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Effect of Dietary Sugar Beet Pulp Supplementation on Growth Performance, Nutrient Digestibility, Fecal Microflora, Blood Profiles and Diarrhea Incidence in Weaning Pigs

이유자돈 사료 내 **Sugar Beet Pulp** 의 첨가가 이유자돈의 성장, 영양소 소화, 분내 미생물 균총, 혈액성상 및 설사빈도에 미치는 영향

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By
Yan Chunlong

School of Agricultural Biotechnology
Graduate School of Seoul National University

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지도교수 **김 유 용**

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엄 춘 룡

엄춘룡의 농학석사 학위논문을 인준함

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위 원 장 ______________________ (인)

부위원장 ______________________ (인)

위 원 ______________________ (인)

Summary

In 2006, the European Union (EU) has decided to forbid use of antibiotics as growth promoters. In addition, in Korea, antibiotics have been banned from use of growth promoters from July 1, 2011. The ban on antibiotics has been reported as the cause of increasing diarrhea followed by impaired growth performance and high mortality of weaning pigs. In this situation, developing alternative antibiotics is the most important way to prevent diarrhea and mortality of weaning pigs. After ban the use of anitibiotics in animal feed, ZnO is widely used particularly in weaning pigs's diet. However Korea government is continually reduced allowance of ZnO in swine diet because it may cause water and soil pollution when high level of ZnO. As an alternative of ZnO in weaning pigs' diet, sugar beet pulp was introduced because of high palatability in weaning pig as well as relatively high fiber. Consequently, this experiment was conducted to evaluate an adequate the level of sugar beet pulp as an alternative ZnO supplementation on growth performance, nutrient digestibility, fecal microflora, blood profiles and incidence of diarrhea in weaning pigs. A total of 200 weaning pigs [(Yorkshire × Landrace) × Duroc], averaging 9.01 ± 1.389 kg of initial body weight, were allotted to 5 treatments in a randomized complete block (RCB) design. Each treatment composed of 4 replicates with 10 pigs per pen. The treatments were control treatment: Corn-SBM basal diet + ZnO (phase 1: 0.05%; phase 2; 0.03%) and four different levels of SBP was supplemented in Corn-SBM basal diet (3, 6, 9 or 12 %). Two phage feeding programs (phase 1: 1-2 weeks; phase 2: 3-5 weeks) were used for 5 week of growth trial.

In growth trial, there were no significant difference in growth performance and incidence of diarrhea among treatments. The *E. coli* counts were not significantly different among dietary treatments but linear response was observed in *Lactobacillus* counts as sugar beet pulp supplementation increased ($P < 0.05$). In addition, IGF-1, IgA and IgG were not affected by dietary treatments. However, the BUN concentration was decreased when pigs were fed the treatments of diets with SBP compared to that of control treatment ($P < 0.05$). In nutrient digestibility, crude fiber and NDF digestibilities were improved as the sugar beet pulp increased ($P < 0.05$) however, digestibilities of crude ash, crude fat, crude fiber and nitrogen retention were not affected by dietary sugar beet pulp levels.

Consequently, this experiment demonstrated that sugar beet pulp can be supplemented in weaning pigs' diet instead of ZnO to prevent postweaning diarrhea without any detrimental effect on growth performance.

Keywords : Sugar beet pulp, Weaning pigs, Dietary fiber, Growth performance, Nutrient digestibility, Diarrhea, Fecal microflora

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List of Abbreviation

ADG	Average daily gain
ADF	Acid detergent fiber
ADFI	Average daily feed intake
BUN	Blood urea nitrogen
BW	Body weight
DDGS	Distillers dried grains with solubles
DF	Dietary fiber
G:F	Gain to feed
GIT	Gastrointestinal tract
IDF	Insoluble dietary fiber
IGF-1	Insulin like growth factor-1
NDF	Neutral detergent fiber
NSP	Non-starch polysaccharide
PWC	Post-weaning colibacillosis
SBM	Soybean meal
SCFA	Short chain fatty acids
SDF	Soluble dietary fiber
WHC	Water holding capacity
VFA	Volatile fatty acid
ZnO	Zinc oxide

I. Introduction

Antibiotics have been used for more than 50 years to increase growth performance and to prevent disease in livestock feeding environments (Smith, 1975; Kunnin, 1993). However, since serious side effect problems have been posed such as indiscreet residues of livestock product, spread of resistance factor, outbreak of resistant bacteria, etc according to indiscreet antibiotic abuse, the coverage or level about legal regulations and measures have been devised.

In 2006, the European Union (EU) has decided ban use of antibiotics as growth promoters(Chen et al., 2005). In addition, in Korea, antibiotics have been banned from use of growth promoters from July 1, 2011. The ban on antibiotics has been reported as the cause of increasing diarrhea followed by impaired growth performance and high mortality of weaning pigs (Casewell et al., 2003). Hence, the ZnO was used and better result in promoting growth performance and preventing diarrhea in post weaning pig (Poulsen, 1989). However, excreted Zn via feces and urea cause environmental issue, so there is a limited usage level to fulfill that issue. As an alternative of ZnO in weaning pigs' diet, sugar beet pulp was introduced because of high palatability in weaning pig as well as relatively high fiber.

Dietary fiber is classified in two types according to their water solubility: insoluble dietary fiber (IDF) and soluble dietary fiber (SDF). And some authors reported that soluble fiber has function of multiple. It could be proved as substrate for some of lactic bacteria, and Bifidobacteria strains that giving positive effect in gut health (Grizard and Barthomeuf, 1999). Because of GIT microflora, SDF could be fermented and it makes stable environment with that GIT. Then, this helps to reduce concentration of diarrhea as well (Molist et al., 2014; Berrocoso et al., 2015). Sugar beet pulp includes high level of soluble fiber such as pectins and glucans (Fadel, 2000). However, there are still lack of reports in the literature about the optimum level of sugar beet pulp supplementation, affects on growth performance and nutrient digestibility in weaning pigs. Therefore, in the experiment, the diets with different level of sugar beet pulp to determine the effects of sugar beet pulp supplementation on growth performance, nutrient digestibility, fecal microflora, blood profile and incidence of diarrhea in weaning pigs.

II. Literature Review

1. Introduction

Enteric infections with pathogenic bacteria occur frequently in young animals. It causes mortality and reduces growth performance and economic losses in animal production. Antibiotics are added to the diet as growth promoters, but, there is some of negative effect as result in using of antibiotics such as occurrence of resistant bacterial species or strains, and the genes from those resistant can affect to other responsive bacteria. Hence, this possess the menace to animal and human health even. So, in 2006, the European Union (EU) has decided to forbid use of antibiotics as growth promoters(Chen et al., 2005). In addition, in Korea, antibiotics have been banned use of growth promoters from 2011.

In consequence, there were various investigation to find out alternative methods to control of enteric bacterial pathogens in animal and human. First one is the occurrence of fermentation by dietary manipulation from hindgut with usage of feed additives or selection of dietary raw materials which can enhance the colonization of resistance associate with commensal flora to deduct the enteric pathogens, so it could help to gut health.

As the main substrate for bacterial fermentation, dietary fiber is conducted as the main factor in the large intestine of non-ruminant animals particularly. In large intestine, DF interacts between mucoas and microflora and doing important role which control of gut health. In review, the characteristic of dietary fiber and its digestion by non-ruminant animals is presented.

2. Dietary fiber

2.1 Dietary fiber and components

Hispsly first named the non-digestible constituents which constitute the plant cell wall as 'dietary fiber' (De Vries et al., 1999). However, different definition have been put forward and used overtime. Hence, the specific definition of DF should contain the physiological effects of fiber. Thus, DF comprise of CHO which are indigestible via endogenous animal enzymes can be important aspect of the definition(AACC, 2001).

Dietary fiber is known as non-starch polysaccharides (NSP) that covers a wide range of carbohydrates and include pectins, cellulose, hemicelluloses, fructans and β-glucans. The dietary fiber fraction also considered resistant starch and oligosaccharides. As appeared in Table 1, The same pentoses, hexoses, deoxyhexoses and uronic acids are invariably produced by the hydrolysis of these carbohydrates (Chesson, 1995). There are badly predictable from the monomeric composition and more relacted to their viscosity, physical structure, solubility and water-holding capacity by the physiological properties of NSP and their fermentability (Asp, 1996).

The hydrolysis of starch is susceptible by salivary and pancreatic enzymes. However, it is not always complete that the hydrolysis of starch (Sajilata et al., 2006). Resistant starch is also considered as a Dietary fiber (Chesson, 1995).

Table 1. Classification of common non-digestible carbohydrates

Type of carbohydrate	Constituent monomers	Solubility, WHC	Common sources in pig diets
Oligosaccharides, 3 < DP < 10			
Fructo-and galacto-oligosaccharides	Fructose, galactose, glucose	+	Soybean meal, peas, rapeseed meal, cereal, milk products
Polysaccharides, 10 < DP			
Starch			
Physical inaccessible starch (RS1)	Glucose	-	Whole or partly milled grains and seeds, legumes
Crystalline resistant granules (RS2)	Glucose	-	Raw potato, sweet potato, some legumes, plantain, high amylose maize
Petrograded amylose (RS3)	Glucose	-	Cooled heat-treated starchy products
Non starch polysaccharides (NSP)			
Cellulose	Glucose	-	Most cereal, legumes and forages, plant cell wall
Hemicellulose	Glucose, fucose, rhamnose, xylose, galatose, arabinose	+/-	Cereal, legums hulls
β-glucans	Glucose	+	Barley, oats, rey
Pectins	Uronic acids	+	Fruits, chicory and sugar beet pulp
Fructans and inulins	Fructose, glucose	+	Yam, rey, Jerusalem artichoke, chicory

(Chesson, 1995; Bach Knudsen, 1997; Montagne et al., 2003; Sajilata et al., 2006)

2.2 Dietary fiber source

2.2.1 Barley

Barley are relative rich in dietary fiber like β-glucan, cellulose and Arabinoxylans. In particular, high level of soluble β-glucan are contained in hulless barleys (Izydorczyk et al., 2000). And it is benefits for the gut health (Brennan and Cleary, 2005). Even within hulless barleys, the variability in total dietary fiber, soluble and insoluble NSP is very wide (Holtekjolen et al., 2006; Jha et al., 2011). Barley contain β-glucan ranging from 1.9 % to 11.0% (Lee et al., 1997). Lambo et al. (2005) reported that 85 % of the β-glucan in barley fiber were insoluble.

2.2.2 Oat

Oat includes two kind of fiber which soluble and insoluble dietary fiber and also high levels of β -glucan, AX, and cellulose (Johansen et al., 1997; Jha et al., 2011). β-glucan play an important role among the dietary fiber components of oat with their functional properties in the GIT (Pieper et al., 2008; Jha et al., 2010). As protein sources primarily, grain legumes are used in pig diets, besides it also has significant amounts of NSP. From the hulls, cellulose and xylans are found, but pectic polysaccharides are found from cotyledons (Choct, 1997; Jha and Leterme, 2012).

2.2.3 Wheat flour milling

A number of coproducts are produced in wheat flour milling industry (wheat bran (WB), millrun, middlings, shorts, etc.), which are classified based on their dietary fiber content (Jha et al., 2012). Due to processing of wheat during produce flour, those coproducts are enriched with dietary fiber than wheat. Furthermore, There are various types of ADF and NDF content varied from 8.0% to 15.5% and 22.9% to 49.2%, respectively (Jha et al., 2012).

2.2.4 Sugar beet pulp

Sugar beet pulp content of starch was lower than in barley and wheat. Also, Sugar beet pulp had a higher content of NSP (430-743 g/kg DM) than barley and wheat (117-182 g/kg DM) (Serena and Knudsen, 2007). Among other nutrients, it contains 10 % protein, 0.8 % clacium, 0.5 % phosphorus (Equuss magazine, 2010). Sugar beet pulp includes high level of soluble fiber such as pectins and glucans (Fadel, 2000).

We can know that sugar beet pulp has higher level of dietary fiber and soluble fiber than other dietary fiber source from Table 2. So, in this experiment, the sugar beet pulp was selected for dietary fiber source to explore influence in weaning pigs.

Table 2. Types and levels of fiber components in some common cereal grains and coproducts (g/kg DM)

	Barley hulled	Barley hulless	Oats hulled	Oats hulless	Wheat bran	DDGS	Sugar beet pulp
Starch	587	645	468	557	222	86	5
Cellulose	39	10	82	14	72	58	203
NCP							
Soluble	56	50	40	54	29	34	290
Insoluble	88	64	110	49	273	158	207
NSP							
Arabinoxylans	12	48	98	36	238	61	165
β-glucan	43	42	28	41	24	63	8
Mannose	2	4	3	3	5	9	8
Galactose	2	3	7	4	9	14	38
Uronic acids	2	2	10	5	15	16	199
Total NSP	167	124	232	116	374	192	700
Lignin	35	9	66	32	75	32	37
Dietary fiber	202	133	298	148	449	322	737

(Jaworski et al., 2015; Bach Knudsen, 1997; Holtekjolen et al., 2006; Jha et al., 2011; Serena and Knudsen, 2007)

3. Processing of sugar beet pulp at the factory

Between the middle of September and the end of the year, beet are produced and then moved to the processing factories. From there, beet and the sugar content are measured and a main sample is collected.

Before going into the slicers, beet are transported to the factory on fast flowing water which washes them. Then, the beet are cut into 2mm wide V-shaped strips and passed to a revolving diffuser drum. At 72℃ water, the slices are submerged and sugar is dispersed from the beet. Inside the revolving diffuser, there are arranged flanges to convey the extracted beet to the exit where the solid material and sugary liquid are separated from each other. By adding quicklime (calcium oxide) to the sugary juice, it precipitates most of the impurities by using cloth filters.

Into the evaporators, the resulting juice is passed to concentrate it and the concentrate is simmered under reduced pressure until supersaturated. When the supersaturation is finished, the solution is taken away from seed with some sugar from a previous batch which causes the sugar to crystalize. While still in the centrifuge, sugar crystals are separated by centrifugation and washed away with hot water. The liquid which left the centrifuge may be re-concentrated before selling as molasses. Before0 being packaged for sale, the sugar leaves the centrifuges which is dried and graded.

The rotating diffuser containing 5-7% dry matter is left from the extracted pulp. Large screw presses which increase the dry matter content to 15-18 % are passed through. Most pulp is molassed and dried but some pulp is sold as pressed pulp at this stage. Molasses which is added to the beet pulp leaves the screw presses and mixed by a series of augers. The quantity of molasses added is closely related on the outside market price for molasses but how much is included is always 18-22 % of the dry matter. The most of the pulp was sold as dried molassed beet pulp (620 000 tonnes) with the rest of those being sold as pressed beet pulp (300 000 tonnes of fresh material) during the 1980. Quantities of triple nuts and magnesium nuts are comparably low (around 14000 tonnes each). In large rotating cylinders with coke or oil fired boilers at the entrance and a large fan at the exit drawing the hot gases through the drier, the molassed pressed pulp is dried. When the wet pulp enters the drier, it faces the hot gases coming from the furnace at a temperature around 1000℃. Next, it is delivered along the drier by a series of flanges and by the draft of the fan. Gases which leave the drier are at a temperature of 120—130℃. Even though, drying the molassed pulp is used with very high temperatures, the high water cotent of the material insure that the real temperature of the pulp does not go up far above 100℃. However, the digestibility of the protein could be decreased even in that temperature for a short period. Primarily the method used for drying pulp is the same as that in use in the 1920's and reported by Woodman and Calton (1928).

4. Interaction between dietary fiber and weaning pigs

4.1 Fermentation of dietary fiber in GIT

Large intestine of non-ruminant animals large have a numerically great and varieties of bacteria such as *Bacteroides, Prevotella, Eubacterium, Lactobacillus, Fusobacterium, Peptostreptococcus, Selenomonas, Megasphaera, Veillonella* and *Streptococcus* (Jensen, 1999). In the proximal regions of the digestive tract, human, pigs and chickens harbour a permanent microflora, mainly consisting of *Lactobacillus* and *Streptococci* in the pig (Jensen, 2001).

The short chain fatty acids (SCFA) is main fermentation products of dietary fiber. In a number of non-ruminant species, 95-99 % of total SCFA produced is absorbed before arriving the rectum (Von Engelhardt et al., 1989). SCFA makes amount of energy to the gut and to the body of non-ruminant animals (Argenzio and Southworth, 1974). SCFA, especially butyrate, have been involved as having roles in human and animal health (Sakata and Inagaki, 2001). In large and small intestine, butyrate has a role as development and growth via stimulating epithelial cell proliferation (Roediger, 1982; Sakata, 1987). The resorption of water and sodium is stimulated by SCFA (Roediger and Moore, 1981), therefore limiting the risk of diarrhea. The growth of some intestinal bacterial pathogens such as *Escherichia coli* and *Clostridium difficile* could be inhibited by SCFA in pigs (Prohaska, 1986; May et al., 1994).

Influence of dietary fiber fermentation have more importance factors include the source of dietary, solubility, processing, degree of lignification, the level of inclusion in the diet, intestinal transit time, animal's age and weight and the microbial composition (Mathers, 1991; Bach Knudsen and Hansen, 1991; Macfarlane and Cummings, 1991; Jensen, 1998, 2001; Houdijk et al., 1999; Williams et al., 2001).

In addition, solubility of dietary fiber can be another important factor, besides indication of fermentability of dietary in vivo derived from intro solubility. Soluble dietary fiber is more easily, rapidly and completely fermented once it arrives within the large intestine than is insoluble dietary fiber (Nyman et al., 1986; Bach Knudsen and Hansen, 1991). In the large intestine, the number and activity of microbes are improved by soluble dietary fiber, besides these effect also work in the ileum (Wenk, 2001). The more insoluble the Dietary fiber, the longer it takes to be degraded and fermented, resulting in fermentation occurring along the full length of the large intestine. Young animals are less effectively use insoluble dietary fiber than older (Fernandez et al., 1986).

4.2 Effects of dietary fiber on intestinal physiology

Effects of dietary fiber on the nutrient digestibility have been well in adult animals including pigs (Low, 1985; Nyachoti et al., 1997; Gdala, 1998; Pluske et al., 2001). However, fewer reports have been shown in young animals (Mosenthin et al., 1999; Pluske, 2001). Generally, authors report that soluble fiber increases transit time of intestine, delays gastric emptying and glucose absorption, increases pancreatic secretion, and slows absorption, while insoluble fiber decrease transit time, promotes water holding capacity and helps faecal bulking in non-ruminant animals. From both endogenous and endogenous source, the dry matter flow and endogenous losses are improved by dietary fiber. Furthermore, non-ruminant animals lose the digestibility of energy and nutrients with starch, protein and lipid due to dietary fiber (Eggum, 1995; Souffrant, 2001). Because of negative effects on digestion of dietary fiber, it has been known as 'anti-nutritive' for animals. Fiber-rich sources in non-ruminant animals to improve the nutritional value are used (Gdala, 1998).

Contrary, dietary fiber has been shown to related with the prevention of many intestinal diseases, particularly cancer (Goodlad, 2001). The diets with fiber may also have positive effects in non-ruminant animals. As an example, high fiber diets of sows, can decrease the incidence of strereotypic behaviour, and improve reproductive performance (Meunier and Salaun, 1999).

4.3 Interaction between dietary fiber and enteric bacterial infection

Many authors have been reported that dietary fiber might increase conservation against enteric infections with harmful bacteria in young non-ruminant animals. In many piglets in the frist 5-10 days after weaning incidence of diarrhea and growth checks are a serious problem. Settlement enterotoxigenic *E. coli* in the small intestine results in a serious diarrhea, named post-weaning colibacillosis (PWC). The PWC has multifactorial condition, and it have various effect to disease (Hampson, 1994).

It has been reported that supplementation some diets with dietary fiber will decrease the incidence and seriousness of PWC. Fiber from oats, barley and wheat are opinioned to be protective against the incidence of PWC and proliferation of *E. coli* in weaning pigs (Palmer and Hulland, 1965; Smith and Halls, 1968; Armstrong and Cline, 1976; Bertschinger and Eggenberger, 1978; Thomlinson and Lawrence, 1981). But other authors reported different. Example, Smith and Halls (1968) found weaning pigs inoculated with enterotoxigenic *E. coli* were prevented disease by barley fiber, but not barley meal. This might higher soluble NSP in barley meal than barley fiber (Bach Knudsen, 1997). McDonald (2001) reported that the occurrence of colonization and diarrhea were increased by pearl barley. All these treatment proposed that weaning pigs diets with soluble dietary fiber have negative effects on piglets growth performance and proliferation of enterotoxigenic *E. coli* in the small intestine. McDonald (2001) showed In the small and large intestine from experimentally infected weaning pigs, there was active connection between the level of soluble NSP and the number of enterotoxigenic *E. coli* and these connection, reported that soluble NSP were important predisposing factors, roughly acting by their effects on improving digesta viscidity. In turn, the severity of PWC was limited by high levels of insoluble fiber (Bertschinger and Eggenberger, 1978).

In healthy pigs, high level of insoluble fiber decreased weight gain (Kass et al., 1980; Low, 1993). This emphasizes a negative effect of some component on growth performance and health, and making some compromise is necessary in diet formulation.

4.4 Interaction between dietary fiber and the epithelium

Many authors have showed that dietary fiber effect on gut anatomy, development, and function. Generally, the digestive organs size and length are increased by dietary ingestion in pigs (Jin et al., 1994; Jorgensen et al., 1996; McDonald, 2001). The alteration of the gut epithelium morphology also related with those effects, and it also affect to hydrolytic and absorptive functions of the epithelium respectively.

It is variable that the effect of dietary fiber on epithelial morphology and cell turnover. Dietary fiber has effects on small and large intestinal mucosa. For example, growing pigs feeding high level of fiber diets (100g wheat straw/kg) over 2 weeks caused an increase of villi and deepening of crepts in the jejunum and ileum, and increased the depth of crypt and cell proliferation rate in large intestine (Jin et al., 1994). In rats, when fed a diet with containing 75 g non-cellulose NSP per kg compared to a semi-synthetic diet with 40 g cellulose per kg significantly increased the rate of crypt-cell production and mucosal protein synthesis rate in the jejunum and ileum (Southon et al., 1985). Non-ruminant animals fed oat bran or fermentable dietary fiber could increase the proliferation of epithelial cell in colonic crypts (Malkki and Virtanen, 2001; Goodlad et al., 1987). Some authors have reported that there were trophic effect on small intestinal villi in feww of dietary fiber sources (Andoh et al., 1999; McDonald et al., 2001). And soluble dietary fiber is viscous, and generally increase the diet viscosity and the intestinal contents. For example, both poultry and pigs, fed oats and barley can cause an increase in the viscosity of intestinal contents (Bedford and Classen, 1992).

The villus height/crypt depth ratio is a useful criterion for estimating the likely digestive capacity the small intestine. Pluske et al. (1997) reported that villus height correlates positively with empty body-weight gain and dry matter intake. The increased villus height/crypt depth ratio by dietary fiber also affect to increase the absorptive capacity of the small intestinal epithelium and the hydrolytic capacity of the epithelium, and vice versa. This effect was observed in the colon of pigs that acts as a strong stimulate for absorption of water and sodium by SCFA, especially butyrate (Argenzio and Whipp, 1979). The osmotic water absorption can be occurred from nutrient absorption, and impaired nutrient absorption affect to decrease water absorption. In addition, there is increased water secretion into the intestinal lumen followed by increased crypt depth. The large intestine is not well developed in young animals, and clinical diarrhea and dehydration is not prevented due to weaning pigs not be capable of absorbing enough fluid (Nabuurs, 1988).

Finally, feeding dietary fiber that increase epithelium morphology might also increase absorption of feed and fluid, and plays important role in alleviating diarrhea (Dobbins and Binder, 1981).

Ⅲ. Effect of Dietary Sugar Beet Pulp Supplementation on Growth Performance, Nutrient Digestibility, Fecal Microflora, Blood Profiles and Incidence of Diarrhea in Weaning Pigs

Abstract : This experiment was conducted to evaluate an adequate the level of sugar beet pulp as an alternative ZnO supplementation on growth performance, nutrient digestibility, fecal microflora, blood profiles and incidence of diarrhea in weaning pigs. A total of 200 weaning pigs [(Yorkshire × Landrace) × Duroc], averaging 9.01 ± 1.389 kg of initial body weight were, allotted to 5 treatments in a randomized complete block (RCB) design. Each treatment composed of 4 replicates with 10 pigs per pen. The treatments were control treatment: Corn-SBM basal diet + ZnO (phase 1: 0.05%; phase 2; 0.03%) and four different levels of SBP was supplemented in Corn-SBM basal diet (3, 6, 9 or 12 %). Two phage feeding programs (phase 1: 1-2 weeks; phase 2: 3-5 weeks) were used for 5 week of growth trial. In growth trial, there were no significant difference in growth performance and incidence of diarrhea among treatments. The *E. coli* counts were not significantly different among dietary treatments but linear response was observed in *Lactobacillus* counts as sugar beet pulp supplementation increased ($P < 0.05$). In addition, IGF-1, IgA and IgG were not affected by dietary treatments. However, the BUN concentration was decreased when pigs were fed the treatments of diets with SBP compared to that of control treatment ($P < 0.05$). In nutrient digestibility, crude fiber and NDF digestibilities was improved as the sugar beet pulp increased ($P < 0.05$). However, digestibilities of crude ash, crude fat, crude fiber and nitrogen retention were not affected by dietary sugar beet pulp levels. Consequently, this experiment demonstrated that sugar beet pulp can be supplemented in weaning pigs' diet instead of ZnO to prevent postweaning diarrhea without any detrimental effect on growth performance.

Keywords : Sugar beet pulp, Weaning pigs, Dietary fiber, Growth performance, Nutrient digestibility, Diarrhea, Fecal microflora

Introduction

Antibiotics have been used in livestock feeding to increase growth performance and to prevent disease. However, In 2006, the European Union (EU) has decided to forbid use of antibiotics as growth promoters (Chen et al., 2005). In addition, in Korea, antibiotics have been banned use of growth promoters from 2011. The ban on antibiotics has been reported as the cause of increasing diarrhea followed by impaired growth performance and high mortality of weaning pigs (Casewell et al., 2003).

Feeding a minimum level of fiber can support normal physiological activity in the digestive tract (Wenk, 2001). Diets or ingredients which have high fiber content in young pigs may affect as negatively to voluntary feed intake and nutrient digestibility, respectively (Kyriazakis, 1995). Recent research, it has shown that dietary fiber supplementation can reduce the incidence of diarrhea and improve performance in weaning pigs (Mateos et al., 2006: Molist et al., 2014). Dietary fiber includes soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). Due to supplemented SDF to weaning pigs, it gives the positive effect to decrease the incidence of diarrhea and improve to gut health. Because of high water holding capacity, SDF could affect to those facts (Serena et al., 2008). In addition, the bacteria from small and large intestine could affect to degrade the most of SDF and partial of IDF (Serena et al., 2008; Urriola et al., 2010; Urriola et al., 2012). When soluble DF arrived into the large intestine, the degree of fermentation is faster and better than insoluble DF (Nyman et al., 1986; Bach Knudsen and Hansen, 1991). In the large intestine, number and activity of microbes are increased by soluble DF and it also worked in the ileum as well (Wenk, 2001).

Sugar beet pulp includes high level of soluble fiber such as pectins and glucans (Fadel, 2000). However, there are still lack of reports in the literature about the optimum level of sugar beet pulp supplementation, affects on growth performance and nutrient digestibility in weaning pigs. Therefore, in the experiment, different level of sugar beet pulp was added to diets to determine the effects of sugar beet pulp supplementation on growth performance, nutrient digestibility, fecal microflora, blood profile and incidence of diarrhea in weaning pigs.

Materials and Methods

Growth trial (Exp 1)

A total of 200 weaning pigs [(Yorkshire × Landrace) × Duroc] with an average body weight of 9.01 ± 1.389 kg, weaned at 25 ± 3 days. Pigs were grouped into a randomized complete block (RCB) design in 4 replicates with 10 pigs per pen. Treatments consisted of 4 different levels of sugar beet pulp (3.0%, 6.0%, 9.0%, 12.0%) and one positive control (Con) treatment. In this experiment, was conducted with corn-SBM-barley based diet and tow phases feeding programs were used. Phase 1 diet contains 20.56% crude protein and 1.35% lysine was feeding 0-2 weeks, phase 2 diet contains 18.88% crude protein and 1.15% lysine was feeding 3-5 weeks. All other nutrients of experimental diets were met or slightly exceeded the nutrient requirements (NRC, 1998). Formulas and composition of the experimental diets were shown in Table 1 and 2.

The weaning house temperature was maintained at 31℃, and then gradually fallen to 26℃ at the end of the experiment. During the 5 weeks growth tail, weaning pigs were allowed ad libitum access to water and diets. Body weight (BW) and feed intake were recorded at 0, 2 and 5 weeks to calculate average daily gain (ADG), average daily feed intake (ADFI) and gain per feed ratio (G/F). During the whole feeding trial period, diarrhea score was recorded once a day (10:00) by counting the diarrhea per pen. The diarrhea score was from 0 (no pigs with diarrhea) to 10 (all pigs with diarrhea).

Blood samples were collected from anterior vena cava of the pigs (5 pigs/treatment). Collected blood samples were quickly centrifuged for 15 minutes at

3,000 rpm and 4℃. Be carefully remove the serums to plastic vials and stored at −20℃. BUN and IGF-1 concentrations were analyzed using blood analyzer (Ciba-Corning model, Express plus, Ciba Corning Diagnostics Co.) and IgA, IgG were analyzed by ELISA assay (ELISA Starter Accessory Package, Pig IgG and IgA ELISA Quantitation Kit; Bethyl).

Fecal *E.coil* and *Lactobacillus* count were analyzed at 0, 2 and 5 weeks. Samples were collected 1 g of fecal and diluted with 9 ml of distilled water. After mixing the solution, it was taken 1 g and diluted with 9 ml of distilled water again. Like this way of dilution, diluted samples to 1/105 percent of initial diluted solution. Each dilution was sprayed on microorganism plate with nutrient agar. There plates were incubated at 37℃. And after 24h of incubation, the number of fecal micro-flora were counted.

Metabolic trial (Exp 2)

According to a completely randomized design (CRD), fifteen weaning pigs (14.42 ± 0.45 kg) were allotted to 5 treatment with 3 replicates. During the experiment, diet was provided twice per day at 7:00 and 19:00h at three times the ME (106kcal of ME/kg of $BW^{0.75}$) and water was provided ad litum (Kim et al., 2012). After 7 days of adaptation period, fecal and urine samples were collected 5 days. Fecal and urine were collected daily and stored −20℃ then fecal dried in air-forced drying oven at 60℃ for 72h, and ground into 1mm paricles in a Wiley mill for chemical analysis.

Chemical analysis and statistical analyses

Experimental diet and excreta were analyzed for contents of dry matter (procedure 967.03; AOAC, 1990); ash (procedure 923.03; AOAC, 1990); CP (Nitrogen × 6.25; procedure 923.03; AOAC, 1990) nitrogen by using the Kjeldahl procedure with Kjeltec (KjeltecTM 2200, Foss Tecator, Sweden). Nitrogen of urine was determined by the Kjeldahl procedure. Experimental data were analyzed as a randomized complete block (RCB) design using the General Linear Model (GLM) procedure of SAS. The data of growth performance, experimental unit considered a pen, while individual pig was used as the unit for data on nutrient digestibility, fecal microflora, blood profile and incidence of diarrhea. Effects of the level of sugar beet pulp was analyzed while linear and quadratic components by orthogonal polynomial contrasts. Differences were determined significant at $P < 0.05$.

Results and discussion

The result of body weight (BW), average daily gain (ADG), average daily feed intake (ADFI) and feed efficiency (G:F ratio) are presented in Table 3. During experimental period, there were no significant differences in BW, ADG, ADFI, G:F ratio. Variable results are showed in the literature with the effect of dietary fiber on growth performance in weaning pigs. Most results reported negative effect of fiber inclusion on growth performance of piglet (Pluske et al., 1998; Pascoal et al., 2012). In contrast, Longland et al. (1994) reported no difference in growth performance of pig weaned at 21 days of age that fed diet with 15% sugar beet pulp. And Gill et al. (2000) reported no adverse effects on ADG when fed a cereal-based diet containing 0 %, 15 % and 18.5 % of sugar beet pulp to 4 − 8 week old piglets. In other experiment with 6 % sugar beet pulp in a wheat − base diet, a positive effect on growth performance was observed after weaning pigs (Lizardo et al., 1997). The growth performance in current study showed no negative effect when weaning pigs were fed diet with sugar beet pulp. The result appear to conflict the held belief that NSP was cannot fermented and utilized by young pigs (Patience and Thacker, 1989; Beames, 1990).

Table 4. shows the incidence of diarrhea and there was no significant differences among treatments in whole experimental period. Sugar beet pulp has a high WHC (water holding capacity) and SWC (swelling water capacity), which increase volume of digest, viscosity and water retention (Jorgensen et al., 2007; González −Alvarado et al., 2008). The results are similar to Berrocoso et al. (2015) results. With those observation, during 7 to 10d postweaning period, pigs adjust to

solid feed consumption and it proves that proper amounts of soluble fiber improve the healthy fermentation of undigested nutrients. Because of GIT microflora, it helps to fermenting soluble fiber sources and the environment of GIT are also improved and stabled, besides the incidence of diarrhea also reduced. (Montagne et al., 2003).In addition, weaning pigs 33 to 39 d old with 12% sugar beet pulp in their diet made improved digestive functions and this was better result than other weaning pigs fed control diet Lizardo et al. (1997).

The effects of sugar beet pulp supplementation on fecal microflore were showed in Table 5. There were linear response on *Lactobacillus* counts as the level of sugar beet pulp increase in whole experimental period (linear, $P < 0.05$). In contrary, in whole experimental period, *E. coli* counts has no significant differences among treatments. Recently, some authors found that the decrease in the enteric *E. coli* after weaning was smaller when fed diet with ZnO (Soyka et al., 1960). So we can know that *E. coil* are on the decrease in weaning pigs in Con treatment and treatments of diet with sugar beet pulp. The results are same previous reports (Bach Knudsen, 1997; McDonald et al., 1999, 2001; Hopwood et al., 2002). Prohaska (1986) and May et al. (1994) reported that fermentation of dietary fiber producted short chain fatty acids (SCFA), which decrease the gut content pH. In an acidic environment, the growth of intestinal bacterial pathogens are restrained by SCFA. Edwards (1996) found that weaning pigs were fed diet with dietary fiber increased intestinal counts of *Lactobacillus* and reduced the incidence of diarrhea. Soluble dietary fiber increases the number and activity of microbes are increased by soluble dietary fiber in the large intestine, and even in the ileum (Wenk, 2001). And a reduce in pH accelerates growth of beneficial bacteria like *Lactobacillus* (Williams et al., 2001).

The effects of sugar beet pulp supplementation on nutrient digestibility and nitrogen retention showed in Table 6. Crude fiber, NDF and ADF digestibility were improved as the sugar beet pulp increased ($P < 0.05$). There is linear response on NDF digestibility as sugar beet pulp increased (linear, $P < 0.05$) and crude ash, crude fat, crude fiber and ADF tended to linear improve as the sugar beet pulp increased (linear, $P < 0.10$). However, nitrogen retention were not affected by the dietary sugar beet pulp level increased.

The results showed that increasing level of sugar beet pulp plays a positive effects in nutrient digestibility. It is the same as the some previous researches. Bindelle et al. (2009) found a linear increase in the digestibility when added 0, 10, 20 and 30 % levels of sugar beet pulp fed to growing pigs. In addition, Freire et al. (2000) reported increasing DM digestibility when 20 % sugar beet pulp was include in a corn-fishmeal diet and Chabeauti et al. (1991) found ATTD of GE was increased in growing pigs when fed 16% sugar beet pulp. Also, the diets with 2.5 or 5 % sugar beet pulp to feed piglet improved ATTP of all nutrients except CP (Berrocoso et al., 2015). Varel (1984) reported celluloytic bacteria like *Fibrovacter succinogenes* and *Ruminococcus flavefaciens* inhabit pigs large intestine. It is activity while fiber utilization is higher or supplementation high level of NSP diets. So there is a positive effect in nutrient digestibility when pigs fed diets with a resonable level of sugar beet pulp.

The blood urea nitrogen (BUN) and insulin like growth factor-1 (IGF-1) concentration were showed in Table 6. In 5 week, the treatments of diets with sugar beet pulp presented lower BUN concentration than Con treatment ($P < 0.05$). In whole experimental period, pigs fed diets with sugar beet pulp treatments showed the numerically higher IGF-1 concentration than Con treatment.

In general, BUN is the indicator for determination of amino acid utilization by pigs and it was directly related to intake of protein and inversely to quality of protein (Eggum, 1970; Hahn et al., 1995). Hahn et al. (1995) found BUN values have negative correlation with ADG and G:F ratio. Therefore, the difference of BUN at 5 week can be explained by the results that the treatments which sugar beet pulp is added got numerically higher results than Con treatment in ADG or G:F ratio until 3 − 5 weeks and it may be improving gut health by increasing the level of sugar beet pulp supplementation.

IGF-1 is secreted when the growth hormones are stimulated. It is affected by nutritional status of animal. IGF-1 plays important effects such as supplies energy for cell growth, plays important roles in regulation of structure, function of cardiovaccular system and born growth (Yakar et al., 2002). In 5 weeks, pigs fed diets with sugar beet pulp showed numerically higher than Con treatment. Lee (2001) reported IGF-1 concentration was increased when someone be taken nutritional supplement. This can be thought as improving of intestine health by addition of sugar beet pulp and taking nutritional supplement by fermentation of sugar beet pulp which is dietary fiber.

There is an intestinal microbiota in the GIT providing different benefits to the host. Its aids stimulates the immune system (Savage, 1986; Liebler et al., 1992). And the immune system was impacted by VFA like butyrate has been found (Weber and Kerr, 2006). However, the data of table 6 showed no significant difference in immunoglobulin A (IgA) and immunoglobulin G (IgG) during the whole experimental period. So, the results explain that supplementation of sugar beet pulp has no effects on IgA and IgG.

Table 1. Formula and chemical composition of diets phase 1

Ingredients, %	Treatments[1]				
	Con	SBP3	SBP6	SBP9	SBP12
Corn	25.01	21.61	17.63	13.37	9.63
Soy bean meal	33.16	33.05	32.88	32.67	32.51
Wheat	9.70	9.88	10.60	11.65	12.12
Barley	15.00	15.00	15.00	15.00	15.00
Whey powder	4.00	4.00	4.00	4.00	4.00
Lactose	8.00	8.00	8.00	8.00	8.00
Sugar Beet Pulp	0.00	3.00	6.00	9.00	12.00
Soy-oil	1.73	2.15	2.62	3.09	3.55
MDCP	1.36	1.40	1.42	1.45	1.48
Limestone	1.03	0.95	0.89	0.81	0.74
L-Lysine-HCl, 78%	0.29	0.29	0.29	0.29	0.29
DL-met, 80%	0.08	0.08	0.08	0.08	0.09
L-threonine, 99%	0.09	0.09	0.09	0.09	0.09
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	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition[4]					
ME, kcal/kg	3265.04	3265.01	3265.01	3265.00	3265.01
Crude protein, %	20.56	20.56	20.56	20.56	20.56
Lysine, %	1.35	1.35	1.35	1.35	1.35
Methionine, %	0.35	0.35	0.35	0.35	0.35
Threonine, %	0.86	0.86	0.86	0.86	0.86
Ca, %	0.80	0.80	0.80	0.80	0.80
P, %	0.65	0.65	0.65	0.65	0.65
Crude fiber[5], %	3.23	3.79	4.29	5.04	5.65
NDF[5], %	13.38	11.55	13.13	14.22	17.03
ADF[5], %	4.27	4.26	5.02	6.00	6.50

[1]Con : Basal diets + ZnO 0.5%, SBP3 : Basal diets + SBP 3% , SBP6 : Basal diets + SBP 6%, SBP9 : Baial diets + SBP 9%, SBP12 : Basal diets + SBP 12%.

[2]Provided the following quantities of vitamins per kg of complete diet : Vit A, 8,000IU; Vit D_3, 1,800IU; Vit. E, 80IU; Vit. K_3, 2mg; Rivoflavin, 7mg; Calcium pantothenic acid, 25mg; Niacin, 27mg; d-Biotin, 200ug; Vit.B_{12}, 50ug.

[3]Provided the following quantities of minerals per kg of complete diet: Fe, 150 mg; Cu, 105 mg; Mn, 51 mg; I, 1 mg; Se, 0.3mg; Zn, 72 mg.

[4]Calculated value.

[5]Analyzed value.

Table 2. Formula and chemical composition of diets phase 2

Ingredients, %	Treatments[1]				
	Con	SBP3	SBP6	SBP9	SBP12
Corn	35.34	31.93	28.44	24.83	20.98
Soy bean meal	28.68	28.55	28.43	28.31	28.16
Wheat	10.40	10.57	10.78	11.09	11.68
Barley	15.00	15.00	15.00	15.00	15.00
Whey powder	2.00	2.00	2.00	2.00	2.00
Lactose	4.00	4.00	4.00	4.00	4.00
Sugar Beet Pulp	0.00	3.00	6.00	9.00	12.00
Soy-oil	1.73	2.16	2.61	3.07	3.53
MDCP	1.16	1.19	1.22	1.25	1.28
Limestone	0.91	0.84	0.76	0.69	0.61
L-Lysine-HCl, 78%	0.19	0.19	0.19	0.19	0.19
DL-met, 80%	0.04	0.05	0.05	0.05	0.05
L-threonine, 99%	0.02	0.02	0.02	0.02	0.02
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	0.03	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition[4]					
ME, kcal/kg	3265.01	3265.01	3265.00	3265.01	3265.02
Crude protein, %	18.88	18.88	18.88	18.88	18.88
Lysine, %	1.15	1.15	1.15	1.15	1.15
Methionine, %	0.31	0.31	0.31	0.31	0.31
Threonine, %	0.74	0.74	0.74	0.74	0.74
Ca, %	0.70	0.70	0.70	0.70	0.70
P, %	0.65	0.65	0.65	0.65	0.65
Crude fiber[5], %	3.54	4.45	4.92	6.15	6.56
NDF[5], %	13.29	13.96	15.15	17.70	18.85
ADF[5], %	4.14	4.68	5.25	6.54	6.98

[1]Con : Basal diets + ZnO 0.3%, SBP3 : Basal diets + SBP 3% , SBP6 : Basal diets + SBP 6%, SBP9 : Basal diets + SBP 9%, SBP12 : Basal diets + SBP 12%.
[2]Provided the following quantities of vitamins per kg of complete diet : Vit A, 8,000IU; Vit D_3, 1,800IU; Vit. E, 80IU; Vit. K_3, 2mg; Rivoflavin, 7mg; Calcium pantothenic acid, 25mg; Niacin, 27mg; d-Biotin, 200ug; Vit.B_{12}, 50ug.
[3]Provided the following quantities of minerals per kg of complete diet: Fe, 150 mg; Cu, 105 mg; Mn, 51 mg; I, 1 mg; Se, 0.3mg; Zn, 72 mg.
[4]Calculated value.
[5]Analyzed value.

Table 3. Effects of sugar beet pulp levels supplementation on growth performance in weaning pigs[1]

Criteria	Treatments[2]					SEM[3]	P-value[4]	
	Con	SBP3	SBP6	SBP9	SBP12		Lin.	Quad.
Body weight, kg								
Initial	9.01	9.01	9.01	9.01	9.01	0.300	-	-
2 week	12.83	12.15	12.48	12.63	12.32	0.380	0.68	0.86
5 week	20.79	19.77	21.21	22.67	21.23	0.625	0.16	0.47
ADG, g								
0-2 week	273	229	248	259	235	11.7	0.80	0.83
3-5 week	379	370	393	478	424	18.9	0.20	0.29
0-5 week	337	314	336	390	349	14.8	0.28	0.37
ADFI, g								
0-2 week	352	308	345	332	293	10.2	0.45	0.73
3-5 week	821	761	857	853	747	22.1	0.83	0.99
0-5 week	634	577	653	645	566	16.3	0.76	0.93
G:F ratio								
0-2 week	0.78	0.73	0.73	0.80	0.81	0.025	0.17	0.52
3-5 week	0.57	0.59	0.64	0.71	0.65	0.033	0.42	0.60
0-5 week	0.68	0.68	0.75	0.81	0.72	0.035	0.58	0.69

[1]A total 200 weaning pigs was fed from average initial body 9.01 ± 1.389 kg.
[2]Con : Basal diets, SBP3 : Basal diets + SBP 3% , SBP6 : Basal diets + SBP 6%, SBP9 : Basal diets + SBP 9%, SBP12 : Basal diets + SBP 12%.
[3]Standard error of means.
[4]Probability values for the effects of SBP3, SBP6, SBP9, SBP12.

Table 4. Effects of sugar beet pulp levels supplementation on incidence of diarrhea in weaning pigs

Criteria	Treatments[1]					SEM[2]	P-value[3]	
	Con	SBP3	SBP6	SBP9	SBP12		Lin.	Quad.
Diarrhea score[4]								
0-2 week	1.71	1.57	1.36	1.43	1.43	0.125	0.77	0.70
3-5 week	1.14	0.95	0.81	0.71	0.76	0.075	0.33	0.53
0-5 week	1.37	1.20	1.03	1.00	1.03	0.071	0.42	0.51

[1]Con : Basal diets, SBP3 : Basal diets + SBP 3% , SBP6 : Basal diets + SBP 6%, SBP9 : Basal diets + SBP 9%, SBP12 : Basal diets + SBP 12%.
[2]Standard error of means.
[3]Probability values for the effects of SBP3, SBP6, SBP9, SBP12.
[4]0 (No pigs with diarrhea) - 10 (All pigs with diarrhea).

Table 5. Effects of sugar beet pulp levels supplementation on fecal microflora in weaning pigs[1]

Criteria	Treatments[2]					SEM[3]	P-value[4]	
	Con	SBP3	SBP6	SBP9	SBP12		Lin.	Quad.
E. coli, cfu/ml								
Initial	5.84	5.84	5.84	5.84	5.84	0.109	-	-
2 week	3.87	4.44	4.22	4.21	4.87	0.131	0.30	0.12
5 week	4.41	4.00	4.17	5.50	4.33	0.214	0.29	0.17
Lactobacillus, cfu/ml								
Initial	6.63	6.63	6.63	6.63	6.63	0.053	-	-
2 week	6.08	6.53	6.36	7.17	6.64	0.130	0.04	0.32
5 week	7.81	8.03	7.96	8.04	8.19	0.047	0.02	0.97

[1]Least squares mens for 4 pigs per treatment.
[2]Con : Basal diets, SBP3 : Basal diets + SBP 3% , SBP6 : Basal diets + SBP 6%, SBP9 : Basal diets + SBP 9%, SBP12 : Basal diets + SBP 12%.
[3]Standard error of means.
[4]Probability values for the effects of SBP3, SBP6, SBP9, SBP12.

Table 6. Effects of sugar beet pulp levels supplementation on nutrient digestibility in weaning pigs[1]

Criteria	Treatments[2]					SEM[3]	P-value[4]	
	Con	SBP3	SBP6	SBP9	SBP12		Lin.	Quad.
Nutrient digestibility, %								
Dry matter	87.08	89.24	87.31	88.15	89.07	0.534	0.49	0.95
Crude protein	85.13	87.55	86.06	85.10	86.25	0.553	0.96	0.69
Crude ash	57.00	71.15	66.92	65.85	71.31	2.013	0.08	0.35
Crude fat	76.09	84.05	79.31	81.34	86.40	1.425	0.07	0.93
Crude fiber	55.07[b]	66.64[ab]	62.92[ab]	74.14[a]	75.84[a]	2.601	0.05	0.49
ADF	44.89[b]	56.89[ab]	53.92[ab]	64.58[a]	66.49[a]	2.741	0.07	0.58
NDF	61.43[c]	68.64[bc]	67.89[bc]	73.61[ab]	76.77[a]	1.681	0.02	0.40
Nitrogen retention, g/d								
N intake	20.16	20.27	19.92	19.66	20.18	0.059	-	-
Fecal N	3.00	2.52	2.78	2.93	2.77	0.110	0.96	0.60
Urinary N	5.74	4.39	7.13	4.50	4.21	0.394	0.21	0.24
N retention[5]	11.42	13.36	10.02	12.22	13.19	0.447	0.37	0.26

[1]A total 15 weaning pigs was fed from average initial body 14.42 ± 0.45 kg.
[2]Con : Basal diets, SBP3 : Basal diets + SBP 3% , SBP6 : Basal diets + SBP 6%, SBP9 : Basal diets + SBP 9%, SBP12 : Basal diets + SBP 12%.
[3]Standard error of means.
[4]Probability values for the effects of SBP3, SBP6, SBP9, SBP12.
[5]N retention = N intake - Fecal N - Urinary N.
[a,b,c]Means with different superscripts within the same row significantly differ ($P<0.05$).

Table 7. Effects of sugar beet pulp levels supplementation on blood profiles in weaning pigs[1]

Criteria	Treatments[2]					SEM[3]	P-value[4]	
	Con	SBP3	SBP6	SBP9	SBP12		Lin.	Quad.
IGF-1, ng/dl								
Initial	53.7	53.7	53.7	53.7	53.7	3.21	-	-
2 week	132.8	158.9	134.6	125.7	113.6	8.31	0.13	0.77
5 week	109.3	169.2	158.5	162.2	153.1	8.40	0.60	0.97
BUN, mg/dl								
Initial	6.96	6.96	6.96	6.96	6.96	0.306	-	-
2 week	10.70	11.06	10.58	11.60	9.48	0.423	0.44	0.45
5 week	12.16[a]	10.40[b]	10.42[b]	9.90[b]	10.08[b]	0.272	0.57	0.89

[1]Least squares mens for 5 pigs per treatment.
[2]Con : Basal diets, SBP3 : Basal diets + SBP 3% , SBP6 : Basal diets + SBP 6%, SBP9 : Basal diets + SBP 9%, SBP12 : Basal diets + SBP 12%.
[3]Standard error of means.
[4]Probability values for the effects of SBP3, SBP6, SBP9, SBP12.

Table 8. Effects of sugar beet pulp levels supplementation on IgA and IgG in weaning pigs[1]

Criteria	Treatments[2]					SEM[3]	P-value[4]	
	Con	SBP3	SBP6	SBP9	SBP12		Lin.	Quad.
IgA, mg/ml								
Initial	0.12	0.12	0.12	0.12	0.12	0.009	-	-
2 week	0.22	0.20	0.19	0.39	0.29	0.028	0.10	0.46
5 week	0.46	0.52	0.45	0.50	0.45	0.029	0.68	0.93
IgG, mg/ml								
Initial	2.83	2.83	2.83	2.83	2.83	0.052	-	-
2 week	2.25	2.59	2.17	2.51	2.39	0.095	0.77	0.50
5 week	3.04	3.63	3.05	3.72	3.11	0.125	0.49	0.96

[1]Least squares mens for 5 pigs per treatment.
[2]Con : Basal diets, SBP3 : Basal diets + SBP 3% , SBP6 : Basal diets + SBP 6%, SBP9 : Basal diets + SBP 9%, SBP12 : Basal diets + SBP 12%.
[3]Standard error of means.
[4]Probability values for the effects of SBP3, SBP6, SBP9, SBP12.

Conclusion

In conclusion, sugar beet pulp as an alternative ZnO could be supplemented in weaning pigs. In growth performance, there was no significant difference among treatments during the experimental period. And pigs fed the treatments of diets with sugar beet pulp showed numerically lower than the treatment of diet with ZnO in incidence of diarrhea. Also, the increased level of sugar beet pulp supplementation, there is an increase in counts of *Lactobacillus*. There are positive effects in nutrient digestibility when pigs fed diets with sugar beet pulp and addition of sugar beet pulp could improve amino acid utilization and taking nutritional supplement. And IgA could be increased by the increased level of sugar beet pulp supplementation.

Consequently, sugar beet pulp as an alternative ZnO could be supplemented in weaning pigs without any detrimental effect on growth performance.

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Ⅴ. Summary in Korean

본 연구는 이유자돈 사료 내 Sugar beet pulp 의 첨가가 이유자돈의 성장성적, 영양소 소화율, 분내 미생물 균총, 혈액성상 및 설사빈도에 미치는 영향에 대해 알아보고, 이를 바탕으로 산화아연 대체제로서의 첨가수준을 규명하기 위해 수행되었다.

평균체중 9.01 ± 1.389 kg 의 3원 교잡종 ([Yorkshire × Landrace] × Duroc) 이유자돈 200두로 공시하였으며, 5처리 4반복, 펜당 10두씩 성별과 체중에 따라 난괴법 (RCBD: randomized complete block design) 으로 배치하였다. 처리구는 옥수수-대두박 기초사료를 바탕으로 Con 처리구는 산화아연을 첨가하였고 (phase 1 : 0.05%; phase 2 : 0.03%) 나머지 처리구는 SBP (3%, 6%, 9%, 12%)를 첨가하였다. 실험은 전기 2주, 후기 3주로 총 5주간 진행 되었다.

사양실험 결과, 실험 전체적인 구간에서 성장성적 방면에서 유의적인 차이는 없었으며 설사방면에서도 유의적인 차이가 없었다. 또한 분내 균총에서는 *E. coil* 는 비록 유의적인 차이가 없었지만 *Lactobacillus* 는 SBP 의 첨가수준이 증가할수록 linear 하게 증가하였다 ($P<0.05$). 영양소 소화율 방면에서는 조섬유소, NDF, ADF 의 방면에서 SBP 의 첨가수준이 높을수록 유의적으로 높게 나타났으며 NDF 의 소화율 방면에서는 SBP 의 첨가수준이 증가할수록 linear 하게 증가 하였고 ($P < 0.05$) 또한 조회분, 조지방, 조섬유소 및 ADF 소화율에서는 SBP의 첨가수준이 증가할수록 linear 하게 증가하는 경향이 나타났다 ($P < 0.1$). 질소 축적율에서는 유의적인 차이가 없었으며 혈액 방면에서는 IGF-1, IgA 와 IgG 에서는 유의적인 차이가 없었지만 BUN 의 수치에 있어서 SBP를 첨가한 처리구들이 모두 SBP를 첨가하지 않은 처리구보다 유의적으로 낮게 나타났다 ($P < 0.05$).

전체적으로 봤을 때 sugar beet pulp는 ZnO 대체제로 이유자돈한테 12% 까지 첨가할 수 있으며 이유자돈한테 긍정적인 영향을 미친다.