Importance of tryptophan in swine fed with animal by-products

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INTRODUCTION

Use the nutritional recommendations within each swine phase, know the digestibility coefficient of protein and amino acids in each raw material, then applying the ideal protein concept and, take advantage of industrial amino acids, nutritionists can formulate lower cost diets with an adequate energy level, essential and conditionally essential nutrients for maximum genetic expression of animals and with minimal environmental effect.

With the diversity of raw materials available for formulation in swine diets, limiting amino acids are those that are present in the diet in a concentration lower than the requirement for the maximum growth for swine. Limiting amino acids are recognized by their order of limitation by giving a chemical score in formulated diet. Also, the limitation order is in accordance with the age of the animal or physiological state. However, the first limiting amino acid in swine will typically always be lysine (Lys) (Henry et al., 1992; Bertechini, 2012). In a diet based on corn and soybean meal for swine, tryptophan is considered the fourth or fifth limiting amino acid after Lysine, Met + Cys and Threonine (Bertechini, 2012 and Pereira, 2014). On the other hand, in countries that allow the use of animal by-products (meat and bone meal, feather meal and gut meal) and, depending on the level used in the diet, the amino acid tryptophan can become the second (Lima et al., 2012) or third limiting, thus requiring dietary supplementation to meet the animal's requirement.

The objective of this article is to show that tryptophan is not only as an essential and limiting amino acid for swine fed diets containing animal by-products, but also the importance of the tryptophan:lysine digestible ratio (Trp:Lys SID) on physiological potential, performance response, animal health and welfare.

Importance of tryptophan in swine diet

The essentiality of tryptophan determines its importance in the deposition of tissues, reflecting on the efficiency of animal growth. Also, this amino acid is involved in the synthesis of niacin (vitamin B3) and melatonin (neurohormone). Tryptophan is an important immune system intermediary as its requirement seems to increase during an inflammatory response (Pereira, 2014).

According to Henry et al. (1992) marginal tryptophan needs should not be overlooked in feed formulations, as this amino acid is a precursor to serotonin in the brain (5-hydroxytyryptamine), a neurotransmitter involved in regulating feed consumption. Serotonin is directly related to mood, behavior and cognition (Richard et al., 2009) which can be directly linked to animal welfare.

In an experiment carried out by Adeola and Ball (1992), it was observed that the maximum serotonin concentration in the swine hypothalamus during the finishing phase occurred in 5 days after the supplementation of tryptophan in the diet (Fig. 1). Also, they found that supplementing tryptophan in the pre-slaughter period can reduce the stress response and decrease the PSE pork.

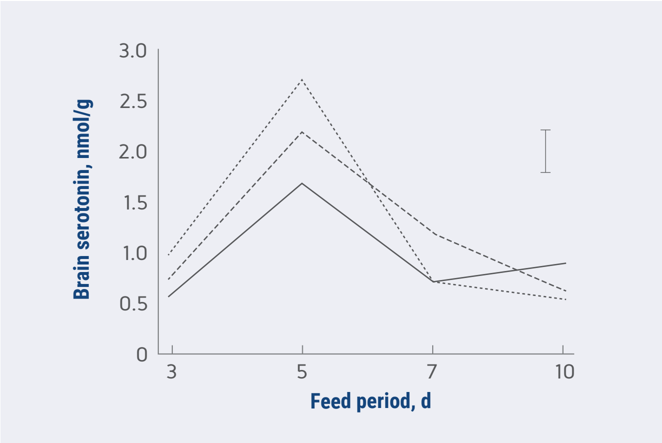


Figure 1. Hypothalamic serotonin concentration in pigs offered supplemental tryptophan at 2.5 (—), 5 (---) or 10 (···) g/kg of diet for 3, 5, 7 or 10 days. The vertical bar represents standard error of the mean.

(Adopted from Adeola and Ball, 1992)

Another important evidence of tryptophan is its direct relationship with the synthesis of ghrelin, a hormone which is present in the stomach, intestine and other organs that impacts appetite in cooperation with the nervous system. It also increases Growth Hormone synthesis (Correia-Silva, 2008).

Zhang et al. (2007) conducted a study to determine whether ghrelin produced mainly by the stomach, was involved in tryptophan-mediated appetite stimulation in swine. They used diets based on corn, corn gluten and soybean meal containing 3 increasing levels of supplemental tryptophan (0.12%; 0.19% and 0.26% in the diet or 0.0 g/kg; 0.07 g/kg and 0.14 g/kg of complete feed); providing Trp:Lys SID ratios of 10%; 15.7% and 21%. The diets were offered *ad libitum* versus limited fed (feeding manner). Weight gain, feed intake and feed conversion were all improved with increased ingestion of dietary tryptophan (Table 1). Dietary tryptophan induced higher ghrelin mRNA levels (P<0.01), but feeding manner (P>0.05) had no effect on the expression of ghrelin in gastric fundus in weanling pigs (Fig. 2A). Feeding 0.19% tryptophan diet induced the higher level of mRNA of ghrelin among the three dietary treatments in two feedings manners. In duodenum tissue, ghrelin mRNA levels was augmented by tryptophan concentration in diet (P<0.01), the 0.26% tryptophan diet induced the highest ghrelin levels in duodenum (Fig. 2B).

Table 1. Effect of dietary tryptophan level on the performance of weanling piglet
(Adopted from Zhang et al., 2007)

Parameters	Feeding manner			Dietary tryptophan, %			
	Limited fed	Ad libitum	S.E.M	0.12	0.19	0.26	S.E.M
WG, g/d	357	487*	10.68	365[a]	435[ab]	465[b]	13.08
FI, g/d	484	704*	13.01	556[a]	594[ab]	632[b]	16.03
FGR	1.37	1.46	0.02	1.53[a]	1.36[b]	1.35[b]	0.02

Means in the same row followed by the different letters are significantly (P<0.05)
WG – weight gain; FI - feed intake; FGR - feed:gain ratio

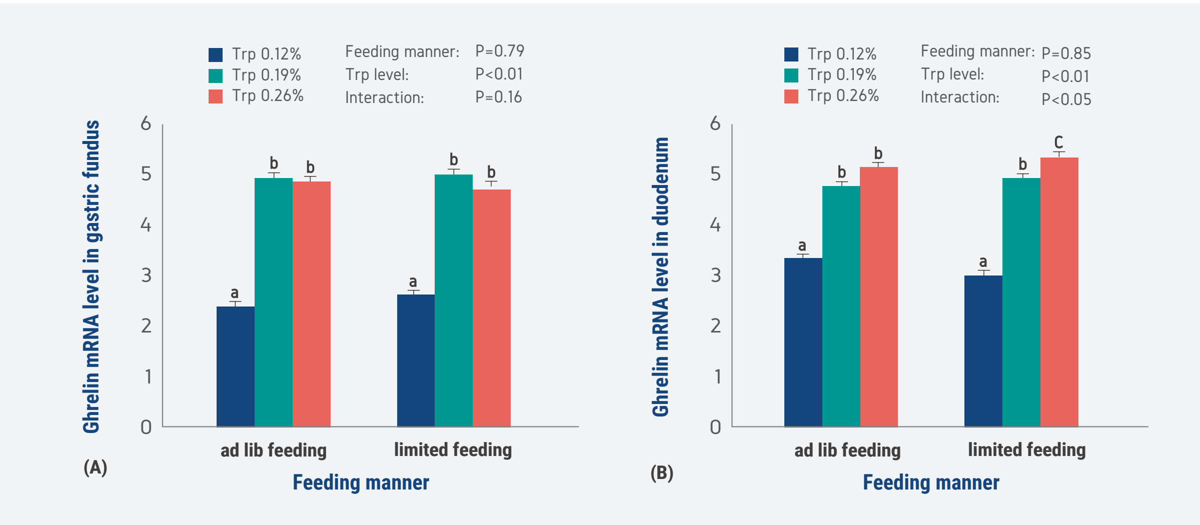


Figure 2. Effects of feeding manner and dietary tryptophan levels on ghrelin mRNA levels in gastric fundus (A) and duodenum (B) in weanling piglet. Ghrelin mRNA levels are mean±S.E.M. Bars with different letters mean significantly different (P<0.05).

Tryptophan and large neutral amino acids (leucine, isoleucine, valine, phenylalanine and tyrosine) compete at the blood-brain barrier, as they share a common transport system. Given this circumstance, the amount of tryptophan in the brain can be reduced if the intake of large neutral amino acids (LNAA) is high (Pereira, 2014). This can negatively impact the synthesis of serotonin. Understanding the relationship between tryptophan/LNAA can be an important factor in the formulation of diets to diagnose the best mechanism for feed consumption, improved health and welfare of swine. In the review carried out by Adeola and Ball (1992), there is evidence that the increasing tryptophan relative to the other LNAA improves the level of serotonin in the brains of rats, broilers and layers causing a sedative effect.

The facts above can be considered crucial when nutritionists are faced with high availability of meat and bone meal, gut meal and feather meal from slaughterhouses and rendering industries because tryptophan can be the second limiting amino acid in swine diets (Lima et al., 2012).
The Trp:Lys SID ratios for swine is referenced by Rostagno et al. (2011) who recommend 18% for the initial, growth and finishing phases. Rostagno et al. (2017) establish 19% for the initial phase and 20% for the growth and finishing phases. For the NRC (2012) the recommendation is 16% for the initial phase and 17% for the growth and finishing phases (barrows, females and entire males).

Animal by-products in the swine diet

Rendering industries in different parts of the world have strict governmental regulations, good manufacturing processes and controls leading to high quality products. This is an important link for sustainable animal production. They are recycling companies and essential for the environment safety, public and animal health (Juzefowicz, 2017).
The production, quality and safety specifications for animal by-products are well documented in the literature (Compendium, 1998; Bellaver, 2001; Bellaver, 2002), being an excellent alternative to reduce the final cost of a diet in view of the high price soybean meal and phosphate (Thaler and Holdon, 2010; Pereira, 2014). It is up to the nutritionists to know the practical and maximum inclusion of animal by-products for swine (Table 2).

Table 2. Inclusion of animal by-products for swine (%)
(Adopted from Rostagno et al., 2011)

Raw Materials	Swine					
	Starter		Grower		Finisher	
	Practical	Maximum	Practical	Maximum	Practical	Maximum
Feather meal	1%	2%	2%	4%	2%	5%
Feather and gut meal	1%	2%	2%	4%	2%	5%
Gut meal for poultry	3%	5%	4%	7%	4%	8%
Gut meal for swine	3%	5%	4%	6%	4%	7%
MBM (41%)	3%	5%	4%	6%	4%	7%
MBM (50%)	4%	6%	4%	7%	4%	8%
Blood meal	1%	2%	1%	3%	2%	4%

The content of calcium and phosphorus present in meat and bone meal may be the limiting factor for its inclusion in the swine diets. Also, it is recommended that the total amount of animal by-products should not exceed 10% to 12% of the diets in grower and finisher phases. In an experiment carried out by Lima et al. (2012) with the objective of evaluating Trp:Lys SID ratios in finishing pig phase (70 to 95 kg), 8% of gut meal and 2% of feather meal had no negative impact on the final performance of animals.
A crucial point for the successful use of animal by-products in swine is to know the content and digestibility of each nutrient, due to variation in the crude protein and amino acid content with the lack of standardization of raw materials (Pereira, 2014).

Effect of tryptophan on swine fed on diets containing animal by-products

In order to understand the effect of tryptophan on swine fed diets containing animal by-products, a research project was carried out by Pereira (2014) at the Federal University of Viçosa in Brazil. To assess the reduction of soybean meal by use of animal by-products in swine fed with two Trp:Lys SID ratio. Pereira (2014) used 96 barrows (PIC x PIC hybrids) in the starter phase (15 to 25 kg), grower phase (30 to 65 kg) and finishing phase (70 to 95 kg). The animals were distributed in a randomized block design, blocked on initial weight (light, medium and heavy), in a 2 x 2 factorial experiment (protein source: vegetable or animal by-products); Trp:Lys SID ratios (18 and 21%) with 12 replicates of two animals each. The experimental diets (Table 3) were formulated to be isonutritive and meet or exceed the recommendations of Rostagno et al. (2011). The inclusion of meat and bone meal and feather meal was observed at the practical levels recommended by Rostagno et al. (2011).
For the 21% Trp:Lys SID ratio, L-Tryptophan replaced starch in the basal diets containing either vegetable or animal by-products. Diets and water were provided *ad libitum* throughout the experimental period. The final weight, daily feed intake, daily weight gain and feed efficiency ($p < 5\%$) were determined by SAS.

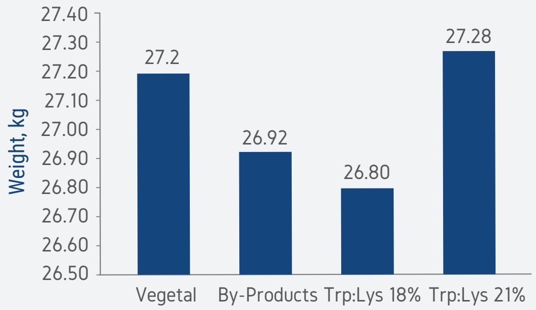
Table 3. Composition of experimental diets
(Adopted from Rostagno et al., 2011)

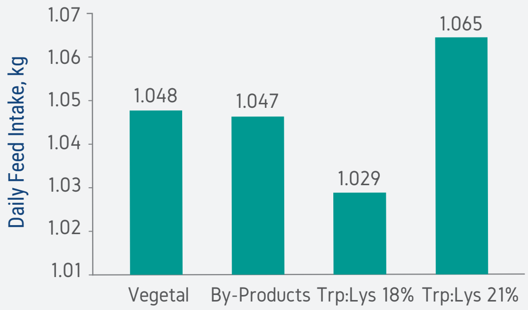
Ingredients	18% Trp:Lys SID					
	15 -25 kg		30 - 65 kg		70 - 95 kg	
	Vegetal,%	By-products,%	Vegetal,%	By-products,%	Vegetal,%	By-products,%
Corn	68.95	72.35	75.08	78.13	80.42	81.41
Soybean meal, 45%	25.70	19.30	20.40	13.60	15.60	10.90
MBM, 44%	--	3.00	--	3.50	--	3.50
Feather meal, 84%	--	1.50	--	2.00	--	2.00
Soybean oil	2.20	1.90	1.80	1.50	1.50	1.30
Dicalcium phosphate	0.958	0.072	1.044	--	1.065	--
Limestone	0.960	0.580	0.590	0.150	0.440	--
Salt	0.460	0.390	0.390	0.320	0.350	0.350
L-lysine	0.295	0.400	0.260	0.355	0.230	0.260
DL-methionine	0.105	0.100	0.085	0.065	0.055	0.033
L-threonine	0.060	0.070	0.045	0.045	0.030	--
L-tryptophan	--	0.025	--	0.025	--	0.010
Premix vitamin	0.100	0.100	0.100	0.100	0.100	0.100
Premix mineral	0.100	0.100	0.100	0.100	0.100	0.100
Starch	0.100	0.100	0.100	0.100	0.100	0.100
Antioxidant	0.010	0.010	0.010	0.010	0.010	0.010
Total	**100**	**100**	**100**	**100**	**100**	**100**
Value Calculated						
Crude protein, %	17.4	17.4	15.45	15.89	14.18	14.79
ME, kcal/kg	3320	3320	3320	3320	3320	3320
Ca, %	0.720	0.720	0.591	0.591	0.529	0.529
P, %	0.350	0.350	0.358	0.358	0.355	0.355
Na, %	0.200	0.200	0.175	0.175	0.160	0.160
Lys, SID, %	1.006	1.006	0.855	0.855	0.718	0.718
Met, SID, %	0.342	0.331	0.303	0.276	0.252	0.233
Met+Cys, SID, %	0.604	0.604	0.539	0.539	0.468	0.485
Thr, SID, %	0.634	0.634	0.556	0.556	0.481	0.481
Trp, SID, %	0.181	0.181	0.154	0.154	0.129	0.129
Val, SID, %	0.724	0.723	0.641	0.641	0.562	0.618
Leu, SID, %	1.411	1.381	1.298	1.288	1.191	1.233
Ile, SID, %	0.647	0.608	0.561	0.533	0.481	0.490

SID - standardized ileal digestibility.
Diet 15 - 25 kg: - 21% tryptophan: lysine DIE ratio, starch was replaced by 0.03% L-Tryptophan.
Diet 30 - 65 kg: - 21% tryptophan: lysine DIE ratio, starch was replaced by 0.025% L-Tryptophan.
Diet 70 - 95 kg: - 21% tryptophan: lysine DIE ratio, starch was replaced by 0.022% L-Tryptophan.

Results

In the starter phase, there was no interaction (P> 0.05) of protein sources and the Trp:Lys SID on weight, daily feed intake, daily weight gain and feed efficiency (Fig. 3).





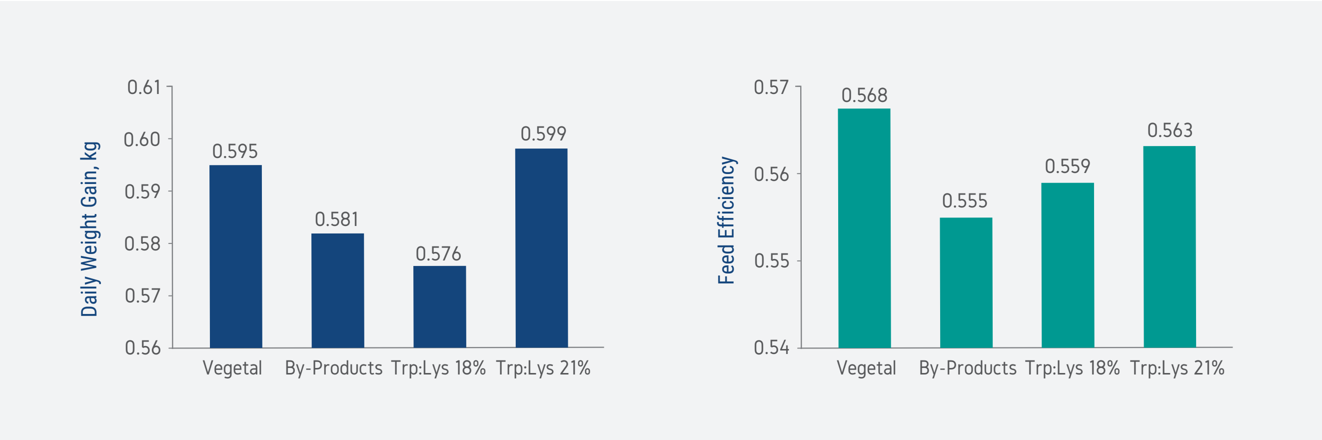


Figure 3. Performance of swine from 15 to 25 kg fed with two protein sources and two Trp: Lys SID ratios (P> 0.05).

For swine weighing 30 to 65 kg (Table 4), there was no interaction between the treatments. Pigs fed diets containing animal by-products had lower daily feed intake (P <0.05). The two protein sources did not influence the final weight, daily weight gain and feed efficiency. On the other hand, swine fed with Trp: Lys SID ratio of 21%, regardless of protein sources, had a higher (P <0.01) final weight, daily weight gain and feed efficiency. No difference in daily feed intake was found between the two Trp:Lys SID ratios. For swine weighing 70 to 95 kg, there was no interaction between protein sources and Trp:Lys SID ratios on animal performance. Protein sources did not affect the final performance of animals. However, pigs fed with Trp:Lys SID ratio of 21%, had greater weight gain, daily feed intake and daily weight gain. Trp:Lys SID ratios did not affect the feed efficiency (Table 5).

Table 4. Performance of swine from 30 to 65 kg fed with two protein sources and two Trp:Lys SID ratios

Parameters	Feeding manner		P-Value	Trp:Lys SID Ratio		P-Value	CV
	Vegetal	By-products		18%	21%		
FW, kg	64.13	63.72	0.418	62.97[b]	64.92[a]	0.014	3.64
DFI, kg	2.128[a]	2.052[b]	0.032	2.064	2.118	0.198	5.92
DWG, kg	1.064	1.048	0.433	1.029[b]	1.085[a]	0.014	6.81
FE	0.501	0.522	0.079	0.499[b]	0.513[a]	0.018	4.01

a or b - means followed by different letters in the lines are different by the F test (P <0.05)
FW – final weight.
DFI – daily feed intake.
DWG – daily weight gain.
FE – feed efficiency.

Table 5. Performance of swine from 70 to 95 kg fed with two protein sources and two Trp:Lys SID ratios

Parameters	Feeding manner		P-Value	Trp:Lys SID Ratio		P-Value	CV
	Vegetal	By-products		18%	21%		
FW, kg	92.62	93.24	0.701	91.71[b]	94.20[a]	0.012	3.01
DFI, kg	2.732	2.724	0.815	2.650[b]	2.810[a]	0.003	5.95
DWG, kg	0.983	0.989	0.828	0.946[b]	1.028[a]	0.002	8.17
FE	0.360	0.363	0.538	0.357	0.366	0.133	5.25

a or b - means followed by different letters in the lines are different by the F test (P <0.05)
FW – final weight.
DFI – daily feed intake.
DWG – daily weight gain.
FE – feed efficiency.

The results demonstrate that animal by-products in the swine diet do not negatively affect the final performance. Its use will depend directly on price, quality and availability to the nutritionist.

For the author, the Trp: Lys SID ratio of 18% was sufficient to meet the performance of swine in the period from 15 to 25 kg. On the other hand, swine over 30 kg fed with the Trp:Lys SID ratio of 21% showed improved performance responses. The modulation of the ghrelin hormone (GH) in the stomach of swine, with consequent GH expression, may have caused a better animal performance (Pereira, 2014; Zhang et al., 2007 and Correia-Silva, 2009). Also, the higher content of tryptophan in diets, regardless of the protein sources used in this experiment, may have promoted the more desirable Trp/LNAA ratio in plasma, thus enhancing the absorption of tryptophan in the blood-brain barrier and improving the synthesis of serotonin (Adeola and Ball, 1992), reflecting in the best final performance of the animals.

Conclusion

Protein sources from vegetables (soybean meal) or animal by-products (meat and bone meal + feather meal) can provide the same final performance in swine. Thus, the price of the animal by-products when associated with the quality and availability seems to be the fundamental criteria for use in diets for pigs over 15 kg.

The Trp:Lys SID ratio of 21% in swine over 30 kg, regardless of the protein sources studied, is an excellent option for nutritionists who aim for improvement of performance, optimal health and welfare of their animals.

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