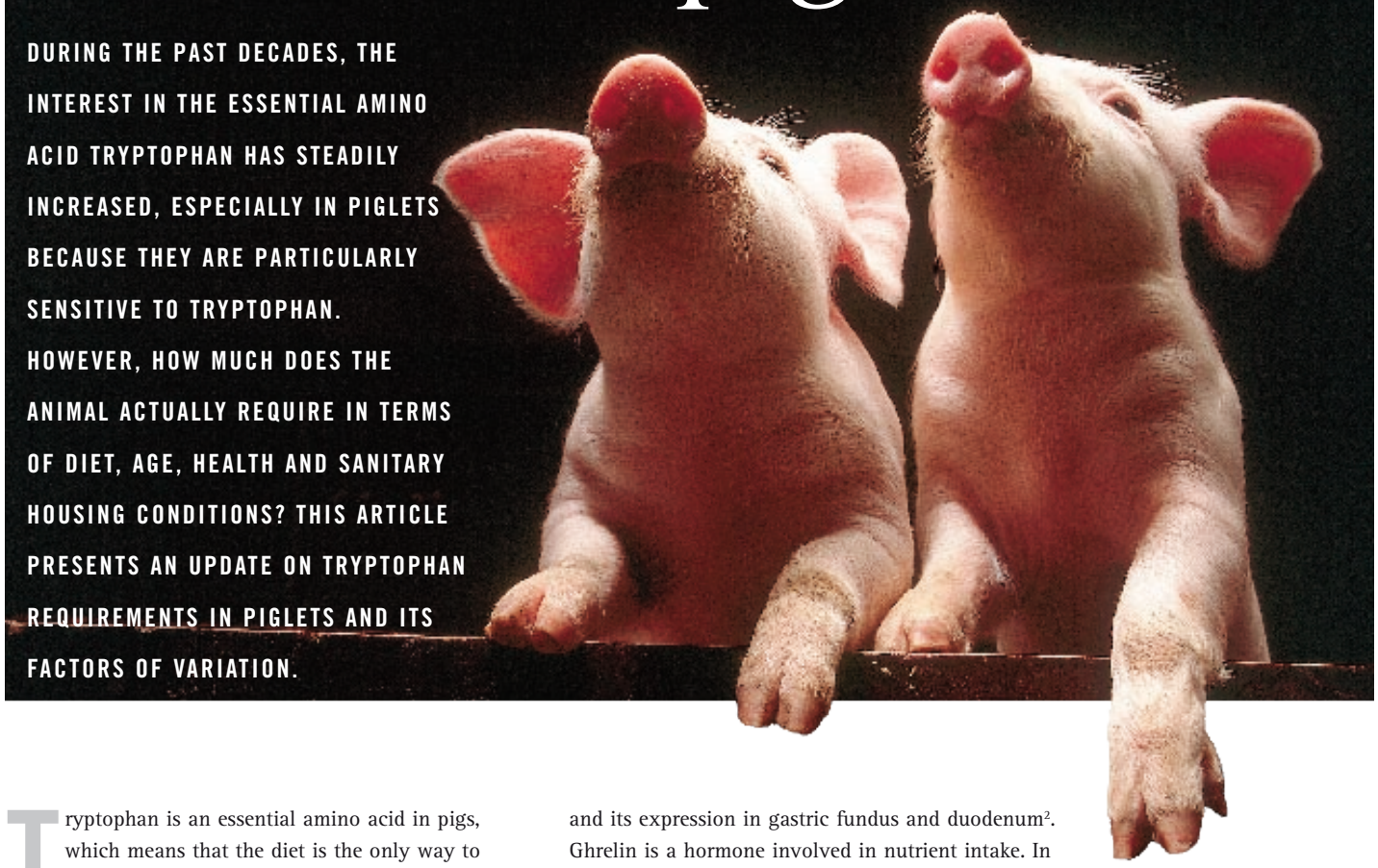
Tryptophan: a key nutrient in pig diets

DURING THE PAST DECADES, THE INTEREST IN THE ESSENTIAL AMINO ACID TRYPTOPHAN HAS STEADILY INCREASED, ESPECIALLY IN PIGLETS BECAUSE THEY ARE PARTICULARLY SENSITIVE TO TRYPTOPHAN. HOWEVER, HOW MUCH DOES THE ANIMAL ACTUALLY REQUIRE IN TERMS OF DIET, AGE, HEALTH AND SANITARY HOUSING CONDITIONS? THIS ARTICLE PRESENTS AN UPDATE ON TRYPTOPHAN REQUIREMENTS IN PIGLETS AND ITS FACTORS OF VARIATION.



Tryptophan is an essential amino acid in pigs, which means that the diet is the only way to supply tryptophan to the animal. Tryptophan is after lysine, methionine plus cysteine and threonine the fourth limiting amino acid in cereal-based diets for piglets and growing pigs under practical conditions. It is, like the other essential amino acids, an important substrate for protein synthesis in the body. When the supply of tryptophan via the diet (relative to the other essential amino acids) is limiting, protein synthesis is compromised and performance is decreased.

APPETITE REGULATION

Besides the production of muscle proteins, tryptophan is involved in different biological functions. One of the most important is the involvement in the regulation of feed intake. In fact, tryptophan is the precursor of the neuromediator serotonin known to play a central role in appetite regulation[1]. Recent studies have also shown that tryptophan infusion and dietary level of tryptophan could modify ghrelin plasma concentration and its expression in gastric fundus and duodenum[2]. Ghrelin is a hormone involved in nutrient intake. In addition to its involvement in feed intake, tryptophan metabolism is involved in inflammatory response[3].

EFFECTS IN DIFFERENT DIETS

Tryptophan requirement was recently studied in young piglets using two diets differing in ingredient composition[4]. A diet deficient in tryptophan based on maize/soybean meal, and a diet deficient in tryptophan based on wheat, barley, soybean meal, peas and whey powder were formulated. Both diets were calculated to contain 1.5 g/kg standardised ileal digestible tryptophan. Both basal diets were supplemented with 0.3, 0.6 and 0.9 g/kg diet free L-tryptophan to obtain diets with 1.8, 2.1 and 2.4 g/kg standardised ileal digestible tryptophan, respectively.

The results are presented in *Table 1*. Over the complete experimental period (0-4 weeks), body weight gain and feed conversion ratio were significantly affected by the nature of the diet (maize/soya vs. wheat/barley) and

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TABLE 1 - EFFECT OF DIET COMPOSITION (MAIZE/SOYABEAN MEAL DIET (I-IV) VS. A DIET BASED ON WHEAT, BARLEY, SOYBEAN MEAL, PEAS AND WHEY POWDER (V-VIII)) AND TRYPTOPHAN CONTENT ON THE PERFORMANCE OF PIGLETS OVER A 4-WEEK EXPERIMENTAL PERIOD (9-24 KG BW). (JANSMAN AND VAN DIEPEN, 2005)

	Trp level[2]	FI (g/d)	BWG (g/d)	FCR
I	1.5	681[a]	450[a]	1.512[d]
II	1.8	801[b]	538[b]	1.487[bcd]
III	2.1	830[bc]	562[bc]	1.479[bcd]
IV	2.4	864[c]	579[cd]	1.492[bcd]
V	1.5	677[a]	452[a]	1.496[cd]
VI	1.8	823[bc]	563[bc]	1.460[ab]
VII	2.1	865[c]	591[cd]	1.464[abc]
VIII	2.4	859[c]	597[d]	1.438[a]
LSD		42	30	0.034
P		<0.001	<0.001	<0.01
Diet				
Maize/soya		794	532[a]	1.492[b]
Wheat/barley		806	551[b]	1.464[a]
LSD		21	15	0.017
P		0.27	<0.05	<0.01
Trp/Lys ratio (%)[1]				
14.7		679[a]	451[a]	1.504[b]
17.6		812[b]	551[b]	1.474[a]
20.5		847[c]	576[c]	1.471[a]
23.4		861[c]	588[c]	1.465[a]
LSD		30	21	0.024
P		<0.001	<0.001	<0.01

[a,b,c]Values with a different superscript in the same column within a factor differ at P<0.05

[1]Ratio based on the standardised ileal digestible basis

[2]Calculated content of standardised ileal digestible tryptophan

the level of tryptophan in the diet (P<0.05). Feed intake was only significantly affected by the level of tryptophan supplementation (P<0.05). Increasing the tryptophan level increased feed intake for the maize/soya diet up to 2.4 g/kg standardised ileal digestible tryptophan and up to 2.1 g/kg standardised ileal digestible tryptophan in the wheat/barley diet (P<0.05).

Results for body weight gain were in line with the results for feed intake. Overall body weight gain was significantly higher for the treatments on the wheat/barley compared to the maize/soya diet (P<0.05) (on average 551 vs. 532 g/d). Increasing the tryptophan level increased body weight gain numerically up to 2.4 g/kg standardised ileal digestible tryptophan in the both types of diets.

Feed conversion ratio was, on average, 1.464 for the treatments on the wheat/barley diet and 1.492 for the treatments on the maize/soya diet (P<0.05). Feed conversion ratio did not improve significantly for the treatments on the maize/soya diet, but was numerically lower in the treatments with 1.8, 2.1 and 2.4 g/kg standardised ileal digestible tryptophan, compared to the treatment with 1.5 g/kg standardised ileal digestible tryptophan. For the treatments on the wheat/barley diet, feed conversion ratio was significantly improved for the treatments with 1.8 and 2.4 g/kg standardised ileal digestible tryptophan compared to the treatment with 1.5 g/kg standardised ileal digestible tryptophan.

CLEAR RESPONSE

It was concluded from the study that in both types of diets there was a clear response of feed intake and body weight gain on supplementation with L-Tryptophan. The requirement for tryptophan in young piglets seemed slightly higher in diets based on maize/soya than in a diet based on wheat/barley. Generally, at the same level of standardised ileal digestible tryptophan in the diet, performance was higher for the piglets fed the wheat/barley based diet compared to piglets receiving the maize/soya based diet. The highest absolute body weight gain was obtained when the diets contained 2.4 g standardised ileal digestible tryptophan per kg diet (equivalent to 23% relative of the requirement value for lysine on a standardised ileal digestible basis).

TRYPTOPHAN AND DIETARY PROTEIN LEVEL

Tryptophan plays a role as a precursor of the neurotransmitter serotonin and the epiphyseal hormone melatonin. In this way tryptophan and its derivatives could have an effect on feed intake, sleeping-waking rhythm, behaviour and pain perception. The transport of tryptophan through cell membranes (at intestinal and brain level) competes with the transport of the large neutral amino acids (LNAA), being the branched chain amino acids (BCAA; valine, leucine, isoleucine), phenylalanine and tyrosine. As a result, the ratio between LNAA and tryptophan in the blood plasma plays a role in the serotonin synthesis in the hypothalamus in the brain. Serotonin (5-hydroxytryptamine; 5-HT) plays an important role in the regulation of feed intake. Diets rich in protein generally reduce the availability of tryptophan for serotonin synthesis. Moreover, it has been found in many tryptophan requirement studies that the use of diets deficient in tryptophan results in a marked reduction in feed intake.

Jansman *et al.* (2000)[5] further studied the interaction between the level of BCAA and tryptophan in the diet on the performance of young piglets. Two basal tryptophan deficient diets with 1.6 g/kg standardised ileal digestible tryptophan and a different tryptophan

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FIGURE 1 - TIME RESPONSE OF PLASMA TRYPTOPHAN MEASURED IN FASTED PIGS SUFFERING FROM LUNG INFLAMMATION (CFA) AND IN CONTROL (CON) HEALTHY PAIR-FED PIGLETS. LUNG INFLAMMATION WAS INDUCED BY AN INTRAVENOUS INJECTION OF COMPLETE FREUND ADJUVANT (CFA). VALUES ARE ADJUSTED MEANS + SEM. EXCEPT FOR BASAL POINT (DAY 0), THE DIFFERENCE BETWEEN TREATMENTS IS SIGNIFICANT (P < 0.01) (MELCHIOR ET AL., 2004).

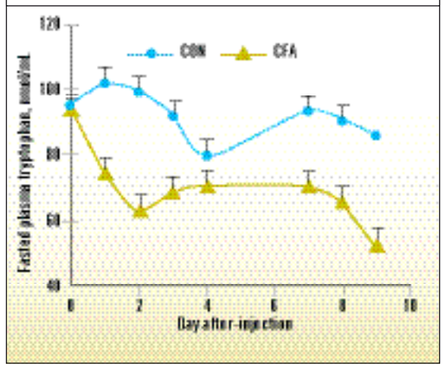
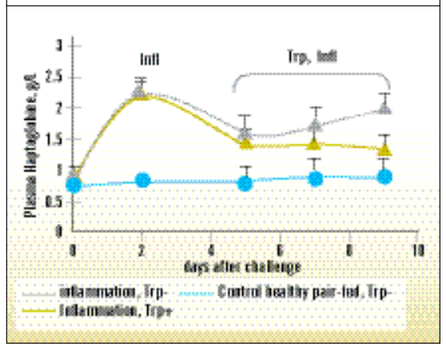


FIGURE 2 - TIME RESPONSE OF PLASMA HAPTOGLOBIN CONCENTRATIONS MEASURED IN CONTROL HEALTHY PIGLETS AND PIGLETS SUFFERING FROM LUNG INFLAMMATION FED WITH A LOW TRYPTOPHAN OR A WELL-BALANCED TRYPTOPHAN DIET (LE FLOC'H ET AL., 2004). VALUES ARE ADJUSTED MEANS + SEM. INFL AND TRP DESIGNS SIGNIFICANT EFFECTS (P < 0.05) OF INFLAMMATION AND DIETARY TRYPTOPHAN ON PLASMA HAPTOGLOBIN CONCENTRATIONS RESPECTIVELY. (MELCHIOR ET AL., 2004).



to BCAA ratio were used. Two levels of tryptophan supplementation (2.0 and 2.4 g/kg standardised ileal digestible tryptophan in the diet) were evaluated. Increasing the level of tryptophan in the diet significantly increased weight gain and feed intake, and decreased feed conversion efficiency (P<0.05). Feed intake and body weight gain was highest for the group receiving the diet with a high tryptophan to BCAA ratio and the highest tryptophan content. Feed conversion ratio was also lowest for this group compared to the other five treatments. The results suggest that at the level of 2.4 g/kg standardised ileal digestible tryptophan in combination with a high tryptophan to BCAA ratio, maximum feed intake and performance may not be achieved and may thus be further enhanced by higher levels of tryptophan supplementation.

It was concluded from this study that the content of tryptophan in the diet is an important factor in determining feed intake and performance in young female piglets. The ratio between tryptophan and branched chain amino acids in the diet also seems of importance in this respect. Feed intake is stimulated by relatively high levels of tryptophan in the diet, exceeding the currently assumed requirement value for standardised ileal digestible tryptophan, particularly in low protein diets with a low content of branched chain amino acids (high tryptophan to BCAA ratio).

HEALTH AND SANITARY CONDITION

In pigs, studies[6] showed that inflammation induced tryptophan metabolism disturbances. Chronic lung inflammation was associated with a decrease in tryptophan plasma concentrations compared to pair-fed healthy piglets (*Figure 1*). One explanation can be an increase in tryptophan catabolism through the kynurenine pathway after activation of the enzyme IDO or indoleamine 2,3 dioxygenase. In fact, pigs suffering from lung inflammation had higher IDO activity in lungs and associated lymph nodes than pair-fed healthy control piglets[7]. In other species, the depletion of free plasma tryptophan has been associated with increased tryptophan degradation under IDO activation occurring in various inflammatory states, since the enzyme IDO is stimulated by pro-inflammatory cytokines, especially interferon-γ[8]. A second hypothesis corresponds with the incorporation of tryptophan in proteins with high tryptophan content, such as acute phase proteins synthesised during inflammatory response[9].

The induction of an IDO pathway has been proposed to be a mechanism that limits the availability of tryptophan during an inflammatory process and may play a crucial role in the regulation of the immune and inflammatory responses[10]. In pigs, it was shown that the level of dietary tryptophan was able to influence the inflammatory response[11] (*Figure 2*). Indeed, pigs suffering from lung inflammation had a lower plasma haptoglobin concentration when they were fed a diet balanced with tryptophan (1.47g/kg) compared to pigs fed a low tryptophan diet (2.02g/kg). Haptoglobin is a major acute phase protein used as an indicator of inflammation in pigs. The activity of IDO measured in the lungs and associated lymph nodes was also lower when the dietary supply of tryptophan was adequate. Moreover, lung

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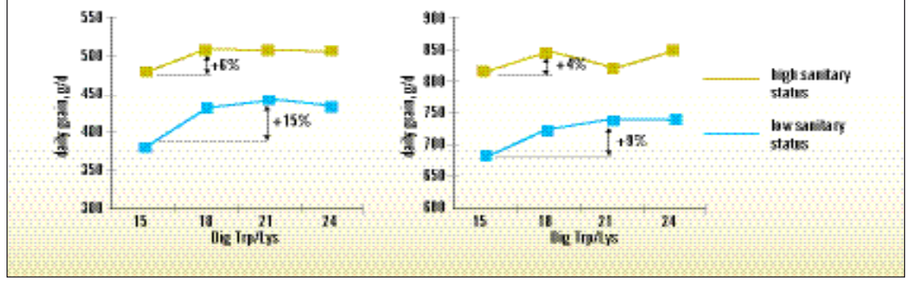
FIGURE 3 - EFFECT OF INCREASE TRYPTOPHAN DIETARY CONTENT (GIVEN AS A RATIO OF DIGESTIBLE (DIG) TRYPTOPHAN TO DIGESTIBLE LYSINE) ON GROWTH RATE AND FEED INTAKE OF 8-30 KG PIGS HOUSED IN GOOD SANITARY CONDITIONS (HIGH SANITARY STATUS) AND POOR SANITARY CONDITIONS (LOW SANITARY STATUS). FOR DAILY GAIN AND DAILY INTAKE, THE DIFFERENCE BETWEEN THE TWO SANITARY STATUSES IS SIGNIFICANT AT P< 0.001 (LE FLOC'H ET AL., 2007).



lesions examined at slaughter were less severe when pigs were fed with a well-balanced control diet. These results suggest that the inflammatory response was reduced when the supply of tryptophan via the diet was adequate.

The consequences of the inflammatory and immune responses on tryptophan metabolism could impair the availability of tryptophan for body protein accretion, growth and all other metabolic processes involving this amino acid. In that way, the deterioration of sanitary housing environment after weaning induced a moderate inflammatory response and modified tryptophan metabolism in piglets. These responses were characterised by reduced growth rate, higher plasma haptoglobin and lower plasma tryptophan concentrations compared to control piglets kept in good sanitary conditions[12]. A reduced growth rate was still observed when control piglets were pair-fed with those reared in poor sanitary conditions. The difference in growth rate as affected by sanitary status can therefore be attributed to modifications of nutrient metabolism. Concerning the response of plasma tryptophan, the pigs kept in poor sanitary conditions displayed lower plasma tryptophan concentrations than control piglets independent of the level of dietary tryptophan[13]. Moreover, increased dietary tryptophan did not fully prevent the consequences of sanitary status deterioration on performance. Nevertheless, the growth rate of piglets kept in poor sanitary conditions was more sensitive to low dietary tryptophan than that of control pigs. As a consequence, the improvement of growth rate induced by increased dietary tryptophan content is higher for pigs submitted to a moderate inflammatory challenge caused by poor sanitary conditions (*Figure 3*). This confirmed that the quality of the environment can be considered as an important factor affecting the tryptophan requirement.

GENERAL CONCLUSION

Health status and dietary crude protein level are factors of variation for tryptophan requirement. Independent on the type of cereals used in the diet, a ratio tryptophan to lysine at 22% (on a standardised ileal digestible basis) allows optimisation of piglet performance. During the piglet period, feed intake and health are two key factors to consider to achieve optimal performance. This shows the importance of maintaining adequate dietary tryptophan supply during this period. <-

References 1-13 are available on request.

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