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Evaluation of Barley to Replace Milk Products in Weaning Pig's Diet

이유자돈 사료내 유제품을 대체하기 위한 보리의 첨가 효과

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Summary

This experiment was conducted to investigate the influence of barley to replace milk products in weaning pig's diet on growth performance, blood profile, nutrient digestibility and diarrhea incidence in weaning pigs. A total of 108 crossbred ([Yorkshire × Landrace] × Duroc) piglets were allotted to one of four treatments in a randomized complete block (RCB) design. Each treatment had 7 replications with 4 pigs per pen. Four different levels of barley (0, 10, 20 and 30%) were used as dietary treatments. Whey powder and lactose were not supplemented at phase 3 diet. During 0-2 week, body weight, ADG and G/F ratio were decreased as dietary barley levels increased (linear response, $P<0.01$). However, no detrimental effects were observed in 3-6 weeks on growth performance. In overall period (0-6 week), all treatments showed no significant difference in body weight and G/F. In digestibility trial, crude fat digestibility was increased linearly as barley increased (linear, $P<0.01$). When pigs were fed diet without barley showed higher daily nitrogen retention among all treatments (linear, $P<0.01$) and higher blood urea nitrogen level was observed in this treatment ($P<0.01$). However, any significant difference was not observed in blood glucose level. Incidence of diarrhea was decreased as dietary barley levels increased (linear, $P<0.01$). Consequently, although the supplementation of barley influenced negatively on growth performance during 0-2 week, incidence of diarrhea and fat digestibility were improved as barley supplementation level increased.

Key words: Barley, milk-product, weaning pigs, blood urea nitrogen, blood glucose level, diarrhea incidence.

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Ⅰ. Review of Literature

List of Abbreviation

AOAC	:	Association of official analytical chemists
ADG	:	Average daily gain
ADFI	:	Average daily feed intake
BW	:	Body weight
CMC	:	Critical micelle concentration
CP	:	Crude protein
FCR	:	Feed conversion ratio
GI	:	Gastrointestinal
HLB	:	Hydrophile-lipophile balance
LCFA	:	Long chain fatty acids
MCFA	:	Medium chain fatty acids
ME	:	Metabolizable energy
NRC	:	National research council
RCB	:	Randomized complete block
SAS	:	Statistical analysis system
SBM	:	Soybean meal
BGL	:	Blood glucose level
NSP	:	Nonstarch polysaccharides
OS	:	Oligosaccharides

I. Introduction

It is well known that corn, SBM (soy bean meal), lactose and whey powder are primary feed ingredients sources for weaning pigs especially in Korea. However, the international price of major feed ingredients has dramatically increased since 2007 because of the increasing demand for animal feed in developing countries. Moreover, in 2012, severe drought was occurred in the United States and middle of EU where are the major cropland in the world. These factors affected the price of feed stuffs as well as milk products. Many swine producers and nutritionists have sought ways to reduce the feed cost with minimally sacrificing animal's productivity because of increased cost of raw materials. Alternative to feed ingredients instead of milk products such as high fiber grains and by-products are focused on amount of production, steady supply and cheap price to improve feed cost and productivity. Currently, barley, broken rice, PKM (palm kernel meal) and tapioca which are cheaper than corn and milk products, have been partially applied as potential alternatives for swine diets. However, the use of these ingredients has been limited because of poor nutrient digestibility and the presence of potential anti-nutritional factors in monogastric animals. These alternative feed ingredients typically contain the high amount of dietary fiber as the form of non-starch polysaccharide (NSP). Among the alternative feed ingredients, the high attention was focused on barley because of its comparable nutritional values and low price compared with corn and milk products. However, it is known that supplementation level of barley in weaning pigs' diet was limited because of high contents of fiber. A few trials demonstrated that the inclusion level of barley with no detrimental effects on growth performance and nutrient digestibility is available in weaned piglets. Therefore, the present study was conducted to investigate the effects of supplementation levels of barley instead of milk products on growth performance, nutrient digestibility, blood profiles and diarrhea incidence and to establish proper inclusion level of this ingredient in weaned pigs.

II. Literature Review

1. Introduction

1.1 World environment and global market

Since 2007, world grain market prices has increased remarkably because of competition among producing feed for livestock and producing crops for biofuel. To make matter worse, extreme change of world climate is extensively affecting grain, even food market in a different way. For instance, severe world drought which has stretched across the major cereal farmland on earth was recorded in 2012 for last decades. According to historical NASS(National Agricultural Statistics Service, 2012) crop production data, approximately 88% of corn grown in the United State was within an area experiencing drought (Figure 1). This fatal disaster is threatening not just livestock feed prices but also dairy products cost (Figure 2).

1.2. Situation of swine industry in Korea

Table 1 shows the cost of pig production in major pork producing countries' structure of finance. It is well known that feed cost is comprised approximately 50~60% of total cost of pig production. Especially pig production cost in Korea is higher than that of other countries because feed industry of Korea depends heavily on imports for the most part of feed ingredients. Moreover tax, shipping charge, storage cost, grain deterioration and even importing a breeding swine also influences negatively on pig production cost.

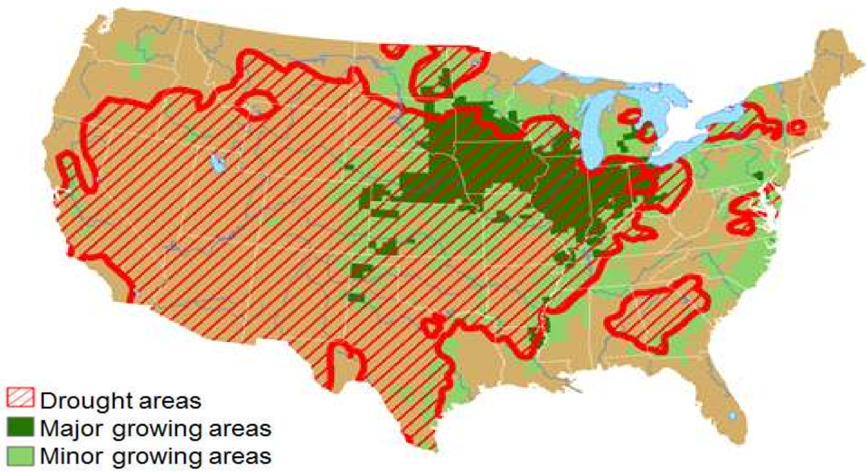

Figure 1. Drought stretched across U.S. in 2012s (USDA, 2012)

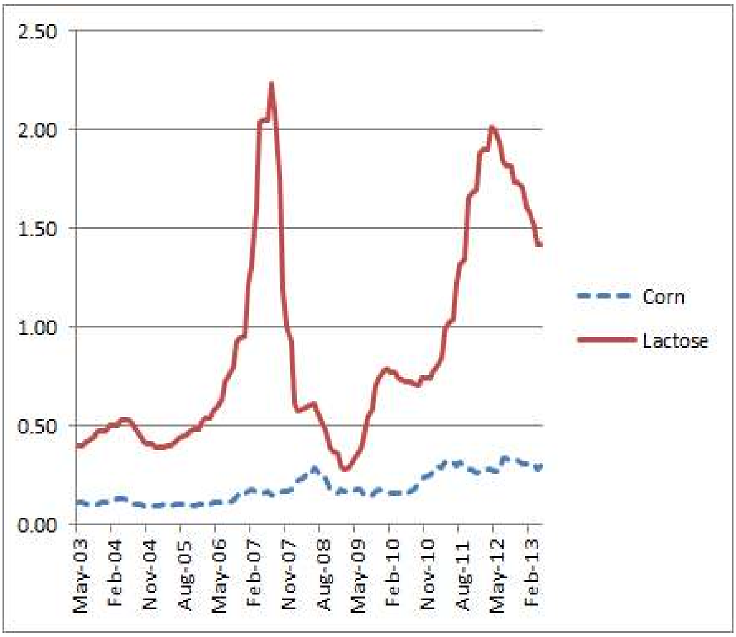

Figure 2. Corn and lactose prices in the world (Unit: $/kg; USDA and CLAL, 2013)

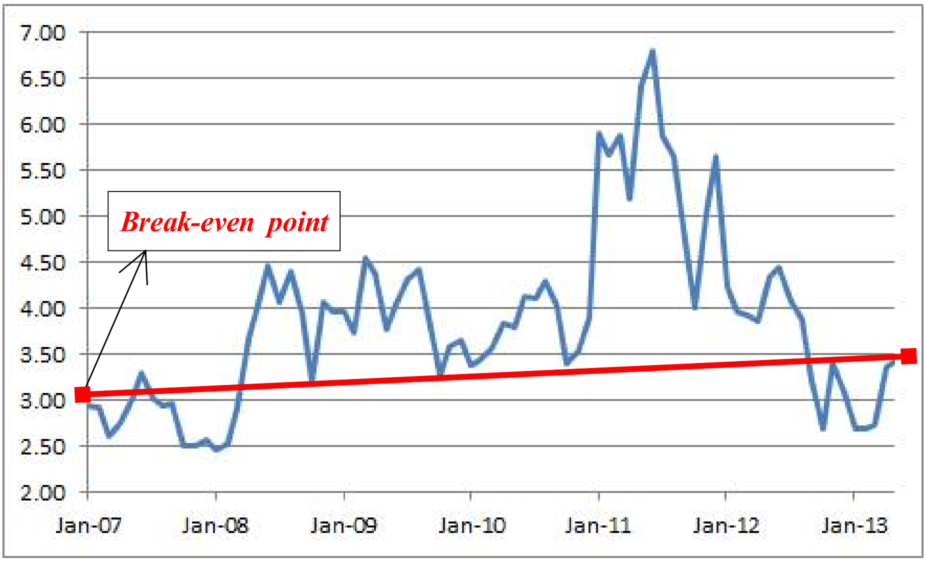

Figure 3. The trend of pork price in Korea (Unit: $/kg; Korea pork association, 2013)

Furthermore, swine industries in Korea have challenged a lot of matters such as FTA (Free trade agreement) with other countries, ban of ocean disposal animal's manure, transmittable diseases such as FMD, PRRS, PMWS. Recently hot weather in summer which influences sow's reproductivity has been negatively influenced on the cost of pig production. Occasionally, after outbreak of FMD in 2010, dramatic increase the number of pigs in Korea resulted in lower pork price since 2012 (Figure 3).

Table 1. The cost of pig production selected countries (2009s, US$ / carcass, kg).

Contents / Countries	Production cost				Total
	Feed	Labor	Building, finance and mice	Other variable cost	
Denmark	1.07	0.22	0.54	0.15	1.98
Netherlands	1.07	0.20	0.54	0.19	2.01
France	1.09	0.22	0.45	0.16	1.92
Germany	1.15	0.20	0.61	0.24	2.21
United Kingdom	1.19	0.22	0.53	0.13	2.06
Korea	1.44(54.75%)	0.10(3.80%)	0.89(33.85%)	0.20(7.60%)	2.63

(UK BPEX, 2010 and Statistics Korea, 2010)

2. Growth of the weaning pig

2.1 Cognizance the weaning pig

Weaning is most stressful period in a pig's life because of the numerous changes it must undergo. Ahead of weaning, pigs consume sows' milk approximately 24 times per day. Sow’s milk comprises of a greatly digestible liquid that contains approximately 35% fat, 30% protein, and 25% lactose (on a dry matter basis). After weaning, pigs are expected to adjust to a dry grain diet with a very different composition. In addition, contrasted with nursing when there was usually ample space for all pigs to have their meal together, feeders do not typically distribute enough space for simultaneous feeding of pigs.

From birth until the pig is approximately 8 weeks of age, there are also a lot of digestive, metabolic, and immunological changes taking place. For instance, the enzymes that are required to break down various dietary ingredients are developing at different rates. As shown in (Figure 4), lactase (the enzyme associated with the digestion of milk

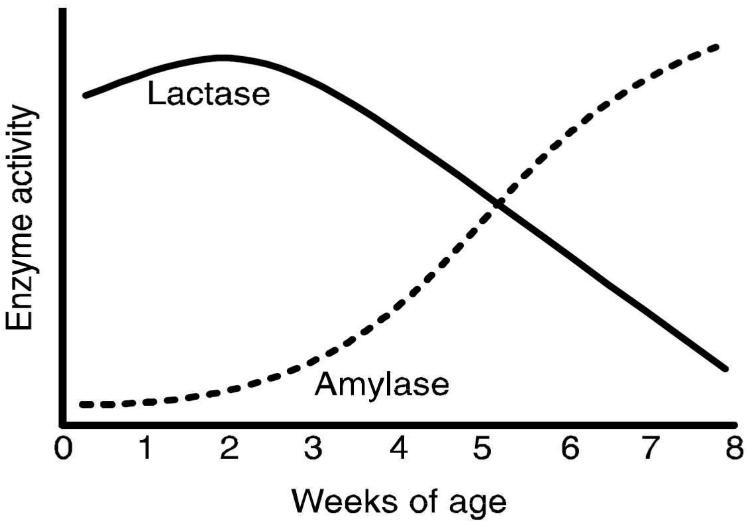

Figure 4. Digestive enzymes' development in the young piglet (Coffey et al., 2000)

carbohydrates) is high at birth, reaches a peak at 2 to 3 weeks of age, and then decreases rapidly. On the other hand, amylase (the enzyme required to break down the carbohydrates found in grains) is relatively low at birth and increases with age. Also, in the digestion of proteins, the pattern for the enzyme involved. Those involved in the breakdown of the simple proteins found in milk are high at birth, while those required for the digestion of the more complex proteins found in cereal grains and oilseed meals are low at birth and increase with age. In light of these facts, the ingredients that should be included in feeds for weaning pigs are greatly dependent on the age at which the pigs are weaned.

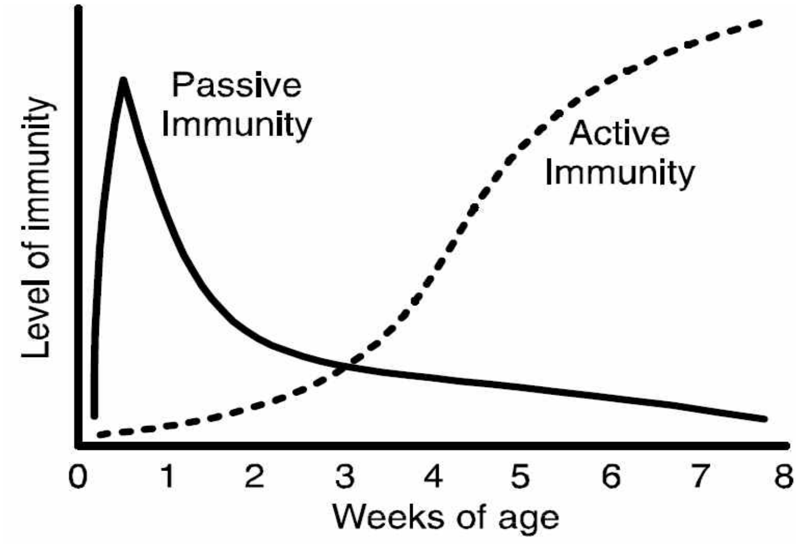

Figure 5. Development of passive and active immunity in the young piglet (Coffey et al., 2000)

Figure 5 shows the immunological changes that are occurring in the young pigs. The neonatal pig receives passive immunity by absorbing the antibodies present in sow's colostrum. These maternally-derived antibodies levels are highest on first day post-farrowing and then decrease to very low levels by the time the pig reaches about 3 weeks of age. The pig's own immune system begins developing at approximately 3 weeks of age, but is not able to reach an effective active immune response until the pig is 4 to 5 weeks of age. This makes the 2- to 4-week-old pig highly susceptible to disease. Because of the behavioral, biological, and immunological changes that are simultaneously occurring at the time of weaning, proper attention to nutrition, management, and the environment is essential for reducing the newly weaning pig impact of growth check. A failure in just one of these areas can cause problems in the nursery and the subsequent growing periods.

Before weaning piglets, creep feeding has been a common practice in swine production. However, the effect of creep feeding has considerable debate. Bruininx et al. (2002a) indicated that creep feeding made short the time between the first eating feed and weaning, and increased feed intake and rate of growth during day 0 to 8 after weaning. It is concept that creep feeding makes suckling pigs to subsequent stressful weaning through prompting gut adaptations to solid feed. Several studies have supported that the supplying of solid diets containing complex carbohydrates to suckling pigs stimulates pepsin and acid secretion in the stomach (Cranwell, 1977, 1985; Cranwell and Stuart, 1984) and improves the activity of pancreatic enzymes and some stomach (Corring et al., 1978; Corring, 1980; de Passillle et al., 1989). Pierzynowski et al. (1990) proposed that alterations in pancreatic output of enzymes and protein around weaning period were developmental adaptations of the intestines to the digestion of the feed, and were more related to the dietary alterations rather than the age of weaning or weaning by themselves. Thus, it could be suggested that suckling pigs consume more solid feed during lactation develop a more advanced digestive tract which helps them more readily cope with a dietary alteration after weaning.

Weaning imposes nutritional (transition from sow's milk to solid feed), psychological (isolation from sow and mingling of different litters), and environmental (shifting from farrowing crates to nursery pens) stresses on weaning pigs. Consequently, weaning pigs show an serious stress response and low growth performance including poor feed intake. It is demonstrated that the earlier the age of weaning the stronger the weaning stress (Worobec et al., 1999). accordingly, to wean young piglets at an older age will enhance the stress indications including the low feed intake (Davis et al., 2006).

The effect of mingling different littermates in a nursery pen on feed intake is controversial. Several reports in the literature showed either declines in rate of growth, feed intake and gain per feed ratio (McGone and Curtis, 1985; Bjork, 1989; Rundgren and Lofquist, 1989) or no shows effects on the growth performance (Friend et al., 1983; Gonyou et al., 1986; Blackshaw et al., 1987; McConnell et al., 1987; McGone et al., 1987) after mingling the unaccustomed piglets together. However, Pluske and Williams (1996) reported piglets from different litters mingled at weaning period ate more feed than those weaned as whole litters. Their results suggest that promoting antagonism by mingling different littermates together may, actually, increasing feed intake, but may have reduced feeding time. They suggested two explanations for the results. Firstly, the reduction in the release of catecholamines by the adrenal gland after the social hierarchy is demonstrated following mingling makes the dominant pigs suffer less from stress-induced suppression of feeding (Vergoni et al., 1990) and consume more than the subordinates after weaning. The increase of feed intake in the dominant pigs after mingling may be higher than in those who do not fight at all, and this in the end effects an increase of overall feed intake after weaning. Secondly, as proposed by Baxter (1991), reducing antagonism in pens may decrease feed intake because it unintentionally decreases social interaction and social facilitation in feeding. Consequently, the formation of social hierarchy following mingling of weaning pigs may raise feeding behavior and thus increase feed intake.

2.2 Regarding Nutrition

It is easily accepted that diets for newly weaned pigs should include high levels of lactose. As age of the piglet at weaning, the initial nursery feed should include from 15 to 25% lactose. Piglets weaned at 14 days or less would require the higher lactose levels, and those weaned at 21 days or higher would require the lower levels of lactose. A high quality, edible-grade dried whey is the most common source of lactose. Dried whey is a by-product of the cheese industry that is produced by drying the liquid whey. The dried whey product contains about 70% lactose as well as some high quality protein (approximately 12%). The nutritional and quality value of dried whey is variable, being mainly influenced by the temperature used in the drying process. Dried whey's color is the best indicator of quality. Whey that has been properly dried will have a creamy to yellow color. Whey that has been overheated in the process of drying will have dark particles or an overall brown color. When overheated, a chemical reaction occurs (Browning reaction) that binds the lactose and lysine, making both of these components less digestible. Because of this, dark-colored whey should not be used in nursery pig's diets.

3. Milk products for weaning pigs

3.1 Lactose for weaning pigs

Lactose is a main component of dried whey and has been shown to be a major factor in improving nursery pig performances (Mahan, 1992). The dietary level of lactose that was necessary to achieve maximum growth rates decreased as pigs became heavier and older, probably because the pigs' digestive system became more mature and the digestive enzymes required to hydrolyze the more complex components in cereal grains were properly secreted.

The effect of varying the complexity of diets fed to nursery pigs (Dritz et al., 1996; Whang et al., 2000; Wolter et al., 2003) and measuring the subsequent responses to market weight have resulted in responses that have been inconsistent. Some reports have indicated that diet complexity during the starter phase has had no effect on the length of time until grower-finisher pigs reach market weight (Dritz et al., 1996; Whang et al., 2000; Wolter et al., 2003), whereas others have shown that lighter-weight pigs at the end of the starter phase reach market weight at an older age (Chiba, 1995; Dritz et al., 1996). A tendency for a greater variation in pig weights by market weight has been reported when a simple nursery diet had been fed (Wolter et al., 2003). Many researchers suggest total inclusion levels of lactose of approximately 10 to 30% during the postweaning (Table 2.).

The inclusion of lactose throughout the starter period may be important in maintaining a good intestinal environment and in decreasing the variability in pig market weights as reported by Wolter et al. (2003).

Table 2. Milk products levels in literatures

Reference	Year	Levels in experiment (%)		
		Lactose	Whey powder	Recommended
Mahan et al.	1993	16 to 47	20, 25	32 to 47
Owen et al.	1993	7 to 23	10 to 20	-
Crow et al.	1995	-	-	at least 15[a)]
Nessmith et al.	1997	0 to 40	-	-
Mahan et al.	2004	10 to 25	10 to 15	23
Cromwell et al	2008	0 to 10	-	25 to 30[b)] / 20 / 10 to 15
Juliano et al.	2010	0, 4, 8, 12	-	up to 7.5

[a)] During d 14 to 21 after weaning
[b)] During d 0 to 7 / d 7 to 21 / d 21 to 35 after weaning

Lactose is the major substrate that enhances the growth of the Lactobacillus spp. (Kenworthy and Crabb, 1963), and its presence may help to suppress some of the hemolytic coliforms and other pathogens that decrease pig performance and their health status (De Mitchell and Kenworthy, 1976; Muralidhara et al., 1977). The Lactobacillus spp. present in the stomach and intestinal tract of the pig at weaning may be important in continuing to maintain a healthy intestinal tract environment throughout the postweaning nursery period (Krause et al., 1995).

Although lactose from either dried whey or crystalline lactose is beneficial during the postweaning period, other simple carbohydrates may be just as effective (Hongtrakul et al., 1998; Oliver et al., 2002).

However, added fiber (Cheeke and Stangel, 1973), the inclusion of fat, and the pelleting of a high-lactose diet (Cheeke and Stangel, 1972) may reduce the effectiveness of the lactose addition on pig performances. In addition, certain breeds or genotypes may not tolerate high levels of whey or lactose, particularly if fed for an extended time (Ekstrom et al., 1976).

Some researchers have investigated diet complexity for weaning pigs and have generally concluded that complex diets improved nursery pig performance during the early postweaning period, but these early diets seemed to have had a minimal affect during the grower-finisher period (Dritz et al., 1996; Whang et al., 2000; Wolter et al., 2003).

3.2 Whey powder for weaning pigs

Whey is the part of milk that separates from the curd during cheese manufacturing. Whey includes about 90% lactose, 20% protein, 40% Ca, and 43% of the P originally present in milk (Leibbrandt and Benevenga, 1991). Dried whey should contain at least 65% lactose, which has been shown to be the best carbohydrate for baby pigs (Cunha, 1977), and it normally contains about 13%–17% of high-quality CP (Seerley, 1991). Generally, the amino acid availability of milk products is considered high, but the product quality can be impaired by over heat treatment. Dried whey is an excellent source of B vitamins, most of which remain in the whey during cheese production, but it may be low in vitamins A and D, which are retained in the cheese (Cunha, 1977; Leibbrandt and Benevenga, 1991; Seerley, 1991). Season, type of cheese produced, and geographic location can affect the mineral content (Leibbrandt and Benevenga, 1991). The type of cheese produced and the addition of salt-laden press drippings influence the salt content of whey (Leibbrandt and Benevenga, 1991).

The high lactose content of whey makes the feedstuff attractive for use by weaning pigs because mucosal lactase activity of the small intestine relative to metabolic body size is greater for pigs from 2-4-weeks-of-age than for pigs 100 or 180 days old (Ekstrom et al., 1975). The efficacy of high-quality dried whey in enhancing growth performance of weaning pigs has been proven (Graham et al., 1981; Cera et al., 1988). Tokach et al. (1995) reported that feeding milk product has beneficial effects in pigs during the starter phase and also in the subsequent grower-finisher phase. Pancreatic enzyme activities in the digestive system appear to be higher in pigs fed diets that include dried whey (Graham et al., 1981; Lindemann et al., 1986), which are highly digestible and can be utilized efficiently (Cera et al., 1988). In addition to its positive effects on digestive enzymes and high nutrient digestibility, other factors in dried whey may be responsible for the beneficial effects on weaning pig performance. By including either lactalbumin or lactose in the diet, Tokach et al. (1989) concluded that both the protein and carbohydrate fractions of dried whey are important. Lepine et al. (1991) and Mahan et al. (1993), however, reported that the protein fraction was not a limiting factor in weaning pig diets. After evaluating the efficacy of lactalbumin and lactose components of dried whey, Mahan (1992) concluded that the lactose component of dried whey was primarily responsible for the beneficial effects of dried whey. It has been shown that edible-grade deproteinized whey and crystalline lactose can replace the lactose provided by high-quality dried whey without affecting pig performance (Nessmith et al., 1997).

Dried whey is a major feed ingredient added to weaning pig diets that has been shown to increase pig growth (Graham et al., 1981, Tokach et al. 1989; Mahan, 1993; Nessmith et al., 1997). Although high protein digestibility and high AA quality enhances the value of whey, its lactose seems to be a primary factor in achieving good performance responses from this product (Mahan, 1992). Most researchers have, however, incorporated it only during the early phase after weaning.

Dried whey can be fed to all classes of pigs, but it is primarily used for weaning pigs. As indicated by Seerley (1991), the inclusion rate of 10%–30% is commonly used, although 30%–45% can be included without any adverse effects. The optimum inclusion rate of dried whey in pig diets should be determined mostly on economical considerations.

Weaning pigs may not consume a sufficient volume of whey to satisfy their amino acid needs and to make whey feeding economical (Modler 1985). Feeding liquid whey can cause a wet environment, increasing stress on young pigs. Limited field experience shows that liquid whey can replace up to half of the daily dry feed intake by gestating sows when the by-product replaces water as the liquid source (Muller 1979). Avoid feeding liquid whey during lactation because large liquid intakes prevent sows from consuming adequate energy. A wet environment caused by whey feeding can also hazard piglet survival. Furthermore, whey is expensive and needed that reduce diet cost without loss of pig performance (Richert et al., 1992).

4. Barley for weaning pigs

Among the alternative feed ingredients, Barley has get much attention because of their correspondingly comparable nutritional values and cheap price compare to corn, SBM and milk products. Barley (*Hordeum vulgare L.*), a common feedstuff in many parts of the world, is used in pig diets primarily as an energy source (Newman and Newman, 1990). The nutrient composition of barley, like that of many other basal ingredients, is subject to a degree of variation that makes accurate diet formulation difficult (Wiseman et al., 1982; Patience and deLange, 1996). This variation in nutrient content is generally attributed to differences among cultivars as well as to variation in growing conditions. Several studies have described the range in the chemical composition of barley. Starch levels have been found to deviate from 48 to 72%, CP from 9 to 16%, total β-glucan from 2 to 11%, ADF from 4 to 8%, and NDF from 12 to 20% (100% DM) (Bhatty et al., 1975; Castell and Bowren, 1980; Ullrich et al., 1984; Henry, 1988). Such differences in chemical constituents among samples most likely explain why the DE content of barley has been found to vary by up to 20%, or approximately 600 kcal of DE/kg of DM.

However, barley is usually not included in diets for young pigs(Li et al., 1996). The development of hulless cultivars of barley with a high DE content may result in increased usage by young pigs. However, this ingredient contains a high fiber and therefore, this has been used restrictively for monogastric animals because of concerning about affecting digestibility from anti-nutrition factors (Table 3). It has been reported that barley usually contains high levels of β-glucans (Campbell et al., 1986). β-glucans, which are present in the endosperm and aleurone cell walls of barley, may interfere with digestion and absorption (Aman and Graham, 1987).

Monogastric animals is limited to digest fiber source in their feed because of absence of fiber degrading enzymes. Wheat, barley, rye etc. are typical ingredients containing soluble fiber but insoluble β-glucan or arabinoxylan are also present (Bedford and Classen, 1992). The soluble fiber is able to increase the viscosity of digesta in the small intestine, diminishing the digestion of nutrients and thereby reducing the growth of the animal. Therefore, feed industries tried to extract and produce enzymes on a commercial scale and now used in many livestock feed.

Diets that are based on barley, oats, or naked oats have been shown to improve pig performance compared with diets based on wheat or corn, and there is evidence that the fiber fraction in barley and oats help improve intestinal health of pigs(Stein, 2011). Infection is common during this period, and dietary interventions may influence immune function at this tenuous period (Adegoke et al., 1999; Hampson, 1986; Johnson et al., 2006). β-glucans supplementation resulted in fewer pathogens isolated from liver, indicating that β-glucan reduced the intestinal translocation of bacteria (Huff et al., 2010; Lowry et al., 2005).

Table 3. Chemical composition of major protein and carbohydrate source for swine including barley (NRC 1998)

Item	Barley	Balrey hulless	Corn	SBM	Whey dried	Lactose
Dry matter (%)	89	88	89	89	96	90
Crude protein (%)	11.3	14.9	8.3	43.8	12.1	-
Ether extract (%)	1.9	2.1	3.9	1.5	0.9	-
ME (kcal/kg)	2910	3360	3420	3180	3190	3786
NDF (%)	18.0	10.1	9.6	13.3	-	-
ADF (%)	6.2	2.2	2.8	9.4	-	-

4.1 Effect of supplementing barley on digestibility

The hull and fiber content of barley are major factors which cause inferior performance of swine fed barley in comparison to those fed grains low in fiber. Various methods of improving barley for swine have been tested. Increasing the available energy content with added fat improved pig performance in trials reported by Heitman (1956), Oldfield and Anglemier (1957), and Anglemier and Oldfield (1957). The superiority of pelleted barley diets for swine has been demonstrated in numerous experiments (Thomas and Flower, 1956; Dinusson et al., 1960; Larsen and Oldfield, 1960; Troelsen and Bell, 1962; Haugse et al., 1966). Joseph (1924) compared hulless Guy Mayle barley to covered White Smyrna barley in swine diets, and the hulless variety was superior to the covered barley and equal to corn as measured by pig performance. The work of Gill et al. (1966) with hulless Godiva and covered Hannchen barleys supported the earlier findings of Joseph (1924). Although cereal β-glucans are readily degraded by microbial populations prececally (Bach Knudsen and Hansen, 1991; Jonsson and

Hemmingsson, 1991), it is possible that the insoluble β-glucan proportion may be passed partially undigested to the large intestine and subsequently utilized by saccharolytic microbial species (Kedia et al., 2008). Oat-derived β-glucans generally exhibit less solubility (Johansson et al., 2004) and are not as comprehensively digested prececally compared with barley (Bach Knudsen et al., 1993a). Inclusion of an appropriate enzyme composite containing β-glucanase and β-xylanase may elucidate the actions exerted by the β-glucan component from the various cereal sources (O'Connell et al., 2005).

The soluble β-glucan fraction is thought to raise digesta viscosity, therefore making it difficult for endogenous enzymes to breakdown substrate for nutrient release (Johnson and Gee, 1981). The addition of exogenous β-glucanase improves the nutrient digestibility of barley as reported in broiler chicks (Vukic Vranjes and Wenk, 1995) and pigs (Skoch et al., 1983; O''Connell et al., 2005b). However, the beneficial effects of fermentable fiber may be removed as a result of enzyme preparations. Heat treatment modifies the composition of cereals (Atwell et al., 1988) by gelatinizing starch, denaturing protein and destroying anti-nutritive factors (Alonso et al., 2000). In doing so heat treatment improves the ileal digestion of non-starch polysaccharides by shifting insoluble NSP to soluble NSP (Fadel et al., 1988). Extrusion cooking also increases the susceptibility of insoluble NSP to fermentation in the large intestine (Fadel, 1988) thus reducing the pH.

4.2 Effect of supplementing barley on diarrhea incidence

It is well established that the manipulation of the intestinal microflora in both ruminant and non-ruminant species has a significant effect on growth rate and the efficiency of feed utilization (Armstrong, 1984, 1986). While the influence that antimicrobial agents in feed have on aspects of rumen function have been well documented, the effect of changes in the microbial population of the small and large intestine are less well understood. A number of antimicrobial compounds, including dietary copper (Braude, 1967), have been shown to be effective in improving growth rates in pigs, and their mode of action has been attributed to factors associated with alteration in the balance of microbial species in the small intestine. These include changes in the structure of the intestinal wall, reduction in the production of toxic compounds such as ammonia or amines, and a reduction in the utilization of essential nutrients by bacterial species (Visek, 1978). Manipulation of the microbial flora in the intestine can also be achieved by the establishment of a specific group of bacterial species within the tract following oral dosing of the animal, the use of so-called 'probiotic' preparations. This method is suggested to be particularly beneficial in reducing the chances of establishing a pathogenic flora within the digestive tract at times of stress and was first proposed by Metchnikoff (1908). Changes in intestinal flora as a result of a range of stress factors have been shown in a number of animal species (Tannock, 1983).

Piglets often experience a growth check and may develop diarrhea in the period after weaning. Post-weaning diarrhea (PWD) is a multifactorial condition associated with proliferation of b-haemolytic strains of *Escherichia coli* in the small and large intestine.

Consequently, many studies have examined how components of a weaner diet may influence piglet health and production after weaning.

The tolerance to high-fiber diets may depend on the type of fiber; for example, barley, a high-fibre cereal grain, is sometimes preferred to wheat or maize in the weaning diet (phase I) to prevent diarrhea, though the reason for this beneficial effect is not well understood(The weaner pig, 2001).

The weaning period in the pig is associated with an increased prevalence of gastrointestinal infections, particularly from enterotoxigenic *E. coli* ETEC) and other gram-negative bacteria (Nabuurs, 1998). Weaning suppresses adaptive immunity for about a week (Juul-Madsen et al., 2009). Specific dietary nutrients such as long-chain PUFA, Gln, and oligosaccharides alter the development of the immune system early in life (Castillo et al., 2008; Ewaschuk et al., 2011; Field, 2005; Johnson et al., 2006; Leonard et al., 2010; Yoo et al., 1997). Dietary intervention at the time of weaning aimed at improving the development of the immune system may assist in immune and gut development and reduce the incidence of infections in young pigs and other species. β-glucans are a diverse class of linked glucose polymers that are present in the cell walls of yeast and fungi and part of the endosperm cell wall of some cereal grains, including barley. Barley-derived β-glucans exert a number of biological effects, including increasing bile acid excretion (Judd and Truswell, 1981), altering microflora (Pieper et al., 2008), increasing colonic short-chain fatty acid content (Pieper et al., 2009), and reducing serum cholesterol (McIntosh et al., 1991). In addition, a number of immune effects have been attributed to β-glucans. However, β-glucans and other similarly structured fibers exert anti-nutritive effects, thus, despite the possibility of immune enhancement, their inclusion in animal feeds may be undesirable (Choct and Annison, 1992; McNab and Smithard, 1992).

5. NSP in barley for swine nutrition

5.1 NSP definition

Nonstarch polysaccharides (NSP) can comprise up to 90% of the cell wall of plants (Selvendran and Robertson, 1990). The most abundant plant cell wall NSP include cellulose, hemicelluloses, and pectins. A smaller group of NSP(fructans, glucomannans, and galactomannans) serve as storage polysaccharides within the plant. Mucilages, β-glucans, and gums are also examples of NSP. Unlike starch, which is hydrolyzed by pancreatic amylase to glucose, NSP are not hydrolyzed by mammalian enzymes; rather, they are fermented by the gastrointestinal tract microflora. The physiological impact of individual NSP is dependent on the sugar residues present and the nature of linkages between these residues. Cellulose and β-glucans are linear 1-4 β-linked glucose polymers. Mixed linkage β-glucans contain 1-3 linkages interspersed with 1-4 linkages. Cellulose occurs in tightly bound aggregates (microfibrils) in plants. Hemicelluloses contain a monosaccharide backbone of xylan, galactan, or mannan, and side chains of arabinose or galactose. Pectin is a polymer of galacturonic acid containing side chains of other sugars such as glucose, galactose, and rhamnose.

In contrast to NSP, oligosaccharides (OS) generally contain only

3 to 9 monosaccharide units. They may have similar or different monosaccharides, various linkage structures, and may be linear or branched chain. Like NSP, OS are not hydrolyzed by mammalian enzymes, but are fermented by the gastrointestinal tract microflora. Fructo-oligosaccharides (FOS) are a mixture of primarily fructose units linked by β-2-1-glucosidic bonds. As will be discussed later, FOS are preferentially used by bifidobacteria in the large intestine. α-Galacto-oligosaccharides (GOS) consist of 1, 2, or 3 units of galactose linked via α-1-3 bonds and bound to a terminal sucrose. The GOS(raffinose, stachyose, and verbascose) are of particular concern to the swine industry because they are poorly utilized by young pigs. Soybean meal, a major dietary ingredient for swine, contains high concentrations of GOS. Lignin is not a polysaccharide but rather a high-molecular-weight polymer composed of phenylpropane residues formed by condensation of the aromatic alcohols, cinnamyl, guaiacyl, and syringyl alcohols (Southgate, 1993). The lignin content of swine feeds is typically low, with cereal and oilseed fibers usually having only a few percent lignin (Dreher, 1999). Lignin is not considered a functional dietary ingredient and is essentially indigestible by swine.

Table 4 shows the NDF, ADF, TDF, and crude fiber concentrations of selected ingredients used in swine feeds. Certain feedstuffs used in the swine industry also contain considerable quantities of the fructosyl OS derivatives and galactosyl OS derivatives (raffinose and stachyose). Barley and wheat contain substantial amounts of both types of OS, while oats contain only the galactosyl OS (Table 4; Henry and Saini, 1989). Because nutritionists are constantly seeking methods to reduce swine production costs and improve pig performance, there is interest in the utilization of “nontraditional” and by-product feedstuffs in swine diets. Many of these alternative feed sources have much higher fiber concentrations than corn or soybean meal.

Table 4. Fiber and oligosaccharide concentrations in common feed ingredients for swine (as-is basis / CRC Press LLC, 2001)

Item	Barley	Corn grain, yellow	SBM	Wheat	Beet pulp
Crude fiber (%)	5.0	2.6	6.2	2.5	-
NDF (%)	18.0	9.6	13.3	13.5	41.1
ADF (%)	6.2	2.8	9.4	4.0	-
TDF [1] (%)	17.3	9.0	-	12.2	56.3
TFOS [2] (mg/g)	1.7	0.0	0.0	1.3	0.1
Sucrose (mg/g)	13.6	-	62.0	7.9	-

[1] Total dietary fiber

[2] fructo-oligosaccharides

5.2 Digestion of NSP and OS by swine

Not unexpectedly, the apparent digestibility of fibrous components by swine is quite variable and may range between 0 and 97% (Mitchell and Hamilton, 1933; Rerat, 1978; Poijarvi, 1944). Addition of high NSP feedstuffs to swine diets reduces apparent digestibility of the diet (Pond et al., 1986; Moore et al., 1986b; Zhu et al., 1993). Numerous factors can affect the efficiency of digestion of NSP including source (Knudsen and Hansen, 1991), processing method (Fadel et al., 1989), and concentration in the diet (Stanogias and Pearce, 1985a; Goodlad and Mathers, 1991).

Swine lack the necessary digestive enzymes to degrade NSP and

OS. Therefore, ingested NSP and OS are acted upon by anaerobic bacteria. Although it is commonly believed that digestion of NSP and OS occurs primarily in the large intestine of the pig, up to 62% of NSP disappearance has been observed in the upper intestine (Graham et al., 1986; Fadel et al., 1989). Knudsen and Hansen (1991) quantified the recovery of wheat NSP at the end of the small intestine as 82 to 104% whereas the recovery was only 64 to 66% for oat NSP, demonstrating that oats were degraded to a larger extent in the small intestine. Graham et al. (1986) demonstrated that feeding pigs a control diet containing barley, wheat, and oats alone or supplemented with 33% wheat bran or 33% beet pulp resulted in a 19.7, 10.6, and 36.8% NSP apparent ileal digestibility, respectively. The degradation products in the small intestine were similar to those in feces, leading to the assumption that the degradation process occurring in the small intestine was also microbial in nature (Graham et al., 1986).

Most NSP and OS are highly fermentable. Compounds such as H_2, CO_2, and small amounts of CH_4 gas are by-products of their bacterial degradation, along with the volatile fatty acids (VFA) such as acetate, propionate, and butyrate.

5.3 Effect of NSP and OS on GIT characteristics

Feeding high-fiber diets generally increases total empty gastrointestinal tract weight (Kass et al., 1980b; Stanogias and Pearce, 1985b; Anugwa et al., 1989), although Jin et al. (1994) observed no change in visceral weights due to inclusion of 10% wheat straw in growing pig diets. The variation in NSP sources used in these studies may explain the differences in results observed. Additional effects of feeding high-NSP diets include increased salivary (Arkhipovets, 1956; Low, 1989), gastric (Zebrowska et al., 1983; Dierick et al., 1989), biliary (Dierick et al., 1989), pancreatic (Partridge et al., 1982; Zebrowska and Low, 1987; Dierick et al., 1989), and possibly intestinal (Taverner et al., 1981) secretions. Both high-NSP and high-OS diets affect intestinal epithelial cell proliferation rate as demonstrated by Jin et al. (1994) and Howard et al. (1995). Growing pigs fed diets containing 10% wheat straw had a 33 and 43% increase in rate of jejunal and colonic cell proliferation, respectively. These pigs also had 65 and 59% more jejunal and ileal cells undergoing programmed cell death, indicating that NSP had actually increased intestinal cell turnover rate (Jin et al., 1994). Width of the intestinal villus and crypt depth also were increased in pigs fed the high-NSP diet (Jin et al., 1994). Similarly, feeding neonatal pigs diets containing 3 g FOS/l formula resulted in an increased cecal epithelial cell density (44.7 vs. 41 cells/crypt) and number of labeled cecal mucosal cells (9.6 vs. 8.2 cells/crypt) (Howard et al., 1995).

In addition to the obvious impact the above-described physiological changes may have on nutrient digestion and absorption, feeding high NSP concentrations also may indirectly increase maintenance energy requirements of swine by increasing nutrient needs for visceral organ development and maintenance.

5.3.1 Fermentation of NSP and OS on GIT characteristics

Fermentative microorganisms are present in the highest concentration in the cecum and colon of the pig. Two of the most abundant cellulolytic species of microbes in the rumen, Fibrobacter succinogenes and Ruminococcus flavefaciens, are present in the pig large intestine (Varel et al., 1984a). Microbes in the large intestine of the pig primarily utilize the dietary plant cell wall polysaccharides, sloughed intestinal mucosa, glycoproteins from saliva, gastric juice, mucinous secretions, and a minor amount of dietary simple sugars and disaccharides (Varel, 1987). Oligosaccharides and possibly resistant starch also serve as fermentable substrates in the cecum and large intestine of the pig. The population of microorganisms in the pig cecum and colon is affected by many dietary factors including feeding of high-NSP diets. Varel et al. (1984b) observed a 38% increase in the number and a 17% increase in the activity of cellulolytic bacteria in fecal samples from growing pigs fed a diet containing 35% alfalfa meal. Similar results were observed by Anugwa et al. (1989) who fed diets containing 40% alfalfa meal. The maximum average rate of fermentation in sows receiving either 0 or 475 g/day orally or 0, 285, 570, or 855 g/day of intracecally purified cellulose was 11 g/kg0.75, and the true efficiency of bacterial protein synthesis was 5.2 g bacterial protein/100 g supplementary cellulose on average (Kreuzer et al., 1991).

Feeding FOS to humans (Modler et al., 1990) promotes growth of Bifidobacterium, but contradictory effects have been reported in swine. Houdijk et al. (1998) fed growing pigs diets supplemented with 7.5, 10, 15, or 20 g nondigestible oligosaccharide per kilogram diet and found no effect on fecal pH, but a decreased fecal DM content. Similarly, Gabert et al. (1995) observed no effect of feeding weaning pigs diets containing 0.2% transgalactosylated OS, 0.2% glucooligosaccharides, or 1% lactitol on bacterial populations in ileal digesta.

Fermentation of NSP in the cecum and colon of the pig results in the production of a mixture of VFA, primarily acetic, propionic, and butyric acids. Elsden et al. (1946) reported that the relative concentrations of individual VFA in the alimentary tract of numerous species including the pig, sheep, ox, red deer, horse, and rabbit were very similar, with acetic acid being the highest at 67%, followed by propionic acid and butyric acid at 19 and 14%, respectively. The specific concentrations of VFA in the swine cecum in this experiment were 62.1% acetic acid, 27.8% propionic acid, and 10.1% butyric acid (Elsden et al., 1946). Both the source and level of dietary NSP can affect fermentative breakdown of fibrous feedstuffs and the molar ratios of VFA produced in the colon of the pig.

5.3.2 Energy value of VFA

VFA(volatile fatty acids) produced by microbial fermentation in the cecum and colon are rapidly absorbed (Latymer and Low, 1987) and can supply between 5 and 28% of the maintenance energy requirement of the pig (Farrell and Johnson, 1970, 1.9 to 2.7% of apparent digestible energy; Rérat et al., 1987, approximately 30% of metabolizable energy for maintenance; Imoto and Namioka, 1978, approximately 10% of metabolizable energy for maintenance; Yen et al., 1991, 23.8% of whole animal heat production; Kass et al., 1980a, 4.8 to 14% of the energy required for maintenance). When considering

VFA as an energy source for the pig, the losses of methane, hydrogen, and fermentation heat must be considered. These losses result in a lower energy value to the animal in comparison with hydrolytic digestion of carbohydrates. The efficiency of utilization of dietary energy is decreased 9 to 22% in animals fed high-NSP diets (Giusi-Perier et al., 1989; Noblet et al., 1994) due to a reduced absorption of glucose and amino-N from the small intestine and an inadequate compensatory increase in the absorption of VFA in the hindgut. These results demonstrate that the energy supplied from the fermentation of NSP is utilized at a lower efficiency than the energy supplied by nutrients digested and absorbed from the small intestine.

Ⅲ. Evaluation of Barley to Replace Milk Products in Weaning Pig's Diet

Abstract: This experiment was conducted to investigate the influence of barley to replace milk products in weaning pig's diet on growth performance, blood profile, nutrient digestibility and diarrhea incidence in weaning pigs. A total of 112 cross bred ([Yorkshire × Landrace]× Duroc, weaned at 28 days of age) piglets were allotted to 4 treatments in a randomized complete block(RCB) design. Each treatment has 7 replications with 4 pigs per pen. Pigs were fed each treatment diet which containing different levels of barley (0, 10, 20 and 30%) at the expense of whey powder and lactose. During 0-2 week, body weight, ADG and G/F ratio were decreased as barley level increased in the diet (linear response, P<0.01). However, no detrimental effects were observed in 2-6 weeks on growth performance. In overall period, all treatments showed no significant differences or responses in BW, ADG, ADFI and G/F. In digestibility trial, crude fat digestibility was linearly increased as barley increased (linear, P<0.01). Blood urea nitrogen was decreased as barley level increased in the diet (linear response, P<0.01) However, no significant differences or responses were observed in blood glucose level. The incidence of diarrhea was improved as increasing barley contents in all phases (linear, P<0.01). These results demonstrated that supplementation of barley influenced negatively on growth performance during 0-2 week, however, the incidence of diarrhea, fat digestibility and later growth performance from 3 week

postweaning was improved as dietary barley level increased. Consequently, barley as an energy source instead of milk products can be recommended in commercial in weaning pigs' diet.

Key words: Barley, milk-product, weaning pigs, growth performance, blood urea nitrogen, blood glucose level, diarrhea incidence.

Introduction

It is well known that corn, SBM (soy bean meal), lactose and whey powder are primary feed ingredients for weaning pigs especially in Korea. However, the international price of major feed ingredients has increased since 2007 because of increasing demand for animal feed in developing countries. Moreover, in 2012, severe drought was occurred in the United States and middle of EU where are the major cropland in the world. These factors affected the price of feed stuffs as well as milk products. Many swine producers and nutritionists have sought ways to reduce the feed cost with minimally sacrificing animal's productivity because of increased cost of raw materials. Alternative to feed ingredients such as high fiber grains and by-products are focused on amount of production, steady supply and cheap price to improve feed cost and productivity. Currently, barley, broken rice, PKM (palm kernel meal) and tapioca which are cheaper than corn and milk products, have been partially applied as potential alternatives for swine diets. However, the use of these ingredients has been limited because of poor nutrient digestibility and the presence of potential anti-nutritional factors in monogastric animals. These alternative feed ingredients typically contain the high amount of dietary fiber which includes non-starch polysaccharide (NSP) mainly. Among the alternative feed ingredients, the high attention was focused on barley because of its comparable nutritional values and low price compared with corn and milk products. However, the supplementation level of barley was limited because of high contents of fiber in monogastric animals and little information about the inclusion level of barley with no detrimental effects on growth performance and nutrient digestibility is available in weaned piglets. Therefore, the present study was conducted to investigate the effects of supplementation levels of barley on the growth performance, nutrient digestibility, blood profiles and diarrhea incidence and to establish proper inclusion level of this ingredient in weaned pigs.

Materials and methods

Animals, management and dietary treatment

A total of 112 crossbred ([Yorkshire × Landrace]× Duroc) piglets were allotted to 4 treatments in a randomized complete block (RCB) design. Each treatment had 7 replications with 4 pigs per pen and four diets containing 0(B0), 10(B10), 20(B20) and 30(B30)% barley were fed to piglets. Animals were housed in a 1.2 × 3.6 m^2 plastic floor, equipped with a feeder and a nipple drinker to allow freely access to feed and water during the experimental period. The ambient temperature in the weaning house was maintained at 31 ℃, and then gradually fallen to 27 ℃ at the end of the experiment. Individual body weight (BW) and feed intake were recorded at 0, 2, 4 and 6 weeks to calculate the average daily gain (ADG), average daily feed intake (ADFI) and gain-to-feed ration (G/F ratio). The diets were formulated to contain 3,350.20, 3,307.21, 3,277.35 kcal ME/kg for phase Ⅰ, Ⅱ and Ⅲ, respectively. For phase Ⅰ and Ⅱ, whey powder and lactose were added to each diets and all other nutrients were met or exceeded requirements of NRC (1998). The experimental diets and chemical composition are presented in Table 2, 3 and 4.

Blood sampling

Blood samples were taken from the jugular vein of each pig for measuring blood urea nitrogen (BUN) concentration and blood glucose level (BGL) when the body weights were recorded. Collected blood samples were centrifuged for 15 min at 3,000 rpm on 4 ℃ (Eppendorf centrifuge 5810R, Germany). The serum was carefully transferred to 1.5 ml plastic tubes and stored at -20 ℃ until analysis. Total BUN concentration was analyzed using a blood analyzer (Ciba-Corning model, Express Plus, Ciba Corning diagnostics Co.).

Nutrient digestibility and chemical analyses

Digestibility trial was conducted in completely randomized design (CRD) with 6 replicates to evaluate the nutrient digestibility and nitrogen relation. Experimental diet of weaning period was provided to each treatment animals. A total of 24 crossbred weaning barrows, averaging 11.74 ± 0.72 kg body weight, were individually allotted to each treatment and housed in an metabolic crate. Total collection method was utilized for the apparent digestibility. After a 5 days adaptation period then 5 day of collection period was followed to determine the first and last day of collections, 1g of ferric oxide and chromium oxide were added in experimental diet, respectively for selection marker. During the experimental period, water was provided *ad libitum* and all pigs were fed 120g twice a day. Excreta and urine were collected daily and stored -20℃ until analysis. Collected excreta were pooled and dried in an air-forced drying oven at 60℃ for 72 h, and ground into 1 mm particles in a Wiley mill for chemical analysis include moisture, protein, fat and ash contents. 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.

Diarrhea incidence

Observation of diarrhea incidence was conducted every 8:00 am for 42 days. Data was recorded by each pen and divided into 3 phases to assess the general pattern (PhaseⅠ, PhaseⅡ and PhaseⅢ). Score of diarrhea incidence was given into 5 numbers by counting pigs with evidence of watery diarrhea (0=No evidence of watery diarrhea, 1=1pig shows evidence of watery diarrhea, 2=2pigs, 3=3pigs and 4=All pigs show evidence watery diarrhea in the pen). After recording data, evidence of watery diarrhea was cleaned away everytime to separate from next day.

Economic analyses

Economic analyses was conducted to compare the feed cost for 1 kg weight gain of the diets containing low milk product and those containing high milk product. Calculation of feed cost as following;

$$\text{Feed cost for 1kg weight gain} = \frac{\text{Cost of feed(\$) X Feed intake per head(kg)}}{\text{Weight gain per head(kg)}}$$

Economic analyse was conducted in each phase. As of January 2012, marker price of feed ingredient was calculated.

Chemical analyses 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), N by using the Kjeldahl procedure with Kjeltec (KjeltecTM 2200, Foss Tecator, Sweden) and CP content (N × 6.25; procedure 981.10; AOAC, 1990). Nitrogen of urine was determined by the Kjeldahl procedure. Statistical analysis was carried out by least squares mean comparisons using PDIFF option of General Linear Model (GLM) procedure of SAS (2004). For data on growth performance, a pen was considered the experimental unit, while individual pig was used as the unit for data on blood profiles, nutrient digestibility, diarrhea incidence and economic analysis. The effects of increasing levels of barley were analyzed as linear and quadratic components by orthogonal polynomial contrasts. Differences were declared significant at $P < 0.05$ and highly significant at $P < 0.01$.

Results and discussion

Growth performance

Table 4 shows the influence of barley supplementation on growth performance in weaning pigs. During the phase I, body weight (BW), average daily gain (ADG) and feed efficiency (G:F ratio) was declined as the supplementation level of barley increased, resulting in linear response (P<0.01). However, there was no significant difference on the parameters of growth performance in phase II and III.

Numerous swine researchers and nutritionists have been demonstrated the positive effects of milk products in young pig. Most of studies (Graham et al., 1981; Cera et al., 1988b; Goodband and Hines, 1988; Lepine et al., 1991) showed the using milk products in combination with cereal grains and soybean meal has resulted in superior postweaning weight gains compared with simple grain and soybean meal mixture diet. Mahan (1993) reported increased growth performance of weaning pigs fed diets containing dried whey from 0 to 35% in early postweaning period and the results of current study is agreed with those suggested, resulting in increased growth performance in phase I. Although little information about the effects of barley supplementation in weaning pigs is available, there were some findings which suggested added fiber may reduce the effect of lactose supplementation on weaning pigs (Cheeke and Stangel, 1973; Shi and

Noblet, 1994; Davidson and McDonald, 1998). Touchette et al. (1995) also reported that lactase activity is higher than amylase activity at three weeks of age and this trend was maintained from d 0 to 14 postweaning, but the response was inconsistent in late phase because lactase activity was decreased relative to amylase activity (Stephas et al., 1996). In the current study, ADG and G:F ratio was affected by the supplementation level of barley in phase I, but this trend was changed in late phase in agreement with that of Stephas et al. (1968), resulting in no significant difference of ADG, ADFI and G:F ration during the whole experimental period.

Nutrient digestibility

The response of barley supplementation on nutrient digestibility was shown in Table 4. Barley supplementation with all levels did not affect on nutrient digestibility of dry matter, crude protein and crude fat. However, linear increase of crude fat digestibility was observed as inclusion level of barley increased, resulting in linear response ($P<0.01$). In the result of nitrogen retention, there was no significant difference among all parameters supporting this observation of crude protein digestibility.

The negative effects of fiber diets on energy and nutrient utilization of pigs was reported many times (Shi and Noblet., 1994; Davidson and McDonald, 1998; Canh et. al., 1998). Although barley contains higher dietary fiber relative to other carbohydrate sources, it also contains high level of free sugar and there was a study suggesting no detectable difference on dry matter, organic matter, nitrogen, NDF and gross energy digestibility between barley and other carbohydrate diets (Lynch et al., 2007). In the present study, the piglets fed high barley diets showed similar digestibility with those fed control diet and these might be explained by the high sugar content and the supplementation level.

Increased feed efficiency and fat digestibility by addition of fat sources have been reported many times in weaned pigs (Crampton and Ness, 1954; Frobish et al., 1970; Allee et al., 1971; Atteh and Leeson, 1983; Lawrence and Maxwell, 1983). The ability of weaned pigs to digest fat was associated with fat source and improves as age increased (Cera et al., 1990). In the present study, digestibility trial was conducted in early phase and increased fat digestibility by fat addition was detected with an agreement of the results in growth performance.

Blood analysis

Table 5 showed the effects of barley supplementation on blood profiles in weaning pigs. The significant differences by the addition of barley on BUN and BGL were not observed during the whole experimental period except BUN concentration in phase III. The pigs fed diets containing high level of barley showed lower BUN concentration relative to those fed diets containing low level of barley in phase III, resulting in linear response ($P<0.01$).

Although little information is available about the effects of barley supplementation on BGL, the high BGL in pigs fed barley diet was expected because of high sugar content of barley. However, there was no response of barley supplementation with an agreement of Qureshi

(1998) who found that BGL was not changed by barley supplementation when inclusion level was relatively low. Kornegay (1978) found the negative correlation between the inclusion level of dietary fiber and nutrient digestibility and there were several researches reporting decreased DM and energy digestibility in pigs fed diet containing high level of barley (Bowland, 1974; Wu and Ewan, 1979). In the previous findings, the piglets were weaned before d 21, but piglets in the present study were weaned at d 28. A reason for no detectable difference of BUN among all diets may be derived from this difference because the gastric function of piglets was changed during one week. Moreover, the surplus energy derived from high content of free sugar in barley diet may affect the protein utilization. Further studies are needed to demonstrate the mode of action of increased BUN.

Diarrhea incidence observation

The effects of barley supplementation on diarrhea incidence in weaning pigs is shown in Table 7. In all phases, diarrhea incidence was decreased linearly as inclusion level of barley increased, resulting in linear response ($P<0.01$).

Schulman (1973) demonstrated that weaning could cause gastric changes increasing counts of *E. coli*, resulting in severe diarrhea and growth depth. However, many researchers indicated that this negative effects of weaning on gastric condition could be decreased by the supplementation of fiber sources and prebiotics (Muralidhara et al., 1977; Mitchell and Kenworthy, 1976; Cherbut et al., 1990). Soluble fiber improves the volume and bulk of intestinal contents and it may cause increased water-holding capacity and viscosity causing low moisture content of feces (Metzler et al., 2008). Moreover, the supplementation of fiber source as a prebiotics is associated with inhibiting harmful bacterial activity (Gibson and Roberfroid, 1995). This mode of action seems to be affected to good effects on diarrhea incidence.

Economic Analyses

To evaluate the effects of barley supplementation on cost of feed and productivity, the economic analyses was conducted at end of growth trial (Table 8). The feed cost/1kg BW was reduced significantly as the inclusion level of barley increased in phase I and II. Although there was no significant difference, feed cost / 1kg BW in phase III was also improved numerically in pigs fed diet containing high level of barley.

Consequently, there was no detrimental effects of barley supplementation on growth performance, nutrient digestibility and blood profiles when the inclusion level was up to 30% and feed cost/1kg BW and diarrhea incidence of weaning pigs were improved in pigs fed diet containing high level of barley.

Conclusion

Supplementation of barley instead of milk products showed negative effects on growth performance in first and second week postweaning. However, there was no drawback in phase II to III on all measurement in this experiment even in the B30 treatment which did not contains milk products. In the results of digestibility trial, there was no significant difference on nutrient digestibility of dry matter, crude protein, but linear increase of crude fat digestibility was detected as inclusion level of barley increased. BGL concentration was not changed by barley supplementation and the pigs fed diets containing high level of barley showed decreased BUN concentration compared with those fed diets containing low level of barley in phase III. During the whole experimental period, diarrhea incidence was improved as inclusion level of barley increased. Consequently, there was no detrimental effects of barley supplementation on growth performance in later phase, nutrient digestibility and blood profiles except growth performance in early phase and diarrhea incidence was improved clearly when the pigs fed diet containing high level of barley.

Table 1. Formula and chemical compositions of the experimental diets in phase I (0 to 2 weeks)

Ingredients, %	B0[1)]	B10[1)]	B20[1)]	B30[1)]
EP corn	12.83	16.64	20.56	24.46
Dehulled-SBM(48%)	39.70	37.36	34.88	32.40
Fish meal	1.70	1.70	1.70	1.70
HP300	1.00	1.00	1.00	1.00
SBP	3.00	3.00	3.00	3.00
Whey powder	9.00	6.00	3.00	0.00
Lactose	30.00	20.00	10.00	0.00
Barley	0.00	10.00	20.00	30.00
Soy-oil	0.01	1.65	3.26	4.88
MCP	1.10	1.05	1.00	0.95
Limestone	0.91	0.86	0.81	0.76
L-Lysine·HCl	0.00	0.00	0.06	0.12
DL-methionine	0.11	0.10	0.09	0.09
Vit. Mix[2)]	0.12	0.12	0.12	0.12
Min. Mix[3)]	0.12	0.12	0.12	0.12
Salt	0.20	0.20	0.20	0.20
Choline-Cl(25%)	0.10	0.10	0.10	0.10
ZnO	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00
Chemical Composition[4)]				
ME (kcal/kg)	3350.23	3350.30	3350.25	3350.28
CP (%)	23.00	23.00	23.00	23.00
Lysine (%)	1.35	1.35	1.35	1.35
Methionine (%)	0.44	0.44	0.44	0.44
Ca (%)	0.80	0.80	0.80	0.80
Total P (%)	0.65	0.65	0.65	0.65

1) Abbreviated B0, 0% barley was supplemented; B10, 10%; B20, 20%; B30, 30%.

2) Provided the following per kilogram of diet: vitamin A, 8,000 IU; vitamin D_3,1,600IU; vitamin E, 32IU; d-biotin, 64g; riboflavin, 3.2mg; calcium pantothenic acid, 8mg; niacin, 16mg; vitamin B_{12}, 12g; vitaminK, 2.4mg.

3) Provided the following per kilogram of diet : Se, 0.1mg; I, 0.3mg; Mn, 24.8mg; $CuSO_4$, 54.1mg; Fe, 127.3mg; Zn, 84.7mg; Co, 0.3mg.

4) Calculated values

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

Ingredients, %	B0[1)]	B10[1)]	B20[1)]	B30[1)]
EP corn	45.97	41.41	36.89	32.34
SBM(44%)	18.09	17.35	16.66	15.95
Dehulled-SBM(48%)	18.09	17.41	16.68	15.98
Whey powder	6.00	4.00	2.00	0.00
Lactose	9.00	6.00	3.00	0.00
Barley	0.00	10.00	20.00	30.00
Soy-oil	0.31	1.30	2.27	3.25
MCP	1.04	1.03	1.01	1.00
Limestone	0.88	0.85	0.81	0.77
L-Lysine·HCl	0.02	0.05	0.08	0.11
DL-methionine	0.06	0.06	0.06	0.06
Vit. Mix[2)]	0.12	0.12	0.12	0.12
Min. Mix[3)]	0.12	0.12	0.12	0.12
Salt	0.20	0.20	0.20	0.20
Choline-Cl(25%)	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00
Chemical Composition[4)]				
ME (kcal/kg)	3,307.23	3,307.25	3,307.21	3,307.17
CP (%)	23.00	23.00	23.00	23.00
Lysine (%)	1.15	1.15	1.15	1.15
Methionine (%)	0.37	0.37	0.37	0.37
Ca (%)	0.75	0.75	0.75	0.75
Total P (%)	0.63	0.63	0.63	0.63

1) Abbreviated B0, 0% barley was supplemented; B10, 10%; B20, 20%; B30, 30%.

2) Provided the following per kilogram of diet: vitamin A, 8,000 IU; vitamin D_3,1,600IU; vitamin E, 32IU; d-biotin, 64g; riboflavin, 3.2mg; calcium pantothenic acid, 8mg; niacin, 16mg; vitamin B_{12}, 12g; vitaminK, 2.4mg.

3) Provided the following per kilogram of diet : Se, 0.1mg; I, 0.3mg; Mn, 24.8mg; $CuSO_4$, 54.1mg; Fe, 127.3mg; Zn, 84.7mg; Co, 0.3mg.

4) Calculated values

Table 3. Formula and chemical compositions of the experimental diets in phase III (4 to 6 weeks)

Ingredients, %	B0[1)]	B10[1)]	B20[1)]	B30[1)]
EP corn	66.92	57.48	48.02	38.56
SBM(44%)	30.52	29.38	28.24	27.11
Barley	0.00	10.00	20.00	30.00
Soy-oil	0.00	0.63	1.28	1.93
MCP	1.04	1.01	0.98	0.95
Limestone	0.75	0.72	0.69	0.66
L-Lysine·HCl	0.17	0.18	0.19	0.19
DL-methionine	0.06	0.06	0.06	0.06
Vit. Mix[2)]	0.12	0.12	0.12	0.12
Min. Mix[3)]	0.12	0.12	0.12	0.12
Salt	0.20	0.20	0.20	0.20
Choline-Cl(25%)	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00
Chemical Composition[4)]				
ME (kcal/kg)	3,277.20	3,277.18	3,277.23	3,277.22
CP (%)	23.00	23.00	23.00	23.00
Lysine (%)	1.05	1.05	1.05	1.05
Methionine (%)	0.34	0.34	0.34	0.34
Ca (%)	0.70	0.70	0.70	0.70
Total P (%)	0.60	0.60	0.60	0.60

1) Abbreviated B0, 0% barley was supplemented; B10, 10%; B20, 20%; B30, 30%.

2) Provided the following per kilogram of diet: vitamin A, 8,000 IU; vitamin D_3,1,600IU; vitamin E, 32IU; d-biotin, 64g; riboflavin, 3.2mg; calcium pantothenic acid, 8mg; niacin, 16mg; vitamin B_{12}, 12g; vitaminK, 2.4mg.

3) Provided the following per kilogram of diet : Se, 0.1mg; I, 0.3mg; Mn, 24.8mg; $CuSO_4$, 54.1mg; Fe, 127.3mg; Zn, 84.7mg; Co, 0.3mg.

4) Calculated values

Table 4. Effect of varying levels of barley supplementation on growth performance in weaning pigs[1)]

Levels	B0[2)]	B10[2)]	B20[2)]	B30[2)]	SEM[3)]	Lin.	Quad.
Body weight, kg							
Initial	7.04	7.05	7.04	7.07	-	-	-
2 wk	10.46	10.02	9.49	9.58	0.320	0.01	0.22
4 wk	15.84	14.88	14.73	15.20	0.457	0.38	0.18
6 wk	23.96	23.08	22.91	24.18	0.064	0.87	0.13
Average daily gain, g							
0-2 wk	244	212	176	176	8.9	0.01	0.30
2-4 wk	384	348	374	402	14.3	0.54	0.27
4-6 wk	580	586	584	642	20.4	0.25	0.46
0-6 wk	403	382	378	407	10.4	0.92	0.15
Average daily feed intake, g							
0-2 wk	308	299	259	284	8.2	0.11	0.26
2-4 wk	728	688	704	682	16.1	0.35	0.76
4-6 wk	1186	1108	1101	1185	36.2	0.96	0.06
0-6 wk	741	699	688	717	17.9	0.41	0.12
Gain/feed ratio							
0-2 wk	0.794	0.710	0.682	0.622	0.0171	0.01	0.72
2-4 wk	0.527	0.505	0.531	0.589	0.0145	0.10	0.24
4-6 wk	0.490	0.528	0.531	0.542	0.0011	0.17	0.63
0-6 wk	0.544	0.546	0.550	0.567	0.0061	0.31	0.49

[1)] A total of 112 crossbred pigs were fed from average initial body weight 7.04 ± 1.39 kg

[2)] Abbreviated B0, 0% barley was supplemented in each phase; B10, 10%; B20, 20%; B30, 30%.

[3)] Standard error of means.

[4)] Values are means for four pens of four pigs per pen.

Table 5. Effect of varying levels of barley supplementation on nutrient digestibility in weaning pigs[1)]

Levels	B0	B10	B20	B30	SEM[2)]	Linear	Quad
Nutrient digestibility, %							
Dry matter	94.02	93.77	93.92	93.87	0.409	0.88	0.84
Crude protein	92.61	92.10	92.33	92.28	0.561	0.80	0.73
Crude ash	74.98	74.22	75.35	76.30	1.898	0.61	0.70
Crude fat	76.66	84.22	87.77	88.96	2.949	0.01	0.11
N-retention, g/day							
N-intake	15.31	14.72	14.16	13.91	-	-	-
N-feces	1.13	1.16	1.09	1.07	0.042	0.59	0.83
N-urine	5.01	5.38	5.12	4.88	0.103	0.46	0.13
N-retention	9.17	8.18	7.95	7.95	0.124	0.17	0.10
N-digest(%)	59.90	55.56	56.16	57.19	1.637	0.30	0.11

[1)] A total of 24 crossbred pigs were fed from average initial body weight 11.74 ± 0.72 kg / 42±5 days of age.
[2)] Standard error of means.

Table 6. Effect of varying levels of barley supplementation on BUN and BGL in weaning pigs[1].

Levels	B0	B10	B20	B30	SEM[2]	Linear	Quad
BUN, mg/dL							
Initial	9.20	9.20	9.20	9.20	-	-	-
2 week	12.45	14.70	14.18	14.15	0.458	0.32	0.27
4 week	14.58	14.82	14.97	13.48	0.619	0.58	0.50
6 week	13.78	10.43	11.67	10.10	0.459	0.01	0.25
BGL, mg/dL							
Initial	93.29	93.29	93.29	93.29	-	-	-
2 week	98.83	94.83	98.67	96.17	1.382	0.72	0.76
4 week	100.33	97.17	96.00	102.50	1.911	0.73	0.18
6 week	104.33	103.33	97.17	104.17	2.612	0.80	0.51

[1] A total of 112 crossbred pigs were fed from average initial body weight 7.04 ± 1.39 kg

[2] Standard error of means.

Table 7. Effect of varying levels of barley supplementation on diarrhea incidence in weaning pigs.

Levels	B0	B10	B20	B30	SEM[2]	Linear	Quad
Diarrhea incidence [1]							
Phase I [3]	1.9	1.8	1.5	1.2	0.09	0.01	0.39
Phase II	0.9	0.7	0.7	0.4	0.07	0.01	0.77
Phase III	0.8	0.6	0.5	0.2	0.05	0.01	0.67

[1] Diarrhea incidence: 0(no occurrence) to 4(all pigs diarrhea); Data were measured by average total diarrhea incidence during each phases.

[2] Standard error of means.

[3] 2 weeks each phase

Table 8. Effect of varying levels of barley supplementation on economic analysis in weaning pigs[1)]

	B0	B10	B20	B30	SEM[2)]	Lin.	Quad.
Phase I (0 to 2 weeks)							
Cost of feed/kg ($)	0.99	0.86	0.74	0.61	-	-	-
Weight gain per head(kg)	3.42	2.97	2.47	2.47	0.124	0.01	0.30
Feed intake per head(kg)	4.31	4.19	3.62	3.97	1.153	0.09	0.25
Feed cost / 1kg ($)	1.26	1.23	1.09	1.00	0.029	0.01	0.59
Phase II (2 to 4 weeks)							
Cost of feed/kg ($)	0.68	0.65	0.60	0.56	-	-	-
Weight gain per head(kg)	5.38	4.87	5.24	5.62	0.201	0.53	0.27
Feed intake per head(kg)	10.19	9.64	9.85	9.54	2.255	0.35	0.76
Feed cost / 1kg ($)	1.31	1.28	1.13	0.95	0.042	0.01	0.17
Phase III (4~6 weeks)							
Cost of feed/kg ($)	0.53	0.53	0.54	0.54	-	-	-
Weight gain per head(kg)	8.13	8.20	8.18	8.98	0.286	0.25	0.46
Feed intake per head(kg)	15.54	14.77	14.50	15.60	5.062	0.95	0.06
Feed cost / 1kg ($)	0.98	0.94	0.94	0.93	0.026	0.29	0.56
Total							
Feed cost / 1kg ($)	1.18	1.15	1.05	0.96	0.022	0.01	0.32

1) A total of 112 crossbred pigs were fed from average initial body weight 7.04 ± 1.39 kg

2) Standard error of means.

IV. Literature Cited

Alonso, R., Grant, G., Dewey, P., Marzo, F., 2000. Nutritional assessment in vitro and in vivo of raw and extruded peas (Pisum sativum L.). J. Agric. Food Chem. 48, 2286–290.

Aman, P., and H. Graham. 1987. Analysis of total and insoluble mixed-linked (1 ® 3), (1 ® 4)-b-D-glucans in barley and oats. J. Agric. Food Chem. 35:704

AOAC. 1995. Official methods of analysis (15th ed). Association of official analytical chemists. Washington, D. C., USA.

Adegoke, O. A., M. I. McBurney, S. E. Samuels, and V. E. Baracos. 1999. Luminal amino acids acutely decrease intestinal mucosal protein synthesis and protease mRNA in piglets. J. Nutr. 129:1871-1878.

Anglemier, A. F. and J. E. Oldfield. 1957. Feeding of various levels of pilchard (California sardine) oil to swine. J. Animal Sci. 16:922.

Armstrong, D. G. (1984). Antibiotics as feed additives for ruminant livestock. In Antimicrobials in Agriculture, pp. 331-347 [M. Woodbine, editor]. London: Butterworths.

Armstrong, D. G. (1986). Gut active growth promoters. In Control and

Manipulation qf Animal Growth, Proceedings of the University of Nottingham 43rd Easter School, 1985, pp. 21-37 [P. J. Buttery, D. Lindsay and N. B. Haynes, editors]. London : Butterworths.

Atwell,W.A., Hood, L.F., Lineback, D.R., Varriano-Marston, E., Zobel, H.F., 1988. The terminology and methodology associated with basic starch phenomena. Cereal Foods World 33, 306–311.

Atteh JO, Leeson S, 1983. Influence of increasing dietary calcium and magnesium content of the drinking water on performance and bone and plasma minerals of broiler chickens. Poultry Sci 62:869.

Allee, G. L., D. H. Baker, and G. A. Leveille. 1971. Fat utilization and lipogenesis in the young pig, J. Nutr., 101:1415.

Baxter, M. R. 1991. The design of the feeding environment for pigs. In Manipulating Pig Production. (Ed. E. S. Batterham). Aust. Pig Sci. Assoc. Victoria, pp. 150-158.

Bedford, M.R., Patience, J.F., Classen, H.L. and Inborr, J. (1992) The effect of dietary enzyme supplementation of rye and barley-based diets on digestion and subsequent performance in weanling pig. Canadian Journal of Animal Science 72, 97–-105.

Braude, R. (1967). Copper as a growth stimulant in pigs. Animal Production 3, 69-75.

Richard D. Coffey, Gary R. Parker, Kevin M. Laurent, 2000. Feeding and Managing The Weanling Pig. Department of Animal Sciences. ASC-149

Bach Knudsen, K. E., and I. Hansen. 1991. Gastrointestinal implications in pigs of wheat and oat fractions 1. Digestibility and bulking properties of polysaccharides and other major constituents. Br. J. Nutr. 65:217–.232.

Bach Knudsen, K. E., B. B. Jensen, and I. Hansen. 1993a. Digestion of polysaccharides and other major components in the small and large intestine of pigs fed on diets consisting of oat fractions rich in β -d-glucan. Br. J. Nutr. 70:537–56

Bhatty, R. S., G. I. Christison, F. W. Sosulski, B. L. Harvey, G. R. Hughes, and J. D. Berdahl. 1974. Relationships of various physical and chemical characters to digestible energy in wheat and barley cultivars. Can. J. Anim. Sci. 54:419-427.

Bruininx, E. M. A. M., G. P. Binnendijk, C. M. C. van der Peet-Schwering, J. W. Schrama, L. A. den Hartog, H. Everts and A. C, Beynen. 2002a. Effect of creep feed consumption on individual feed intake characteristics and performance of group-housed weanling pigs. J. Anim. Sci. 80:1413-1418.

Bjork, A. K. K. 1989. Is social stress in pigs a detrimental factor to health and growth that can be avoided by amperzoide treatment. Appl. Anim. Behav. Sci. 23:39-47.

Blackshaw, J. W., D. A. V. Bodero and A. W. Blackshaw. 1987.
The effect of group composition on behaviour and performance of weaned pigs. Appl. Anim. Behav. Sci. 19:73-80.
Bowland, J. P. 1974. Comparison of several wheat cultivars and a barley culrivar in diets for young pigs. Can. J. Anim. Sci. 54:629.

Campbell, G. L., H. L. Classen, P. A. Thacker, B. G. Rossnagel, J. W. Grootwassink, and R. E. Salmon. 1986. Effect of enzyme supplementation
on the nutritive value of feedstuffs. Proc. 7th Western Nutrition Conference, Saskatoon, SK, Canada.

Canh, T.T., A.L. Sutton, A.J.A. Aarnink, M.W.A. Verstegen, J.W. Schrama, and G.C.M. Bakker. 1998. Dietary carbohydrates alter the fecal composition and pH and the ammonia emission from slurry of growing pigs. J. Anim. Sci. 76: 1887-1895.

Castell, A. G., and K. E. Bowren. 1980. Comparison of barley cultivars in diets for growing and finishing pigs. Can. J. Anim. Sci. 60:159-167.

Castillo, M., S. M. Martin-Orue, J. A. Taylor-Pickard, J. F. Perez, and J. Gasa. 2008. Use of mannanoligosaccharides and zinc chelate as growth promoters and diarrhea preventative in weaning pigs: Effects on microbiota and gut function. J. Anim Sci. 86:94-101.

Corring, T. 1980. The adaptation of digestive enzymes to the diet: its physiological significance. Rep. Nutr. Devel. 20:1217-1235. Corring, T., A. Aumaitre and G. Durand. 1978. Development of digestive enzymes in the piglet from birth to 8 weeks. I. Pancreas and pancreatic enzymes. Nutr. Meta. 22:231-241.

Cranwell, P. D. 1985. The development of acid and pepsin (EC 3.4.23.1) secretory capacity in the pig: effects of age and weaning. 1. Studies in anaesthetized pig. Br. J. Nutr. 54:305-320.

Cranwell, P. D. and S. J. Stuart. 1984. The Effect of diet and liveweight on gastric secretion in the young pig. Proc. Aust. Soc. Anim. Prod. 15:669.

Chiba, L. I. 1995. Effects of nutritional history on the subsequent and overall growth performance and carcass traits of pigs. Livest. Prod. Sci. 41:151–-161.

Cheeke, P. R., and D. E. Stangel. 1972. Lactose-amino acid interactions in rations. J. Anim. Sci. 34:757–761.

Cheeke, P. R., and D. E. Stangel. 1973. Lactose and whey utilization by rats and swine. J. Anim. Sci. 37:1142–-1146.

Cunha, T. J. 1977. Swine Feeding and Nutrition. Academic Press, New York.

Choct, M., and G. Annison. 1992. Anti-nutritive effect of wheat pentosans in broiler chickens: roles of viscosity and gut microflora. Br. Poult. Sci. 33:821-834.

Cera, K. R., D. C. Mahan, and G. A. Reinhart. 1988. Effects of dietary dried whey and corn oil on weanling pig performance, fat digestibility and nitrogen utilization. J. Anim. Sci. 66: 1438-1445.

Cera, K. R., Mahan, D. C. and Reinhart, G. A. 1990. Evaluation of various extracted vegetable oils, roasted soybeans, medium-chain triglyceride and an animal vegetable fat blend for postweaning swine. J. Anim. Sci. 68:2756.

Crampton, E. W. and Ness, O. M. 1954. Ameal mixture suitable as the entire ration to be self-fed dry to pigs weaned at ten days of age. J. Anim. Sci. 13:357.

Cherbut, C., Albina, E., Champ, M., Coublier, J.L. and Lecannu, G. (1990) Action of guar gums on the viscosity of digestive contents and on the gastrointestinal motor function in pigs. Digestion 46, 205–213.

Fadel, J.G., Newman, C.W., Newman, R.K., Graham, H., 1988. Effects of extrusion cooking of barley on ileal and faecal digestibility of dietary components in pigs. Can. J. Anim. Sci. 68, 891–97.

Davis, M. E., S. C. Sears, J. K. Apple, C. V. Maxwell and Z. B. Johnson. 2006. Effect of weaning age and commingling after the nursery phase of pigs in a wean-to-finish facility on growth, humoral and behavioral indicators of well-being. J. Anim. Sci. 84:743-756.

Davidson, M. H. and McDonald, A. 1998. Fiber: Forms and functions. Nutr. Res. 18:617.

de Passille, A. M. B., G. Pelletier, J. Menard and J. Morisset. 1989. Relationships of weight gain and behavior to digestive organ weight and enzyme activities in piglets. J. Anim. Sci. 67:2921-2929.

De Mitchell, I., and R. Kenworthy. 1976. Investigations on a metabolite from *Lactobacillus bulgaricus* which neutralizes the effect of enterotoxin from *Escherichia coli* pathogenic for pigs. J. Appl. Bacteriol. 41:163–-174.

Dinusson, W. E., P. A. Nystuen, D. W. Bolin and C. N. Haugse. 1960. Pelleted feeds: Effect of hull and fiber on gain and e~ficiency of swine. N. D.
Agr. Exp. Sta. Res. Rpt. 2.

Dritz, S. S., K. Q. Owen, J. L. Nelssen, R. D. Goodband, and M. D. Tokach. 1996. Influence of weaning age and nursery diet complexity on growth performance and carcass characteristics and composition of high-health status pigs from weaning to 109 kilograms. J. Anim. Sci. 74:2975–-2984.

Ekstrom, K. E., N. J. Benevenga and R. H. Grummer. 1975b. The effects of diets containing dried whey on the lactase activity of the small intestinal
mucosa and the contents of the small intestine and cecum of the pig. J. Nutr. 105:851-860.

Ekstrom, K. E., R. H. Grummer, and N. J. Benevenga. 1976. Effects of diets containing 40% dried whey on the performance and lactase activities in the small intestine and cecum of Hampshire and Chester White pigs. J. Anim. Sci. 42:106–-113.

Ewaschuk, J. B., G. K. Murdoch, I. R. Johnson, K. L. Madsen, and C. J. Field. 2011. Glutamine supplementation improves intestinal barrier function in a weaned piglet model of *E. coli* infection. Br. J. Nutr. 106:870-877.

Friend, T. H., D. A. Knabe and T. D. Tanksley. 1983. Behaviour and performance of pigs regrouped by three different methods at weaning. J. Anim. Sci. 57:1406-1411.

Field, C. J. 2005. The immunological components of human milk and their effect on immune development in infants. J. Nutr. 135:1-4.

Frobish, L. T., Hays, V. W., Speer, V. C. and Ewan, R. C. 1970. Effect of fat source and level on utilization of fat by young pigs. J. Anim. Sci. 30:197.

Gill, D. R., J. E. Oldfield and D. C. England. 1966. Comparative values of hulless barley, regular barley, corn and wheat for growing pigs. J. Animal Sci. 25:34.

Gonyou, K. A., K. A. Rohde and A. C. Echeverri. 1986. Effects of sorting pigs by weight on behavior and productivity after mixing. J. Anim. Sci. 63 (Suppl. 1):163-164.

Graham, P. L., D. C. Mahan, and R. G. Shields, Jr. 1981. Effect of starter diet and length of feeding regime on performance and digestive activity of 2-week-old weaned pigs. J. Anim. Sci. 53:299–-307.

Goodband, R. D. and R. H. Hines. 19871 The effect of barley particle size on slarter and finishing pig performance. J. Anim. Sci. 65(Suppl. I):317 (Abstr.).

Gibson, G.R., Beatty, E.R., Wang, X. and Cummins, J.H. (1995) Selective stimulation of Bifidobacteria in the human colon by oligofructose and inulin. Gastroenterology 108, 975–982.

Haugse, C. N., W. E. Dinusson, D. O. Erickson and D. W. Bolin. 1966. Effect of physical form of barley in rations for fattening pigs. N. D. Agr.
Exp. Sta. Res. Rpt. 17.

Hampson, D. J. 1986. Attempts to modify changes in the piglet small intestine after weaning. Res. Vet. Sci. 40:313-317.

Henry, R. J. 1988. The carbohydrates of barley grains; A review. J. Inst. Brew. 94:71-78.

Heitman, H, Jr. 1956. Use of stabilized tallow in swine rations. J. Animal Sci. 15 : 1046.

Hongtrakul, K., R. D. Goodband, K. C. Behnke, J. L. Nelssen, M. D. Tokach, J. R. Bergstro¨m, W. B. Nessmith, Jr., and I. H. Kim. 1998. The effects of extrusion processing of carbohydrate sources on weanling pig performance. J. Anim. Sci. 76:3034–-3042.

Huff, G. R., W. E. Huff, M. B. Farnell, N. C. Rath, S. F. Solis de Los, and A. M. Donoghue. 2010. Bacterial clearance, heterophil function, and hematological parameters of transport-stressed turkey poults supplemented with dietary yeast extract. Poult. Sci. 89:447-456.

Johnson, I. R., R. O. Ball, V. E. Baracos, and C. J. Field. 2006. Glutamine supplementation influences immune development in the newly weaned piglet. Dev. Comp. Immunol. 30:1191-1202.

Johnson, I. T., and J. M. Gee. 1981. Effect of gel-forming gums on the intestinal unstirred water layer and sugar transport in vitro. Gut 22:398.

Joseph, W. E. 1924. Feeding pigs in a dry lot. Mont. Agr. Exp. Sta. Bul. 169.

Jonsson, E., and S. Hemmingsson. 1991. Establishment in the piglet gut of lactobacilli capable of degrading mixed-linked betaglucans. J. Appl. Bacteriol. 70:512–.516.

Juul-Madsen, H. R., K. H. Jensen, J. Nielsen, and B. M. Damgaard. 2009. Ontogeny and characterization of blood leukocyte subsets and serum proteins in piglets before and after weaning. Vet. Immunol. Immunopathol. 133:95-108.

Judd, P. A., and A. S. Truswell. 1981. The effect of rolled oats on blood lipids and fecal steroid excretion in man. Am. J. Clin. Nutr. 34:2061-2067.

Kenworthy, R., and W. E. Crabb. 1963. The intestinal flora of young pigs with reference to early weaning *Escherichia coli* and scours. J. Comp. Pathol. 73:215–-228.

Krause, D. O., R. A. Easter, B. A. White, and R. I. Mackie. 1995. Effect of weaning diet on the ecology of adherent lactobacilli in the gastrointestinal tract of the pig. J. Anim. Sci. 73:2347−-2354.

Kedia, G., J. A. Vazquez, and S. S. Pandiella. 2008. Enzymatic digestion and in vitro fermentation of oat fractions by human Lactobacillus strains. Enzyme Microb. Technol. 43:355−.361.

Larsen, L. M. and J. E. Oldfield. 1960. Improvement of barley rations for swine. II. Effects of pelleting and supplementation with barley malt. J. Animal Sci. 19:601.

Lawrence, N. J. and Maxwell, C. V. 1983. Effect of dietary fat sources and level on the performance of neonatal and early weaned pigs. J. Anim. Sci. 57:936.

Leonard, S. G., T. Sweeney, B. Bahar, B. P. Lynch, and J. V. O'Doherty. 2010. Effect of maternal fish oil and seaweed extract supplementation on colostrum and milk composition, humoral immune response, and performance of suckled piglets. J. Anim. Sci. 88:2988-2997.

Leibbrandt, V.D. and N.J. Benevenga. 1991. Utilization of Liquid Whey in Feeding Swine. Pgs 559-571. In: Swine Nutrition. Ed. by E.R. Miller, D.E. Ullrey and A.J. Lewis. Butterworth- Heinemann, Boston.

Lowry, V. K., M. B. Farnell, P. J. Ferro, C. L. Swaggerty, A. Bahl, and M. H. Kogut. 2005. Purified beta-glucan as an abiotic feed additive up-regulates the innate immune response in immature chickens against Salmonella enterica serovar Enteritidis. Int. J. Food Microbiol. 98:309-318.

Lindemann, M. D., S. G. Cornelius, S. M. El Kandelgy, R. L. Moser, and J. E. Pettigrew. 1986. Effect of age, weaning and diet on digestive enzyme levels in the piglet. J. Anim. Sci. 62:1298–1307.

Lepine, A. J., D. C. Mahan, and Y. K. Chung. 1991. Growth performance of weanling pigs fed corn-soybean meal diets with or without dried whey at various L-lysine.HC1 levels. J. Anim. Sci. 69:2026.

Lynch, M. B., T. Sweeney, J. J. Callan, and J. V. O'Doherty. 2007. Effects of increasing the intake of dietary β-glucans by exchanging wheat for barley on nutrient digestibility, nitrogen excretion, intestinal microflora, volatile fatty acid concentration and manure ammonia emissions in finishing pigs. Animal 1:812–819.

Mahan, D. C. 1992. Efficacy of dried whey and its lactalbumin and lactose components at two dietary lysine levels on postweaning pig performance and nitrogen balance. J. Anim. Sci. 70:2182-2187.

Mahan, C. C. 1993. Evaluating two sources of dried whey and the effects of replacing the corn and dried whey components with corn gluten meal and lactose in the diets of weanling swine. J. Anim. Sci. 71:2860--2866.

McConnell, J. C., J. C. Eargle and R. C. Waldorf. 1987. Effects of weaning weight, commingling, group size and room temperature on pig performance. J. Anim. Sci. 65:1201-1206.

McGone, J. J. and S. E. Curtis. 1985. Behaviour and performance of weanling pigs in pens equipped with hide area. J. Anim. Sci. 60:20-24.

McNab, J. M., and R. R. Smithard. 1992. Barley beta-glucan: an anti-nutritional factor in poultry feeding. Nutr. Res. Rev. 5:45-60.

Metchnikoff, E. (1908). Prolongation of Life. New York: G. P. Putnam and Sons.

Metzler, B. U., and R. Mosenthin. 2008. A review of interactions between dietary fiber and the gastrointestinal microbiota and their consequences on intestinal phosphorus metabolism in pigs. Asian-australas. J. Anim. Sci. 21:603–615.

Muralidhara, K. S., G. G. Sheggeby, P. R. Elliker, D. C. England, and W. E. Sandine. 1977. Effect of feeding *lactobacilli* on the coliform and *lactobacillus flora* of intestinal tissue and feces from piglets. J. Food Prot. 40:288--295.

McGone, J. J., W. F. Stanbury and L. F. Tribble. 1987. Effects of heat and social stressors and within-pen weight variation on young pig performance and agonistic behaviour. J. Anim. Sci. 65:456-462.

McIntosh, G. H., J. Whyte, R. McArthur, and P. J. Nestel. 1991. Barley and wheat foods: influence on plasma cholesterol concentrations in hypercholesterolemic men. Am. J. Clin. Nutr. 53:1205-1209.

Modler, H. W., R. C. McKellar, and M. Yaguchi. 1990. Bifidobacteria and bifidogenic factors. Can. Inst. Food Sci. Technol. J. 23:29.

Mitchell, I. De G. and R. Kenworthy. 1976. Investigations on a metabolite from Lactobacillus bulgaricus which neutralizes the effect of enterotoxin from Eschericbia coil pathogenic for pigs.

Oldfield, J. E. and A. F. Anglemier. 1957. Feeding of crude and modified menhaden oils in rations for swine. J. Animal Sci. 16:917.

Nabuurs, M. J. 1998. Weaning piglets as a model for studying pathophysiology of diarrhea. Vet. Q. 20(Suppl. 3):S42-S45.

Nessmith, W. B., Jr., J. L. Nelssen, M. D. Tokach, R. D. Goodband, and J. R. Bergstro¨m. 1997. Evaluation of the interrelationships among lactose and protein sources in diets for segregated earlyweaned pigs. J. Anim. Sci. 75:3214–-3221.

Newman, C. W., and R. K. Newman. 1990. Nutritional aspects of barley as a livestock feed. Proc. West. Sect. Am. Soc. Anim. Sci. 41:99-107.

NRC. 1998. Nutrient Requirements of Swine. 10th ed. Natl. Acad. Press, Washington, DC.

O'Connell, J. M., J. J. Callan, C. Byrne, T. Sweeney, and J. V. O'Doherty. 2005. The effect of cereal type and exogenous enzyme supplementation in pig diets on nutrient digestibility, intestinal microflora, volatile fatty acid concentration and manure ammonia emissions. Anim. Sci. 81:357–364.

Oliver, W. T., S. A. Mathews, O. Phillips, E. E. Jones, J. Odle, and R. J. Harrell. 2002. Efficacy of partially hydrolyzed corn syrup solids as a replacement for lactose in manufactured liquid diets for neonatal pigs. J. Anim. Sci. 80:143–-153.

Pierzynowski, S. G., B. R. Westrom, J. Svendson and B. W. Karlsson. 1990. Development of exocrine pancreas function in chronically cannulated pigs during 1-13 weeks of postnatal life. J. Pedia. Gastroent. Nutr. 10:206-212.

Kornegay, E. T. 1978. Feeding value and digestibility of soybean hulls for swine. J. Anita. Sci. 47 : 1272.

Pieper, R., J. Bindelle, B. Rossnagel, K. A. Van, and P. Leterme. 2009. Effect of carbohydrate composition in barley and oat cultivars on microbial ecophysiology and proliferation of Salmonella enterica in an in vitro model of the porcine gastrointestinal tract. Appl. Environ. Microbiol. 75:7006-7016.

Pieper, R., R. Jha, B. Rossnagel, A. G. Van Kessel, W. B. Souffrant, and P. Leterme. 2008. Effect of barley and oat cultivars with different carbohydrate compositions on the intestinal bacterial communities in weaned piglets. FEMS Microbiol. Ecol. 66:556-566.

Pluske, J. R. and I. H. Williams. 1996. The influence of feeder type and the method of group allocation at weaning on voluntary food intake and growth in piglets. Anim. Sci. 62:115-120.

Qureshi MS (1998). Relationship of pre and post partum nutritional status with reproductive performance in Nili-Ravi buffaloes under the conventional farming system in NWFP, Pakistan. Ph.D. Thesis, Univ. Agric. Faisalabad, Pakistan.

Rundgren, M. and I. Lorfquist. 1989. Effects on performance and behaviour of mixing 20-kg pigs fed individually. Anim. Prod. 49:311-315.

Richert, B. T. ; Hancock, J. D. ; Hines, R. H. ; Gugle, T. L., 1992. Extruded corn, sorghum and soybean meal for nursery pigs. Kansas State University Swine Day 1992 Patience, J. F., and C.F.M. de Lange. 1996. Swine nutrition in the 21st century. Anim. Feed Sci. Technol. 58:19-27.

Seerley, R. W., 1991. Major feedstuffs used in swine diets. In Swine Nutrition, Miller, E. R., D. E. Ullrey, and A. J. Lewis, Eds., Butterworth-Heinemann, Boston, 451

SAS Institute. 1991. SAS Users Guide. SAS Institute Inc., Cary, NC.

Shi, X. S. and Noblet, J. 1994. Effect of body weight and feed composition on the contribution of the hindgut to digestion of energy and nutrients in pigs. Livest. Prod. Sci. 38:225.

Schulman, A. 1973. Effect of weaning on plq changes of the contents of the piglet's stomach and duodenum. Nord. Vet. Med. 25:220.

Skoch, E.R., Binder, S.F., Deyoe, C.W., Allee, G.L., Behnke, K.C., 1983. Effects of steam pelleting conditions and extrusion cooking on a swine diet containing wheat middlings. J. Anim. Sci. 57, 929.935

Stephas, E. L., M. R. McMurty, R. M. DeGregorio and B. L. Miller. 1996. Performance of piglets fed phase II starters differing in lactose level. J. Anim. Sci. 74(Suppl. 1):52(Abstr.).

Ullrich, S. E., D. C. Honeyfield, and J. A. Froseth. 1984. Variation in the composition of Western grown barley. Proc. West. Sect. Am. Soc. Anim. Sci. 35:163-166.

Vergoni, A. V., R. Poggiolli, D. Marrama and A. Bertolini. 1990. Inhibition of feeding by ACTH-(1-24): behavioural and pharmacological aspects. Euro. J. Pharmac. 179:347-355.

Tannock, G. W. (1983). Effect of dietary and environmental stress on the gastrointestinal microbiota. In Human Intesrinal Microflora in Health and Disease, pp. 517-539 [D. J. Hertges, editor]. London: Academic Press.

Tokach, M. D., J. L. Nelssen, and G. L. Allee. 1989. Effect of protein and (or) carbohydrate fractions of dried whey on performance and nutrient digestibility of early weaned pigs. J. Anim. Sci. 67:1307–-1312.

Tokach, M. D., J. E. Pettigrew, L. J. Johnston, M. Overland, J. W. Rust, and S. G. Cornelius. 1995. Effect of adding fat and(or) milk products to the weanling pig diet on performance in the nursery and subsequent grow-finish stages. J. Anim. Sci. 73: 3358-3368.

Touchette, K. J., S. D. Crow, G. L. Allee, and M. D. Newcomb. 1995. Lactose response is dependent on plasma in the diet of weaned pigs. J. Anim. Sci. 73(Suppl. 1):171 (Abstr.).

Thomas, O. O. and A. E. Flower. 1956. The value of pelleting rations for swine. Mont. Agr. Exp. Sta. Cir. 214.

Troelsen, J. E. and J. M. Bell. 1962. Ingredient and Processing Inter-relationships in Swine Feeds. IV. Effects of various levels and kinds of fibrous diluents in finisher rations, fed as meal or pellets, on performance and carcass quality of swine. Can. J. Animal Sci. 42:63.

Vukic Vranjes, M., Wenk, C., 1995. The influence of extruded vs. untreated barley in the feed, with and without dietary enzyme supplement on broiler performance. Anim. Feed Sci. Technol. 54, 21–2.
Visek, W. J. (1978). The mode of growth promotion by antibiotics. Journal of Animal Science 46, 1447-1469.

Wiseman, J., D.J.A. Cole, and D. Lewis. 1982. Energy values in pig nutrition. III. The digestible and metabolizable energy content of barley, wheat, maize, oats, and rye. J. Agric. Sci. 98:89-102.

Whang, K. Y., F. K. M. McKeith, S. W. Kim, and R. A. Easter. 2000. Effect of starter feeding program on growth performance and gains of body components from weaning to marker weight in swine. J. Anim. Sci. 78:2885–-2895.

Wolter, B. F., M. Ellis, B. P. Corrigan, J. M. DeDecker, S. E. Curtis,

E. N. Parr, and D. M. Webel. 2003. Impact of early postweaning growth rate as affected by diet complexity and space allocation on subsequent growth performance of pigs in a wean-to-finish production system. J. Anim. Sci. 81:353–-359.

Wu, J. F. and R. C. Ewan. 1979. Utilization of energy of wheat and barley by young swine. J. Anim. Sci. 49:1470.

Yoo, S. S., C. J. Field, and M. I. McBurney. 1997. Glutamine supplementation maintains intramuscular glutamine concentrations and normalizes lymphocyte function in infected early weaned pigs. J. Nutr. 127:2253-2259.

Ⅴ. Summary in Korean

실험: 이유자돈 사료내 유제품을 대체하기위한 보리의 첨가효과가 성장성적, 영양소 소화율, 혈액 성상 및 설사에 미치는 영향

본 연구는 이유자돈 사료내 유제품을 대체하기 위한 보리의 첨가효과가 이유자돈의 성장성적 (Growth performance), 영양소 소화율 (Nutrient digestibility), 혈중요소태질소 (Blood urea nitrogen) 및 설사빈도 (Diarrhea incidence)에 미치는 영향을 규명하기 위해 수행하였다. 평균 체중 7.04 ± 1.39kg인 삼원 교잡종 ([Yorkshire x Landrace] x Duroc) 이유자돈 112두를 공시하였으며, 6주 동안 사양실험을 수행하였다. 사양실험은 총 4처리 7반복으로 돈방 당 4두씩 성별과 체중에 따라 난괴법 (RCBD; Randomized Completely Block Design)으로 배치하였다. 처리구는 성장단계별 유제품의 함량을 줄이고, 보리를 첨가한 수준에 따라 설정하였으며, 다음과 같다. Phase I - 1)B0 : 유제품 39% 첨가 + 보리 0% 첨가 (NRC (1998) 사양표준을 충족시키는 corn-soy bean meal based diet) 2)B10 : 유제품 26% + 보리10% 첨가 3)B20 : 유제품 13% + 보리 20% 첨가 4)B30 유제품 0% + 보리 30% 첨가 5, Phase II - 1)B0 : 유제품 15% 첨가 + 보리 0% 첨가 2)B10 : 유제품 10% + 보리10% 첨가 3)B20 : 유제품 5% + 보리 20% 첨가 4)B30 : 유제품 0% + 보리 30% 첨가, PhaseⅢ - 1)B0 : 유제품 0% 첨가 + 보리 0% 첨가 2)B10 : 유제품 0% + 보리10% 첨가 3)B20 : 유제품 0% + 보리 20% 첨가 4)B30 : 유제품 0% + 보

리 30% 첨가로 실험을 수행하였다. 성장성적은 phase I(0~2주)에서 체중, 일당증체량 및 사료효율에서 보리의 첨가량이 증가함에 따라 감소하는 Linear response가 발견되었다(P<0.01). 사료섭취량에서는 모든 처리구의 수준이 실험 전체 기간 동안 같은 수준으로 나타났다. 비록 phase I에서 그러나 Phase II(3~4주)에서 모든 처리구, 모든 항목에서 유의적인 차이가 발생하지 않았다. 모든 phase(0~6주)를 종합한 결과, 모든 항목에 있어서 유의적인 차이는 발견되지 않았다.

영양소 소화율에서 각각의 처리구를 비교하였을 때, 다른 항목에서는 유의적인 차이가 없었으나, 지방 소화율에서 각 처리구 간에 linear effect가 발견되었다(P<0.01). 혈액성상 분석에서는 phase III에서 보리의 첨가수준이 증가함에 따라 BUN의 수치가 낮아지는 linear response가 발견되었다(P<0.01). BGL에서는 실험 전체기간동안 어떠한 차이도 나타나지 않았다. 설사 빈도측정에서는 보리의 첨가수준이 증가함에 따라 설사빈도가 감소하는 linear effect가 각각의 phase에서 발견되었다(P<0.01). 경제성 분석에서는 보리의 첨가량이 이유자돈 1kg 증체당 소요되는 비용을 약 30%까지 낮출수 있는 것으로 나타났다. 결론적으로 phase I에서 보리의 첨가는 유제품함량이 높은 처리구들에 비해 성장수준이 떨어지는 것으로 나타났으나, 보리를 포함한 곡류사료에 대한 적응의 시작이 더 빨리 진행되는 것으로 사료되며, 이는 장내 건강성에 긍정적인 영향을 주어 설사를 줄여주는 보리의 장점과 더불어 phase II에서 상대적으로 높은 사료 효율을 나타내었고, 이로 인해 phase I의 성장 부진이 보상되는 결과가 나타났다. 보리의 첨가는 이유자돈의 설사를 줄여주며, 곡류사료의 적응성 증대로 이유자돈의 성장과 경제적 효과에 긍정적인 영향을 미치는 것으로 사료된다.

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