietary SID Val:Lys ratios of 88 to 113% were found to be optimal for minimizing backfat loss and maximizing the piglet growth rate, respectively (Xu et al., 2017). Otherwise, increasing the Val:Lys ratios (0.68:1 to 1.1:1) of the diet did not improve sow or litter performance (Craig et al., 2016).

Although there have been many studies of the dietary Val:Lys ratios in sows, it is difficult to determine the adequate ratio. In addition, the mode of action by which valine improves sow productivity is not well understood and needs to be evaluated further (Strathe et al., 2016). Therefore, this study was carried out to investigate the effect of the dietary Val:Lys ratios on body changes, reproductive performance, blood profiles and milk composition in lactating sows.

MATERIALS AND METHODS

Animals and housing

All experimental procedures involving animals were conducted in accordance with the Animal Experimental Guidelines provided by the Seoul National University Institutional Animal Care and Use Committee (SNUIACUC; SNU-180321-3).

Atotal of 40 sows (F1, Yorkshire × Landrace; Darby, Korea) with an initial mean body weight of 236.0 ± 3.06 kg and an average parity of 3.0 were used for a trial at a research farm at Seoul National University (Eumseong-gun, Chungcheongbuk-do, Korea). Sows were allotted to each treatment based on body weight and backfat thickness in a completely randomized design (CRD) with 10 replicates. 110 day of gestation, the sows were moved into a farrowing barn and placed in individual farrowing crates (2.4 × 1.8 m). Each farrowing crate was equipped with a feeder, water cup and baby house with a heating lamp for the piglets. The room temperature was maintained at an average of 20 ± 3.2℃ before parturition and 28 ± 2.4℃ postpartum for the lactating sows. However, this experiment was conducted in summer season (2016. 07 ~ 2016. 08), therefore the room temperature was increased at an average of 28 ± 2.0℃ during lactation. The baby house was kept at 32 ± 2.4℃ under the heating lamp.

Experimental diets and treatments

The experimental diets for the lactating sows contained different dietary valine:lysine ratios, and the treatments were 1) V100: 1:1, 2) V110: 1.1:1, 3) V120: 1.2:1 and 4) V130: 1.3:1. All the diets were formulated to be isocaloric (3,300 kcal of ME/kg) with equal amounts of crude protein (12.56%) and 0.90% lysine, and contained vitamins, minerals, calcium, total phosphorus and limiting AAs (methionine and threonine) in amounts exceeding the recommendations (NRC, 2012). During gestation period, all the sows were fed same commercial gestation diet. Sows at second parity were fed 2.2 kg/d, while those at third and fourth parities were fed 2.4 kg/d before 5 days of parturition. Also, the gestating sows were fed once a day (08:00), and the feed was reduced by 0.2 kg/d for 5 days before the due date of parturition. Gestating sows were housed in individual gestation stalls (2.20 × 0.65 m) until 110 days of gestation. After 110 day of gestation, the sows were washed and moved into farrowing crates (2.40 × 1.80 m). The experimental diets were given to the sows from the 110 day of pregnancy through the 28 day of lactation. After farrowing, the lactation diet was increased gradually from 1.0 to 5.0 kg/d over 5 days, and the sows were fed the diet *ad libitum* until weaning. Weaning was performed at approximately 28 days. The formulas and chemical compositions of the experimental diets are presented in Table 1.

Sample collection and blood analysis

The body weight and backfat thickness (P_2 position) in sows and total number of piglets born were measured at 24 hour postpartum and on 21 day of lactation. Body weight was measured on an electric scale (CAS Co. Ltd., Yangju-si, Gyeonggi-do, Korea) and backfat thickness was measured with an ultrasound lean meter (Anyscan BF, Songkang GLC Co. LTD, Seongnam-si, Gyeonggi-do, Korea). The weaning to estrus interval (WEI) of the sows was calculated from weaning to first estrus period. The voluntary feed intake of the lactating sows was determined from records of the feed supply and wastage during the lactation period. Within 24 hours postpartum, the numbers of total born, live born, stillbirth and mummy were

recorded, along with the weight of the piglets (CAS Co. Ltd., Yangju-si, Gyeonggi-do, Korea). Individual litter size and piglet weight of lactating sows were recorded at 24 hour postpartum and on 21 day of lactation.

Blood sample (n = 4, for each treatment; based on the nearest of mean BW) were taken from the jugular vein for measuring BUN, IgG and creatinine concentrations when the body weights were recorded. Collected blood samples were centrifuged for 15 min at 3,000 rpm on 4℃ (Eppendorf centrifuge 5810R, Germany). The sera were carefully transferred to 1.5 ml plastic tubes and stored at -20℃ until later analysis. All the blood concentrations were analyzed using a blood analyzer (Modular analytics, P, Roche, Germany).

Amino acid analysis

Amino acid analysis of blood concentration was measured on 110 day of gestation and at 24 hours postpartum, on 21 day of lactation. Blood samples (n = 4, for each treatment; based on the nearest of mean BW) were collected and stored as described above. Green Cross Lab Cell (Sungnam-si, Gyeonggi-do, Korea) analyzed the blood samples. Physiological samples were analyzed with a TRAQ™ Reagents Application Kit for Use with LC/MS/MS Systems. A 3200 Q TRAP (AB SCIEX, U.S.A) analyzer was used for liquid chromatography tandem mass spectrometry.

Milk composition

Colostrum at 24 hours postpartum and milk on 21 day of lactation were collected from the second and third teats of sows (n = 4, for each treatment; based on the nearest of mean BW) that had been injected with 5 IU of oxytocin (Komi oxytocin inj., Komi Pharm International Co., Ltd., Siheung-si, Gyeonggi-do, Korea) in the ear vein. The collected milk samples were stored at -20℃ in a freezer until later analysis. Proximate analysis of the colostrum and milk was conducted at the National Institute of Animal Science (NIAS) (Wanju-gun, Jeollanbuk-do, Korea) by means of Milkoscan FT 120 (FOSS, Hillerod, Denmark).

Statistical analysis

All the collected data were subjected to least squares mean comparisons and were evaluated with the General Linear Model (GLM) procedure of SAS (SAS Institute, 2004). Individual sows and their litters were used as the experimental unit and were analyzed by two-way ANOVA. Orthogonal polynomial contrasts were used to detect linear and quadratic responses to the valine:lysine ratios when a significant effect of valine was detected. Differences were declared significant at $P<0.05$ or highly significant at $P<0.01$, and tendencies for all analyses were determined at $0.05 \geq P<0.10$.

RESULTS

Effect of dietary Val:Lys ratios did not affected on body weight, backfat thickness or their changes and weaning to estrus interval in lactating sows (Table 2). The reproductive performance did not differ significantly among the treatments (Table 3). However, the number of weaning pigs increasing linearly as increasing dietary Val:Lys ratios (linear, P=0.07). V130 resulted in an average of 11.6 weaning pigs, which was significantly higher than other treatments. Average daily feed intake was not affected by the dietary Val:Lys ratios. The litter performance of sows was not affected as dietary Val:Lys ratios (Table 4). IgG, BUN and creatinine of blood profiles were not significantly influenced by the dietary Val:Lys ratios in lactating sows and their progeny (Table 5). There was no significant variation in lysine, threonine, leucine, isoleucine and valine concentrations in blood on lactating sows and their progeny (Table 6). Milk composition did not change significantly as dietary Val:Lys ratios increased (Table 7).

DISCUSSION

Richert et al (1997a) reported that increasing the dietary valine from 0.70 to 1.07% (Val:Lys ratios from 0.80 to 1.25) did not impact the survival rate, sow performance or litter performance. Furthermore, recent studies have demonstrated that the body shape did not differ among treatments of lactating sows treated with different dietary valine ratio (0.68 to 1.10:1, Craig et al., 2016; 0.63 to 1.23:1, Xu et al., 2017). There were no differences in sow weight loss or the subsequent number of total birth across dietary treatments with different SID Val:Lys ratios (0.50 to 1.0:1, Boessen et al., 2018). The results of our research are in agreement with the findings of these studies, and also correspond with the results of Gaines et al (2006), who found no difference in piglet growth or changes in sow body condition when the total dietary Val:Lys ratios was 0.73 to 1.25:1 in sows nursing 10 piglets. A major difference between the present research and previous studies that have investigated the dietary Val:Lys ratios, besides the high production level of the sows, was the substantial loss of BW (23.2 to 29.3 kg), but in this results were similar to those of a study on random sows in 8 Danish herds (Alban et al., 2013).

The effect of dietary Val:Lys ratios for lactating sows on litter growth and sow body mobilization are equivocal (Richert et al., 1996; Gaines et al., 2006). In a recent study, valine addition trials involving more than 13 piglets also indicated a need for more valine than lysine (Craig et al., 2016). The results of our experiment are in agreement with their studies. In the present study, the average number of total born was 13.8, and the different dietary Val:Lys ratios had no negative effect on the number of total born, stillbirth, mummy and live born. Contrasting results were obtained by Richert et al (1997b), who reported that increasing dietary valine from 44.7 to 64.7 g/d (Val:Lys ratios of 0.78 to 1.15%) increased the litter weight (d 14, 46.5 vs. 48.0 kg; weaning, 62.0 vs. 64.1 kg) and litter weight gain (d 14, 29.8 vs. 31.0 kg; weaning, 45.4 vs. 47.1 kg) at d 14 and weaning. Average feed intake was lower than previous study, because of summer season, and it comes to low valine intake (38.9 to 47.65 g/d, Val:Lys ratios of 1:1 to 1.3:1) of this study. However, the

number of weaning pigs was significantly increased as the dietary Val:Lys ratios increased (linear, P=0.07). These results demonstrated that a definite ratio of AAs may be needed by the mammary gland for milk synthesis and/or tissue maintenance. Paulicks et al (2003) reported that a valine intake of at least 6.5 g/kg (5.5 g/kg of apparent ileal digestible valine) tended to increase for sows than a very high dietary valine supplies of 14.5 g/kg. Strathe et al (2016) also found a small decrease in the feed intake of lactating sows as the dietary valine content increased. There are no further experimental results available on the effects of very high valine concentrations on the feed intake and performance of lactating sows. Therefore, lower feed intake lead to no detrimental effect on sow performance, despite of dietary high valine:lysine ratio in lactation.

Carter et al (2000) reported that the return-to-estrus interval averaged 7.24 day and was not affected by dietary valine concentrations from 0.76 to 1.22:1 (P>0.10). Yang et al (2000) reported that dietary lysine (0.4 to 1.6%) did not influence the weaning to pro-estrus interval (mean of 4.7 day). In this study, the dietary Val:Lys ratios had no effect on the weaning days to estrus interval (WEI), these results were in accordance with previous studies.

Based on litter growth, Rousselow and Speer (1980) determined the valine requirement of the lactating sow to be 0.68% in a diet containing 0.58% of lysine (117% Val:Lys ratios). The results of another study indicated that a dietary valine concentration of at least 6.5 g/kg was necessary for lactating sows to avoid severe reductions in their milk yield and the growth performance of their piglets (Paulicks et al., 2003). Our experimental diet was formulated with at least 9.0 g/kg of valine; thus, there was no negative effect on litter performance of sows. Furthermore, Johnston et al (1993), Monegue et al (1993) and Richert et al (1997b) reported that increased litter or weaning pig weights when lysine intake increased from approximately 35 to 55 g/d. The lysine intake in our experiment (35.6 to 38.9 g/d) was corresponded with those previous studies. In this situation, the number of weaning pigs was tend to be higher as dietary Val:Lys increased (linear, P=0.07). These findings may improve that the valine requirement of hyper-prolific sows for

maximum pig growth is at least 130% of the dietary Val:Lys ratios requirement with 0.90% of lysine.

The AAs absorbed from the small intestine or released from body tissues enter the blood as free AAs. Therefore, the concentrations of blood free AAs may provide useful information on AA metabolism, and this information can be used to assess whole-body protein turn-over, independently assess AA requirements and evaluate dietary protein quality (Abumrad and Miller, 1983). Rousselow and Speer (1980) reported no changes in blood urea nitrogen (BUN) with increasing dietary valine. One of the constituents of protein, the valine, is not likely to be synthesized in the body, so synthetic valine should be supplied to the diet. If the supplied amount is low, immunity of sows may deteriorate due to damage to cellular immune functions. The optimum amount of total valine is considered to be 0.90% or more (Paulicks et al., 2003), based on the minimum amount of lysine and the fact that there are no negative effects on blood components such as IgG in this level. The relationship between valine and other AAs such as lysine or the other BCAAs seems to be important. Interestingly, when IgG was transferred from sows to piglets, the immunity of the piglets was found to be about 1.5 times higher than that of piglets. In this study was in total agreement with these previous studies. Serum creatinine concentrations increased numerically, matching the response of BUN. This may indicate that the muscle catabolism and turnover rate increases to meet the increased need for milk production (based on the number of weaned pigs) of sows fed a greater amount of valine (Richert et al., 1996). However, increasing Val:Lys ratios in lactating sows did not affect on IgG, BUN and creatinine concentrations of the sows or their progeny. AA utilization in the mammary gland is affected by the AA concentration in blood and the efficiency of AA uptake into mammary cells (Hurley et al., 2000). AA excess or imbalance during lactation could reduce AA availability in the mammary gland (Guan et al., 2004).

Dietary Val:Lys ratios has been reported to affect the milk concentration of valine without influencing litter growth (Strathe et al., 2015). No significant increases in milk AA concentrations were found when the total dietary Val:Lys

ratios was raised from 0.64:1 to 0.99:1. Paulicks et al (2003) reported that piglet growth, milk yield and sow body weight were affected when the total Val:Lys ratios was increased from 0.45:1 to 0.55:1. However, there was no variation when the ratio was further increased from 0.64:1 to 1.44:1. Another study indicated that increasing the dietary Val:Lys ratios altered the backfat and also reduced the milk fat (Richert et al., 1996). However, AA concentrations in milk decreased when the total Val:Lys ratios was lowered to 0.54:1 or 0.45:1 (Roth-Maier et al., 2004). The dietary Val:Lys ratios in our study (1:0 to 1.3:1) were higher than those of the previous studies, because we expected the maximum growth performance and litter size of the piglets in the lactation period when the sows were fed a diet containing at least 0.90% of total valine. Moser et al (2000) found no effect of the valine level on milk fat. It is known that valine is used by the mammary gland for metabolic processes other than protein synthesis. Therefore, oversupplied valine may up-regulate some fat synthesis mechanism. Although, milk composition was not affected by the dietary Val:Lys ratios in this study.

CONCLUSION

Consequently, this study recommended that of optimum total valine to lysine ratio should be 1.3:1 (1.17% of valine to 0.90% of lysine) in lactation period.

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Table 1. Formulas and chemical compositions of the experimental diets in lactation[1)]

Ingredients, %	Treatment[2)]			
	V100	V110	V120	V130
Ground corn	69.61	69.72	69.86	70.00
SBM-46	11.80	11.63	11.44	11.22
Wheat	6.00	6.00	6.00	6.00
Wheat bran	6.00	6.00	6.00	6.00
Tallow	2.72	2.68	2.63	2.59
L-lysine-HCL, 78%	0.45	0.46	0.46	0.47
DL-methionine, 99%	0.03	0.03	0.03	0.03
L-threonine, 99%	0.14	0.14	0.14	0.15
L-valine, 99%	0.34	0.43	0.53	0.63
MDCP	1.34	1.34	1.34	1.34
Limestone	0.97	0.97	0.97	0.97
Vit. Mix[3)]	0.10	0.10	0.10	0.10
Min. Mix[4)]	0.10	0.10	0.10	0.10
Choline chloride-50	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.30
Total	100.00	100.00	100.00	100.00
Chemical composition				
ME, kcal/kg[5)]	3,300.28	3,300.42	3,300.19	3,300.25
Crude protein, %[6)]	12.56	12.85	12.95	12.94
Crude fat, %[6)]	3.24	3.45	3.17	3.96
Crude ash, %[6)]	1.98	2.12	2.43	2.39
Lysine, %[5)]	0.90	0.90	0.90	0.90
Methionine, %[5)]	0.24	0.24	0.24	0.24
Threonine, %[5)]	0.60	0.60	0.60	0.60
Ca, %[5)]	0.90	0.99	1.08	1.17
Total P, %[5)]	0.60	0.60	0.60	0.60

[1)]Diets were fed to sows from d 5 antepartum to d 21 postpartum.
[2)]V100: Val:Lys ratio, 1:1; V110: Val:Lys ratio, 1.1:1; V120: Val:Lys ratio, 1.2:1; V130: Val:Lys ratio, 1.3:1 (total lysine 0.90%).
[3)]Provided vitamins per kg of complete diets: vitamin A, 8,000 IU; vitamin D_3, 1,600 IU; vitamin E, 32 IU; d-biotin, 64g; riboflavin, 3.2mg; calcium pantothenic acid, 8mg; niacin, 16mg; vitamin B12, 12μg; vitamin K, 2.4mg.
[4)]Provided minerals per kg of complete diets: Se, 0.1mg; I, 0.3mg; Mn, 24.8mg; CU, 54.1mg; Fe, 127.3mg; Zn, 84.7mg; Co, 0.3mg.
[5)]Calculated value.
[6)]Analyzed value.

Table 2. Effect of dietary Val:Lys ratios on body changes in lactating sows

Criteria	Treatment[1)]				SEM[2)]	P-value[3)]	
	V100	V110	V120	V130		Lin.	Quad.
No. of sows	10	10	10	10	-	-	-
Body weight, kg							
24 hrs postpartum	235.7	234.1	238.8	235.3	3.06	0.80	0.91
21 d of lactation	212.5	205.2	209.5	209.9	3.09	0.99	0.44
BW change (1 - 21 days)	-23.2	-28.9	-29.3	-25.4	1.38	0.41	0.32
Back fat thickness, mm							
24 hrs postpartum	23.5	22.8	23.5	23.0	0.62	0.91	0.76
21 d of lactation	22.8	20.3	23.1	20.4	0.64	0.43	0.83
BF change (1 - 21 days)	-0.7	-2.5	-0.4	-2.6	0.29	0.51	0.90
WEI, days	3.6	3.9	4.0	3.8	0.17	0.68	0.41

[1)]V100: Val:Lys ratio, 1:1; V110: Val:Lys ratio, 1.1:1; V120: Val:Lys ratio, 1.2:1; V130: Val:Lys ratio, 1.3:1 (total lysine 0.90%).
[2)]Standard error of the mean.
[3)]Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 3. Effect of dietary Val:Lys ratios on reproductive performance in lactating sows

Criteria	Treatment[1)]				SEM[2)]	P-value[3)]	
	V100	V110	V120	V130		Lin.	Quad.
Reproductive performance							
Total born	13.9	13.9	13.8	13.8	0.42	0.97	0.63
No. of stillbirth	0.3	0.2	0.3	0.2	0.09	1.00	0.97
No. of mummy	0.1	0.4	0.2	0.4	0.08	0.55	0.62
No. of born alive	13.5	13.3	13.3	13.2	0.38	0.86	0.33
After cross-fostering	12.0	12.0	12.0	12.0	-	-	-
No. of weaning pig	10.8	10.9	11.5	11.6	0.16	0.07	0.83
ADFI, g	4,326	4,216	3,955	4,070	146.0	0.40	0.64

[1)]V100: Val:Lys ratio, 1:1; V110: Val:Lys ratio, 1.1:1; V120: Val:Lys ratio, 1.2:1; V130: Val:Lys ratio, 1.3:1 (total lysine 0.90%).
[2)]Standard error of the mean.
[3)]Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 4. Effect of dietary Val:Lys ratios on litter performance in lactating sows

Criteria, g	Treatment[1)]				SEM[2)]	P-value[3)]	
	V100	V110	V120	V130		Lin.	Quad.
Litter weight							
Total litter weight	21,042	21,081	20,658	21,042	476.9	0.91	0.40
Litter birth weight	19,988	19,452	19,016	19,209	485.0	0.27	0.28
After cross-fostering	19,367	19,447	19,222	19,221	353.5	0.94	0.61
21 day of lactation	55,675	55,640	57,631	58,530	1,487.3	0.51	0.94
Litter weight gain	36,307	36,194	38,208	39,308	1,405.6	0.49	0.85
Piglet weight							
Birth weight	1,467	1,479	1,456	1,426	33.4	0.34	0.44
After cross-fostering	1,614	1,621	1,602	1,602	29.5	0.94	0.64
21 day of lactation	5,165	5,059	4,989	5,065	96.9	0.65	0.73
Piglet weight gain	3,551	3,439	3,370	3,464	89.3	0.64	0.61

[1)]V100: Val:Lys ratio, 1:1; V110: Val:Lys ratio, 1.1:1; V120: Val:Lys ratio, 1.2:1; V130: Val:Lys ratio, 1.3:1 (total lysine 0.90%).
[2)]Standard error of the mean.
[3)]Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 5. Effect of dietary Val:Lys ratios on blood profiles in lactating sows and their progeny

Criteria, mg/dL	Treatment[1)]				SEM[2)]	P-value[3)]	
	V100	V110	V120	V130		Lin.	Quad.
Lactating sows	4	4	4	4	-	-	-
IgG							
24 hrs postpartum	---------- 353.7 ----------				19.22	-	-
21 d of lactation	409.3	437.3	478.7	426.0	12.45	0.27	0.24
BUN							
24 hrs postpartum	---------- 11.9 ----------				1.84	-	-
21 d of lactation	8.8	8.9	10.2	11.5	0.64	0.26	0.85
Creatinine							
24 hrs postpartum	---------- 2.6 ----------				0.70	-	-
21 d of lactation	2.8	2.4	3.0	3.3	0.12	0.18	0.11
Piglets	4	4	4	4	-	-	-
IgG							
24 hrs postpartum	---------- 531.0 ----------				23.92	-	-
21 d of lactation	294.3	229.7	316.7	297.7	23.04	0.69	0.67
BUN							
24 hrs postpartum	---------- 14.0 ----------				2.40	-	-
21 d of lactation	7.7	4.2	8.6	3.8	0.88	0.26	0.64
Creatinine							
24 hrs postpartum	---------- 0.7 ----------				0.37	-	-
21 d of lactation	0.9	0.9	0.9	0.9	0.03	0.57	0.84

[1)]V100: Val:Lys ratio, 1:1; V110: Val:Lys ratio, 1.1:1; V120: Val:Lys ratio, 1.2:1; V130: Val:Lys ratio, 1.3:1 (total lysine 0.90%).
[2)]Standard error of the mean.
[3)]Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 6. Effect of dietary Val:Lys ratios on blood amino acid concentrations in lactating sows and their progeny

Criteria, μmol/L	Treatment[1)]				SEM[2)]	P-value[3)]	
	V100	V110	V120	V130		Lin.	Quad.
Lactating sows	4	4	4	4	-	-	-
24 hrs postpartum							
Lysine	---------- 301.5 ----------				57.35	-	-
Threonine	---------- 305.8 ----------				17.15	-	-
Leucine	---------- 195.5 ----------				16.34	-	-
Isoleucine	---------- 125.8 ----------				12.67	-	-
Valine	---------- 561.8 ----------				131.93	-	-
21 d of lactation							
Lysine	160.0	191.7	226.7	176.0	17.38	0.67	0.36
Threonine	126.3	97.0	150.0	145.7	13.99	0.39	0.66
Leucine	133.3	141.0	218.7	129.7	17.44	0.66	0.19
Isoleucine	68.7	70.0	63.0	66.7	7.38	0.53	0.14
Valine	454.3	454.3	457.7	469.0	23.38	0.44	0.58
Piglets	4	4	4	4	-	-	-
24 hrs postpartum							
Lysine	---------- 357.8 ----------				68.43	-	-
Threonine	---------- 134.5 ----------				31.70	-	-
Leucine	---------- 225.0 ----------				41.32	-	-
Isoleucine	---------- 45.8 ----------				10.43	-	-
Valine	---------- 469.5 ----------				68.95	-	-
21 d of lactation							
Lysine	209.5	197.5	175.7	167.3	17.38	0.67	0.36
Threonine	145.0	187.3	132.3	168.0	17.18	0.93	0.93
Leucine	164.3	192.0	136.0	143.3	17.44	0.66	0.19
Isoleucine	103.3	92.7	116.0	90.3	4.47	0.65	0.34
Valine	245.7	249.0	242.0	225.0	11.43	0.61	0.74

[1)]V100: Val:Lys ratio, 1:1; V110: Val:Lys ratio, 1.1:1; V120: Val:Lys ratio, 1.2:1; V130: Val:Lys ratio, 1.3:1 (total lysine 0.90%).
[2)]Standard error of the mean.
[3)]Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 7. Effect of dietary Val:Lys ratios on milk composition during lactation

Criteria, %	Treatment[1)]				SEM[2)]	P-value[3)]	
	V100	V110	V120	V130		Lin.	Quad.
Fat							
24 hrs postpartum	---------- 10.62 ----------				2.515	-	-
21 d of lactation	5.25	6.12	8.26	6.45	1.265	0.12	0.17
Lactose							
24 hrs postpartum	---------- 4.26 ----------				0.693	-	-
21 d of lactation	6.08	5.91	5.62	6.03	0.206	0.53	0.19
Protein							
24 hrs postpartum	---------- 7.06 ----------				1.331	-	-
21 d of lactation	4.35	4.49	4.66	4.45	0.130	0.70	0.62
Solid not fat							
24 hrs postpartum	---------- 12.74 ----------				1.054	-	-
21 d of lactation	10.97	10.79	11.92	10.85	0.532	0.46	0.15
Total solid							
24 hrs postpartum	---------- 25.08 ----------				6.086	-	-
21 d of lactation	16.94	17.74	20.44	18.12	1.502	0.15	0.17
Casein							
24 hrs postpartum	---------- 6.23 ----------				1.333	-	-
21 d of lactation	4.12	4.19	4.22	4.21	0.045	0.76	0.94

[1)]V100: Val:Lys ratio, 1:1; V110: Val:Lys ratio, 1.1:1; V120: Val:Lys ratio, 1.2:1; V130: Val:Lys ratio, 1.3:1 (total lysine 0.90%).
[2)]Standard error of the mean.
[3)]Abbreviation: Lin. (linear) and Quad. (quadratic).

Chapter VI. Overall Conclusion

This study was carried out to research the dietary energy, amino acid levels and valine:lysine ratios on growth performance, physiological responses and reproductive performance, in grower - finisher pigs and gestating - lactating sows. Three different experiments were conducted;

1) to evaluate the effect of dietary energy and amino acid levels on growth performance, blood profiles, meat quality and economic analysis in grower - finisher pigs, 2) to determine the effect of dietary amino acid levels on body changes, reproductive performance, blood profiles and milk composition in gestating to lactating sows, and 3) to investigate the effect of dietary valine:lysine ratio on body changes, reproductive performance, blood profiles and milk composition in lactating sows.

In experiment 1, significant higher body weight of growing pigs was observed when pigs were fed diet with 3,300 kcal of ME/kg ($P<0.01$) during the whole experimental period. Also, dietary amino acid level influenced on G:F ratio, and it was improved more efficiently in high energy treatment compared to low energy treatment ($P<0.02$) during 0 - 3 weeks. The blood profiles had no difference among treatments. Moisture content of carcass was increased after slaughter ($P<0.01$) as dietary energy level increased. In addition, WHC was increased as dietary energy level increased ($P=0.04$). Net profit of pork production from HL [3,300 kcal of ME/kg with NRC (1998) AA requirement] treatment was the highest among treatments, because of similar days of slaughter and lower feed cost per kg weight gain and improved pork grade compared with other treatments. Consequently, this experiment demonstrated that dietary energy should be 3,300 kcal of ME/kg with NRC (1998) amino acid requirement for growing period to maximize growth performance as well as higher net profit from pig production.

In experiment 2, there were no significant differences in body weight and backfat thickness of sows during gestation and lactation. In addition, dietary higher amino acid levels did not show positive in reproductive performance. However,

there was a quadratic effect on litter weight on 21 day of lactation (quadratic, P=0.03) and on litter weight gain (quadratic, P=0.02) in AA90 treatment. Analysis based on quadratic response in growth performance of piglets, 93.7% of NRC (2012) AA requirement showed the highest litter size. The piglet weight on 21 day of lactation (quadratic, P=0.03) and the piglet weight gain (quadratic, P=0.02) were also higher in AA90 treatment. There were no significant differences in blood of sows and their progeny. However, lysine (linear, P=0.08), methionine (linear, P=0.05) and threonine (linear, P=0.02) concentrations of blood AA at 110 day was lower or tended to be lower as dietary amino acid level decreased. Dietary amino acid levels were not affected on milk composition. Consequently, this study recommended that 93.7% of NRC (2012) AA requirement for gestating sows is adequate level, and higher dietary amino acid level did not show positive responses.

In experiment 3, dietary Val:Lys ratio had no significant effects on body weight and backfat thickness in lactating sows. The number of total born, stillbirth, mummy and live born were not affected by dietary treatments. The number of weaning pigs was linearly increased as the dietary Val:Lys ratio increased (P<0.05). Average daily feed intake was not affected by dietary Val:Lys ratio. Regarding the reproductive performance, the litter weight and piglet weight did not differ according to the dietary Val:Lys ratio. The IgG, BUN and creatinine in blood of sows and their progeny were not affected by the dietary Val:Lys ratio of lactating sows. During lactation, there was no significant variation in the blood AA concentrations and milk composition by dietary Val:Lys ratio. Consequently, these results demonstrated that the optimum total valine to lysine ratio should be 1.17:0.90% (1.3:1) for higher reproductive performance of lactating sows.

In this dissertation, three different experiment demonstrated that 1) the energy requirement for grower-finisher pigs should be 3,300 kcal of ME/kg with amino acid requirement of NRC (1998), 2) the level of dietary amino acid in diet should be 93.7% amino acid requirement of NRC (2012) both in gestating and lactating sows, 3) the optimum total valine to lysine ratio should be 1.17:0.90% for higher reproductive performance of lactating sows.

Chapter VII. Summary in Korean

본 논문에서는 1) 육성-비육돈 사료내 에너지와 아미노산 수준이 육성-비육돈의 성장성적, 혈액성상, 돈육품질 및 경제성분석에 미치는 영향과, 2) 임신돈 사료내 아미노산 수준이 임신돈과 포유돈의 체형변화, 번식성적, 혈액성상 및 유성분에 미치는 영향, 그리고 3) 포유돈 사료내 발린:라이신 비율이 포유돈의 체형변화, 번식성적, 혈액성상 및 유성분에 미치는 영향을 규명하기 위해 수행되었다.

실험 1. 육성-비육돈 사료내 에너지와 아미노산 수준이 육성-비육돈의 성장성적, 혈액성상, 돈육품질 및 경제성분석에 미치는 영향

본 연구는 육성-비육돈 사료내 에너지와 아미노산 수준이 육성-비육돈의 성장성적, 혈액성상, 돈육품질 및 경제성분석에 미치는 영향을 알아보기 위해 수행되었다. 평균 체중 29.52 ± 4.04 kg, ([Yorkshire x Landrace]) x Duroc) 육성돈 180두를 2 x 3 요인법으로 설계하여 3 반복, 반복당 10두씩 체중에 따라 공시하였다. 요인 1은 2가지 에너지 수준 (3,200 vs 3,300 kcal of ME/kg), 요인 2는 3가지 아미노산 수준 [NRC, (1998), NRC (1998과 2012의 중간값)과 NRC (2012) 요구량]이며, 실험처리구는 다음과 같다. 1) LL: 3,200 kcal of ME/kg + NRC (1998) 아미노산 요구량, 2) LM: 3,200 kcal of ME/kg + NRC (1998과 2012의 중간값) 아미노산 요구량, 3) LH: 3,200 kcal of ME/kg + NRC (2012) 아미노산 요구량, 4) HL: 3,300 kcal of ME/kg + NRC (1998) 아미노산 요구량, 5) HM: 3,300 kcal of ME/kg + NRC (1998과 2012의 중간값) 아미노산 요구량, 6) HH:

3,300 kcal of ME/kg + NRC (2012) 아미노산 요구량. 총 14주간의 실험결과, 전 구간에서 고에너지 처리구가 유의적으로 높은 체중을 기록했다 (P<0.01). 또한 육성전기 (0 - 3주)의 일당증체량 (P<0.05)과 사료효율 (P<0.01)에서 HH 처리구가 유의적으로 높게 나타났다. 혈액성상에서는 10주차 크레아티닌 농도에서 에너지 수준이 높을수록 낮은 경향을 보였다 (P=0.06). 면역성상에서는 사료내 에너지와 아미노산 첨가수준에 따른 어떠한 차이도 발견되지 않았다. 도체특성에서는 고에너지 처리구에서 더 높은 수분함량을 기록했으며 (P<0.01), 보수력에서도 고에너지 처리구가 더 높은 것으로 확인됐다 (P=0.04). 돈육품질 내 육색 변화에서는 처리구간 어떠한 차이도 발견되지 않았다. 경제성분석에 있어 에너지와 아미노산의 첨가 수준이 높을수록 사료 원가는 비싸지만, 출하후 높은 등급출현율로 HL 처리구에서 가장 순이익이 높은것으로 나타났다 (P=0.03). 결론적으로 육성-비육돈 사료내 고에너지 (3,300 kcal of ME/kg) 및 저아미노산 (NRC, 1998) 요구량을 충족할때, 육성-비육돈의 성장 증가와 도체등급 상향으로 인한 양돈장의 수익성 향상을 기대할 수 있을 것으로 사료된다.

실험 2. 임신돈 사료내 아미노산 수준이 임신돈과 포유돈의 체형변화, 번식성적, 혈액성상 및 유성분에 미치는 영향

본 연구는 임신돈 사료내 아미노산 수준이 임신돈과 포유돈의 체형변화, 번식성적, 혈액성상 및 유성분에 미치는 영향을 알아보기 위해 수행되었다. 임신이 확인된 평균 체중 194.4 ± 2.84 kg인 F1 (Yorkshire x Landrace) 모돈 60두 (평균 1.7산; 1-3산차)를 임신 35일령에 공시하여, 4처리 15반복, 반복당 1두씩 체중과 등지방 및 산차에 따라 완전임의배치법 (CRD; completely randomized design) 으로 설정하였으며, 실험처리구

는 다음과 같다. 1) AA110: NRC (2012) 아미노산 요구량의 110%, 2) AA100: NRC (2012) 아미노산 요구량의 100%, 3) AA90: NRC (2012) 아미노산 요구량의 90%, 4) AA80: NRC (2012) 아미노산 요구량의 80%. 임신기 사료는 1산차 2.0 kg/일, 2산차 2.2 kg/일 그리고 3산차는 2.4 kg/일로 급여하였으며, 분만 예정일 5일 전부터 하루에 200g씩 감량급이하였다. 포유기에는 실험처리구에 관계없이 모두 동일한 사료로 무제한 급이하였다. 임신기부터 포유기까지 모돈의 체중 및 등지방 두께 변화에서는 사료내 아미노산 수준에 따른 유의적인 차이가 나타나지 않았다. 총산, 사산, 미라, 생시, 이유자돈수의 번식성적에서도 유의적인 영향은 발견되지 않았다. 하지만 AA90 처리구에서 자돈의 복당체중 (quadratic, P=0.03)과 복당증체량 (quadratic, P=0.02)이 유의적으로 높았고, 자돈의 개체당체중 (quadratic, P=0.03)과 개체별증체량 (quadratic, P=0.02)에서도 유의적으로 높은 성적을 기록했다. quadratic 분석 결과, NRC (2012) 기준 아미노산 요구량의 93.7% 수준에서 가장 높은 번식성적을 기록했다. 모돈과 자돈의 혈액내 IgG, BUN 및 Creatinine의 농도 분석 결과, 처리구간 어떠한 차이도 발견되지 않았다. 혈액내 아미노산 농도 분석에 있어서는 임신 110일령에 라이신 (linear, P=0.08), 메치오닌 (linear, P=0.05) 및 트레오닌 (linear, P=0.02) 농도가 사료내 아미노산 수준이 적을수록 유의적으로 감소 혹은 감소하는 경향을 나타냈다. 또한 돈유내 영양소함량 분석에서는 사료내 아미노산 첨가 수준에 따른 어떠한 영향도 나타나지 않았다. 결론적으로 임신돈 사료내 NRC (2012) 아미노산 요구량의 93.7% 수준을 첨가하는 것이 가장 높은 생산성을 나타내는 것을 확인하였다.

실험 3. 포유돈 사료내 발린:라이신 비율이 포유돈의 체형변화, 번식성적, 혈액성상 및 유성분에 미치는 영향

본 연구는 포유돈 사료내 발린:라이신 비율이 포유돈의 체형변화, 번식성적, 혈액성상 및 유성분에 미치는 영향을 규명하기 위하여 수행되었다. 임신이 확인된 평균 체중 236.0 ± 3.06 kg 인 F1 (Yorkshire x Landrace) 모돈 40 두 (평균 3.0 산; 2-4 산차)를 임신 109 일령 모돈 40 두 (평균 3 산; 2-4 산차 이용)를 공시하여, 4 처리 10 반복, 반복당 1 두씩 체중과 등지방 및 산차에 따라 완전임의배치법 (CRD; completely randomized design) 으로 설정하였으며, 실험처리구는 다음과 같다. 1) V100: Val:Lys (1:1, 0.90%:0.90%), 2) V110: Val:Lys (1.1:1, 0.99%:0.90%), 3) V120: Val:Lys (1.2:1, 1.08%:0.90%), 그리고 4) V130: Val:Lys: (1.3:1, 1.17%:0.90%). 임신기 사료는 사료는 2 산차 2.2 kg/일, 3 산차 2.4 kg/일 그리고 4 산차는 2.4 kg/일로 급여하였으며, 분만예정일 5 일 전부터 200g 씩 감량급이하였다. 포유돈 실험사료는 실험처리구에 관계없이 모두 무제한 급이하였다. 포유돈 사료내 발린:라이신 비율에 따른 모돈의 체형변화에서는 처리구간 어떠한 유의적인 차이도 발견되지 않았다. 또한 번식성적에 있어 총산, 사산, 미라, 생시자돈수에서는 유의적인 차이가 나타나지 않았지만, 이유자돈수에서 사료내 발린:라이신 비율이 높아질수록 유의적으로 높아지는 경향을 보였다 (linear, P=0.07). 모돈과 자돈의 혈액내 IgG, BUN 및 Creatinine 농도에서는 처리구간 어떠한 차이도 나타나지 않았다. 또한 혈액내 아미노산 농도 분석 및 유성분 변화에 있어서도 유의미한 차이가 발견되지 않았다. 결론적으로 포유돈 사료내 발린:라이신 비율이 1.3:1 (발린: 1.17%, 라이신: 0.90%) 를 충족할때, 가장 높은 번식성적을 기대할 수 있을 것으로 사료된다.

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Woo Lim, Chung
Seoul National University
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