

Research progress on Tryptophan requirement of piglets and growing and finishing pigs

Lu Ning Liu Qian

(National Feed Engineering Technology Research Center, Beijing, 100193)

Abstract: Besides Lysine (Lys), Threonine (Thr) and Methionine (Met), Tryptophan (Trp) is considered as the fourth limited amino acid in swine feed and the second limited amino acid in corn-soybean meal diets with low protein level. As crystal Lys, Met and Thr are widely used in animal feed, the restriction effect of Trp on swine feed has become more obvious. This article has reviewed researches about the application of Trp in swine feed and provides theoretical basis to determine the proper Trp requirement for piglets, growing and finishing pigs.

Keywords: Tryptophan piglets growing and finishing pigs requirement

In recent 20 years, a lot of researches have been conducted to study the ideal amino acids profile for pigs and the accuracy of the profile has been improved further. However, little research has been conducted to study Tryptophan (Trp) requirement in the profile. Most existing researches only focused on the study of the mechanism of feed intake regulation by Trp but little focused on the study of the requirement based on the profile (Burgoon et.al., 1992; Lin and Jiang, 1999; Su, 2004; Zhang, 2006).

As one of the essential amino acids for pigs (NRC, 1998), Trp is considered as the fourth limited amino acid for pigs besides Lys, Thr and Met, and the second limited amino acid in corn-soybean meal diets with low protein level due to its considerable effect on nutritional restriction (Wu, 2003). Therefore, it's important to understand Trp requirement. This article has reviewed researches about the application of Trp in swine feed and provides theoretical basis to determine the proper Trp requirement for piglets, growing and finishing pigs.

1 Trp requirement for piglets

Weanling can result in a series of stress responses including considerable drop of feed intake, suppressed growth performance and poor health condition in which the drop of feed intake is considered as the main factor leading to the reduction of growth performance and health condition. Trp is the precursor of the hypothalamus synthesis of 5-Hydroxytryptamine which is a kind of neurotransmitter participating in the regulation of animal's feed intake. Therefore, not only has Trp the impact on protein accretion, but it's also the key nutritional factor of feed intake regulation in piglets. Proper Trp content in diet and ideal protein profile play very important role in piglet's growth, but it has been reported that there is a great discrepancy of Trp:Lys ratio in the model for piglets in the existing researches (See Table 1).

Table 1 Trp requirement for piglets weighing 5-20 kg

Average weight kg	Initial-final weight kg	CP %	Trp %	TTrp %	Trp/Lys	TTrp/TLys	Source
5-10 kg							
4.0	3-5	26.0	0.27	0.24	18.0	17.9	NRC, 1998
6.3	5.2-7.3	-	0.24	0.21	-	15.6	Guzik et.al., 2002
6.4	3.8-9.0	20.0	0.28	0.25	19.5	18.0	Lin et.al., 2001
7.5	5-10	23.7	0.24	0.22	17.8	18.5	NRC, 1998
8.3	6.3-10.2	-	0.23	0.2	-	16.8	Guzik et.al.,2002
Average value			0.25	0.22	18.4	17.4	
10-20 kg							
11.0	6-16	22.0	0.19	-	-	-	Burgoon et.al., 1992
11.0	6-16	16.8	0.24		21.5		Hsia, 2005
11.0	7-15	18.8	-	0.22	-	21.0	Ettle & Roth, 2004
12.0	7-17	19.0	0.26	0.23	21.0	20.5	Pluske & Mullan, 2000
13.0	10.3-15.7		0.22	0.18	-	17.8	Guzik et.al., 2002
14.0	8-20	18.5	0.21	-	17.8	-	Lin et.al.,1999
15.0	10-20	-	0.22	-	18.0	-	Chung & Baker, 1992
15.0	10-20	18.0	0.16	0.14	-	-	Hanet.al., 1993
15.0	10-20	20.9	0.21	0.18	18.3	17.8	NRC, 1998
15.0	10-20	17.5	0.16	-	14.0	-	Sato et.al., 1987
15.5	8-23	18.4	0.24	-	20.0	-	Su et.al., 2004

15.8	8.7-22.8	18.0	0.22	-	17.9	-	Wu et.al., 1994
16.9	9.8-24.0	16.3	0.2	-	18.2	-	Wu, 2003
18.0	10-26	17.0	0.26	0.23	22.4	21.5	Jansman et.al., 2002
19.5	11-28	19.2	-	0.23	-	20.5	Castaing et.al., 2002
19.5	12-27	18.4	0.23	0.19	19.0	18.0	Le Bellego & Noblet, 2002
20.0	10-30	18.5	0.29	0.25	23.0	22.0	Lynch et.al., 2000
20.0	15-25	17.8	-	0.22	-	23.0	Ettle & Roth, 2004
22.5	15-30	22.0	-	0.23	-	19.2	Buraczewska et.al., 2005
Average value			0.22	0.21	19.2	20.1	

Note: CP, Dietary Crude protein; Trp, Total Tryptophan; TTrp, True Digestible Tryptophan; Trp/Lys, Total Tryptophan/Total Lysine ratio; TTrp/TLys, True Digestible Tryptophan/True Digestible Lysine ratio.

It can be found in Table 1 that there is a great discrepancy of Trp/Lys ratio in amino acids profile for piglets reported in researches issued since 1987. The change of Trp/Lys ratio and TTrp/TLys are similar. TTrp/TLys ratio ranges from 16-23. The average value of TTrp/TLys ratio for pigs in 5-10 kg is 17.4 which is slightly lower than NRC estimate and TTrp content is 0.22% which is similar to TTrp estimated by NRC (1998). The average TTrp/TLys ratio is 20.2 and TTrp content is 0.21% for pigs weighing 10-20 kg. In this growth phase, both TTrp/TLys ratio and TTrp content are higher than NRC estimate (1998).

Burgoon et.al., (1992) has carried out researches to study Trp requirement for pigs weighing 6-16 kg which were fed corn-fish meal-corn gluten meal diet. Results showed that as dietary Trp level was increased, the growth performance of experimental pigs was improved and a clear plateau phase existed when Trp/Lys exceeded 18. The best growth performance was achieved in the group with the Trp level of 0.205%. Lin et.al., (1999) has reported total Trp requirement for 8-20 kg pigs fed similar diets of 0.205% (Trp/Lys=18) which can meet the requirement for the best growth performance. Results suggested by both two researches are lower than 0.22% which is shown in Table 1. Guzik et.al., (2005) suggested in their research where piglets weighing 10.3-15.7 kg were fed by corn-pea diets that dietary Trp supply should be slightly higher than the recommendation in order to regulate feed intake by using excessive Trp and thus improve the growth performance in the whole growth period of pigs. As Trp level was increased, although daily weight gain was varied within the range of 0.18-0.255%, feed intake was increased correspondingly. With regards of the effect of feed intake on piglets, researches tend to suggest higher Trp requirement estimate and that's why Table 1 shows higher estimate of Trp requirement.

2 Trp requirements of growing and finishing pigs

Trp requirement of growing and finishing pigs reported since 1992 are summarized in Table 2. It can be found in Table 2 that the average true ileal digestible Trp requirement is 0.15% for 20-50 kg growing pigs and the average ratio in ideal amino acids profile is 19%. In the feeding experiment where pigs were fed corn-corn gluten meal diet, Lin et.al., (2002) reported the optimal true ileal digestible Trp requirement for 24-54 kg pigs of 0.14% which is 21% of dietary true ileal digestible Lys. Guzik et.al., (2005) has conducted research using corn-soybean meal-pea diet and reported true ileal digestible Trp requirement determined using plasma urea N for 30.9 and 51.3 kg growing pigs of 0.17 and 0.15% respectively which are similar to the dates shown in Table 2.

Eder et.al., (2003) has conducted researches focusing on 50-80 kg early-finishing pigs and reported the standard ileal digestible Trp requirement of at least 0.17% which is 21% of dietary standard digestible Lys. Meanwhile, Eder et.al., (2003) also conducted N balance experiment in 56 kg pigs and found that when the optimal protein accretion:protein efficiency ratio was achieved, standard ileal digestible Trp requirement was at least 0.17% which is similar to the data determined by animal feeding experiment. Hahn and Baker (1995) reported the true ileal Trp requirement of 0.11% which is 20% of dietary true ileal digestible Lys. Dietary true ileal digestible Trp requirement of 50-80 kg pigs shown in Table 2 is 0.13% and the average ratio in ideal protein profile is 20% which is significantly different from the data reported by Eder et.al., (2003).

Table 2 Trp requirement for growing and finishing pigs weighing 20-120 kg

Average weight kg	Growth phase kg	CP %	Trp %	TTrp %	Trp/Lys	TTrp/TLys	Source
20-50 kg							
30	25-35	17.92	-	0.17	-	0.19	Zhang et.al., 2001
35	20-50	18.00	0.17	0.15	0.18	0.18	NRC,1998
35	20-50	13.30	0.23	0.20	0.22	0.23	Eder et.al., 2003
36	22-50	15.50	0.13	-	0.14	-	Burgoon et.al., 1992
39	24-54	14.20	0.15	0.14	0.20	0.21	Lin et.al., 2002
45	30-60	14.00	-	0.14	-	0.18	Tang et.al., 2008
46.5	38-55	12 和 16	0.16	-	0.20	-	Henry et.al., 1996
47.5	35-60	15.43	-	0.12	-	0.18	Luo et.al., 1999
47.5	35-60	16.67	-	0.13	-	0.18	Luo et.al., 2003
Average value			0.17	0.15	0.19	0.19	
50-80 kg							
65	50-80	15.50	0.14	0.12	0.19	0.18	NRC, 1998
65	50-80	13.10	0.20	0.17	0.20	0.21	Eder et.al., 2003
67	55-79	12.00	0.09	-	0.13	-	Burgoon et.al., 1992
73	56-90	11.00	-	0.11	-	0.20	Hahn & Baker, 1995
80	60-100	12.00	0.13	0.11	0.21	0.21	Lin et.al., 2002
80	60-100	13.20	-	0.11	-	0.20	Luo et.al., 2001
Average value			0.13	0.13	0.17	0.20	
80-120 kg							
97.5	80-115	10.70	0.16	0.12	0.22	0.22	Eder et.al., 2003
100	80-120	13.20	0.11	0.10	0.18	0.19	NRC, 1998
101	90-112	10.00	-	0.10	-	0.20	Hahn & Baker, 1995
101.05	88.5-113.6	8.70	-	0.08	-	0.15	Kendall et.al., 2007
107.25	91.2-123.3	9.30	-	0.09	-	0.17	Kendall et.al., 2007
111.1	98.8-123.4	10.00	-	0.09	-	0.17	Kendall et.al., 2007
Average value			0.12	0.10	0.18	0.19	

Note: CP, Dietary Crude protein; Trp, Total Tryptophan; TTrp, True Digestible Tryptophan; Trp/Lys, Total Tryptophan/Total Lysine ratio; TTrp/TLys, True Digestible Tryptophan/True Digestible Lysine ratio.

Kendall et.al., (2007) has conducted 3 experiments including 3 weight ranges to determine true ileal digestible Trp requirement for 90-125 kg pigs. They reported true ileal digestible Trp of 0.08, 0.09 and 0.09% which are equivalent to 15, 17 and 17% of dietary true ileal digestible Lys for pigs weighing 88.5-113.6 kg, 91.2-123.3 kg and 98.8-123.4 kg respectively. After the compiled analysis of the data from three experiments and the comparison with the data from previous researches, Kendall suggested that the range of the ratio of true ileal digestible Trp requirement in ideal protein profile of 90-125 kg pigs is 14.5-17%. However, as shown in Table 2, the average true ileal digestible Trp requirement of 80-120 kg pigs is 0.10% and the average ratio in ideal protein profile is 19% which are different from the data reported by Kendall et.al., (2007). The difference may be resulted from the different breeds and weight range of pigs used in the researches.

It has been reported by NRC (1998) that true digestible Trp requirement of growing pigs weighing 20-50 kg, 50-80 kg and 80-120 kg are 0.15, 0.12 and

0.10% respectively and the ratio in ideal protein profile are 18, 18 and 19% respectively. These data are basically consistent with the average value shown in Table 2 which indicates that the estimate of Trp recommended by NRC (1998) for pigs in different growth phase are of guidance significance.

Figure 1 shows the changes of true digestible Trp requirement for different growth phase of pigs summarized in Table 1 and 2. Specific amino acids requirement can be estimated using the model determined by the figure:

$$\text{True digestible Trp requirement (TTrp, \%)} = 0.2346 \times e^{-0.009\text{BW}} \quad (R^2 = 0.821)$$

The true digestible Trp requirement calculated by the above formula and the NRC estimates (1998) are compared in Table 3. It can be found in Table 3 that true digestible Trp requirements calculated by the formula are close to NRC (1998) estimates in which the requirement of 5-10 kg and 80-120 kg pigs are the same.

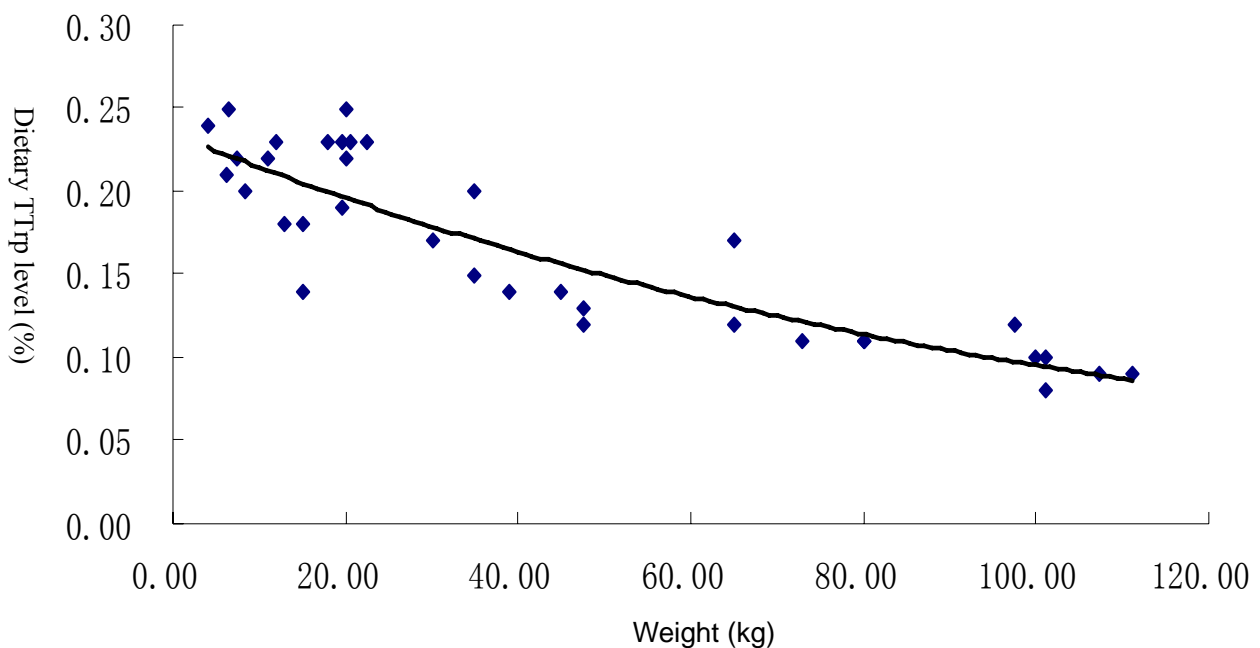


Table 3 Comparison between Trp requirements calculated by the formula and NRC (1998) recommendation

Weight, kg		True digestible Trp %		
Range	Average	Calculated	NRC (1998)	Relative increase %
3-5	4.0	0.23	0.24	-4.17
5-10	7.5	0.22	0.22	0.00
10-20	15.0	0.20	0.18	11.11
20-50	35.0	0.17	0.15	13.33
50-80	65.0	0.13	0.12	8.33
80-120	100.0	0.10	0.10	0.00

3 Trp requirement of pigs fed low protein diet

Swine low protein diet is the diet in which the dietary protein level is decreased by 2-4% but meets the requirement of the type, ratio and amount of amino acids without affecting animal's growth performance. In actual production, low protein diet plays very important role in saving feedstuff resource, reducing production cost, improving protein utilization and reducing the environmental pollution induced by excessive N excretion (Tang et.al., 2008).

Su et.al., (2005) reported in the study of weaning piglets weighing 8-22 kg that when dietary protein level was decreased by 2.5% compared with NRC (1998) estimate and total Trp level was 0.28% and its ratio to total Lys was 2:3, there was no significant difference of growth performance between low protein diet and high protein group. However, when dietary protein level was decreased by 4.8% and total Trp level was 0.20%, best daily weight gain and daily feed intake were achieved (Wu, 2003).

Normal growth performance of growing pigs can be achieved when dietary protein level is decreased by

2% and total Trp is 0.19% (Chen, 2005); however, the optimal growth performance can be achieved when protein level is decreased by 4% but total Trp is 0.18% which is equivalent to 0.14% of true digestible Trp (Liang, 2005). It has been reported by Kendall et.al., (2007) that the true digestible Trp requirement of 88-123kg finishing pigs was ranged within 0.08-0.09% when dietary crude protein level was decreased by 4.5, 3.9 and 3.2% compared with NRC (1998) estimate.

It can be concluded that all studies of Trp in low protein diet are based on ideal protein amino acids profile issued by NRC (1998) and therefore all results of Trp requirement are similar to NRC (1998) estimate.

4 Prospects

Protein resource is deficient in China. It's estimated that the shortage of oil-cake protein resources is about 20 million t. Meanwhile, as the development of animal husbandry and social progress, more and more attention has been paid on environmental protection. Therefore, it has been a global concern to save protein

resource, decrease pollution and protect environment. It has been reported that the reduction of dietary protein level can help reduce N excretion and improve the environment without affecting animal's growth performance (Yue and Qiao, 2008; Yin et.al., 2008; Yang et.al., 2008). Each 1% of protein level reduction can reduce urea and ammonia gas excretion by 20% (Knabe, 1995). Therefore, the reduction of dietary protein level and its rational preparation have become important subjects in animal nutrition researches.

The study of the effect of Trp which is the second limited amino acid in swine low protein diet on feed intake and growth performance can not only provide theoretical basis for determining the optimal Trp requirement and preparing swine diet more scientifically, but also can improve the ideal protein amino acids profile. Therefore, the study of the optimal Trp requirement of pigs in different growth phase based on ideal amino acids profile is of great importance and practical significance to reduce the shortage of protein resource and the environmental pollution induced by animal husbandry.

Reference

- Burgoon, K.G., D. A. Knabe, and E. J. Gregg. 1992. Digestible tryptophan requirements of starting, growing and finishing pigs. *Journal of Animal Science* 70:2493-2500.
- Castaing, J., D. Cambeilh, and C. Relandeau. 2002. Intérêt de la supplémentation en L-tryptophane de l'aliment porcelet deuxième âge à base de maïs. *Journées Rech. Porc.* 34:115-120.
- Chen, E.Y., Y.F Yang, and J.G. Qiao. 1995. A Study on the Effects of Lysine, Methionine, Threonine and Tryptophan Supplements to Different Low Protein Diets on Piglets. *Journal of JiangXi Agricultural University* 5: 764-768.
- Chung, T. K., and D. H. Baker. 1992. Ideal amino acid pattern for 10 kg pig. *Journal of Animal Science* 70 :3102-3111. Commonwealth Agricultural Bureaux, Slough, Great. Britain.
- Easter, R. A., and D. H. Baker. 1980. Lysine and protein levels in corn-soybean meal diets for growing-finishing swine. *Journal of Animal Science* 50:467-471.
- Eder, K., H. Nonn, H. Kluge, and S. Peganova. 2003. Tryptophan requirement of growing pigs at various body weights. *Journal of Animal Physiology and Animal Nutrition* 87:336-346.
- Ettle, T., and F. X. Roth. 2004. Specific dietary selection for tryptophan by the piglet. *Journal of Animal Science* 82:1115-1121.
- Guzik, A. C., L. L. Southern, D. Bidner, and B. J. Kerr. 2002. The tryptophan requirement of nursery pigs. *Journal of Animal Science* 80:2646-2655.
- Guzik, A. C., J. L. Shelton, L. L. Southern, B. J. Kerr, and T. D. Bidner. 2005. The tryptophan requirement of growing and finishing barrows. *Journal of Animal Science* 83: 1303-1311.
- Hahn, J. D., and D. H. Baker. 1995. Optimum ratio to lysine of threonine, tryptophan, and sulfur amino acids for finishing swine. *Journal of Animal Science* 73: 482-489.
- Han, Y., T. K. Chung, and D. H. Baker. 1993. Tryptophan requirement of pigs in the weight category 10 to 20 kilograms. *Journal of Animal Science* 71:139-149.
- Henry, Y., A. Rerat, and P. Ganier. 1996. Growth performance and brain neurotransmitters pigs as affected by tryptophan, protein, and sex. *Journal of Animal Science* 74:2700-2710.
- Hsia, L. C., J. H., Hsu, and C. T. Liao. 2005. The effect of varying levels of tryptophan on growth performance and carcass characteristics of growing and finishing broilers. *Asian-Aust. Journal of Animal Science* 18(2): 230-234
- Jansman, A. J. M., W. Sminka, P. van Leeuwena, and M. Rademacher. 2002. Evaluation through literature data of the amount and amino acid

- composition of basal endogenous crude protein at the terminal ileum of pigs. *Animal Feed Science and Technology* 98: 49-60.
- Kendall, D. C., A. M. Gaines, B. J. Kerr, and G. L. Allee. 2007. True ileal digestible tryptophan to lysine ratios in ninety- to one hundred twenty-five-kilogram barrows. *Journal of Animal Science* 85:3004-3012.
- Knabe, D. A. 1996. Optimizing the protein nutrition of growing-finishing pigs. *Animal Feed Science and Technology* 60: 331-341.
- Le Bellego, L., and J. Noblet. 2002. Performance and utilization of dietary energy and amino acids in piglets fed low protein diets. *Livestock Production Science* 76:45-58.
- Liang, F.G. 2005. Ideal Amino Acid pattern for growing and finishing pigs with different genotypes. PhD thesis, China Agricultural University, Beijing.
- Lin, Y.C., and Z.Y. Jiang... 1999. Tryptophan requirement of weaning piglets. *Journal of Animal Nutrition (China)*, 11 (3): 44-50.
- Lin, Y.C., Z.Y. Jiang, and D.Q. Yue. 2001. Ileal digestible Methionine, Threonine and tryptophan requirement of 3.6-9 kg early weaned piglets. *Chinese Journal of Animal Nutrition* 13 (3): 30-39.
- Lin, Y.C., Y.H. Liu, and Z.Y. Jiang. 2002. Digestible tryptophan requirement of growing and finishing pigs. *China Feed* 11: 15-17.
- Luo, X.M., D.W. Chen, and K.Y. Zhang...2001. Digestible amino acids requirement of 60-100 kg finishing pigs. *Yang Zhu* 1: 2-4.
- Luo, X.M., D.W. Chen, and K.Y. Zhang...2002. Digestible amino acids requirement of 35-60 kg growing pigs. *Chinese Journal of Animal Science* 38 (1): 9-10.
- Luo, X.M., D.W. Chen, and K.Y. Zhang...2003. Effect of ideal protein level on the growth performance and N accretion of growing pigs. *Livestock and Poultry Industry* 6: 22-23.
- Lynch, P. B., S. van Cauwenberghe, and P. Fullarton. 2000. Response of weaned pigs to dietary level of tryptophan. *Proc. EAAP Meeting, The Hague*, pp:342.
- NRC. 1998. *Nutrient Requirements of Swine*. 10th ed. National Research Council. Washington, D.C.
- Pluske, J. R., and B. P. Mullan. 2000. Determining the optimum tryptophan:lysine ratio in diets for weaner pigs. Division of Veterinary and Biomedical Sciences, Murdoch University, Australia (report).
- Sato, H., T. Kobayashi, R. W. Jones, and R. A. Easter. 1987. Tryptophan availability of some feedstuffs determined by the pig growth assay. *Journal of Animal Science* 64:191-200.
- Su, Y.J. 2004. Effects of Lower Protein Diets Supplemented with Tryptophan on Performance and Hypothalamic 5-Hydroxytryptamine Concentration for Piglets. PhD Thesis. China Agriculture University, Beijing.
- Tang, M.Y., X.D. Chen, and F.G. Liang. 2008. Balance pattern of digestible Lysine, Methionine+Cystine, Threonine and Tryptophan in low protein diet of growing pigs. *Chinese Journal of Animal Nutrition* 04: 397-403.
- Tang, Y.J., S.R. Zhang, and Z.Y. Yuan. 2008. Nutritional physiology effect of Tryptophan and its application in swine low protein diets. *Guangdong Siliao* 8: 26-28.
- Wu, X.L.. 2003. Effect of dietary Tryptophan level on growth performance and nutrition metabolism of piglets. Msc Thesis. South China Agricultural University, Guangzhou.
- Wu, X.L., Z.C. Gao, and Z.Y. Yang. 1994. Effect of Tryptophan level on growth performance and blood biochemical index of piglets. *Chinese Journal of Animal Nutrition* 6 (2): 11-19.
- Yang, Q., S.R. Zhang, and X. He. Effect of energy level in low protein diet on growth performance

- and carcass traits of finishing pigs. *Chinese Journal of Animal Nutrition* 4: 371-376.
- Yin, H.H., S.R. Zhang, and J.G. Sun. 2008. Effects of net energy level in low protein diet on growth performance and nutrient digestibility of pigs. *Chinese Journal of Animal Science* 13: 25-28.
- Yue, L. Y., and S. Y. Qiao. 2008. Effects of low-protein diets supplemented with crystalline amino acids on performance and intestinal development in piglets over the first 2 weeks after weaning. *Livestock Science* 115: 144-152.
- Zhang, H.W.. 2006. Regulation of Tryptophan on gene expression of hormone related to feed intake of piglets. PhD Thesis. China Agriculture University, Beijing.
- Zhang, K.Y., X.M. Luo, and D.W. Chen. 2001. Digestible amino acids requirement of 25-35 kg growing pigs. *Chinese Journal of Animal Science* 37 (2): 26-27.