Final Report
Summary

Utilisation of synthetic amino acids by poultry

May 2015 – October 2019

AgriFutures® Chicken Meat

Background

For chicken meat production, there is considerable interest in the successful development of reduced crude protein (CP) diets that contain high inclusion levels of non-bound amino acids. In fact, modest reductions in CP are being realised by inclusions of non-bound (crystalline or synthetic) methionine, lysine and threonine in meat chicken diets that have been routinely practised for decades. As inclusion costs of non-bound amino acids decline with economies of scale from increased production, the economic advantages of lower feed ingredient costs will emerge. Reduced-CP diets have the potential to provide real advantages, including less environmental pollution due to decreased outputs of nitrogen and ammonia; increased bird welfare from better quality litter; and lower incidences of footpad dermatitis and enhanced flock health from less undigested protein entering the large intestine to fuel the proliferation of potential pathogens such as Clostridium perfringens, the causative organism of necrotic enteritis.

Reduced-CP diets contain more feed grains (wheat and/or sorghum), less protein meals (soybean meal and/or canola meal), but more non-bound amino acids so that amino acid requirements are met despite the reductions in dietary CP. Moderate reductions in dietary CP levels can be achieved without compromised meat chicken performance when coupled with careful inclusions of non-bound amino acids. Nevertheless, there appears to be a threshold where CP reductions negatively influence growth performance, especially feed-conversion ratio (FCR), which is associated with increased fat deposition. If reduced-CP diets are to be developed successfully, there is a need to improve understanding of the utilisation of non-bound amino acids in chicken meat production.

This project explored three aspects of the utilisation of non-bound amino acids by meat chickens. These comprised investigations into the impacts of: (i) daily feed access intervals (Yin et al., 2019a); (ii) whole grain feeding (Yin et al., 2019b); and (iii) dietary starch:protein ratios (Greenhalgh et al., 2020). These studies have resulted in three publications in peer-reviewed journals that are specifically listed in the references and links to them are provided.

Daily feed access intervals

In a series of pivotal studies, Ted Batterham demonstrated that the utilisation of lysine hydrochloride (HCl) was superior in pigs fed on an ad libitum or unrestricted basis rather than on a restricted, 'set-fed' basis (Batterham, 1974; Batterham and O'Neill, 1978; Batterham and Morrison, 1981; Batterham and Bayley,1989). The implication is that meat chickens with extended lighting intervals may better utilise lysine HCl (and other non-bound amino acids) than chickens reared under shorter lighting intervals.

In this project's first study, chickens were offered diets without and with 3.5 g/kg lysine HCl, with daily feed access intervals of 12, 16, and 20 hours, from 7 to 28 days post-hatch. The addition of lysine HCl significantly improved weight gain and FCR irrespective of daily feed access intervals. This indicates that lysine HCl utilisation in poultry, unlike in pigs, is not influenced by feed access intervals or lighting regimes. This outcome was not anticipated; importantly however, extending feed access intervals significantly increased relative crop and gizzard weights and quantities of retained digesta in these organs. It appears that effective lysine HCl utilisation in poultry, irrespective of feeding frequency, stems from anticipatory feeding behaviour and 'cropping-up', enhanced crop and gizzard functionality, particularly feed retention in the crop. Relative empty crop weights doubled (7.7 versus 3.8 g/kg) after daily feed access was reduced from 20 to 12 hours, and there was an even greater increase in retained digesta in the crop. This appears to modulate relative intestinal uptakes of lysine HCl and protein-bound amino acids, including lysine, such that imbalances at sites of protein synthesis are negligible. Therefore, it was concluded that daily feed access intervals, or lighting regimes, will not influence the utilisation of lysine HCl and, presumably, other non-bound amino acids.

Whole grain feeding

Given the outcomes of the first study, it was proposed that whole grain feeding (WGF) may enhance the performance of meat chickens offered reduced-CP, wheat-based diets as a consequence of heavier, more functional gizzards and more episodes of reverse peristalsis. Moreover, the impact of WGF needs to be ascertained, given its high level of acceptance by the chicken meat industry. In this study, male chickens were offered wheat-based diets with either 215 or 165 g/kg CP, and three levels of whole grain (0, 12.5 and 25%) in a 2 x 3 factorial array of treatments, from 14 to 35 days post-hatch. Reducing CP compromised FCR by 5.99% (1.576 versus 1.487; $P < 0.005$) but FCR was not influenced by WGF ($P < 0.30$). Reducing CP increased relative fat-pad weights by 12.2% (8.02 versus 7.15 g/kg; $P < 0.02$); however, WGF significantly reduced fat-pad weights ($P < 0.025$) by up to 14.6% (6.91 versus 8.09 g/kg) with 25% whole wheat. This level of whole wheat significantly increased relative gizzard weights by 54.9% (13.51 versus 8.72 g/kg), which is a robust response. WGF significantly enhanced energy utilisation (AME, ME:GE ratios, AMEn). Nevertheless, WGF did not improve the performance of chickens offered reduced-CP diets, other than reducing fat-pad weights.

Free amino acid concentrations in both portal (anterior mesenteric vein) and systemic (brachial vein) plasma were determined in this study and there was little difference between the two outcomes. The reduction from 215 to 165 g/kg CP increased concentrations of glutamic acid plus glutamine by 17.0% (227.3 versus 194.2 µg/mL) in the portal circulation and by 19.7% (188.2 versus 157.2 µg/mL) in the systemic circulation. This is of interest in that it implies that more glucose and less glutamic acid/glutamine was being catabolised in the gut mucosa to provide energy to the gut. This may be related to the relatively rapid digestion rate of wheat starch favouring the catabolism of glucose. If so, it would mean that chickens have to deaminate more glutamic acid/glutamine.

Dietary starch:protein ratios

After reductions in dietary CP, it is obvious that dietary starch:protein ratios increase. This translates to higher jejunal and ileal dietary starch:protein disappearance rate ratios in the bird. This phenomenon may be contributing to the compromised FCR and increased fat deposition in chickens offered reduced-CP diets. Thus, the hypothesis was developed that limiting the expansion or 'capping' of dietary starch:protein ratios could be beneficial in this context. Capping dietary starch:protein ratios can be achieved by substituting soybean meal (475 g/kg CP) with lower protein content feedstuffs, including full fat soy (360 g/kg CP), which was the approach effectively adopted in this study. Male meat chickens were offered diets containing 198, 180 and 163 g/kg CP with either standard or capped dietary starch:protein ratios in a 3 x 2 factorial array of treatments. A seventh treatment with 215 g/kg CP served as a positive control from 7 to 35 days post-hatch.

The performance of chickens offered the 180 and 163 g/kg CP wheat-based diets was especially inferior, and feathering issues became evident. However, similar outcomes were observed in a subsequent study with 165 g/kg CP wheat-based diets. One possibility is this may have been due to high blood ammonia levels derived from deamination of excess amino acids, supressing feed intakes, which is being investigated. Some support for this proposal has been generated in rats (Noda, 1975; Noda and Chikamori, 1976) and meat chickens (Namroud et al., 2008). Nevertheless, the growth performance of the chickens offered 215 and 198 g/kg CP diets, with dietary starch:protein ratios of 1.63 or 1.97, was entirely acceptable and, importantly, capping ratios appear to hold promise when these three dietary treatments are considered. For example, chickens offered capped ratio diets (1.63) outperformed their standard ratio diet (1.97) counterparts by 10.4% (2,161 versus 1,958 g/bird; $P < 0.01$) in weight gain, by 3.10% (3,492 versus 3,387 g/bird; $P < 0.02$) in feed intake and numerically improved FCR by 4.04% (1.616 versus 1.684). Moreover, there was a negative linear relationship ($r = -0.443$; $P < 0.025$) between distal jejunal starch:protein disappearance rate ratios and weight gain in chickens offered the 215 or 197.5 g/kg CP diets (Figure 1). Indeed, there is an even more pronounced linear relationship ($r = -0.501$; $P < 0.001$) between the distal ileal ratio and weight gain. Both regressions support the concept that capping dietary starch:protein ratios in reduced-CP diets is advantageous.

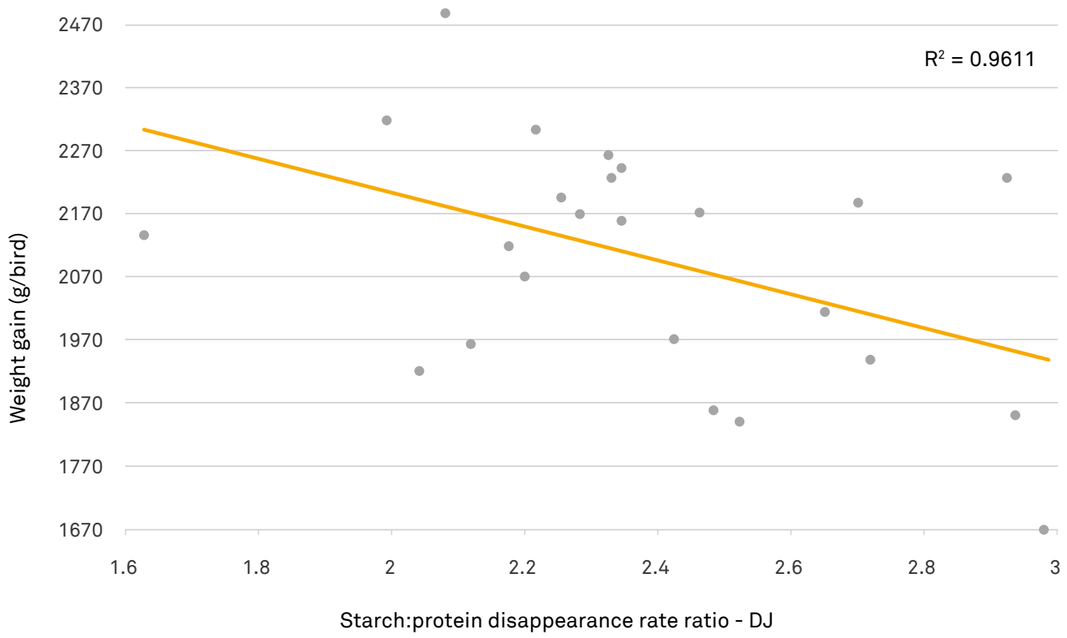

Figure 1: The linear relationship (r = -0.443; P = 0.030) between distal jejunal (DJ) starch:protein disappearance rate ratios and weight gain in chickens offered three diets containing 215 or 197.5 g/kg CP and dietary starch:protein ratios of 1.63 or 1.97, where y(weight gain) = 2721 – 262 x starch:protein disappearance rate ratio (derived from Greenhalgh et al., 2020).

Surprisingly, there was poor feathering and even some feather pecking in this study, chiefly among the poorly performed chickens on 180 and 163 g/kg CP diets. Presumably, the feathering issues were expressions of amino acid imbalances or inadequacies in the reduced-CP diets. Given the feathering problems observed, the amino acid profile of feathers from chickens offered the 201.5 g/kg CP diet was determined. The feathers contained 931 g/kg crude protein, and the dominant amino acids were cysteine (8.2%), glutamic acid (8.2%), glycine (11.4%), proline (10.6%) and serine (13.7%) – molar proportions are shown in brackets. Concentrations of all these amino acids were lower in the 180 and 163 g/kg CP diets than in the 215 and 198 g/kg CP diets. Presumably, a shortage of any one of these amino acids would impede feathering.

Conclusions

The important outcomes of this project were, firstly, that the utilisation of lysine HCl (and presumably other non-bound amino acids) in meat chickens, unlike pigs, is not influenced by daily feed access intervals and, by extension, lighting regimen. This appears to stem from the chickens' capacity to 'crop-up' from anticipatory feeding. Secondly, WGF does not appear to influence the performance of chickens offered reduced-CP diets, although reductions in abdominal fat-pad weights were observed. Finally, it was shown that capping dietary starch:protein ratios holds promise. Further investigations into this approach in the development of reduced-CP diets are certainly merited.

Publications arising from PRJ-010623

Yin D, Chrystal PV, Moss AF, Choy KYE, Liu SY, Selle PH (2019a) Extending daily feed access intervals does not influence lysine HCl utilisation but enhances amino acid digestibilities in boiler chickens. Poultry Science 98, 4801-4814.

doi.org/10.3382/ps/pez200

Yin D, Chrystal PV, Moss AF, Liu SY, Selle PH (2019b) Effects of reduced crude protein and whole grain feeding on performance and amino acid metabolism in broiler chickens offered wheat-based diets. Animal Feed Science and Technology 260, 114386.

doi.org/10.1016/j.anifeedsci.2019.114386

Greenhalgh S, McInerney BV, McQuade LR, Chrystal PV, Khoddami A, Zhuang MAM, Liu SY, Selle PH (2020) Capping dietary starch:protein ratios in 197.5 g/kg crude protein wheat-based diets showed promise but further reductions in crude protein generated feathering issues and inferior growth performance in broiler chickens from 7 to 35 days post-hatch. Animal Nutrition 6, 168-178.

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AgriFutures®
Chicken Meat

AgriFutures Australia Publication No. 20-119
AgriFutures Australia Project No. PRJ-010623
ISBN: 978-1-76053-107-2

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