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PROTEIN EFFICIENCY AND ANIMAL WELFARE – IS THERE A TRADE-OFF?

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Abstract: Improving nutrient efficiency in pig farming is essential for promoting environmental sustainability and reducing reliance on imported protein sources. Reducing dietary crude protein content, especially in conjunction with precise amino acid balancing, has been shown to reduce nitrogen excretion and ammonia emissions while maintaining growth performance. Furthermore, genetic selection is a promising way to increase protein efficiency and provide an additional approach to alleviating the environmental impact of swine production. However, such dietary modifications require careful monitoring, as deficiencies in essential amino acids can disrupt natural behaviours, increase stress susceptibility and endanger animal welfare. Neurophysiological pathways, particularly those associated with serotonin and cortisol regulation, highlight the welfare implications of amino acid imbalances. This brief review highlights the importance of taking a tailored, multidisciplinary approach to enhance protein efficiency and safeguard animal welfare under practical production conditions.

Key words: Nitrogen excretion, Amino acid balance, Genetic selection, Behavioural responses, pigs

Environmental Implications of Protein-Reduced Diets

Protein efficiency in pig production is gaining increasing relevance, both from an environmental and economic perspective (Pomar et al., 2021). Reducing dietary crude protein (**CP**) content has been shown to significantly increase protein efficiency and decrease nitrogen (**N**) losses through faeces and urine. In comparison with a standard diet, a 20% reduction in dietary CP supply from 20–100 kg body weight has been shown to reduce N losses by ~130–230 g/pig. Research has demonstrated that, upon attaining a body weight of 140 kg, the reduction increases to approximately 470–500 g of N per pig. This represents approximately double the reduction previously observed in just 40 kg body weight gain (Ruiz-Ascacibar et al., 2017). This has substantial implications for mitigating the environmental footprint of pig farming.

Protein-restricted dietary protocols, particularly during the finishing phase, are a strategy for enhancing environmental sustainability by reducing reliance on imported protein sources such as soybean meal. Furthermore, these protocols are a viable approach within conventional production systems and do not adversely affect performance. Documented reductions in the use of protein-rich feed ingredients have been observed to range from 11 to 16% under these methodologies (Bee, unpublished).

Individual Variation and Genetic Potential for Nutrient Efficiency

Interestingly, individual variation in protein efficiency plays a major role in how pigs respond to low-protein diets. In the study of Ruiz-Ascacibar et al. (2017), around 30% of pigs fed low CP diets exhibited growth performance comparable to those on standard diets. This suggests considerable individual differences either in essential amino acid (**EAA**) requirements or genetic capacity for efficient EAA utilization. Subsequent genetic evaluations indicated that as much as 51% of the phenotypic variability in protein efficiency may be ascribed to genetic factors, yielding a heritability coefficient of $h^2 = 0.51$ (Ewaoluwagbemiga et al., 2023). Interestingly, apart from the considerable heritability related to protein efficiency, there was a notable genetic linkage with phosphorus efficiency (0.61 ± 0.16), as well as moderate genetic connections with the feed conversion ratio (− 0.55 ± 0.14) and average daily feed intake (− 0.53 ± 0.14), coupled with a rather low genetic association with average daily gain (− 0.19 ± 0.19). These findings open realistic opportunities for breeding strategies targeting improved nitrogen efficiency without compromising performance.

Nutritional Challenges and Behavioural Consequences

However, feeding regimes characterised by reduced CP content can have unforeseen consequences for the welfare of pigs. Deficits in EAAs, such as methionine, threonine and tryptophan, can alter natural behaviors (Jensen et al., 1993). Reports of increased oral manipulation behaviours, such as tail and ear biting, have been linked to dietary protein restriction (Jericho & Church, 1972; Schrøder-Petersen & Simonsen, 2001). Empirical investigations have demonstrated that pigs provided with *ad libitum* diets deficient in CP exhibit increased foragingrelated activities, including standing, walking and rooting (Jensen et al., 1993). This highlights the importance of unmet nutritional requirements in modifying natural behaviour.

The concept of the “ideal protein” serves as the foundation for formulating balanced pig diets. Typically, lysine is the first limiting amino acid in diets of growing-finishing pigs. The requirements for other EAAs are expressed in relation to lysine. A deficiency in EAAs such as methionine, threonine, or tryptophan can influence feed choice and intake patterns (Ettle & Roth, 2004, 2009; Roth et al., 2006). One possible behavioural consequence of such deficiencies is exploratory or manipulative behaviour, potentially escalating to biting and aggression (McIntyre & Edwards, 2009). These behavioural changes underscore the need for careful dietary formulation to ensure that nutritional requirements are met while still achieving the goal of reducing dietary CP levels.

Neurophysiological and Immune-Related Mechanisms

One plausible explanation is that EAAs act as precursors for neurotransmitters. Tryptophan, for example, is a serotonin precursor. Pigs exhibiting tail-biting behaviour have been found to have lower blood serotonin levels, which may indicate higher levels of anxiety or arousal (Ursinus et al., 2014). Furthermore, inadequate protein intake or imbalanced amino acid profiles can compromise immune function, especially when animals encounter immunological challenges that elevate their EAA requirements (Wu et al., 2014).

Contextual Considerations for Practical Implementation

It is important to recognise that controlled feeding trials are usually conducted under idealised conditions, such as strict hygiene measures and low stocking density, which may not reflect commercial production environments. Consequently, feeding recommendations are formulated with safety margins to account for variations in health, housing and management. Behavioural studies under different housing and dietary conditions revealed that pigs housed under suboptimal conditions and fed low-protein diets with unbalanced EAA profiles were more likely to exhibit abnormal behaviours (van der Meer et al., 2017). Conversely, the supplementation of methionine, threonine, and tryptophan (+20%) could mitigate some of these effects.

Several physiological explanations have been put forward. One theory posits that low dietary tryptophan reduces serotonin synthesis, thereby increasing stress sensitivity and aggression. Another considers the downstream effects on cortisol and melatonin regulation, which further influence stress physiology and behaviour (Martínez-Trejo et al., 2009; Ursinus et al., 2014). Furthermore, pigs with high or low growth potential may both be susceptible to behavioural disorders due to a discrepancy between metabolic demand and nutrient supply, particularly when health is suboptimal or the immune system is activated.

Conclusions

In conclusion, reducing the amount of crude protein in pigs' diets can significantly improve protein efficiency and environmental sustainability by lowering nitrogen excretion and emissions. However, if not carefully managed, this approach may compromise animal welfare due to deficiencies in essential amino acids and related behavioural issues. A balanced, holistic approach that integrates precise amino acid formulation, robust animal health, appropriate housing and genetic selection is essential to ensure that improving protein efficiency and animal welfare are mutually reinforcing goals, not mutually exclusive ones.

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