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Various Levels of Rapeseed Meal in Weaning Pig Diet on Growth Performance, Blood Profiles, Carcass Characteristics and Economic Analysis in Pigs from Weaning to Finishing

자돈 사료 내 채종박의 수준이 자돈, 육성 그리고 비육돈에 성장성적, 혈액성상, 도체 품질 그리고 경제성분석에 미치는 영향

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Summary

In domestic pig industry, unstable feed cost is the main cause to increase cost of swine production. Moreover, Korea is being imported about 95% of feed ingredients from other countries. Soybean meal (SBM) is a widely available feed for livestock because of high protein, high biological value and digestibility, and considerable energy content. Unfortunately, SBM supply has become unstable during decades subsequently other protein source is urgently sought instead of SBM. There are many alternatives to SBM for protein source in animal feed such as rapeseed meal (RSM), palm kernel meal (PKM) and copra meal (CP). The RSM is a by-product of oil extraction from rapeseed and it contains high protein as well as balanced amino acids. However, RSM has an anti-nutritional factors known as glucosinolates and erucic acid which definitely have negative effects on growth of young animals. However, the price of RSM is relatively cheaper than SBM consequently swine producers can save cost of production if RSM can be used in diet of weaning pig. The present study was performed to evaluate the influence of dietary levels of RSM in weaning pigs' diet on growth performance, blood profiles, carcass characteristics subsequently economical analysis in weaning to finishing pigs. A total of 120 cross bred ([Yorkshire × Landrace] × Duroc) weaning pigs were allotted to 5 treatments in a randomized complete block (RCB) design. Five different levels of RSM (0, 2, 4, 6 or 8%) were used as dietary treatments in 4 replicates with 6 pigs per pen. During the whole experimental period, all treatments showed no significant difference in growth performance although dietary levels of RSM increased. However, the blood urea nitrogen (BUN) concentration was decreased as dietary level of RSM increased in 6 week (linear, $P<0.01$). Total cholesterol, high density lipoprotein (HDL) cholesterol, low density lipoprotein (LDL) cholesterol, T_3, T_4 and immune response (IgG, IgA) showed no significant difference among dietary treatments. Influence of RSM supplementation on nutrient digestibility and nitrogen retention was also not affected by dietary rapeseed meal level increased. As dietary level of RSM in diet of weaning pig was increased, there was no differences in proximate analysis. In addition, there were no significant difference in pork color L*, a*, b* values and pH at 0, 3, 6, 12, 24h after slaughtering. In economic benefit, any significant difference was not examined. Consequently, weaning pig's diet containing RSM had affected BUN concentration and IgA, but there were no detrimental effects on the growth performance of weaning pigs although RSM was supplemented up to 8%.

Keywords : Rapeseed meal, Weaning pigs, Total cholesterol, HDL cholesterol, LDL cholesterol

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List of Abbreviation

AA	Amino acid
ADG	Average daily gain
ADFI	Average daily feed intake
AOAC	Association of official analytical chemists
BUN	Blood urea nitrogen
BW	Body weight
CP	Crude protein
DE	Digestible energy
DM	Dry matter
EU	European union
FMD	Foot-and-mouth disease
ME	Metabolizable energy
NE	Net energy
NRC	National research council
RCB	Randomized complete block
SAS	Statistical analysis system
SBM	Soybean meal
RSM	Rapeseed meal
PKM	Palm kernel meal
CP	Copra meal
FTA	Free trade agreement
GE	Gross energy
AEE	Hydrolyzed ether extract
NDF	Neutral detergent fiber
ADF	Acid detergent fiber
AID	Apparent ileal digestibility
SID	Standard ileal digestibility
ATTD	Apparent total tract digestibility

I. Introduction

The economics of swine feeding are largely dependent on local conditions of feedstuff availability and competition for the same foodstuff for the use by either humans or other animals. Since protein sources are generally more expensive than energy sources, to reduce the cost of the feed, many attempts have been made to use alternative ingredients of protein and energy. The domestic pig industry needed to find alternatives to SBM for animal feed in South Korea. SBM is the most widely used protein supplement throughout the world whereas increasing dietary supplementation level of SBM could be increased feed cost in pig diet (Patrick et al., 2010). Thus, more research is required on alternative sources.

RSM is a by-product which could be removed by crushing, solvent extraction or a combination of both techniques (Bell, 1984). RSM contains up to 40% protein and has been found to be used in animal diet. However, In pig industry RSM has not been used weaning pig diets because of glucosinolates which cause thyroid hypertrophy to young animals and erucic acid appears to have toxic effects on the heart at high enough doses, an association between the consumption of rapeseed oil (Mawson et al., 1994). In addition, voluntary feed intake could be affected by inclusion of RSM in the diets because of high content of erucic acid, bitter taste of sinapine and astringent effect in the mouth by tannin (Mawson et al., 1994).

Consequently, this experiment was conducted to evaluate various levels of RSM in weaning pig's diet on growth performance, blood profiles, carcass characteristic and economic analysis in weaning to finishing pigs.

II. Literature Review

1. Introduction

1.1 Situation of swine industry in Korea

Rising per capita incomes and the rapid economic growth in South Korea during the last two decades, has brought about a significant change towards life styles and diets. This change has led to an increase in consumption of animal protein. South Korea is ranked as 11th in world pork production but 5th in the world for consumption. The livestock industry makes up 35.5% of total agriculture, and the swine industry represents 30% of livestock industry. However, the high costs of production (including feed costs), low production efficiency, and forced culling due to a foot and mouth disease (FMD) outbreak starting in 2000 resulted in the loss of many hog farming households in the country, reducing supply in the face of continued demand, positioning South Korea as a net importer in the global pork industry.

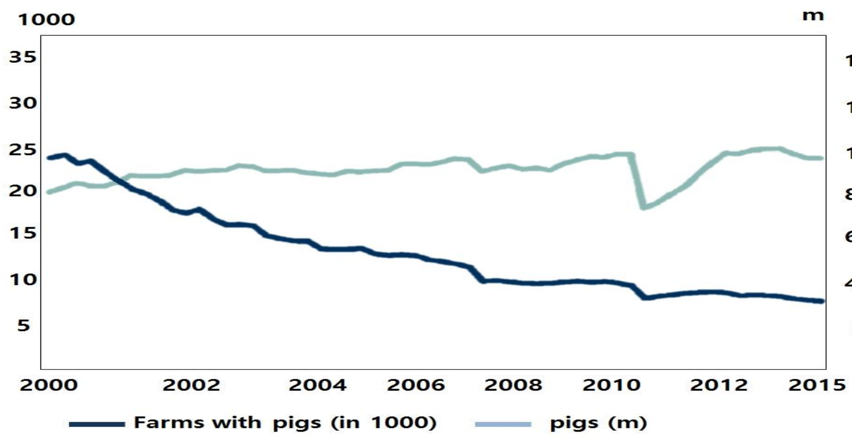

Figure 1. Pig count increases while farms fall in South Korea (Agrifuture, 2015)

Around 9.7m pigs are kept on 5,300 farms with a sow herd of 860,000. In recent years the number of farms has reduced rapidly from around 25,000 in 2000. Above all, the smaller farms with under 1,000 pigs have been reduced most. The pig population has at the same time increased from 8 to 10 million. However, the high costs of production (including feed costs), low production efficiency, and forced culling due to a FMD outbreak starting in 2000 resulted in the loss of many hog farming households in the country, reducing supply in the face of continued demand. By 2013, the surviving farms were stocked with an average 1,800 pigs producing within closed systems. compared other countries, consumption of pork and total import of pork in South Korea (Figure 3, 4) was constantly increased. However, production of pork have not been changed.

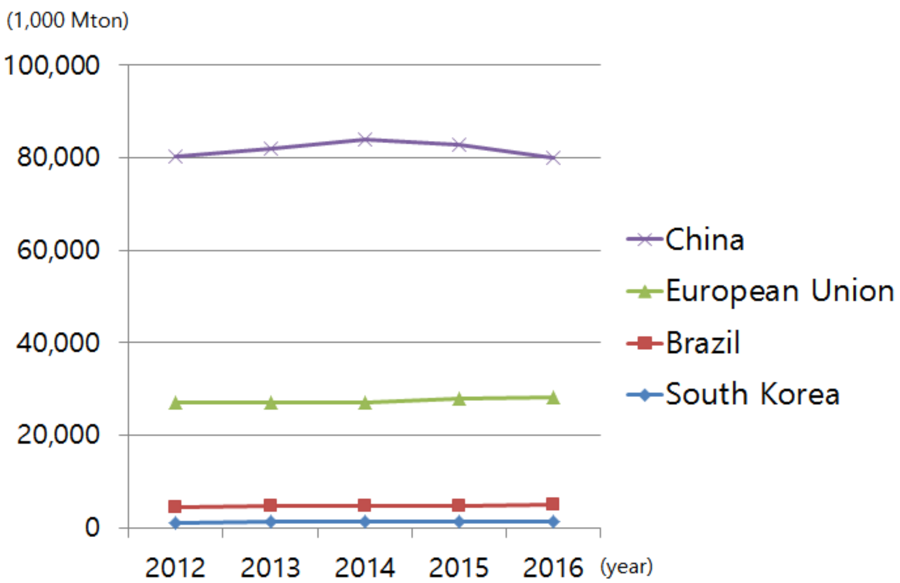

Figure 2. Production of pork selected countries (USDA, 2016)

Imports of pork into South Korea have grown during the first half of 2015, with volumes ahead by 35% compared to 2014. This emphasises the strength of consumer demand for pork, aided by outbreaks of Avian Influenza, which have encouraged consumers to switch from poultry meat to pork. Alongside this, a range of promotional campaigns within South Korea have helped increase consumption.

The problem of the Korean swine feed sector is that feed prices are too high because about 95% of feed ingredients are imported. Since feed accounts for most of the total cost for pig farming, Korean pig farmers are suffering from that. Moreover, the more pork have been imported since FTA between South Korea and EU. It has led to decrease the price of pork in South Korea because intense competition is against many other countries. Therefore, pork producers need to decrease production cost as well as to improve feed efficiency or find alternative feed ingredients.

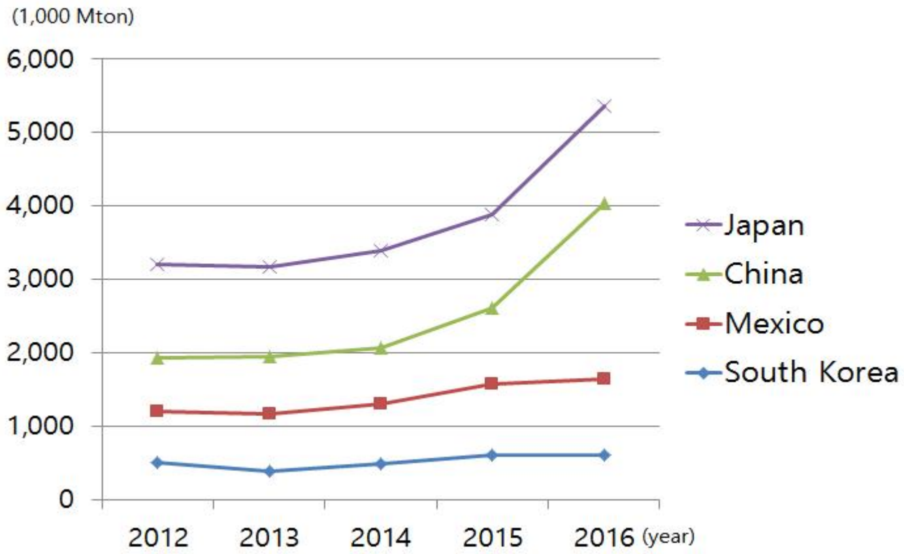

Figure 3. Total imports of pork selected countries (USDA, 2016)

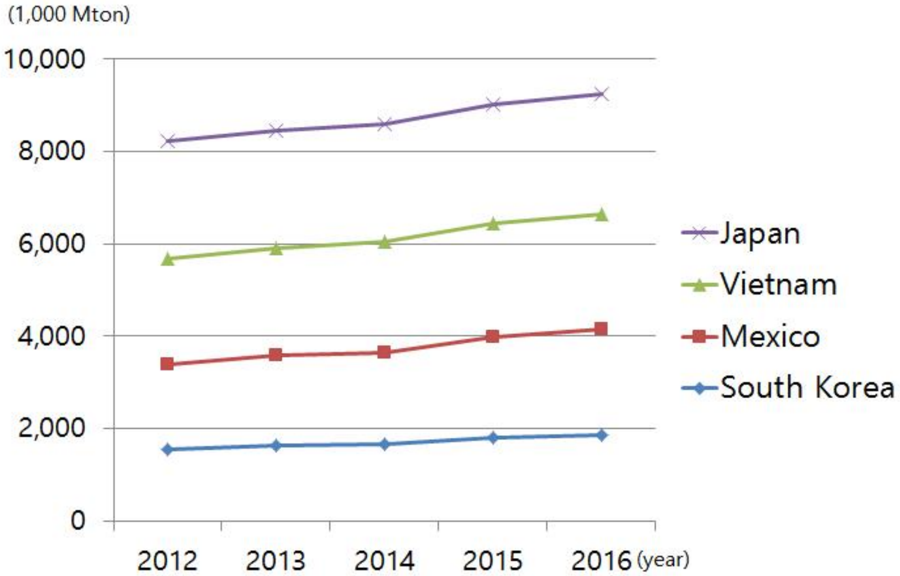

Figure 4. Consumption of pork selected countries (USDA, 2016)

1.2 Major alternative feed in animal diets

In particular, alternative feed ingredients are suited study for South Korea swine industry, because unstable price of corn and SBM caused high price of animal feed. While corn and SBM have been industry standards for supplying energy and protein, there are many suitable alternatives that meet nutritional requirements while reducing the cost of the ration and these could be included cost effectively as demand for corn and SBM increases (McDonald et al., 1998). Energy and protein are the main nutrient components in a swine ration. Grains such as corn, barley, wheat and oats have traditionally supplied energy, while protein has come from meals produced from oilseeds such as SBM, RSM, palm kernel meal (PKM), copra meal (CM). When using those ingredients in monogastric animals, it could have strengths and weaknesses aspects. Anti-nutritional factors are in a feed ingredient that interfere with nutrient digestibility. These may include trypsin inhibitors, tannins, lectins or glucosinolates. For example, raw whole soybeans contain a trypsin inhibitor. As a result, they must be heat-processed or they will cause a reduction in performance due to decreased protein digestibility and absorption (Sundu and Dingle, 2003).

Therefore, pros and cons about using alternative ingredients must be taken into consideration.

1) Palm kernel meal

PKM is a by-product of oil extraction from the kernel in the palm nut. PKM is usually used in ruminant animal feeds rather than non-ruminant due to its high fiber content, low palatability, and low digestibility of amino acids and energy (McDonald et al., 1998). PKM has as anti-nutritional factors such as mannan and galactomannan in monogastric animal which has no endogenous enzymes to degrade these NSPs. The NSPs in PKM consisted of 78% pure mannan, 3% arabinoxylans and 3% glucoronoxylans. The β-mannan contents in PKM is 30~35% of DM (Sundu and Dingle, 2003).

2) Copra meal

CM, a by-product of the coconut oil industry, is often available as a protein source for swine and poultry. CM contains 15 to 25% protein and 60% carbohydrate but essential amino acid such as lysine and methionine is low (Lachance and Molina, 1974). Previous studies suggested that CM may be used for pigs, but for best results an supplementation level of approximately 30% could be proper in the diets for growing pigs (Creswell and Brooks, 1971a). The carbohydrate is regarded as undigestible fiber consisting principally of mannan, galactomannan and cellulose (Knudsen, 1997). Therefore, the high fiber content in CM is an important factor that limits its use in swine diet.

3) Rapeseed meal

Rapeseed meal is by-product which remaining after rapeseed is processed and the oil removed that can be used as feed for livestock. The digestibility of RSM is lower than SBM. Protein is well digested, but the protein digestion coefficient and the availability of amino acids are low. Although SBM contains more lysine than RSM, the methionine and cystine content of rapeseed is higher (Aherne and Kennelly, 1985). RSM is hard to use for monogastric animals because of anti-nutritional factors known as glucosinolates and erucic acid. These compounds appeared to negative effect on feed intake when supplemented to swine diet (Lee and Hill, 1983). However, previous studies reported supplementation of RSM in swine diet has cost effective (Choi et al. 2014).

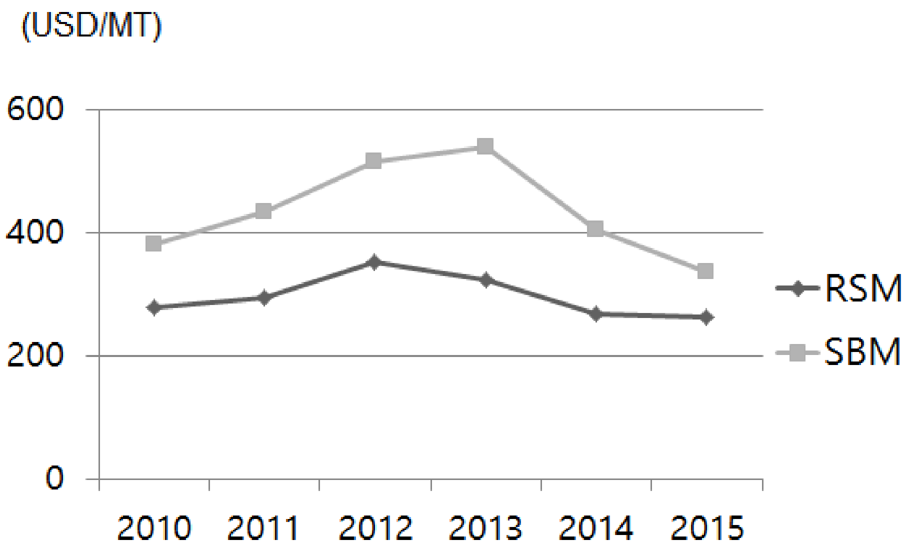

Figure 5. RSM and SBM price in U.S. (USDA, 2016)

2 Rapeseed Meal

2.1 Characteristics of rapeseed meal

SBM is by far the major oilseed meal produced worldwide but RSM is the second by rank (Figure 6). The use of whole oilseed rape (*Brassica napus L.* and *Brassica campestris L.*, the latter common- ly termed turnip rape) in the diets of livestock has also increased in recent years, as the oil provides a concentrated source of energy. In addition, rapeseed fatty acid profile could result in changes to the fatty acid profile of meat, milk and eggs that might negative effect on health benefits to the humans (Bell and Keith, 1987). However, there are some longstanding concerns about the use of rapeseed products in livestock diets. These arise from the presence of a range of anti-nutritive factors in the seed. Some of these have been largely bred out of modern genotypes of oilseed rape, while others could potentially be neutralized by processing of the seed. Consumption of rapeseed meal has grown strongly in the EU (Figure 7) which is deficient in protein feed and where these new supply was replacing imported soybean meal. China with its extraordinary economic development has seen its plant protein needs explode, from which rape has benefited. Some other countries, like Iran, Vietnam and Indonesia, are progressively adding rapeseed meal to their list of feedstuffs.

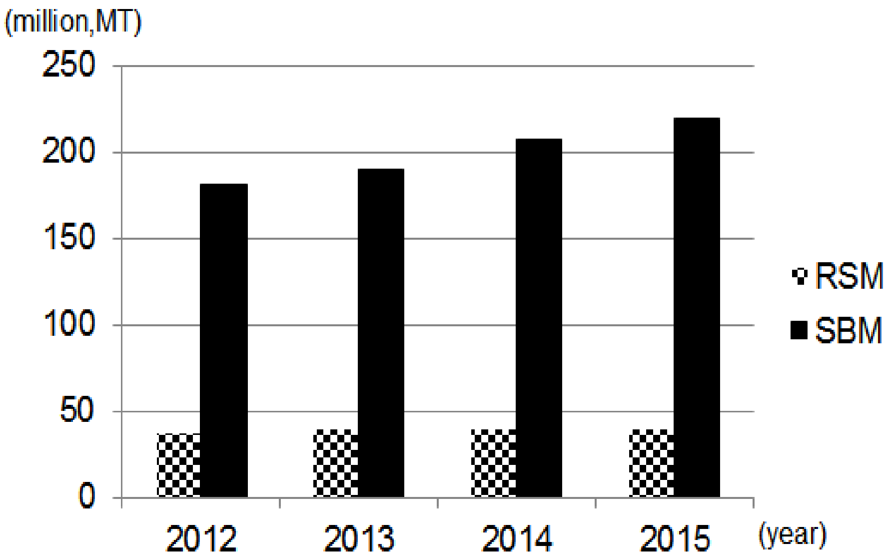

Figure 6. Production of RSM and SBM (USDA, 2016)

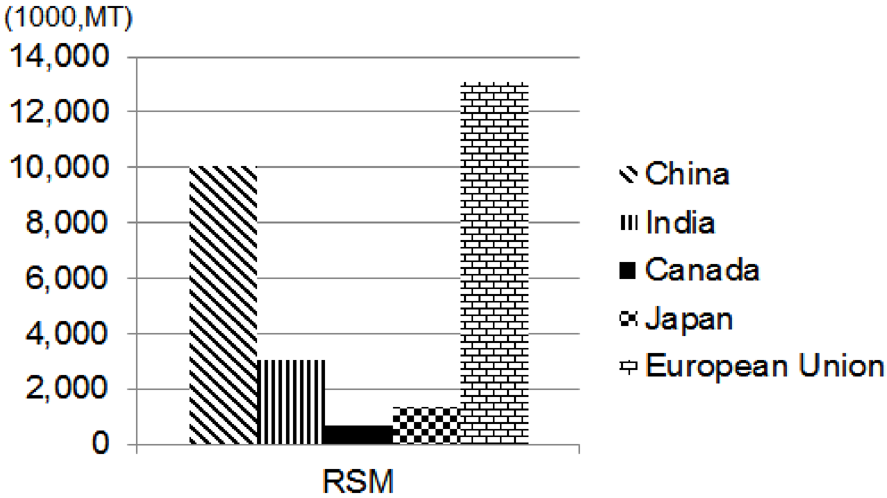

Figure 7. Domestic consumption of RSM by country (USDA, 2016)

2.2 Nutritional value

The amino acid composition of RSM protein compares favorably with that of SBM (Table 1). Rutkowski, (1971) suggested that RSM has well balanced amino acid (AA) composition. Furthermore, sulphur-amino acid such as cystein, methionine levels higher than SBM. However, when supplementation of RSM in animal diet, RSM might reduce feed intake or affect performance (Mawson et al., 1994).

The apparent digestibility of crude protein in pigs was affected by NDF content of RSM (Bell and Belzile, 1965). Protein quality in RSM could be defined in many ways. To avoid denaturation of the storage proteins and inactivate enzymes (especially myrosinase) minimum heat necessary is needed during processing conditions. Excessive heat leads to reduced availability of amino acids, especially lysine (Clandinin et al. 1966). RSM is a rich source of both mono and polyunsaturated fatty acids, and is a particularly rich source of linolenic acid (C18:3). Composition of the residual oil in RSM depends upon the method of oil extraction (Rutkowski, 1971). When compared to SBM, RSM is higher than contents of minerals (Clandinin et al., 1966). However, because of the presence of phytic acid and indigestible fiber, RSM could have lower availabilities of P, Ca, Mg and Zn. Khajali and Slominski (2012) suggested that RSM contains less Na and K than SBM, and so the dietary electrolyte balance is poor, which should be corrected for by adding Na to the diet.

Table 1. Fatty acid, mineral composition of rapeseed meal and soybean meal

Item	Rapeseed Meal	Soybean Meal
Fatty acid composition (%)		
Palmitic acid (16:0)	8.9	7.88
Stearic acid (18:0)	2.9	2.85
Oleic acid (18:1)	51.3	16.28
Linoleic acid (18:2)	26.8	39.83
Arachidonic acid (20:0)	0.2	-
Saturated fatty acid	12.9	10.8
Monounsaturated fatty acid	52.0	16.4
Polyunsaturated fatty acid	33.1	45.4
Mineral composition (ppm)		
Cu	5.2	15.1
Zn	66.7	48.8
Mn	81.5	35.5
Fe	161.5	98.2

(Clandinin and Robblee, 1981)

Table 2. Amino acid contents of rapeseed meal and soybean meal (as DM basis

Item	Rapeseed Meal	Soybean Meal
Essential amino acids (% of protein)		
Arginine	6.4	3.2
Histidine	2.7	1.3
Leucine	5.1	3.4
Lysine	5.5	2.8
Methionine	2.1	0.6
Phenylalanine	5.3	2.3
Threonine	3.4	1.8
Valine	3.1	1.9
Non-essential amino acids (% of protein)		
Alanine	1.6	1.9
Aspartate	2.5	4.9
Cystine	2.7	0.7
Glutamate	6.1	7.9
Glycine	1.8	1.9
Proline	2.3	2.4
Serine	1.6	2.1
Tyrosine	2.5	1.6

(Rutkowski, 1971; NRC, 2012; AmiPig, 2000)

2.3 Nutritional digestibility of rapeseed meal

Energy digestibility in RSM could vary depending on the concentration of gross energy (GE) and acid hydrolyzed ether extract (AEE), which could affect to the digestible energy (DE) and metabolic energy (ME). Canola expellers and rapeseed expellers have greater GE than canola meal and rapeseed meal due to the increased concentration of oil in canola expellers compared with canola meal. Therefore, the concentration of DE and ME in canola and rapeseed expellers is higher than in canola and rapeseed meal (4,107 vs. 3,790 kcal/kg DE and 3,978 vs. 3,564 kcal/kg ME) when used in growing pig diets (Bourdon and Aumaître. 1990; Woyengo et al., 2010). When supplemented canola meal from 7.5 to 22.5 % in growing pig diets, DE and NE might be decreased because 15 of an increase in neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentrations, but growth performance were not affected (Montoya and Leterme, 2010).

The digestibility of AA in canola meal, rapeseed meal are variable depending on the processing temperature of canola meal, the age of pigs, and sources of canola meal. The age of pigs may affect the digestibility of AA in canola meal. The apparent ileal digestibility (AID) of AA in lactating sows is greater than in growing pigs (Stein et al., 1999), and gestating sows have greater standardized ileal digestibility (SID) of CP (crude protein) and AA compared with growing pigs and lactating sows (Stein et al., 2001). The digestibility of AA could be affected by the source of canola meal, and the AID of all AA among 6 canola meal samples was different (Fan et al., 1996). The digestibility of Arg, His, and Met is relatively high, ranging from 79.4 to 84.4%, from 76.5 to 81.0%, and from 77.3 to 82.4%, whereas the digestibility of Thr and Trp is relatively low, ranging from 59.7 to 66.5% and from 61.7 to 67.5 % (Fan et al., 1996). The digestibility of indispensable AA (except Arg) is negatively correlated with the concentration of NDF in canola meal (Fan et al., 1996). The SID of Lys, Met, Thr, and Trp in rapeseed meal is relatively great, ranging from 74 to 75%, from 85 to 87%, from 73 to 75%, and from 76 to

80% (Sauvant et al., 2004). Different methods to extract oil from canola seeds also might affect SID values of canola and rapeseed products (Woyengo et al., 2010).

Because most P in canola meal is bound to phytic acid (Newkirk, 2009), the digestibility of P in canola meal by pigs and poultry is around 25-30% of total 16 phosphorus (Sauvant et al., 2004; NRC, 2012). The apparent total tract digestibility (ATTD) of P in canola and rapeseed meal by growing pigs ranges from 24 to 52% (Woyengo et al, 2010; Rodríguez et al., 2013). However, supplementation of microbial phytase at 500, 750, or 1,000 units/kg to growing pig diets could improve the digestibility of P in canola meal and rapeseed meal (Woyengo et al, 2010; Rodríguez et al., 2013). The ATTD of Ca in canola meal by growing pigs was 43%, and supplementation of microbial phytase at 1,500 units/kg in the diets increased the digestibility of Ca in canola meal (González-Vega et al., 2013).

3. Anti Nutritional Factors of Rapeseed Meal

3.1 Glucosinolate

The glucosinolates (or thioglucosides) are biologically inactive, but the hydrolysis of glucosinolates bring about the production of goitrogenic and toxic compounds. The total concentration of glucosinolates, and the relative proportions of the individual glucosinolates, is affected by the genotype of the plant and the agronomic conditions. In addition, supplying large amounts of both N and S to the crop not only increases the total glucosinolate concentration, but also increases the proportion of 2-hydroxy-3-butenyl in the glucosinolate fraction (Zhao et al., 1994).

The enzyme myrosinase (thioglucoside glucohydrolase EC 3.2.3.1), which hydrolyses the glucosinolates, occurs naturally in the seeds of oilseed rape but is physically separated from the glucosinolates (Smithard, 1993). Hydrolysis of the glucosinolates occurs when the seeds are crushed and when moisture is present. The goitrogenic activity of rapeseed meal could be manipulated by the processing of the seed to ensure the earliest possible destruction of myrosinase. However, this approach is at best only partially successful as bacterial thiogucosidases produced in the gut will hydrolyse any residual glucosinolate in the meal (Chubb, 1982; McDonald et al., 1995). The products of glucosinolate hydrolysis contain as isothiocyanates, thiocyanates and nitriles (Figure 8.)(Chubb, 1982). Isothiocyanates have a strong anti-tumourogenic effect, and suppress the propagation of cancers of the lungs and alimentary tract in humans (Johnson, 2002).

The isothiocyanates also give rise to the most actively goitrogenic compounds by being cyclized to form 14 oxazolidone-2-thiones (Chubb, 1982). The most goitrogenic compound is 5-vinyl-oxazolidone-2-thione, commonly known as goitrin. The glucosinolate that leads to goitrin is 2-hydroxy-3-butenyl glucosinolate or progoitrin (Chubb, 1982; Aherne and Kennelly, 1985). This is the predominant glucosinolate in oilseed rape, representing between 50 and 70% of the total glucosinolate concentration (Zhao et al., 1994). The goitrin that is produced from the hydrolysis of progoitrin reduces the synthesis of iodine into the precursors of thyroxine, and interferes with the secretion of thyroxine

(Chubb, 1982). The brain's hypophysis responds by increasing its secretion of thyroid-stimulating hormone (Aherne and Kennelly, 1985). The result of this is that the thyroid gland enlarges.

The thiocyanates which are derived from rapeseed meal inhibits the active uptake of iodine by the thyroid gland (Aherne and Kennelly, 1985). This mode of action means that the effects of thiocyanate are most remarkable in situations where iodine is limiting (Aherne and Kennelly, 1985). In addition to their action on the thyroid gland, the thiocyanates also effect on the liver cells (Smithard, 1993).

The nitriles do not occur in themselves goitrogenic. However, the end-products of nitrile metabolism (which include thiocyanates) are goitrogenic. Nitriles have also been observed to cause death with lesions in both the liver and kidney in rats and chicks (Aherne and Kennelly, 1985), and have been suspected of being the causal agent in liver haemorrhages in poultry (Chubb, 1982).

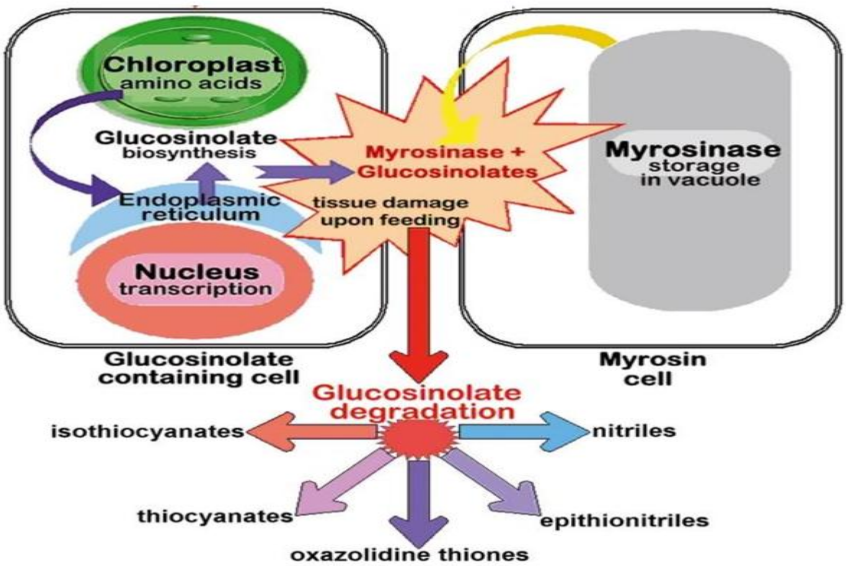

Figure 8. Hydrolysis of glucosinolate (Ishita et al., 2010)

3.2 Erucic acid

Erucic acid, a fatty acid with the configuration C22:1 n-9. Erucic acid contains about 30–60% of the total fatty acids of rapeseed (Food standards australia New Zealand, 2003). Erucic acid was poorly oxidized in heart muscle because erucic acid which has other long chain fatty acids is poorly available as a substrate by the β–oxidation enzymes (Food standards australia New Zealand, 2003). Furthermore, In liver, the presence of erucic acid affect to induce the peroxisomal β–oxidation system, causing a gradual decline in erucic acid accumulation and also reduced inhibition of fatty acid oxidation. This is thought to reduce the influx of erucic acid to the heart (Food standards australia New Zealand, 2003). In addition, It has been known to cause heart lesions in animals (McDonald et al., 1995). In nursling pigs, erucic acid leads to increase myocardial lipidosis at 900 mg/kg bw/day. Nursling pigs less sensitive than adult pigs because immature myocardium and liver might be less able to oxidize long–chain fatty acids (Food standards australia New Zealand, 2003). Feeding weaning pigs milk replacers containing rapeseed oil high 15 in erucic acid bring about a reduction in the number of blood platelets, and an increase in platelet size (Kramer et al., 1998). In general, the erucic acid do not have a toxicity when rapeseed meal is supplemented, as it is extracted with the oil fraction of the seed during processing. It is potentially a problem when full fat rapeseed is fed, although the quantities of erucic acid present in the double low varieties of oilseed rape are extremely small (less than 20 mg/g). Rapeseed meals with a high concentration of erucic acid could enter the animal feed market from the extraction of oilseed rape developed for industrial uses, as these do have a high concentration of erucic acid (Kramer et al., 1998). Although most of the erucic acid would be extracted with the oil, some would remain in the rapeseed meal.

The tolerance by livestock to such rapeseed meals may be lower than for more conventional ‘double low’ rapeseed meals, but no evidence could be found in the literature concerning a any investigation of the use of rapeseed meal from high erucic acid varieties of oilseed rape (Rymer and Short, 2003).

4. Rapeseed Meal in Swine Diet

Several studies have looked at the inclusion of rapeseed in various forms in pig diets. In addition, most studies have used different varieties of rapeseed and different ages of pigs making comparisons difficult. Glucosinolates in rapeseed meal were a limiting factors in swine diet (Bell, 1984). However, many factors (plant breeding, environment, etc) have been affected to glucosinolates contents in rapeseed. Lee and Hill (1983) replaced soyabean meal in the pig diet with rapeseed meal at an inclusion rate of 260g/kg diet. They used different varieties of oilseed rape and observed that the British variety resulted in the lowest voluntary intake by pigs because glucosinolates appeared to have the most marked negative effect on voluntary feed intake, as the British variety of rapeseed meal had a especially high progoitrin content. A further examination of their data (assuming that sinapine, glucosinolates and tannins were absent in the soyabean meal used as a control) confirms that glucosinolates had the adversely affected pigs' digestion.

In growing pigs diet, supplemented rapeseed cake 17% (glucosinolates contents is higher than rapeseed meal) did not affect to serum free tri-iodothyronine (Spiegel and Blum, 1993). However, feed intake was severely reduced when the pigs were fed rapeseed cake. bitter taste of glucosinolates brings about reduced growth rates and feed intake in pigs fed rapeseed cake (Spiegel and Blum, 1993).

Landero et al (2012) suggested that the maximum appropriate level of dietary glucosinolates for weaning pigs has not been established. Some authors indicate that young pigs are more sensitive when glucosinolates was fed (Corino et al., 1991) whereas others indicated that finishing pigs are more affected (Roth-Maier et al., 2004). supplementation of up to 25% solvent-extracted canola meal (improved breed of rapeseed) in weaning pig diets (6 to 23 kg BW) did not affect ADG or voluntary feed intake, but improved G:F ratio (Eason and King, 2000; King et al., 2001), and using canola meal or canola expellers in concentrations of up to 15 to 20% in diets had no negative effects on growth performance in weaning pigs (Seneviratne et al., 2010; Landero et al., 2011; Landero et al., 2012). The glucosinolates in rapeseed meal (RSM) have been known to cause thyroid dysfunction in young pigs (Bowland et al., 1965). In addition, when pigs fed RSM enlargement of the thyroid gland, reduced serum thyroid hormone levels, and glandular hypertrophy as well as increased cellular components have been described (Bowland et al., 1965).

Ⅲ. Various Levels of Rapeseed Meal in Weaning Pig Diet on Growth Performance, Blood Profiles, Carcass Characteristics and Economical Analysis in Pigs from Weaning to Finishing

ABSTRACT: This experiment was conducted to investigate the influence of rapeseed meal (RSM) supplementation in weaning pig diet on growth performance, blood profile, carcass characteristics and economic analysis on weaning to finishing pigs. A total of 120 cross bred ([Yorkshire × Landrace] × Duroc) weaning pigs were allotted to 5 treatments in a randomized complete block (RCB) design. Each treatment had 4 replications with 6 pigs per pen. Five different levels of RSM (0, 2, 4, 6 and 8%) were used as dietary treatments. In overall period, all treatments showed no significant difference in growth performance when dietary as RSM level increased. However, The blood urea nitrogen (BUN) concentration was decreased as dietary RSM level increased in 6 week (linear response, $P<0.01$). Total cholesterol, high density lipoprotein (HDL) cholesterol, low density lipoprotein (LDL) cholesterol, T_3, T_4 showed no significant difference and there was no significant differences on immune response (IgG and IgA). Influence of rapeseed meal supplementation on nutrient digestibility and nitrogen retention were not affected by the dietary rapeseed meal level increased. As dietary RSM level of weaning pig diet was increased, there were no differences in proximate analysis and physiochemical property of the pork after slaughter among dietary treatments. In addition, there were no significant difference in pork color L*, a*, b* value and pH at 0, 3, 6, 12, 24h after slaughter. In economic benefit, any significant difference was not examined. Consequently, weaning pig's diet containing RSM had affected BUN concentration but there was no detrimental effects on the growth performance of weaning pigs when up to 8% RSM was fed.

Keywords : Rapeseed meal, Weaning pigs, Total cholesterol, HDL cholesterol, LDL cholesterol

Introduction

Soybean meal (SBM) is widely used due to good amino acid balance and digestibility (Archimède et al., 2011). However, in a European context where potential of forage soybeans cannot be economically produced. There are many alternatives to SBM for protein source in animal feed (Lee and Hill, 1983). However, amino acid availability and profile must be appropriate for animals. RSM is a by-product of oil extraction from rapeseed and contains 33 to 35% protein, 10% crude fiber but energy is not high (Bell, 1984). In addition, rapeseed called canola which is an offspring of rapeseed. Canola was bred through standard plant breeding techniques to have low levels of erucic acid (< 2%) and glucosinolates (< 30 μmol/g) (Higgs et al., 1996). Although lysine content of RSM is lower than SBM, sulphur containing amino acids such as cysteine and methionine are much higher. *Brassica* plant such as RSM uses sulphur to synthesise glucosinolates and phytoalexins (Clandinin, 1967). Cysteine could reduce sulphur for glucosinolate biosynthesis and for the synthesis of phytoalexins including camalexin (Ishita et al., 2009). RSM has been used in growing-finishing pig diets because of glucosinolates which causes thyroid hypertrophy to young animals (Schöne et al., 2002). When insect herbivory or tissue damage brings glucosinolates and myrosinase together and facilitates hydrolysis of glucosinolates into thiocyanates, isothiocyanates, nitriles, oxazolidine-2-thiones and epithionitriles (Mawson et al., 1994). Erucic acid appears to have toxic effects on the heart at high enough doses, an association between the consumption of rapeseed oil. In addition, RSM in the diets could decrease feed consumption because of high content of erucic acid, bitter taste of sinapine (Mawson et al., 1994). Therefore, the objective of the present study was to evaluate the effect of dietary supplementation levels of RSM in weaning pig diet on growth performance, blood profiles, carcass characteristic and economic analysis in weaning to finishing pigs.

Materials and Methods

Animal management and housing

A total of 120 weaning pigs ([Yorkshire × Landrace] × Duroc), 7.28 ± 0.86 kg initial BW, were used in a 19-week feeding trial at experimental farm of Seoul National University. Pigs were allotted to one of five treatments by BW and sex in 4 replications with 6 pigs per pen in a randomized complete block (RCB) design. All pigs were housed in an environmentally controlled building with plastic-slotted floors facility (1.95 by 1.42m^2) during weaning periods and fully-concrete floors facility (2.60 by 2.84m^2) during growing to finishing periods. each pen was equipped with a feeder and a nipple drinker to provide *ad-libitum* access. Body weight and feed intake were recorded at 0, 3, 6, 10, 14, 17 and 19 week to calculate the average daily gain (ADG), average daily feed intake (ADFI) and gain-to-feed ratio (G:F ratio).

Experimental diets

Dietary treatments were: 1) CON : corn-SBM based diet, 2) RSM2 : corn-SBM based diet + rapeseed meal 2%, 3) RSM4 : corn-SBM based diet + rapeseed meal 4%, 4) RSM6 : corn-SBM based diet + rapeseed meal 6%, 5) RSM8 : corn-SBM based diet + rapeseed meal 8%. After weaning period, all pigs were fed same commercial diet but conducted phase feeding method (early growing, lated growing : 8 weeks) (early finishing, lated finishing : 5 weeks). All nutrients were met or exceeded the requirement of NRC (1998). In addition, experimental diets formula and chemical compositions were presented in table 1 and 2.

Blood sampling and analysis

Blood samples were taken (0, 3, 6 weeks) from anterior vena cava of 6 pigs in each treatment for measuring blood urea nitrogen (BUN), Immunoglobulin G (IgG), immunoglobulin A (IgA), Total cholesterol, LDL cholesterol, HDL cholesterol, T3, T4. Collected blood samples were quickly centrifuged for 15 min by 3,000 rpm at 4℃. Then, sera samples were aspirated by pipette and stored at −20℃ until later analysis. The BUN concentration was analyzed using blood analyzer (Ciba-Corning model, Express Plus Ciba Corning Diagnostics Co.). IgG, IgA were determined by ELISA assay, according to the manufacture’s guidelines (ELISA Stater Accessory Package, Pig IgG ELISA Quantitation Kit, Pig IgA ELISA Quantitation Kit; Bethyl). All samples were assayed in duplicates with 1:20,000 (IgG) or 1:10,000 (IgA) fold dilution. Total cholesterol, LDL cholesterol, HDL cholesterol were measured by enaymatic colorimetric assy (Modular analytics, PE model). T3, T4 were measured by ELISA assay (Modular analytics, PE model).

Glucosinolates were extracted from RSM with 2 mL of boiling methanol solution (70% vol/vol) and 200 μL internal standard spike solution of glucotropaeolin (ChromaDex, Irvine, CA, USA) was added immediately (International Standards Organization, 1992) and extracted glucosinolates were purified on aDEAE Sephadex A-25 anion exchange column (St. Louis, MO, USA). Three types of glucosinolates in RSM were determined by using High Performance Liquid Chromatography (HPLC; Sunnyvale, CA, USA). Desulfo-glucosinolates were separated using a Synergi Fusion-RP 80A (100×3 mm, 4 um, Phenomenex, CA, USA) with a flow rate of 1 mL/min. Glucosinolates (progoitrin, sinigrin and gluconapin) were confirmed by a Finnigan LCQ Deca XP plus Ion Trap Mass Spectrometer system (Thermo Finnigan, CA, USA) which confirmed by LC-ESIMS in positive mode.

Erucic acid content in RSM was analyzed on a 7890 Agilent Gas Liquid Chromatograph (Agilent Technologies, Palo Alto, CA, USA) and equipped with flame ionization detector and the column was SP-2560 (i.d. 100 m×0.25 mm ×0.20 ㎛ film). Nitrogen was used as carrier gas, injector core temperature was 250°C, detector temperature was 260°C and column temperature was programmed to begin at 170°C and then increase to 250°C then remained at 240°C for 40 min. Chromatography was calibrated with a mixture of 37 different fatty acids (FAME 37; Supelco Inc., Bellefonte, PA, USA) and the standard contained fatty acids ranging from C4:0 to C24:1n9 and samples were added 250 ㎕ of internal standard spike solution (Pentadecanoic acid; Sigma) by the method of AOAC (1990).

Pork quality and carcass traits

In each treatment, 3 pigs were slaughtered for the carcass analysis. Longissimus muscles were used from nearby 10^{th} rib on right side of carcass. Because of chilling procedure, 30 minutes after slaughter was regarded as initial time. The time to measure pH and pork color were in 0, 3, 6, 12 and 24 hour. The pH was determined by pH meter (Model, Themo Orion, U.S.A) and pork color was determined by CIE color L*, a* and b* value using a CR300 (Minolta Camera Co., Japan). Proximate of pork samples were analyzed by the method of AOAC (1995).

Centrifuge method was used for water holding capacity of pork (Abdullah and Najdawi, 2005). Longissimus muscle samples were grounded and sampled in filter tube, and heated in water bath at 80℃ for 20 min and centrifuged for 10 min at 2,000 rpm and 10℃ (Eppendorf centrifuge 5810R, Germany). Then after that, to calculate the cooking loss, longissimus muscles were packed with polyethylene bag and heated in water bath until core temperature reached 72℃ and weighed before and after cooking. After heated, samples were cored (0.5 inch in diameter) parallel to muscle fiber and the cores were used to measure the shear force using as alter (Warner Bratzler Shear, USA). Cooking loss, shear force, and water holding capacity of pork were analyzed by animal origin food science, Seoul National University.

Metabolic trial

A total of 15 pigs ([Yorkshire×Landrace]×Duroc) with an initial BW 13.41 ± 0.32 kg were allotted to five treatments in a completely randomized design. Each pig was housed in an individual metabolic crate (82 by 40 cm^2) in a room of steady temperature (27°C), controlled with a heating lamp. The experimental diets were supplied twice a day at 08:00 hand 20:00 h according to the rate of 2.0 times of the maintenance requirement for ME (106kcal of ME/kg of $BW^{0.75}$) based on initial BW of pigs. Water was provided ad libitum. After 5 days adaptation period, pigs were subjected to 5 days collection and 0.5 % of chromic oxide and 0.5 % of ferric oxide were used as initial and end marker, respectively. Spread glasswool thinly for filtering the foreign objects on the funnel to collect the urine, pour 10 % sulfuric acid (50 Ml) over to prevent volatilization of ammonia. Collected excreta and urine were stored at –20°C during the collection period and dried (65°C, 72 h) and ground (2 mm screen, Wiley mill) for chemical analysis at the end of trial.

Chemical Analyses

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 analyses were repeated if results from duplicate samples varied more than 5% from the mean. The DM of diet samples were determined by oven drying at 135°C for 2 h (method 930.15; AOAC International, 1995). Aspartic acid was used as a calibration standard, and CP was calculated as N × 6.25 (method 988.05; AOAC International, 1995) and diets were also analyzed for ash (method 942.05; AOAC International, 1995). Crude fat was hydrolized in HCl solution to release bound fat and then extracted with diethyl ether and petroleum ether (method 920.39; 1995). Collected excreta were pooled and dried in an air-forced drying oven at 60°C for

72 h, and ground into 1 mm particles in a Wiley mill for chemical analysis include moisture, protein, fat and ash contents (AOAC, 1995). Total urine was collected daily in a plastic container containing 50 Ml of 4N H_2SO_4 and frozen during the 5 day collection period for nitrogen retention analyses.

Economic analysis

Economic analysis was calculated by feed cost and feed efficiency (G:F ratio). The total feed cost (Won) per body weight gain (kg) was calculated using total feed intake and feed price. The feed cost per weight gain was calculated based on price of raw materials during the time of the experiment. The days to market weight (115 kg) were estimated from the body weight at the end of feeding trial and ADG of 19 weeks.

Statistical analysis

The experimental data was analyzed as a randomized complete block design using the General Linear Model (GLM) procedure of SAS. For data on growth performance and economic analysis a pen was considered as an experimental unit, while individual pig was used as an unit for data on blood profiles, immune response, pork quality and economic analysis. Linear and quadratic effects for equally spaced treatments were assessed by measurement of orthogonal polynomial contrast. The differences were declared significant at $P < 0.01$.

Results

Table 5, table 6 showed the influence of rapeseed meal (RSM) supplementation on growth performance in weaning pigs and growing to finishing pig period (Table 5, 6). There was no significant difference on growth performance during the whole experimental period. In addition, Total cholesterol, HDL cholesterol, LDL cholesterol, T_3, T_4 were not affected by dietary RSM supplementation in weaning pig diets (Table 7). However, the blood urea nitrogen (BUN) concentration was decreased as dietary RSM level increased in 6 week (linear response, $P<0.01$). Table 8 showed the influence of RSM supplementation on immune response in weaning pigs. There was no significant differences on IgG and IgA. Influence of rapeseed meal supplementation on nutrient digestibility and nitrogen retention were not affected by the dietary rapeseed meal level increased (Table 9). As dietary RSM level of weaning pig diet was increased, there were no differences in proximate analysis and physiochemical property of the pork after slaughter among dietary treatments (Table 10). In addition, there were no significant difference in pork color L*, a* and b* value (Table 11) and pH at 0, 3, 6, 12, 24h after slaughter (Table 12). In economic benefit, any significant difference was not examined (Table 13) but compared control treatment, supplemented RSM 2% in weaning pig diet had the greatest economical profit .

Discussion

In the current study, growth performance in weaning to finishing periods was not affected by dietary supplementation of RSM up to 8% in weaning pig diet. RSM in pig diet which could be used to replace SBM was limited up to 5% in young pigs. RSM had anti-nutrition factors such as glucosinolates, erucic acid. glucosinolates appeared to have negative effect on feed intake because of high content of progoitrin which were associated with bitter taste (Lee and Hill, 1983). Gill et al. (1991) reported that 3 weeks of weaning pig were particularly sensitive to RSM and showed reductions of feed intake in the first week. In addition, when pigs (weighing 23 to 45 kg) fed 5 or 10% of RSM showed 17% reduction of daily gain and 7% less feed intake (Bell et al., 1984). Hanne (2010) suggested that it is possible to use up to 15% RSM (glucosinolates content 23 μmol/g) to weaning pig diet without significantly affecting productivity negatively because low content of 4-hydroxy-glucobrassicin in RSM, which indicates that the products were damaged by heat-treatment and that glucosinolates had disintegrated, which affected pigs' productivity negatively. Generally accepted glucosinolates tolerance level was 2.0–2.4 mol/g for growing pigs but the maximum tolerable level of dietary glucosinolates for weaning pigs remains to be proved (Landero et al., 2012). In addition, Inclusion of up to 25% solvent-extracted canola meal (glucosinolates contents 4-9.5 mol/g) in diets fed to weaning pigs (6 to 23 kg BW) did not affect ADG or voluntary feed intake (Eason and King, 2000; King et al., 2001), and supplemented canola meal (glucosinolates contents 10-22 mol/g) up to 15 to 20% in weaning pig diets had no negative effects on ADG, ADFI, and G:F (Seneviratne et al., 2010; Landero et al., 2011; Landero et al., 2012). In this study indicated same result that RSM supplementation up to 8% in weaning pig diet did not affect to growth performance during weaning to finishing periods.

The amino acid composition of RSM, sulfur containing amino acids like methionine and cysteine is higher than SBM. Although SBM contains more lysine than RSM, amino acid balance compares well with SBM (Clandinin, 1967). However, digestibility of RSM containing diets could not be well compared with SBM (Patric et al., 2010). Nutrient digestibility may be affected by fiber of rapeseed hulls, anti-nutritional factors (tannin, sinapine, erucic acid and glucosinolates) and dietary formulation (Patric et al., 2010). In this present experiment, BUN concentration was decreased as dietary RSM level increased. This result is associated with the results of Fenwick and Curtis (1980) that combination with SBM and RSM could make some clear advantages. Protein of RSM is less digestible than that of the SBM (72% vs. 88%), but the amino acids balance is better than in the soybean meal (for the sulphur amino acids) (Koreleski, 1993). Clandinin et al (1959) suggested that lysine is sensitive to excessive heat which leads to undesirable reactions and reduced availability of amino acids. Any reduction in lysine availability will seriously affect the competitive position of RSM for monogastric use. When supplementation of RSM in animal diet, minimum heat necessary to inactivate enzymes (especially myrosinase) and to avoid denaturation of the proteins (Clandinin et al. 1959). In this study, supplemented up to RSM 8% in weaning pig diet had no negative effect on BUN concentration.

The hydrolysis product of glucosinolates are known to depress iodine metabolism in the thyroid gland and inhibit the synthesis of thyroid hormones T3 and T4 (Bell and Belzile, 1965). When these compounds especially thiocynates interfere with iodine uptake, leading to hypothyroidism and enlargement of the thyroidgland. In addition, these changes on the metabolism in all tissues and reproductive organ are affected (Halkier and Gershenzon, 2006). Maison (2013) suggested that dietary content of glucosinolates (9-10 μmol/g) Induced iodine deficiency, hypothyroidism, reduced bone and serum zinc content and alkaline phosphatase activity. Consequently, There were no significant effect on T3,T4hormone by supplementation of RSM up to 8% (glucosinolates content 3.04 μmol/g) in weaning pig diet.

Fatty acid composition of RSM consists oleic (51%), linoleic (25%), linolenic (14%) acids. When pigs fed a lot of monounsaturated fatty acids specifically oleic acid in feed, those could be exchanged for saturated fatty acid and serum HDL cholesterol levels was increased without changing LDL cholesterol levels (Keys et al., 1965). Kaneko (1970) suggested that increased cholesterol concentration was indicator of hypothyroidism because thyroid hormone is an important modulator of intermediary metabolism by hypercholesterolemia of hypothyroidism which related with increase serum LDL cholesterol concentration. Consequently, Total cholesterol, HDL cholesterol, LDL cholesterol and thyroid hormones concentration were not affected in current experiment.

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 (Snoeck et al., 2006). 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 (Haye and Karnegay et al., 1979). It could have a function in controlling diarrhea and infection via binding many types of pathogenic antigens (Bourne, 1973). Dietary exposure of animals to glucosinolates, many negative effect break out such as low growth performance and impaired fertility. Some of the glucosinolate breakdown products, especially the nitriles, might lead to mucosal irritation in the gastro-intestinal tract and transient impairment of liver and kidney functions (EFSA, 2008). However, Hydrolysis of glucosinolates could occur with creation of isothiocyanates that are the significant effect on the synthetic bio-fumigants in intestinal mucosa (Sarwar et al. 1998). In the current study, IgG and IgA were not affected by increased RSM in weaning pig diet.

Rapeseed meal contains 16.5 to 18.7% hull, dry basis (Appelqvist and Ohlson, 1972). Sarwar et al. (1981) suggested that the contents of hulls could reduce the digestibility of protein so hull protein was highly indigestible (Leslie et al., 1973; Seth and Clan- dinin, 1973; Bayley and Hill, 1975; Sarwar et al., 1981). Compared with SBM, RSM has a poorly digestible non-starch polysaccharides and oligosaccharides (Slominski and Cambell 1990). Especially, glucosinolates levels in particular have presented a problem where RSM is used as a dietary ingredient (Mawson et al. 1993). The digestibility of CP and AA in CP could vary depending on the age of pigs and quality of protein (Stein et al., 1999a). In addition, nutrient digestibility of RSM could be affected many factors such as different genetic selections, environments, and oil extracted using different processes (Maison, 2013). In this study showed that no significant difference in nutrient digestibility as dietary RSM level increased.

In the present study, there were no differences in proximate analysis and physiochemical property of the pork after slaughter among dietary treatments. Growth performance of weaning pigs are influenced by nutrients of feed but chemical composition of the carcass in finishing pigs were not affected (Frape, 1959). WHC of the meat could be increased with time after slaughter due to the proteolytic action of cathepsins, which break down the enzymes of the myofibrillar structure and changes in the electrical charges. These changes increase the absorption many kind of ions such as potassium, calcium, sodium (Marina et al., 2013). Maturation time could effect on meat tenderer. During the time after slaughter, shear force may decrease because of proteolysis of the myofibril structural components. If WHC decreased shear force was increased (Marina et al., 2013). With WHC of the muscle increases, greater percentage of fluid to be released during cooking (Apple et al., 2001).

RFN (reddish, firm and non-exudative), pale, PSE (pale, soft and exudative) and of DFD (dark, firm and dry) meat are intimately related with pH. The initial pH is regarded as an indication of PSE pork and the final pH is acknowledged as an estimation of DFD (Maganhini et al., 2007). Time after maturation periods, pH values decreased. This result could be explained by the growth of lactic acid bacteria, which optimally grow at pH < 6 (Marina et al., 2013). In pork color, decreasing in redness and increasing in yellowness has a negative effect on the freshness of pork (Bendall and Wismer-Pederson, 1962). Redness is closely associated with the state and amount of myoglobin in the meat. Low-pH conditions, it causes a denaturation of globin, leaving the heme function unprotected and accelerate oxidation of the metmyoglobin. The increase in the time after slaughter of the meat could accelerate darker and yellowness tends to increase over time (Marina et al., 2013). In present experiment, there were no significant difference in pork color L*, a* and b* value and pH at 0, 3, 6, 12, 24h after slaughter.

The raw material price for the analysis of the experiment was based on the cost of the feed supply at the time of the experiment and was compared based on the feed price due to the raw material feed except for processing costs and labor costs of the experiment etc. Statistical analysis showed no significant difference between treatments but treatment RSM6 showed the highest numerical value in weight gain, feed cost, and days to market weight compared to other treatments and treatment RSM2 was 3% lower in weight gain and feed cost compared to control treatment. Also, days to market weight (reached 115kg body weight) reached 4 days earlier than control treatment. These results showed RSM in weaning pig diet was considered to be the most economical one when it was supplemented up to 2%.

Conclusion

Several impacts of increasing RSM levels in weaning pig diets were not observed in growth performance, blood profiles, carcass characteristics. However, BUN was decreased when RSM was supplemented up to 8%. Economic analysis showed that supplementation of RSM 2% was the most beneficial effect. Consequently, RSM could be used for weaning pig up to 8% without any detrimental effect on growth performance but considering the economic efficiency, 2% is the best.

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Table 1. Formula and chemical compositions of the experimental diets in phase1 (0 to 3 weeks)

	Treatments[1]				
	CON	RSM2	RSM4	RSM6	RSM8
Ingredients, %					
Corn	37.29	36.55	35.79	35.07	34.30
SBM	31.33	29.80	28.28	26.77	25.25
Barley	15.00	15.00	15.00	15.00	15.00
Rapeseed meal	0.00	2.00	4.00	6.00	8.00
Whey powder	4.00	4.00	4.00	4.00	4.00
Lactose	6.00	6.00	6.00	6.00	6.00
Soypeptide	1.81	1.81	1.81	1.81	1.81
Soy-oil	1.14	1.44	1.75	2.04	2.35
MDCP	1.38	1.33	1.30	1.24	1.20
Limestone	1.02	1.02	1.01	1.01	1.01
L-lysine-HCl, 78%	0.28	0.29	0.30	0.30	0.31
DL-met, 80%	0.07	0.07	0.06	0.05	0.05
L-threonine, 99%	0.08	0.09	0.10	0.11	0.13
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
Salt	0.30	0.30	0.30	0.30	0.30
ZnO	0.10	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition					
ME, kcal/kg[4]	3,265.02	3,265.02	3,265.03	3,265.01	3,265.03
Crude protein, %[5]	19.21	18.47	18.17	18.31	18.59
Crude fat, %[5]	2.67	2.60	2.88	3.18	3.55
Crude ash, %[5]	5.86	6.24	6.13	5.98	6.24
Lysine, %[4]	1.35	1.35	1.35	1.35	1.35
Methionine, %[4]	0.35	0.35	0.35	0.35	0.35
Ca, %[4]	0.80	0.80	0.80	0.80	0.80
P, %[4]	0.65	0.65	0.65	0.65	0.65

[1] Control: corn-SBM diet, RSM2: corn-SBM diet + RSM2%, RSM4: corn-SBM diet + RSM4%, RSM6: corn-SBM diet + RSM6%, RSM8: corn-SBM diet + RSM8%

[2] Provided the following quantities of vitamins per kg of complete diet : vitamin A, 8,000 IU; vitamin D3, 1,800IU; vitamin E, 60IU; thiamine, 2mg; riboflavin, 7mg; calcium pantothenic acid, 25mg; niacin, 27mg; pyridoxine, 3mg; biotin, 0.2mg; folic acid, 1mg; vitamin B12, 0.03mg

[3] Provided the following quantities of minerals per kg of complete diet : Se, 0.3mg; I, 1mg; Mn, 51.6mg; CuSO4, 105mg; Fe, 150mg; Zn, 72mg; Co, 0.5mg

[4] Calculated value

[5] Analyzed value

Table 2. Formula and chemical compositions of the experimental diets in phase1 (4 to 6 weeks)

	Treatments[1]				
	CON	RSM2	RSM4	RSM6	RSM8
Ingredients, %					
Corn	47.25	46.25	45.79	45.03	44.31
SBM	27.08	25.54	24.03	22.51	20.98
Barley	15.00	15.00	15.00	15.00	15.00
Rapeseed meal	0.00	2.00	4.00	6.00	8.00
Whey powder	2.00	2.00	2.00	2.00	2.00
Lactose	3.00	3.00	3.00	3.00	3.00
Soypeptide	1.81	1.81	1.81	1.81	1.81
Soy-oil	1.01	1.30	1.60	1.91	2.20
MDCP	1.20	1.15	1.10	1.05	1.00
Limestone	0.89	0.89	0.88	0.89	0.88
L-lysine-HCl, 78%	0.18	0.19	0.19	0.20	0.21
DL-met, 80%	0.03	0.03	0.02	0.01	0.01
L-threonine, 99%	0.01	0.02	0.03	0.05	0.06
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
Salt	0.30	0.30	0.30	0.30	0.30
ZnO	0.05	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition[4]					
ME, kcal/kg[4]	3,265.04	3,265.05	3,265.02	3,265.01	3,265.00
Crude protein, %[5]	17.64	17.91	17.22	17.77	18.88
Crude fat, %[5]	3.18	2.57	2.89	3.02	3.40
Crude ash, %[5]	6.01	5.65	5.26	4.94	5.44
Lysine, %[4]	1.15	1.15	1.15	1.15	1.15
Methionine, %[4]	0.30	0.30	0.30	0.30	0.30
Ca, %[4]	0.70	0.70	0.70	0.70	0.70
P, %[4]	0.60	0.60	0.60	0.60	0.60

[1] Control: corn-SBM diet, RSM2: corn-SBM diet + RSM2%, RSM4: corn-SBM diet + RSM4%, RSM6: corn-SBM diet + RSM6%, RSM8: corn-SBM diet + RSM8%

[2] Provided the following quantities of vitamins per kg of complete diet : vitamin A, 8,000 IU; vitamin D3, 1,800IU; vitamin E, 60IU; thiamine, 2mg; riboflavin, 7mg; calcium pantothenic acid, 25mg; niacin, 27mg; pyridoxine, 3mg; biotin, 0.2mg; folic acid, 1mg; vitamin B12, 0.03mg

[3] Provided the following quantities of minerals per kg of complete diet : Se, 0.3mg; I, 1mg; Mn, 51.6mg; $CuSO_4$, 105mg; Fe, 150mg; Zn, 72mg; Co, 0.5mg

[4] Calculated value

[5] Analyzed value

Table 3. Anti-nutritional factors and chemical composition contents of rapeseed meal (as dry matter basis)

Item	Rapeseed Meal
Glucosinolates, μmole/g	
Progoitrin	0.32
Sinigrin	8.12
Gluconapin	29.52
Total glucosinolates	37.97
Erucic acid, mg/g	7.37
Crude protein, %	32.80
Crude fat, %	1.03
Crude ash, %	8.57

Table 4. Glucosinolates and erucic acid intake in weaning pigs during weaning periods[1,2]

Item	RSM2	RSM4	RSM6	RSM8
Glucosinolates in diet, μmol/g[3]	0.76	1.52	2.28	3.04
Daily Glucosinolates intake, μmol/g[3]	568.48	1019.92	1527.60	2048.96
Erucic acid in diet, mg/g[3]	0.15	0.29	0.44	0.59
Daily erucic acid intake, mg/g[3]	112.20	194.59	294.80	397.66

[1] Con: corn-SBM diet, RSM2: basal diet + RSM2%, RSM4: basal diet + RSM4%, RSM6: basal diet + RSM6%, RSM8: basal diet + RSM8%.

[2] Glucosinolates content in the diets was equivalent to 0.76, 1.52, 2.28 and 3.04 μmol/g for 2, 4, 6 and 8 % of RSM supplementation respectively. Eucic acid content in the diets was equivalent to 0.15, 0.29, 0.44 and 0.59 mg/g for 2, 4, 6 and 8 % of RSM supplementation respectively.

[3] Calculated value

Table 5. Influence of various rapeseed meal levels in weaning pig diet on growth performance in weaning pigs[1]

Criteria	Treatment[2]					SEM[3]	*P*-value[4]	
	CON	RSM 2	RSM 4	RSM 6	RSM 8		Lin.	Quad.
Body weight, kg								
Initial	7.28	7.28	7.28	7.28	7.28	0.188		
3 week	10.75	11.04	10.68	10.55	10.24	0.333	0.27	0.98
6 week	22.18	22.90	22.40	21.91	21.41	0.566	0.20	0.93
ADG, g								
0-3 week	165	178	163	155	142	9.0	0.28	0.97
4-6 week	545	565	558	541	532	11.9	0.19	0.90
0-6 week	355	372	361	348	337	9.9	0.20	0.93
ADFI, g								
0-3 week	305	314	309	293	290	11.8	0.42	0.92
4-6 week	1,042	1,181	1,032	1,047	1,059	33.4	0.21	0.16
0-6 week	673	748	671	670	674	21.8	0.23	0.26
G:F ratio								
0-3 week	0.540	0.562	0.528	0.530	0.471	0.0147	0.16	0.66
4-6 week	0.524	0.479	0.541	0.525	0.508	0.0089	0.50	0.10
0-6 week	0.528	0.497	0.538	0.526	0.501	0.0072	0.96	0.10

[1] A total 120 crossbred pigs was fed from average initial body 7.28 kg and the average final body weight was 22.16 kg
[2] Control: corn-SBM diet, RSM2: corn-SBM diet + RSM2%, RSM4: corn-SBM diet + RSM4%, RSM6: corn-SBM diet + RSM6%, RSM8: corn-SBM diet + RSM8%
[3] Standard error of mean.
[4] Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 6. Influence of various rapeseed meal levels in weaning pig diet on growth performance in growing-finishing pigs

Criteria	Treatment[1]					SEM[2]	P-value[3]	
	CON	RSM 2	RSM 4	RSM 6	RSM 8		Lin.	Quad.
Body weight, kg								
6 wk	22.18	22.90	22.40	21.91	21.41	0.566	0.20	0.93
10 wk	43.32	45.02	44.43	41.81	42.63	0.822	0.18	0.52
14 wk	67.20	72.75	69.42	65.62	67.59	1.415	0.13	0.18
17 wk	90.23	96.26	93.06	89.11	91.42	1.546	0.17	0.20
19 wk	106.63	111.85	109.42	105.37	108.27	1.567	0.28	0.22
ADG, g								
6-10 wk	755	790	787	716	753	12.9	0.20	0.26
11-14 wk	853	990	892	789	891	31.0	0.28	0.11
6-14 wk	803	890	840	780	822	17.0	0.12	0.10
15-17 wk	1,097	1,119	1,126	1,110	1,127	17.9	0.93	0.77
18-19 wk	1,171	1,113	1,169	1,161	1,205	20.4	0.27	0.89
15-19 wk	1,127	1,117	1,143	1,131	1,162	14.4	0.52	0.84
6-19 wk	893	940	956	915	953	19.3	0.80	0.53
ADFI, g								
6-10 wk	1,778	1,744	1,711	1,738	1,679	31.9	0.72	0.57
11-14 wk	2,357	2,373	2,408	2,365	2,376	67.7	0.94	0.99
6-14 wk	2,068	2,059	2,059	2,052	2,027	45.6	0.87	0.89
15-17 wk	2,999	2,273	2,990	3,058	2,883	86.0	0.81	0.35
18-19 wk	3,735	3,861	4,154	3,812	3,872	81.0	0.45	0.94
15-19 wk	3,294	3,231	3,456	3,359	3,279	76.6	0.90	0.50
6-19 wk	2,539	2,510	2,596	2,555	2,509	53.4	0.88	0.66
G:F ratio								
6-10 wk	0.425	0.456	0.461	0.412	0.449	0.0072	0.29	0.08
11-14 wk	0.368	0.418	0.375	0.331	0.376	0.0117	0.25	0.07
6-14 wk	0.392	0.433	0.410	0.382	0.406	0.0007	0.13	0.05
15-17 wk	0.373	0.403	0.385	0.371	0.391	0.0110	0.70	0.37
18-19 wk	0.316	0.290	0.284	0.304	0.311	0.0059	0.11	0.89
15-19 wk	0.350	0.348	0.335	0.339	0.354	0.0072	0.65	0.49
6-19 wk	0.352	0.374	0.372	0.360	0.380	0.0060	0.86	0.23

[1]Commercial diet was fed in growing-finishing periods.
[2] Standard error of mean.
[4]Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 7. Influence of various rapeseed meal levels in weaning pig diet on blood profiles in weaning pigs[1]

Criteria	Treatment[2]					SEM[3]	P-value[4]	
	CON	RSM 2	RSM 4	RSM 6	RSM 8		Lin.	Quad.
BUN3), mg/dL								
Initial	11.07	11.07	11.07	11.07	11.07	-	-	-
3 week	14.35[A]	13.08[A]	11.80[AB]	12.68[A]	9.10[B]	0.632	0.15	0.11
6 week	10.21[a]	11.08[a]	9.55[ab]	7.47[bc]	7.00[c]	0.443	<0.01	0.63
Total cholesterol, mg/dL								
Initial	161.00	161.00	161.00	161.00	161.00	-	-	-
3 week	59.33	60.17	68.67	60.50	66.83	2.007	0.77	0.76
6 week	82.17	80.67	86.83	73.71	85.17	1.941	0.76	0.33
LDL cholesterol, mg/dL								
Initial	106.33	106.33	106.33	106.33	106.33	-	-	-
3 week	29.17	31.00	33.33	31.50	33.83	2.394	0.85	0.68
6 week	45.67	44.17	45.67	40.00	43.50	3.790	0.88	0.71
HDL cholesterol, mg/dL								
Initial	52.50	52.50	52.50	52.50	52.50	-	-	-
3 week	23.00	23.33	27.50	22.33	28.00	0.941	0.46	0.33
6 week	28.83	29.67	32.67	31.33	33.33	0.767	0.55	0.79
T3 ng/mL								
Initial	0.16	0.16	0.16	0.16	0.16	-	-	-
3 week	0.14	0.11	0.24	0.25	0.16	0.027	0.96	0.14
6 week	0.14	0.25	0.29	0.15	0.23	0.032	0.40	0.42
T4 µg/dL								
Initial	24.45	24.45	24.45	24.45	24.45	-	-	-
3 week	23.97	21.60	22.09	23.28	20.76	1.290	0.99	0.53
6 week	19.91	23.33	21.12	23.18	16.57	1.220	0.11	0.48

[1] Least squares means for 6 pigs per treatment.
[2] Con: corn-SBM diet, RSM2: corn-SBM diet + RSM2%, RSM4: corn-SBM diet + RSM4%, RSM6: corn-SBM diet + RSM6%, RSM8: corn-SBM diet + RSM8%.
[3] Standard error of mean
[4] Blood urea nitrogen.
[AB] 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).
[5] Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 8. Influence of various rapeseed meal levels in weaning pig diet on immune response in weaning pigs[1]

Criteria	Treatment[2]					SEM[3]	*P*-value[4]	
	CON	RSM2	RSM4	RSM6	RSM8		Lin.	Quad.
Serum IgG (mg/ml)								
Weaning	2.67	2.67	2.67	2.67	2.67	-	-	-
3 week	2.67	2.50	1.97	2.37	2.54	0.088	0.23	0.32
6 week	2.78	3.23	2.73	3.38	3.25	0.180	0.94	0.65
Serum IgA (mg/ml)								
Weaning	1.39	1.39	1.39	1.39	1.39	-	-	-
3 week	3.50	3.36	3.43	3.80	4.16	0.242	0.37	0.82
6 week	0.56	0.57	0.54	0.55	0.51	0.036	0.77	0.93

[1] Least squares means for 6 pigs per treatment.
[2] Con: corn-SBM diet, RSM2: corn-SBM diet + RSM2%, RSM4: corn-SBM diet + RSM4%, RSM6: corn-SBM diet + RSM6%, RSM8: corn-SBM diet + RSM8%.
[3] Standard error of mean.
[4] Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 9. Influence of various rapeseed meal levels in weaning pig diet on nutrient digestibility in weaning pigs[1]

Criteria	Treatment[2]					SEM[3]	*P*-value[4]	
	CON	RSM2	RSM4	RSM6	RSM8		Lin.	Quad.
Nutrient digestibility, %								
Dry matter	91.28	89.94	90.02	88.66	89.79	0.727	0.88	0.91
Crude protein	88.97	86.73	85.98	84.91	87.61	1.026	0.59	0.71
Crude ash	73.82	72.99	71.91	68.73	70.59	2.113	0.87	0.85
Crude fat	86.80	76.39	81.50	83.77	86.13	2.182	0.12	0.54
Nitrogen retention, g/d								
N intake	20.14	19.93	19.58	19.03	19.57	0.197	0.85	0.22
Fecal N	2.22	2.63	2.72	2.88	2.42	0.195	0.60	0.76
Urinary N	3.75	3.20	3.15	4.17	3.57	0.196	0.31	0.29
N retention[5]	14.17	14.10	13.71	11.97	13.58	0.329	0.79	0.19

[1] Least squares means for 3 pigs per treatment. Initial BW : 13.22kg
[2] Con: corn-SBM diet, RSM2: corn-SBM diet + RSM2%, RSM4: corn-SBM diet + RSM4%, RSM6: corn-SBM diet + RSM6%, RSM8: corn-SBM diet + RSM8%.
[3] Standard error of mean.
[4] Abbreviation: Lin. (linear) and Quad. (quadratic).
[5] N retention=N intake − Fecal N − Urinary N.

Table 10. Influence of various rapeseed meal levels in weaning pig diet on pork quality of longissimus muscle[1]

Criteria	Treatment[2]					SEM[3]	*P*-value[4]	
	CON	RSM2	RSM4	RSM6	RSM8		Lin.	Quad.
Proximate analysis, %								
Moisture	74.31	74.31	73.52	73.70	73.65	0.131	0.57	0.53
Crude protein	24.64	24.41	23.72	23.51	24.11	0.134	0.72	0.12
Crude fat	1.68	1.39	2.12	1.87	1.46	0.150	0.81	0.21
Crude ash	1.17	1.34	1.20	1.25	1.17	0.032	0.17	0.51
Physiochemical property								
Cooking loss, (%)	30.05	31.97	32.24	31.88	31.85	0.357	0.34	0.59
Shear force, ($kg/0.5inch^2$)	7.64	7.44	5.89	6.71	6.71	0.275	0.89	0.59
WHC[4],(%)	68.81	63.67	66.13	66.32	65.48	0.665	0.20	0.12

[1] Least squares means for 3 pigs per treatment.
[2] Phase 2 diet was fed (Con: corn-SBM diet, RSM2: corn-SBM diet + RSM2%, RSM4: corn-SBM diet + RSM4%, RSM6: corn-SBM diet + RSM6%, RSM8: corn-SBM diet + RSM8%).
[3] Standard error of mean.
[4] Abbreviation: Lin. (linear) and Quad. (quadratic).
[5] Water holding capacity.

Table 11. Influence of various rapeseed meal levels in weaning pig diet on pork pH after slaughter[1]

Criteria	Treatment[2]					SEM[3]	*P*-value[4]	
	CON	RSM2	RSM4	RSM6	RSM8		Lin.	Quad.
Time after slaughter								
0 hour	5.53	5.88	5.90	5.66	5.71	0.056	0.10	0.39
3 hour	5.44	5.73	5.54	5.59	5.42	0.049	0.08	0.74
6 hour	5.46	5.63	5.56	5.49	5.46	0.043	0.23	0.69
12 hour	5.70	5.61	5.61	5.63	5.57	0.026	0.99	0.40
24 hour	5.79	5.68	5.69	5.68	5.63	0.028	0.95	0.36

[1] Least squares means for 4 pigs per treatment.
[2] Con: corn-SBM diet, RSM2: corn-SBM diet + RSM2%, RSM4: corn-SBM diet + RSM4%, RSM6: corn-SBM diet + RSM6%, RSM8: corn-SBM diet + RSM8%.
[3] Standard error of means.
[4] Abbreviation: Lin. (linear) and Quad. (quadratic).

Table 12. Influence of various rapeseed meal levels in weaning pig diet on pork color after slaughter[1]

Criteria	Treatment[2]					SEM[3]	*P*-value[7]	
	CON	RSM2	RSM4	RSM6	RSM8		Lin.	Quad.
Hunter value, L[4]								
0 hour	40.26	38.78	40.28	40.40	38.92	0.391	0.91	0.06
3 hour	39.45	39.13	40.57	41.54	38.02	0.521	0.40	0.08
6 hour	42.06	40.25	43.84	42.83	41.26	0.634	0.96	0.15
12 hour	43.69	42.03	43.21	44.09	43.46	0.418	0.33	0.31
24 hour	45.52	44.53	45.02	46.39	45.97	0.437	0.37	0.60
Hunter value, a[5]								
0 hour	1.96	1.98	1.62	1.89	1.40	0.085	0.16	0.36
3 hour	2.52	2.28	2.11	2.96	1.75	0.175	0.49	0.06
6 hour	3.46	2.87	3.15	3.61	3.14	0.158	0.27	0.06
12 hour	4.08	3.59	4.11	4.68	4.74	0.210	0.07	0.52
24 hour	4.93	4.68	4.99	4.96	5.07	0.178	0.38	0.73
Hunter value, b[6]								
0 hour	4.20	4.24	4.08	3.88	4.74	0.078	0.97	0.28
3 hour	4.03	4.08	4.24	4.73	3.77	0.112	0.27	0.05
6 hour	5.31	4.74	5.51	5.44	5.20	0.148	0.53	0.20
12 hour	5.65	5.13	5.74	5.95	6.18	0.164	0.09	0.61
24 hour	6.21	6.29	6.68	6.78	6.86	0.165	0.58	0.91

[1] Least squares means for 4 pigs per treatment.
[2] Con: corn-SBM diet, RSM2: corn-SBM diet + RSM2%, RSM4: corn-SBM diet + RSM4%, RSM6: corn-SBM diet + RSM6%, RSM8: corn-SBM diet + RSM8%.
[3] Standard error of means.
[4] Abbreviation: Lin. (linear) and Quad. (quadratic).
[5] L - luminance or brightness (vary from black to white).
[6] a - red·green component (+a=red, -a=green).
[7] b - yellow·blue component (+b=yellow, -b=blue).

Table 13. Influence of various rapeseed meal levels in weaning pig diet on economic benefits[1]

Criteria	Treatment[2]					SEM[3]	P-value[4]	
	CON	RSM2	RSM4	RSM6	RSM8		Lin.	Quad.
Feed cost per weight gain, won/kg								
0-3 week	965	928	993	984	1,142	31.7	0.11	0.45
4-6 week	885	972	859	899	928	16.6	0.59	0.08
7-10 week	1,215	1,133	1,117	1,252	1,147	19.8	0.33	0.10
11-14 week	1,394	1,220	1,371	1,592	1,349	51.0	0.41	0.06
15-17 week	1,356	1,245	1,324	1,382	1,272	43.3	0.78	0.28
18-19 week	1,532	1,666	1,705	1,588	1,545	31.5	0.10	0.97
0-19 week	7,347	7,165	7,368	7,697	7,382	93.6	0.50	0.17
Total feed cost per pig, won/head								
0-3 week	3,298	3,414	3,371	3,201	3,176	128.0	0.45	0.90
4-6 week	10,138	11,500	10,081	10,261	10,410	325.3	0.25	0.16
7-10 week	25,595	22,205	24,625	25,019	24,160	858.1	0.42	0.30
11-14 week	33,400	33,626	34,115	33,512	33,657	959.6	0.94	0.99
15-17 week	31,242	29,287	31,145	31,847	30,033	896.2	0.81	0.35
18-19 week	25,098	25,944	27,916	25,620	26,018	551.0	0.45	0.94
0-19 week	128,771	125,976	131,252	129,460	127,455	2,836.6	0.98	0.62
Total feed cost per pig, won/head (reached 115kg)								
	141,565	132,891	141,808	145,260	138,945	2,162.0	0.47	0.10
Days to market weight (reached 115kg)								
	141	137	138	142	138	1.4	0.43	0.12

[1] Least squares means of 3 observations per treatment.
[2] Weaning periods (Con: corn-SBM diet, RSM2: corn-SBM diet + RSM2%, RSM4: corn-SBM diet + RSM4%, RSM6: corn-SBM diet + RSM6%, RSM8: corn-SBM diet + RSM8%). Growing-finishing periods was fed commercial diet.
[3] Standard error of means.
[4] Abbreviation: Lin. (linear) and Quad. (quadratic).

Ⅴ. Summary in Korean

본 연구는 자돈 사료 내 단백질 공급원인 대두박을 대체하기 위한 원료로서 채종박을 자돈 사료에 사용하여, 이에 대한 영양적 가치 평가 및 첨가수준을 규명하고자 수행 되었다. 채종박의 첨가수준은 0, 2, 4, 6, 8%로 5개의 처리구로 사양실험이 진행되었다. 평균 체중 7.28 ± 0.863 kg의 3원 교잡종 ([Yorkshire × Landrace]) × Duroc) 이유자돈 160두를 공시하였으며, 전체 5처리 4반복, 반복 당 6두씩 성별과 체중에 따라 난괴법 (RCBD; Randomized Complete Block Design)으로 배치하였다. 실험의 처리구는 다음과 같다. 1) CON : NRC (1998)의 영양소 요구량을 충족하는 옥수수-대두박 위주의 기초사료, 2) RSM2 : 기초사료 + 채종박 2% 3) RSM4 : 기초사료 + 채종박 4% 4) RSM6 : 기초사료 + 채종박 6%, 5) RSM8 : 기초사료 + 채종박 8%첨가한 처리구를 구성하였으며, 육성-비육기 동안 모든 처리구의 실험돈들은 시판사료를 동일하게 급여하였다. 사양실험 결과, 자돈기 성장성적에서 통계적인 유의차가 나타나지 않았다. 자돈기에 채종박을 수준별로 급여받은 돼지의 육성, 비육기 사양실험 결과에서도 성장성적에서 통계적인 유의차가 나타나지 않았다. 따라서 자돈 사료 내 채종박을 8%까지 첨가하여 기존 단백질원료인 대두박을 어느정도 대체가능할 것으로 사료된다.

혈액성상에서는 채종박의 첨가수준이 증가함에 따라 6주차 BUN농도가 linear하게 감소하였으며, total cholesterol, LDL cholesterol, HDL cholesterol, T3, T4의 분석결과 처리구간 통계적 유의차가 발생하지 않았으며 자돈 사료 내 채종박의 첨가는 돼지의 갑상선 기능 및 혈중 콜레스테롤 농도에도 부정적인 영향을 미치지는 않는 것으로 나타났다.

면역성상 결과에서는 IgA, IgG 모두 처리구간 유의적인 차이가 없

는 것으로 보아 자돈 사료 내 채종박을 8%까지 첨가하여도 면역성상에 부정적인 영향을 끼치지 않을 것으로 생각된다.

소화율 결과, 영양소 소화율, nitrogen retention모두 처리구간 유의적 차이가 나타나지 않았다. 돈육분석 결과 pH, 육색, 일반성분 및 이화학적 특성에서 처리구간의 통계적 유의차가 발생되지 않았으며, 육색과 pH 모두 정상적인 수치를 기록한 점을 보아 자돈 사료 내 채종박의 첨가가 돈육에 부정적인 영향을 미치지 않는 것으로 나타났다. 경제성 분석에서는 자돈사료 내 채종박을 2%첨가한 처리구가 다른처리구에 비해 가장 경제적으로 나왔다.

결론적으로 대두박 대체목적으로 자돈 사료 내 채종박을 8% 까지 첨가하여도 자돈, 육성·비육돈의 성장성적, 돈육품질, 혈액성상, 영양소 소화율에 부정적인 영향을 미치지 않을 것으로 사료되지만 경제성 측면에서는 첨가량을 고려해 봐야 할 것이다.