The application of crystal amino acids in low protein diets of growing pigs

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Abstract: The study of low protein diet has been developed since early 1960s. As the establishment of ideal amino acid (AA) pattern and industrialization of AA production, researches of low protein diets have been developed. Meanwhile, more researches of AA nutrition have been carried out due to the rapid rise of protein material prize, such as soybean meal. In this article, latest researches of AA nutrition in low protein diet which have been conducted in China as well as other countries are summarized. The discussion of the application of crystal AA in low protein diet in growing pigs is introduced from the points of view of growth performance and carcass quality.

Keywords: low protein diet crystal amino acid growth performance carcass quality

From the animal nutrition point of view, the nutrition of protein is the nutrition of amino acids. As long as the requirements of amino acids have been maintained, the reduction of protein level in diet to some degree can still ensure the optimal growth performance of pigs. The establishment of low protein diet is based on the ideal protein pattern of pigs, the improvement of the study of nutrient requirement of pigs and the development of industrial production of amino acids.

1 Industrial production of AA —— premise of the application of low protein diet

There have been four types of AA - Lysine (Lys), Tryptophan (Trp), Threonine (Thr) and Methionine (Met) - utilized in the formation of pig diets. L-lysine·HCl is the most widely-used format in the industry. It has been reported from current researches that D-Lysine is not able to be utilized effectively by animals. Therefore, L-lysine is the only bio-active lysine which can be used by pigs and poultry. Both D- and L-Methionion are available for pigs and poultry. Valid feed-grade Methionine are in forms of DL–Methionion (99% purity) and Methionine hydroxyl analogue (liquid containing 88% Methionine hydroxyl analogue). There's a great variation of bioefficiency of Trp in pigs with different genotype. The most used feed-grade Trp is in type of L-Tryptophan (98.5% purity). There are four chemical isomers of Thr, D- and L-Threonion, D- and L-allo-Threonion. Since only L-Threonion can be used by pigs, L-Threonion with 98.5% purity has been widely used in the industry.

Table 1 Effects of crystal amino acids supplementation in low protein diet on growth performance in growing pigs

Reduction of dietary CP level %	Diet type	BW (kg)	Type and amount of AA supplementation (%)						Effect degree on growth performance (%)			Author
			Lys	Met	Thr	Trp	Iso	Val	ADG	ADFI	G/F	
1.2%(16.5%-15.3%)	Sorghum-soybean meal	20-50	Suppl.	-	Suppl	-	-	-	-6.60	-1.09	-5.56	Cervantes et.al., (1992)
1.3%(16.3%-15.0%)	Corn-soybean meal	20-50	0.15	0.05	0.08	0.03	-	-	-2.47	0.74	-3.19	Figueroa et.al., (2002)
1.6%(16.6%-15.0%)	Corn-soybean meal	20-55	0.14	-	0.06	0.03	-	-	-1.25	0	0	Tuitoek et.al., (1997)
2.0%(16.0%-14.0%)	Sorghum-soybean meal	21-45	0.11	-	-	-	-	-	-9.35	-5.91	-3.66	Hansen et.al., (1993)
3.2%(20.5%-17.3%)	Corn-soybean meal	20-50	-	-	-	-	-	-	-3.42	6.10	-8.97	Fabian et.al., (2002)
3.5%(20.7%-17.2%)	Corn-soybean meal	25-41	0.29	0.10	0.17	0.02	-	-	-0.14	2.40	-2.48	Kerr et.al., (2003)
3.6%(16.6%-13.0%)	Corn-soybean meal	20-55	0.28	-	0.12	0.05	0.07	0.03	-1.25	-1.04	-0.21	Tuitoek et.al., (1997)
3.6%(16.5%-12.9%)	Sorghum-soybean meal	20-50	-	-	-	-	-	-	-4.60	-1.64	-3.01	Cervantes et.al., (1992)
3.6%(15.9%-12.3%)	Corn-soybean meal	31-55	0.33	0.08	0.13	0.05	-	-	-4.90	2.78	-6.38	Go´mez et.al., (2002)
3.9%(20.1%-16.2%)	Corn-soybean meal	27-64	0.41	0.12	0.17	0.04	0.02	0.09	2.04	-5.12	7.55	Le Bellego et.al., (2002)
4.0%(16.0%-12.0%)	Corn-soybean meal	29-55	0.25	-	-	0.06	-	-	1.35	5.79	-4.20	Schoenherr et.al., (1990)
4.0%(16.0%-12.0%)	Sorghum-soybean meal	23-45	-	-	0.12	0.05	-	-	-6.91	2.29	-8.99	Hansen et.al., (1993)
4.0%(17.0%-13.0%)	Corn-soybean meal	27-50	0.42	0.13	0.19	0.05	-	-	2.94	-14.00	19.70	Shriver et.al., (1999)
4.1%(16.3%-12.2%)	Corn-soybean meal	20-50	0.45	0.14	0.21	0.08	-	-	5.98	4.65	1.28	Figueroa et.al., (2002)
4.3%(15.9%-12.3%)	Corn-soybean meal	31-54	0.33	0.04	0.08	0.01	-	-	-8.65	-1.40	-8.16	Go´mez et.al., (2002)
4.5%(20.1%-15.6%)	Corn-soybean meal	27-64	0.43	0.10	0.17	0.04	0.03	0.08	-0.19	-4.45	4.46	Le Bellego et.al., (2002)
4.6%(18.2%-13.6%)	Corn-soybean meal	16-50	Equal to NRC (1998) recommendation				-	-	-12.27	-5.83	1.94	Deng et.al., (2007)

5.2%(20.5%-15.3%)	Corn-soybean meal	20-50	-	-	-	-	-	-	-3.97	19.57	-19.69	Fabian et.al., (2002)
5.5%(16.0%-10.5%)	Corn-soybean meal	20-40	Suppl.	Suppl.	Suppl.	Suppl.	-	-	1.24	7.32	-5.66	Cervantes et.al., (1991)
5.5%(16.0%-10.5%)	Corn-soybean meal	24-40	Suppl.		Suppl.	-	Suppl.	-	-12.4	-4.73	-8.06	Cervantes et.al., (1991)
5.5%(17.1%-11.6%)	Corn-soybean meal	20-50	0.57	0.18	0.27	0.10	-	-	-14.49	-2.92	-11.91	Figueroa et.al., (2003)
6.0%(16.0%-10.5%)	Sorghum-soybean meal	20-50	Suppl.	Suppl.	Suppl.	-	Suppl.	-	-17.07	-12.64	-5.07	Cervantes et.al., (1992)
6.2%(17.0%-10.8%)	Corn-soybean meal	24-40	0.63	0.08	0.08	0.07	0.11	0.11	-9.54	0.54	-10.02	Kephart et.al., (1990)
6.2%(16.3%-10.1%)	Corn-soybean meal	20-51	0.55	0.17	0.25	0.09	-	-	-23.67	-5.58	-19.16	Figueroa et.al., (2002)
7.9%(20.5%-12.6%)	Corn-soybean meal	20-50	-	-	-	-	-	-	-12.05	26.36	-30.40	Fabian et.al., (2002)

Table 2 Effects of crystal amino acids supplementation in low protein diet on growth performance in finishing pigs

Reduction of dietary CP level %	Diet type	BW (kg)	Type and amount of AA supplementation (%)						Effect degree on growth performance (%)			Author
			Lys	Met	Thr	Trp	Iso	Val	ADG	ADFI	G/F	
1.4%(14.2%-12.8%)	Corn-soybean meal	55-100	0.15	-	0.06	0.027	-	-	0	1.08	-2.94	Tuitoek et.al., (1997)
2.2%(15.7%-13.5%)	Corn-soybean meal	58-82	0.226	-	0.113	0.022	-	-	0.84	1.43	-0.58	Kerr et.al., (2003)
2.5%(14.5%-12.0%)	Corn-soybean meal	105-155	0.35	0.10	0.03	0.04	-	-	12.23	1.01	10.89	Kerr et.al., (2006)
2.9%(14.3%-11.4%)	Rye-soybean meal	55-110	0.3	-	0.09	-	-	-	0.57	0.51	0.06	Myer et.al., (1996)
3.2%(15.0%-11.8%)	Wheat-soybean meal	55-110	0.33	-	0.08	-	-	-	1.72	-1.39	3.16	Myer et.al., (1996)
3.2%(14.2%-11.0%)	Corn-soybean meal	55-100	0.29	-	0.12	0.05	0.08	0.02	-8.51	-1.79	-6.84	Tuitoek et.al., (1997)
3.8%(15.5%-11.7%)	Corn-soybean meal	70-110	0.293	-	0.108	0.024	-	-	-2.06	2.78	-4.71	Knowleset.al., (1998)
3.8%(17.5%-13.7%)	Corn-soybean meal	64-100	0.39	0.08	0.15	0.04	0.03	0.07	-6.48	-11.18	5.30	Le Bellegoet.al., (2002)
4.0%(19.5%-15.5%)	Wheat-soybean meal	50-70	0.141	0.016	0.021	-	-	-	0.03	0	0.06	Portejoieet.al., (2004)
4.2%(17.5%-13.3%)	Corn-soybean meal	64-100	0.41	0.07	0.15	0.04	0.04	0.07	-8.49	-10.57	2.32	Le Bellegoet.al., (2002)
4.5%(16.0%-11.5%)	Corn-soybean meal	82-110	0.21	-	0.085	0.021	-	-	-6.10	-1.02	-5.13	Kerret.al., (2003)
5.0%(23.0%-18.0%)	Corn-soybean meal	73-108	-	-	-	-	-	-	15.19	4.52	10.20	Cromwellet.al., (1990)
8.3%(19.5%-11.2%)	Wheat-soybean meal	50-70	0.541	0.085	0.192	0.024	-	-	-0.04	0	-0.01	Portejoieet.al., (2004)
9.0%(23.0%-14.0%)	Corn-soybean meal	73-108	-	-	-	-	-	-	17.72	4.64	12.50	Cromwellet.al., (1990)
12.0%(23.0%-11.0%)	Corn-soybean meal	73-108	-	-	-	-	-	-	5.06	1.17	3.85	Cromwellet.al., (1990)

Table 3 Effects of crystal amino acids supplementation in low protein diet on carcass quality in pigs

Reduction of dietary CP level (%)	Slaughter weight (kg)	Type of AA suppl.	10^{th} rib fat (%)	Average backfat thickness (%)	Area of longissimus muscle (%)	Lean meat (%)	Author
3.10%	102	Lys,Met,Thr,Trp,Ile	-0.68	-	-5.65	-0.20	Knowleset.al., (1998)
3.20%	100	Lys,Thr,Trp,Ile,Val	-	14.28	-	-	Tuitoeket.al., (1997)
3.50%	120	Lys,Met,Thr,Trp,Ile,Val	6.75	-	-3.34	-1.84	Knowleset.al., (1998)
3.60%	55	Lys,Thr,Trp,Ile,Val	-	3.14	-	-	Tuitoeket.al., (1997)
3.80%	110	Lys,Thr,Trp	0.55	-	-2.02	0.29	Knowleset.al., (1998)
4.00%	105	Lys,Thr	15.61	-	-4.62	-2.71	Schoenherret.al., (1990)
3.10%(35-50 kg)							
3.30%(51-82 kg)							
4.00%(83-113 kg)	113	Lys,Met,Thr,Trp,Ile,Val	1.34	10.40	-4.81	-1.49	Shriveet.al., (2003)
4.10%	50	Lys,Met,Thr,Trp	-	30.56	-2.97	-	Figueroaet.al., (2002)
4.40%	50	Lys,Met,Thr,Trp	-	0.98	0.65	-	Figueroaet.al., (2003)
5.00%	108	-	3.90	-	-	-1.53	Cromwellet.al., (1990)
5.20%	110	-	-	-3.66	-	-0.85	Gondretet.al., (2002)
5.50%	50	Lys,Met,Thr,Trp	-	-10.43	-12.90	-	Figueroaet.al., (2003)
6.20%	50	Lys,Met,Thr,Trp	-	-2.78	-18.62	-	Figueroaet.al., (2002)
7.90%	50	-	-	47.11	-	-	Fabianet.al., (2002)
9.00%	108	-	10.24	-	-	-1.70	Cromwellet.al., (1990)
12.00%	108	-	18.05	-	-	-4.94	Cromwellet.al., (1990)

2 Effect of crystal AA supplementation in low protein diet on growth performance in growing pigs

Nowadays experts are having dispute on the reduction of protein level at which the growth performance of pigs can be affected. It has been suggested that when adding crystal AA, daily weight gain and feed conversion were not affected if the dietary protein level was reduced by 2-3% (Tuitoek et.al., 1997). Alternatively, it has been reported by others that daily weight gain and feed conversion were not affected when the dietary protein level was reduced by 3% (Hahn et.al, 1995; Kerr et.al., 1995).

The study on growing-finishing pigs by Tuitoek et.al., (1997) has shown that there was no effect on 20-55 kg pigs when dietary protein level was reduced by 3.6% with crystal AA supplemented. This result is consistent with the study by Figueroa et.al., (2002) that when the dietary protein level was reduced by 4%, the difference of growth performance between low protein group and control group was not significant. However, when the reduction reached 5%, the difference was significant (Figueroa et.al., 2003). Table 1 shows the summary of effects of the reduction of dietary protein level on the growth performance in pigs.

It can be found in Table 1 that reducing dietary protein level at less than 4% has little effect on the average daily weight gain, average daily feed intake and feed conversion. It has been reported that adding crystal AA at proper level can help improve the growth performance of pigs (Schoenherr et.al., 1990; Shriver et.al., 1999; Le Bollego et.al., 2002). Although it has been reported that the growth performance of pigs was not affected when the dietary protein level was reduced by more than 4%, more research indicated that the growth rate of pigs were compromised (See Table 1).

There're also many researches conducted focusing on the effect of low protein diets on growth performance in finishing pigs. It has been reported by Knowles et.al., (1998) that the growth performance of finishing pigs (74-117 kg) was not affected when dietary protein level was reduced by 3.5%. Daily weight gain, daily feed intake and feed conversion were not affected when dietary protein level was reduced by 4%. However, daily weight gain was decreased when protein level was reduced by 8.3% while daily feed intake and feed conversion were not different from the control group (Portejeie et.al., 2004). Table 2 shows the effect of dietary protein reduction level on the growth performance in finishing pigs reported in recent researches.

It can be found in Table 2 that the effect on growth performance of finishing pigs is little when dietary protein level is reduced by less than 3%. However, when the reduction rises to more than 5%, there exists the dispute on whether there are effects of low protein diet with crystal AA supplemented on growth performance in finishing pigs. Research by Cromwell et.al., (1990) has indicated that the growth performance was improved by lowering dietary protein level without adding crystal AA. It also indicated that growth performance can be improved even though dietary protein level was reduced by 12%, but the similar result has never been reported in other researches. Le Ellego et.al., (2002) has reported that although Lys, Met, Thr, Trp, Val and Ile have been supplemented, the growth performance of finishing pigs was decreased when dietary protein level was reduced by 4.2%. The main reason to explain the significant difference between these two researches may be the difference of breed of pigs used in the researches. Due to a great variety of the improvement achieved by the development in animal breeding, potential growth and requirement of protein and

specific AA have been changed a lot resulting in the variety between different researches.

Results from Table 1 and 2 indicate that the effect of low protein diet in growing pigs is more significant than the effect in finishing pigs. It may due to that the requirements of specific nutrients are various in different growth phase. It may also relate to the increase of feed intake in finishing phase. It can be found from literatures published in recent 10 years that the growth performance of both growing and finishing pigs are decreased when dietary protein level is reduced by more than 4%. The explanation may be:

(1) The ideal dietary AA composition, especially the rate of sulfur AA and Thr and Lys, varies when the pig's weight is increased (Tuitoek et.al., 1997; Go'mez et.al., 2002).
(2) The reduction of dietary total N supply in which the ratio of total N:Lys is lower can limit the pig's growth (Tuitoek et.al., 1997).
(3) The efficiency of body protein accretion by using crystal AA is lower than using AA from the protein. In purified diet, crystal AA enters hepatic portal vein prior to AA which is separated from protein or peptides. Body protein synthesis needs all available AA to achieve a proper ratio at the same time which means that crystal AA inclines to be oxidized before being used for protein synthesis (Tuitoek et.al., 1997).

Non-limited AA or non-essential AA may become limited AA or essential AA when dietary protein level is reduced (Dean, 2005; Tuitoek et.al., 1997; Go'mez et.al., 2002).

3 Effect of low protein diet with crystal AA supplemented on carcass quality in pigs

There are disputes about the effect of low protein diet with crystal AA supplemented not only on the growth performance in pigs, but also on the carcass quality. The main effects of low protein diet with crystal AA added on carcass quality are the increase of backfat thickness and the reduction of lean meat rate etc. Researches by Knowles et.al., (1998) have indicated that 10^{th} rib fat, area of longissimus muscle and lean meat rate were affected when dietary protein level was reduced by 3.1, 3.5 and 3.8%. Kerr et.al., (2003) has obtained similar results that carcass quality was not different from the control group when dietary protein level was reduced by 4%. Table 3 shows the summary of the effects of dietary protein reduction level on carcass quality of pigs.

Most researches have shown that the carcass quality is decreased when dietary protein level is reduced (See Table 3). Nowadays, the two main explanations are:

(1) Due to the net energy in diet is increased to the degree which has exceeded the requirement for lean meat growth. Noblet (1998) has suggested that the net energy for each gram of digestible protein is 2.7 kcal while 3.4 kcal for each gram of starch. When formulating low protein diets, protein feedstuff is usually substituted by energy feedstuff resulting in the increase of net energy.
(2) When dietary protein level is reduced, the requirement for maintenance of pig is decreased, so the energy becomes excessive resulted from the unchanged total energy. Because of the reduction of protein intake by pigs, activities of glands related to protein digest such as pancreas and liver etc are decreased and thus heat production is decreased; biochemical reaction related to AA metabolism is decreased (Dean, 2005; Knowles et.al., 1998); protein turnover in animals body is decreased; AA metabolite excretion is reduced in which the reduction of urine excretion result in the reduction of heat loss (Fuller et.al., 1987; Noblet et.al., 1987; Reth et.al., 1999).

4 Prospects

The application of low protein diet in practice can help reduce the use of protein source and the excretion of N in feces without influencing pig's growth performance. The use of low protein diet has a great economic value and significance of environment protection when the prize of protein feedstuff keeps rising and environmental pollution induced by animal husbandry becomes more serious. More work is needed to improve the low protein diet system and its application, such as the study on the requirement of specific nutrient especially essential AA and the study on the relationship between net energy requirement and protein level. Furthermore, in order to improve the low protein diet system on theoretical basis, more researches have to be conducted to study the mechanism of its effects on the requirement of energy and nutrient metabolism.

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