Recent Advances in the Use of Enzymes for Environment-Friendly Swine Diets

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환경친화성양돈사료를 위한 효소제 사용의 최근 경향

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국문요약

본 논문의 목적을 위한 외인성 효소 즉 phytase, β-glucanase, pentosanase는 전 세계적으로 양돈사료에 첨가제로서 광범위하게 사용하고 있다. 이러한 효소의 화학적 효과는 이해가 잘 되고 있다. 하지만 돼지에서 이러한 효소들의 효과에 대해서는 아직까지 논란의 여지가 있다. Phytase는 곡류내 존재하는 피틴태 인의 이용성을 증가시킬 수 있어 배설되는 분 중 인의 오염도를 낮출 수 있고 사료내 사용하는 무기태 인의 양을 감소시킬 수 있다. 또한, 보리와 귀리에 존재하는 β-glucanase와 호밀과 밀에 존재하는 용해성 pentosans과 같은 효소들은 양돈사료에서 찾을 수 있는 항영양소 인자들을 분해하는 효과가 있다. 그래서 비전분과당류들의 소화율을 증가시키는 결과를 초래한다. 앞으로 이 분야의 연구는 현재 효소들의 효율적인 사용, 효과적인 다른 생산품의 개발 그리고 열 안정성 효소들의 개발들을 포함하고 있다.

색인어 : 돼지, phytase, β-glucanase, pentosanase

Ⅰ. Introduction

In the past, the aim of feeding program and diet formulations were maximizing production performance without special concern for nutrient oversupply. However, with the increased public concerns on environment, animal production has to minimize excessive N and P output in animal excreta. Therefore, animal nutrition has recently focused on not only improving of animal productivity, but also developing low-pollution diets.

N and P are the most important contributors to pollution from animal manure. Excretion of N and P in swine and poultry manure can be substantially reduced by several nutritional strategies. One of effective ways to reduce pollutants from animal manure is to use exogenous enzyme and yucca extract supplementation.

Endogenous enzymes break down the carbohydrates, proteins and fats contained in the diets into a form that can be utilized by the pigs(Corring, 1982). Enzymes are also involved in activating and hastening the many chemical reactions which take place in the animal's body. Therefore, it is possible, under conditions where enzyme production may be limiting that pig performance could be improved by the addition of enzyme to the diets. However, the expense of the enzyme products limits its practical use.

Many publications have demonstrated performance benefits of enzymes when added to barley(Classen et al., 1985 ; Elwinger and Saterby, 1987 ; Marquardt et al., 1994), wheat(Classen et al., 1995 ; Bedford and Morgan, 1996) and more corn based diets (Wyatt et al., 1997, 1999 ; Steenfeldt et al., 1998).

This paper is a review of the effects of exogenous enzyme supplementation for development of low-pollution swine diets.

Ⅱ. Exogenous enzyme

(1) Phytase

1) Environmental concerns

Environmental concerns as a results of agricultural production can be divided into those related to the soil, to the surface and ground water and to the air. Farrell(1997) estimates the current world-wide feed requirement for pigs and poultry at 632 million tons ; which is based on both industrially feedmilled and home-mixed rations. This requirement is forecast to increase to 758 million tons in 2002. However, large percentage of the P in pig diets is not utilized, much of the dietary P is excreted in the manure. Large amounts of P in manure pose an environmental concern, especially in parts of the world where land and water resources are scarce and animals are density populated. Of the 1 million tons of P excreted annually by farm animals, approximately 200,000 and 120,000 tons of P come from swine and poultry, respectively.

2) Phytate phosphorus

P is an essential component of animal body, which plays an important role in the development and maturation of the skeletal system, as well as in numerous other metabolic pathways. However, the requirement has not been determined precisely because of the variable bioavailabilities of feedstuffs from plant origin. The bioavailability of P in various feedstuffs of plant origin varies from 10 to 60%. Digestibility and availability of the P differed considerably depending on the feedstuffs. A large proportion(over 55%) of the P found in cereals and oilseeds is bound in phytate(Jongbloed et al., 1991). The digestive tract of monogastric animals dose not contain sufficient amounts of phytase. Thus, P in the phytate is poorly available to monogastric animals(Peeler, 1972).

Phytate has the potential of binding Ca and trace minerals, resulting in a decreased absorption of these minerals(Oberleas 1973). Phytate reportedly has the highest binding affinity for Cu and Zn. Specially phytic acid forms complex with other minerals, also reducing their availability. But phytase has been shown to increase the availability and retention of Ca(Simons et al, 1990) and improve the absorption of Mg, Cu, Fe and Zn(Lei et al., 1993b).

Microbial phytase supplementation improves the availability P in feedstuffs of plant origin(Simons et al., 1990 ; Denbow et al., 1995) and reduce excretion of P in the manure of pigs(Harper et al., 1997) and poultry(Um et al., 1998). Thus, a reduction of P excretion in this way will have favorable impact on the environment. Recently, a microbial phytase from Asperigillus has been used to improve the availability of phytate P in corn-soybean meal diets(Simons et al., 1990 ; Cromwell et al., 1993 ; Lei et al., 1993a). Supplemental phytase in swine diets has resulted in improved pig performance and bone mineralization by increasing the digestibility and retention of P and Ca and has resulted in decreased excretion of both P and Ca(Simons et al., 1990 ; Jongbloed et al., 1993 ; Lei et al., 1993c).

3) Effects of phytase for swine

Dietary supplementation with phytase improves growth performance and phytate P availability in growing-finishing pigs. Young et al.(1993) found that performance and bone ash of weanling pigs were maintained compared to the control diet when dietary P decreased by 0.17% and 500 PTU was fed. Addition of 1,000 PTU did not further improve growth or percent bone ash, however, did restore bone ash weight which is a more sensitive indicator of an improvement in bone strength than bone ash percent(Cromwell et al., 1995). Response of growth performance of weanling pigs to increasing exogenous phytase levels diminishes at phytase levels greater than 700 PTU(Yi et al., 1996). The report of Young et al.(1993) supports this finding. The coefficient of digestibility of P in weanling pigs fed a corn-soybean meal diet has been improved from 0.27 to 0.68 when a low-P diet was fed with 1,200 PTU of exogenous phytase(Lei et al., 1993c).

Other studies with low-P diets observed an increase in the coefficient of digestibility from 0.46 to 0.69 with 750 PTU(Lei et al., 1993a) or from 0.32 to 0.55 with 800 PTU(Mroz et al., 1994). When higher levels of P were fed the coefficient of P diegestibility increased from 0.60 to 0.65 or 0.63 to 0.74 when 1,500 or 1,000 PTU, respectively, were fed(Young et al., 1993 ; Adeola et al., 1995). Digestibility is typically higher in pigs fed diets containing P at or above the NRC(1998) estimated requirement for 10-20kg pigs than when P is supplied at half the estimated requirement. Therefore, the response to exogenous phytase would be expected to be diminished when P is fed near the nutrient requirement. Beers and Jongbloed(1992) fed 1,450 PTU exogenuos phytase to pigs consuming a corn-barley-soybean meal-potato protein diet. The coefficient of P digestibility increased from 0.39 to 0.60 in 25kg pigs when exogenous phytase was added.

Yi et al.(1996) suggested that adding 1,050 U of phytase to the basal diet increased P apparent absorption by 23%, decreased fecal P excretion by 10%, increased average daily gain by 30%, increased average daily feed intake by 24% and increased gain/feed by 11%. Harper et al.(1997) reported that apparent digestibility of P was linearly improved with addition of 250 and 500 U/kg microbial phytase to the low P diet. On another trail conducted by Veum et al.(1996) using a grain sorghum-canola meal diet, performance including average daily gain, average daily feed intake and gain/feed ratio were similar to feds a low P diet with 200 to 800 U/kg of added phytase and pigs fed on adequate P diet.

Use of cereal phytase of various feeds may be a more practical alternative than the use of microbial phytase. Pointillart et al.(1984, 1987) showed positive effects of cereal phytase of wheat and triticale on dietary phytate P utilization by pigs, but their experiments lasted for approximately 6 wk, and their diets contained too much(over 80%) wheat or triticale to be applicable in the swine industry. Also, Han et al.(1997) suggested that cereal phytase in the commonly used dietary levels of wheat bran was also shown to be almost as effective as microbial phytase in improving phytate P utilization for body weight, but not for bone mineralization in weaning through finishing.

(2) β -glucanase

The mixed-linked(1→3)(1→4)-β -D-glucans which are frequently present in the endosperm cell walls of barley(Aman and Graham, 1987) may interfere with digestion and absorption of nutrients and energy. Although there physiological reasons for augmenting the digestive capacity of pigs with supplementation of β -glucanase, the responses to supplementation have been inconsistent.

Most studies on β -glucanase supplementation to barley-based diets have been carried with starter pigs(Inborr and Ogle, 1988 ; Bedford et al., 1992 ; Thacker et al., 1992 ; Inborr et al., 1993 ; Officer, 1995 ; Baidoo et al., 1998 ; Jensen et al., 1998 ; Defa Li et al., 1999) and growing and finishing pigs(Graham et al., 1986 ; Graham et al., 1989 ; Thacker et al., 1992). With supplementation of β -glucanase, there is an increase in the breakdown of endosperm cell wall components, resulting in more complete digestion of starch and protein in the small intestine(Hesselman and Aman, 1986).

The mechanisms by which β -glucans interfere with digestion and absorption are closely related to their physicochemical properties. β -glucans differ from cellulose in that approximately 30% of the linkages between glucose units are in the form of β (1→3) and 70% in the form of β (1→4)(Fleming and Kawakami, 1977). This branched structure prevents compact folding of the molecules and increases the water-holding capacity which results in its characteristic viscosity and gelling properties. The viscosity and gelling properties tend to hinder intestinal motility(Holt et al., 1979) thereby decreasing the mixing of digesta, digestive enzymes and other necessary components required for digestion and absorption(Vahouny and Cassidy, 1985). These properties may delay or decrease the digestion and absorption of nutrients by increasing the unstirred fluid layer, creating a physical barrier at the absorption surface on the microvilli(Johnson and Gee, 1981).

Graham et al.(1986) founded that there was no effect of β-glucanase on nutrient digestibility in 30 to 50kg of pigs fed barley-based diets. Dietary β-glucanase improved numerically ileal digestibility of starch and β-glucan by 1.7 % and 1.4 %, respectively in 80kg of pigs(Graham et al. 1989). Some β-glucan degradation also appears to occur in the stomach, although it has not been resolved whether this reflects enzymic or acid hydrolysis. Several researches conducted with pigs showed no or little improvement on growth performance. Some improvement in growth and feed conversion as well as digestible energy and protein have been reported in pig fed barley diet(Newman et al., 1983 ; Bedford et al., 1992) in response to enzyme supplementation. However, the entire field of research was open to the criticism of poorly defined enzyme sources, in some cases at least β-glucanase source successful for poultry had little effect on swine (Thacker et al., 1988, 1989, 1991).

(3) Pentosanase

Rye also has been evaluated in diets for growing-finishing pig with and without pentosanase. Thacker et al. (1991) reported a significant reduction in growth rate of pigs fed rye-based diets compared with barely-based diets, whenever diets were supplemented with pentosanase. Bedford et al. (1992) reported that supplementation of pentosnase to a rye-based diet tended to increase viscosity of the small intestine digesta in baby pigs, suggesting pentosan solubilization was occurring at a greater rate than xylan hydrolysis. Supplementation of pentosanase to rye-based diets tended to improved average daily gain and gain/feed of growing-finishing pigs, but there was no effect in barley-based diets(Thacker and Baas, 1996). In studies with weanling pigs fed barley, both daily gain and feed conversion were improved by enzyme supplementation (Thacker et al., 1992) and a reduction in post-weaning diarrhea was reported by Inborr and Ogle(1988).

(4) α-galactosidase

Swine feed compounders can improve the metabolizable energy and N digestibility of soybean meal by means of a feed enzyme that targets the less-well-known anti-nutritional factors called α -galactosides. Soybean meal is undoubtedly the feed industry's most widely used vegetable protein source. However, it is not an ideal ingredient because it contains high amounts of anti-nutritional factors. The offending compounds include trypsin inhibitors that interfere with protein digestion, as well as non-starch polysaccharides, including arabinoxylans, pections β -glucans and many more. particularly troublesome are oligosaccharides from the α -galactosides series. The α -galactosides consist of one sucrose unit(fructose-glucose) to which is attached a chain of variable length formed by several galctose units, linked by α -1,6 bonds. Nutritionists have known about these polysaccharides for a long time, however, recently have begun to consider them of significant importance.

Like other anti-nutritional substances, α -galactosides cannot be digested by the pigs endogenous enzymes and no α -1,6 galactosidase activity has been found in the intestinal mucosa(Gitzelamnn and Auricchio, 1965). Only when the micro organisms of the gastrointestinal tract ferment these oligosaccharides can the pigs obtain usable energy from them. However, α -galactosides are only changed into volatile fatty acids. This means their contribution to the total net energy supply of the animal is lower than if they were converted directly into monosaccharides. Moreover, an immediate consequence of this fermentation process is the decrease in the metabolizable energy value of diet that is rich in these oligosaccharides.

Use of feed enzyme clearly show activity over their specific substrates such as like β -glucans or xylans, with best results in the animals that are least able to digest these polysaccharides. Therefore, the use of specific enzymes, capable to act upon the α -galactosides should as an alternative or a complement to physical processing. The use of the α -galactosidase enzyme against the raffinose series of oligosaccharides would allow hydrolysis of the compound to minimize the anti-nutritional effects of these oligosaccharides.

Using α -galactosides as a supplement in conventional corn-soybean meal diet for pigs, there is a clear improvement in the metabolizable energy and N digestibilities of the soybean meal.

Ⅲ. Conclusion

Exogenous enzymes which, for the purpose of this paper, include phytase, β-glucanase, pentosanase andα-galactosidase, are now extensively used throughout the world as additives in swine diets. The chemical effects of these enzymes are well understand. However, the manner in which their benefits to the swine are brought about is still under debate. Phytase was to increase the availability of plant phytate phosphorus, which reduces phosphorus pollution and allows reductions in the amount of inorganic phosphate used. Also, enzymes have been discovered which have the potential to break down deleterious compounds commonly found in swine rations such as β-glucanase contained in barley and oats and the soluble pentosans found in rye and wheat thus increasing the digestibility of these non-starch polysaccharides. Future research in these area will allow for more efficient use of the current enzymes, development of more efficient future products and development of more thermotolerant enzymes.

Key words : 색인어 : 돼지, phytase, β-glucanase, pentosanase

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