The effect of the host nutritional status and coccidiosis infection on chicken productivity.

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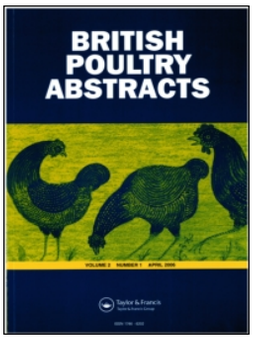

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2019 Abstracts

Oral communications, invited talks and posters presented at the WPSA UK Branch Meeting held at the Edinburgh International Conference Centre, Edinburgh (10–11 April 2019). These summaries have been edited for clarity and style by the WPSA UK Programme Committee but have not been fully peer-reviewed.

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The effect of the host nutritional status and coccidiosis infection on chicken productivity.
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Long in energy – short in protein, a role for the bioethanol industry

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One major long-term global quest will be to supply sufficient protein for the needs of the growing population. Energy is no longer seen as the priority, the world is long in energy, short in protein. Long term there is predicted to be a scarcity in protein. The term 'perfect storm' has already been coined to describe the situation based on the changing population demographic demands and the increased green-house gas footprint of protein production. The situation is particularly dire for Europe that is only 31% self-sufficient in terms of high-quality protein for feed formulation and already relies on imported soya bean meal as a supply of protein for animal feed. The case for an additional EU supply of alternative protein is irrefutable. Several new initiatives have been launched to fill the protein gap but few if any are past the early development stage. Indeed, not only are these projects far from commercialisation it is questionable whether they will be capable of supplying the critical volume essential for commercial feed production, will have the necessary resilience in the supply chain or will be consumer acceptable. The bioethanol industry in European processes an immense quantity of grain. In 2017, 11.6 MM tonnes of cereal (approx. 3.8% of cereal production) which equated to approximately 1.16 MM tonnes of protein (assuming a mean grain protein concentration of 10%) were processed. From the dry-grind ethanol process a large proportion of the protein is marketed as a commodity product, Distillers Dark Grains and Solubles (DDGS). Whilst DDGS is a valuable mid-range protein product, it is restricted in terms of its use in diets for neonates and is not suitable for use in diets for carnivorous fish (salmon and trout). Both of these segments of feed nutrition would benefit greatly from an alternative protein that is capable of replacing soya bean meal. A processing technology development program has successfully developed a mechanical separation process that recovers a portion of the protein present in DDGS together with a major proportion of the yeast generated in the bioethanol process from a dry-grind bioethanol plant. The product is a 50% protein product formed from a mixture of the grain gluten-type proteins plus spent yeast (25% yeast on a dry matter basis in the product). Current production is in excess of 200 Ktons/annum rising to over 300 Ktons/annum at the end of 2019 from a number of bioethanol plants in the USA. Production of the alternative protein is of a magnitude required for commercial feed production with resilience in the supply chain via several plants producing the identical product and the material is regulatory compliant. From the dry-grind ethanol process the commodity co-product, DDGS, has a reputation for being variable in quality but the new alternative

protein supplement, produced without any down-stream mixing, is highly consistent in terms of nutrient composition both within an individual ethanol plant and between plants. The product has been extensively tested in a wide range of feed formulations, across a wide range of species and in neonates. As an alternative to soya bean meal the new protein is more benign and does not contain the anti-nutritional components found in soya bean meal. The spent yeast proportion of the material also provides immune stimulatory components that significantly add to the benefits of the product. Results of the extensive *in-vivo* testing program will be presented that demonstrate the significant value of the product and efficacy as an alternative protein that can be used to replace soya bean meal and soya isolate protein in feed formulation for all classes of livestock and in diets for aquaculture. Use of grain for bioethanol production is cited as a significant negative for the use of grain to produce fuel in the fuel versus food debate. Using the dry-grind bioethanol co-product to produce a high-value protein from EU dry-grind ethanol plants is one means of producing a non-GM alternative protein to substantially replace the importation of soya bean meal and thereby reduce the carbon foot-print of EU feed manufacture. The technology demonstrates the value of physical grain processing to produce high-quality nutritional components that greatly improve the efficiency of feed formulation in supplying high-density nutrients for modern day genetically improved livestock. Crop breeding to increase grain yield has tended to decrease grain protein content with the pleiotropic lag in seed protein content. Grain is becoming increasingly less of an ideal raw material for high-density feed formulation. The future of feed production may well lie in large-scale grain processing, as found in bioethanol plants, with inherent economies of scale, to produce relatively pure sources of nutrients that can then be reformulated to the exact nutritional requirements of the target livestock. The full role and value of bioethanol grain processing technology may yet be realised in terms of the scope of the technology to capitalise right now, on the leading position of the EU in grain production and convert sustainably plant material into a wide range of useable products with zero waste. Not waiting 10 years for projects that are still very speculative.

Wheat breeding for protein and yield: current and future challenges

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Due to increases in global population, world food production is expected to need to increase by 60% by 2050 (Alexandratos & Bruinsma, 2012). Therefore, there is a high pressure to increase crop yields. Wheat is a major staple crop for human consumption and is a valuable food source for livestock agriculture. It is clear that to meet future demand for food wheat yields must increase. There have previously been great strides in boosting the productivity of wheat. Most notably, the introduction of reduced height genes, spearheaded by Norman Borlaug during the Green Revolution, dramatically increased wheat yields (Peng et al., 1999). Since then, through the efforts of modern plant breeding, wheat yields have been steadily increasing.

There are a number of complications when wheat-breeding efforts focus solely on increasing yield. For example, the reduced height genes introduced during the green revolution are linked with reduced grain quality (Flintham, Börner, Worland, & Gale, 1997). Protein content, a key component for bread making as well as for animal feed, reduces when grain yield increases, primarily due to dilution of protein within the grain (Simmonds, 1995). In order to meet the demands of millers, bakers and the animal industry, breeding efforts must not sacrifice grain quality in order to increase yield. Added to this, breeding efforts must also focus on improved resistances to pests and diseases, especially with the number of available chemicals to farmers reducing. All of these goals must be met whilst weather becomes more extreme and the climate changes.

There are a number of modern techniques that are in a breeder's toolbox that can aid the effort of increasing yields whilst maintaining quality. The development of Single Seed Descent (SSD) and Doubled Haploid (DH) breeding methods has sped up the breeding process and allowed new varieties to be quickly developed. The development of marker-assisted selection (MAS) along with the recent sequencing of the wheat genome (International Wheat Genome Sequencing Consortium (IWGSC), 2018) can enable new traits to be discovered and selected for within breeding programmes. The rapid development of markers will assist with the identification of quality traits such as protein in high yielding wheat. Further to this, new developments with GM and genome editing may allow newly discovered traits to be introduced into elite varieties more quickly in the future.

In order to advance yield and quality, it will be important to discover new traits from outside the existing gene pool. KWS is a global plant breeding company breeding a range of crops including Cereals, OSR, Maize and Sugar beet. KWS is involved in a number of research projects involving collaborations between a number of private and public institutions. Collaborations in various projects allow commercial plant breeders to integrate novel findings into breeding programmes. Whilst there are a number of projects currently ongoing to identify new yield traits to further improve yield and some that focus on improving quality, there is still a need for further research to identify novel quality characteristics to sustainably increase traits such as protein in order to meet the needs of end users in the future. Collaboration between various organisations will be vital in order to meet the demands of farmers and end-users in the future for both yield and protein.

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Effect of turmeric supplementation on haematochemical parameters of broiler chickens under a hot, humid, tropical condition

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Application

Livestock farmers can make use of turmeric rhizome powder to ameliorate the effect of heat stress on broiler chickens.

Introduction

Tropical climates are a harsh environment for broiler production as a result of high ambient temperatures and relative humidity (Farooq et al., 2005) but dietary manipulation such as addition of antioxidants may ameliorate this in some months in the year (Flachowsky, Engelman, Sunder, Halle, & Sallmann, 2002). The phenolic compound, turmeric (*Curcuma longa*), has known antioxidant properties (Ammon, Safayhi, Mack, & Sabieraj, 1993) so this study investigated the influence of turmeric rhizome powder on physiological responses and performance under a tropical climate.

Material and methods

Two hundred and forty Marshall day-old broiler chicks, having been granted permission by the College ethical committee, were randomly assigned to four dietary treatments having 4 replicates of 15 birds each in a complete randomized design. Broiler birds were fed maize-soybeans based basal diets and supplemented with 0, 4, 8 and 12 g of turmeric powder/Kg of diet (CT, TG, FT and SG, respectively) for 8 weeks. Mash diets were formulated to meet NRC (1994) nutrient recommendations for the starter phase (0–4 weeks) and the finisher (4–8 weeks) feeding phase of the birds. Data were collected on feed intake and body weights weekly. Blood samples were collected from eight birds per treatment at week 6 for the determination of haematochemical parameters.

Results

The results generally showed that turmeric at the dose of 8g/kg was optimum for broiler birds under hot humid conditions. This is in agreement with the findings of Isroli et al. (2017a, 2017b) who indicated that turmeric improved stress responses in chickens.

Conclusion

Turmeric rhizome powder improved the physiological response of broiler chicken under hot humid tropical climate in a dose-dependent characteristic and the optimum supplementation rate of 8g/kg of diet was recorded.

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Table 1. Effect of different levels of turmeric rhizome powder on haematochemical parameters of broiler chickens.

	Turmeric doses (g/Kg diet)					
Treatment	0	4	8	12	SEM	P-Value
Packed cell volume, %	30.67^{b}	28.33^{c}	33.00^{a}	29.67^{b}	0.54	<0.001
Haemoglobin, g/dl	8.70^{b}	8.30^{c}	9.23^{a}	8.70^{b}	0.10	<0.001
Red blood cell ($x10^{12}$/l)	2.33^{b}	1.80^{c}	3.00^{a}	2.37^{b}	0.13	<0.001
White blood cell($X10^{9/L}$)	10.47^{c}	12.63^{a}	12.83^{a}	11.90^{b}	0.03	<0.001
Heterophil.	31.67	30.33	29.33	30.00	0.38	0.153
Lymphocyte	68.67^{a}	66.67^{b}	70.00^{a}	69.33^{a}	68.67	0.017
Eosinophil	0.00	0.67	0.67	0.00	0.14	0.119
Basophil	0.00^{b}	0.67^{a}	0.00^{b}	0.10^{a}	0.01	0.006
Total protein	4.83^{a}	4.17^{c}	4.37^{b}	4.33^{bc}	0.09	<0.001
Albumin	2.77^{a}	2.00^{c}	2.93^{a}	2.30^{b}	0.11	<0.001
Globulin	2.17^{a}	2.10^{a}	1.40^{b}	2.07a	0.10	<0.001
Glucose	153.67^{a}	131.67^{b}	124.33^{c}	136.00^{b}	3.32	<0.001
Triglyceride	94.33^{a}	75.67^{c}	84.33^{b}	68.67^{d}	2.97	<0.001
AST	62.67^{a}	62.67^{a}	45.00^{c}	54.33^{b}	2.32	<0.001
ALT	23.67^{b}	25^{ab}	27.33^{a}	19.33^{c}	0.94	0.001
FCR	2.35^{a}	2.05^{b}	1.79^{c}	1.85^{c}	0.061	<0.001

^{a,b,c}means in the same row having different superscripts differ significantly ($P < 0.05$)

Effect of the duration of collection period on the estimate of dietary metabolisable energy and nutrient retention in broiler chicken

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Application

The duration of collection period should be taken into account when determining the dietary metabolisable energy and nutrient retention coefficients in broilers.

Introduction

There is effect of the duration of prefeeding period on nutrient digestibility in chickens (Kluth & Rodehutscord, 2010), but information on the effect of the duration of the collection period is lacking. The reported study evaluated the effect of two collection periods, 48 h and 96 h on N – corrected apparent metabolisable energy (AMEn), total tract dry matter (DMR), nitrogen (NR) and fat (FR) retention coefficients of three *ad libitum* fed mash diets with different energy density in broilers.

Materials and methods

The experiment was conducted at the National Institute of Poultry Husbandry and approved by the Harper Adams University Research Ethics Committee. A basal diet containing 499.5 g/kg of wheat, 235.0 g/kg soybean and 100.0 g/kg of maize, as major ingredients, was mixed. The basal diet was then split into three batches and one of them was used as a control (Diet 1), a second lot had 100 g/kg of vegetable oil added (Diet 2), and the third lot had 100 g/kg of soy hulls added (Diet 3). At the beginning of the study at 24d old, 144 male Ross 308 broiler chickens, previously reared in a common floor pen and fed the same standard diet, were randomly allocated to 48 raised floor pens (0.36 m^2), giving three birds per pen, each diet being replicated 16 times. The birds were fed the experimental diets for 4 days adjustment period prior to their allocated collection period (48 h (8 replicates per dietary treatment) or 96 h (8 replicates per dietary treatment)). At the start of the collection period when birds were 28 d age, the solid floor of each pen was replaced with a wire mesh and all excreta were collected for 48 h, or for 96 h, respectively. Feed intakes were also measured for the same period as excreta collection. Data were statistically analysed by ANOVA using a 2 × 3 factorial arrangement of treatments.

Table 1. The effects of the duration of collection period on N-corrected apparent metabolisable energy (AMEn), total tract dry matter (DMR), nitrogen (NR) and fat (FR) retention coefficients in broilers.

Treatment factor	AMEn (MJ/kg DM)	DMR	NR	FR	Feed intake (g DM/bird/day)
Diet					
1	12.87[a]	0.692[a]	0.578[ab]	0.847[a]	101.4
2	15.33[b]	0.727[b]	0.600[a]	0.878[b]	105.0
3	12.25[c]	0.656[c]	0.549[b]	0.881[b]	105.2
SEM	0.106	0.0066	0.0131	0.0092	2.89
Days collection					
2	13.63	0.701	0.591	0.875	104.6
4	13.34	0.682	0.559	0.863	103.2
SEM	0.086	0.0054	0.0107	0.0075	2.36
p-Value					
Diets	<0.001	<0.001	0.034	0.022	0.578
Days collection	0.022	0.016	0.042	0.244	0.667

[a,b,c]Means in the same row having different superscripts differ significantly ($P < 0.05$).

Results

The determined AMEn, DMR and NR values for 48 h collection period were higher compared to 96 h collection period ($P < 0.05$) (Table 1). There was no difference ($P > 0.05$) for FR regarding time of collection. Diet 2 had the highest AMEn ($P < 0.001$), DMR ($P < 0.001$) and NR ($P < 0.05$) coefficients followed by diet 1 and diet 3. Diet 1 had lower FR ($P < 0.05$) compared to diet 2 and diet 3. There were no ($P > 0.05$) collection period x dietary treatment interactions. There were no differences ($P > 0.05$) in average daily bird feed intake.

Conclusion

The results demonstrated that the duration of collection period has an impact on the estimate of dietary metabolisable energy and nutrient retention coefficients.

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Nutritional evaluation of blanched *Anthonotha macrophylla* seed meal in the diet of broilers

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Application

7.5% dietary level of inclusion of blanched *Anthonotha macrophylla* seed meal replacing soya bean meal supports broiler performance at a reduced cost.

Introduction

Competition for conventional feedstuffs among man, industries and animals has led to a search for alternative materials that are cheap, with little or no processing for use in animal feed. *Anthonotha macrophylla* is widely available in the south-eastern states of Nigeria and not competed for by man or industry. It has a crude protein content of 21–27% and a metabolizable energy of about 2070 kcal/kg. However, it has been found to contain anti-nutritional factors and hence requires processing before usage (Ogwumike, 2012). The objective of this study was to determine the effect of dietary inclusion level of blanched *Anthonotha macrophylla* seed meal on the performance of broilers.

Materials and methods

A total of 120 one-week-old broiler chickens (Marshall breed) were randomly assigned to four dietary treatments, having three replicates and 10 birds per replicate in a completely randomized design. A protein-based straight diet (feeding one diet from starter to finisher) in a mash form was formulated for the birds. Diet one (0% blanched *Anthonotha macrophylla* seed meal), while diets 2–4 contained 5%, 7.5% and 10% inclusion levels of blanched *Anthonotha macrophylla* seed meal quantitatively replacing soya bean meal, respectively. Seeds were blanched by plunged into boiling water for 5 min and then into cold running water to halt the boiling process before use. Feed and water were given *ad libitum* for 56 days. Growth performance, carcass parts and organ weights were evaluated according to Scott, Nesham, Parson, and Bucknes (1969), while diet economics was calculated as described by Shonaiya, Williams, and Oni (1986). Data were analysed by ANOVA and significant means were separated using new Duncan multiple range (Duncan, 1955).

Results

Birds fed diet 3 (7.5% blanched *Anthonotha macrophylla* seed meal) had higher final live weight, weight gain and lowest FCR (Table 1). Cost/kg weight gain was improved for diets 3 and 4 over the control diet. For carcass-parts (Table 1), diet 3 had the highest value for prime parts (thigh, drumstick and breast). Organ weight did not show any significant difference ($P < 0.05$).

Conclusion

The use of 7.5% bleached *Anthonotha macrophylla* seed meal in diet of broiler chickens resulted in better feed conversion ratio, carcass weights, comparable organ weights and the least cost/weight gain and hence is the recommended inclusion level found in this study. *Anthonotha macrophylla* seed meal might provide an alternative protein source to reduce feed costs in areas where it is widely available.

Acknowledgements

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Table 1. Growth, cut parts and economics of diets of broilers fed blanched *Anthonotha macrophylla* seeds meal.

Parameters	T1 (0%)	T2 (5%)	T3 (7.5%)	T4 (10%)	SEM	p-Value
Initial weight/bird (g)	100.00	100.00	100.00	100.00	0.00	0.00
Final weight/bird (g)	1933.00^{b}	2033.00^{ab}	2133.00^{a}	2000.00^{ab}	47.87	0.09
Weight gain/bird/day (g)	37.41^{b}	39.45^{ab}	41.50^{a}	38.78^{ab}	0.98	0.09
Feed Intake/bird (g)	82.44	83.81	87.19	84.19	2.51	0.61
Feed Conversion Ratio (FCR)	2.20	2.13	2.10	2.18	0.08	0.76
Thigh/bird (%)	10.98^{b}	12.81^{ab}	13.48^{a}	10.84^{b}	0.63	0.04
Drumstick/bird (%)	10.98^{b}	12.81^{ab}	13.48^{a}	10.98^{b}	0.63	0.05
Breast-cut/bird (%)	24.38	26.77	26.98	26.50	1.034	0.33
Cost/kg weight gain/bird (N)	336.60^{a}	306.30^{ab}	295.20^{b}	299.00^{b}	10.75	0.09

^{a,b}Means within a row with different superscript differ significantly ($p < 0.05$).

Response of improved Nigerian indigenous chicken to diets containing black soldier fly meal

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Application

Partial or total replacement of fishmeal with defatted black soldier fly meal may not negatively influence the performance of dual purpose birds between 0 and 6 weeks.

Introduction

In an attempt to significantly reduce the environmental and financial cost incurred by the use of traditional protein sources such as fishmeal, there is a growing interest in alternative protein sources with high protein content and the right amino acid profile. Insects are consumed naturally by free-range chicken and wild birds on a daily basis. They have high feed conversion efficiencies and act as bio-transformers to produce larvae, pre-pupae and pupae of high nutritional value from organic wastes (Diener, Zurbrügg, & Tockner, 2009). Black soldier fly, *Hermetia illucens* (Linnaeus), can be used to recover nutrients from waste by converting organic matter into feed grade protein. Therefore, the study evaluated the influence of the dietary inclusion of Black Soldier Fly Meal (BSFM) on the performance of improved Nigerian indigenous chicken.

Materials and methods

A total of 600 birds comprising 300 *FUNAAB-Alpha* and 300 *Noiler* day-old dual purpose chicks were randomly allotted to 5 dietary treatments with 6 replicates containing 10 birds each. Five isocaloric and isonitrogenous diets comprising a control diet (basal diet with 100% fishmeal and 0% of Defatted BSFM) and basal diets with one of the four levels of inclusion of defatted BSFM (25%, 50%, 75% and 100%) as a replacement for fishmeal were prepared and fed *ad libitum*. The experiment was laid out in a 2 × 5 factorial arrangement within a randomized complete block design. The feeding trial lasted for a period of 42 days (0–6 weeks). The weekly feed intake and the body weight were monitored and recorded. From these, weight gain and feed to gain ratio were calculated. Data obtained were subjected to Analysis of Variance. Significant means at 5% confidence level were separated using Duncan's Multiple Range Test. The research procedure was approved by the Animal Care and Review Committee of the Centre of Excellence in Agricultural Development and Sustainable Environment, Federal University of Agriculture Abeokuta, Nigeria.

Results

Chicks that received the control diet (0% BSFM) and those that were fed diet with 100% BSFM inclusion had equivalent but significantly ($P < 0.05$) higher final weight and body weight gain compared to chicks fed diets with 25%, 50% and 75% BSFM inclusion. Birds in the control group had significantly ($P < 0.05$) high feed intake value which was similar to those recorded for birds that received 25% and 100% BSFM. Birds fed 75% BSFM had significantly ($P < 0.05$) better feed efficiency which is closely related to those fed control diet and 100% BSFM. However, there were no significant ($P > 0.05$) differences observed in the final weight, body weight gain, feed intake and feed conversion ratio of the two breeds evaluated for this study.

Conclusion

Birds fed diets with partial (75%BSFM) and total replacement of fish meal (100%BSFM) had similar body weight gain and feed efficiency with those fed control diet. The results of this feeding trial indicate that Defatted BSFM could be incorporated into the diet of both *FUNAAB-Alpha* and *Noiler* breeds of birds.

Table 1. Performance of chicks (0-6weeks) as influenced by the inclusion of Black Soldier Fly meal.

	BSFM level of inclusion							Breeds				
Parameters	0%	25%	50%	75%	100%	SEM	P-Value	*FUNAAB-Alpha*	*Noiler*	SEM	P-Value	Breed × Level
IBW (g)	40.00	39.35	39.80	39.56	39.60	0.658	0.967	40.01	39.32	0.416	0.244	NS
FBW (g)	547.7^{a}	465.4^{b}	473.8^{b}	486.0^{b}	537.6^{a}	12.3	0.000	517.07	487.15	7.76	0.009	NS
BWG (g)	507.7^{a}	426.0^{b}	434.0^{b}	446.5^{b}	498.0^{a}	11.8	0.000	477.06	447.83	7.44	0.008	NS
FI (g)	999.3^{a}	966.6^{a}	897.3^{b}	829.9^{c}	994.8^{a}	16.1	0.000	949.7	925.50	10.2	0.099	**
FCR	1.97^{bc}	2.28^{a}	2.07^{b}	1.87^{c}	1.99^{bc}	0.038	0.000	2.01	2.07	0.024	0.053	NS

BSFM: black soldier fly meal; IBW: initial body weight; FBW: final body weight; BWG: body weight gain; FI: feed intake; FCR: feed conversion ratio; NS: not significant at $P > 0.05$, *$0.05 > P > 0.01$, **$0.01 > P > 0.001$, ***$P < 0.001$. Means with different superscripts (a,b,c) within the same row differ significantly ($P < 0.05$).

Acknowledgements

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Efficacy of a novel xylo-oligosaccharide in supporting the performance and gut health of broilers

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Application

Use of xylanase with a xylo-oligosaccharide may modulate the cecal microbiota so have a positive effect on bird gut health.

Introduction

Exogenous xylanase is routinely used as a performance enhancer due to its role in non-starch polysaccharide degradation (Bedford, 2000; Cowieson & Masey O'Neill, 2013). However, more recently it has been suggested that xylanase may also produce xylo-oligosaccharides (XOS) *in situ*, providing a potential pre-biotic effect. This study examined the efficacy of feeding 2 XOS products, one from a novel source and a corn-derived XOS, both with and without the addition of exogenous xylanase, when compared to a control diet in broiler chicks.

Materials and methods

A total of 384 male, Ross 308 day-old broilers were placed in 48 pens with 8 birds per pen. Birds were randomly assigned experimental diets in a 3 by 2 factorial study. Treatments were: control (A), Control + 35g/T corn-derived XOS (B), Control + 35g/T novel XOS (C), Control + Xylanase (Econase XT at 16,000BXU/kg) (D), Diet B plus xylanase (E) and Diet C + xylanase (F). Diets were based on wheat soya bean meal basal designed to meet the age and strain of the bird, with phytase added to all diets at 500FTU (Quantum Blue), and fed throughout as mash. Birds and feed were weighed weekly to calculate body weight gain, FCR and feed intake. On days 7 and 42, 1 bird per pen was humanely euthanized via cervical dislocation and the caeca were removed and weighed as a pair. This study was approved by the NTU college ethics committee. Data were compared using univariate analysis to assess xylanase and XOS effects and one-way ANOVA to compare between diets where no interactions were seen, using SPSS (v24).

Results

There was no significant difference in the performance data between diets. Feed intake was also numerically increased in all the diets containing xylanase (P = 0.053). At day 21, there was no significant difference in caeca weight between treatments; however, by day 42, both the groups supplemented with XOS products and xylanase had caeca that were larger than the control, but birds supplemented with Corn XOS + Xylanase were significantly larger (P = 0.002). (Table 1)

Conclusion

In conclusion, supplementing broilers with XOS did not have a significant effect on performance. The preliminary results of this study show that XOS administered with xylanase did significantly increase caeca weight. It is possible that the microbial population of the caeca have been modulated by the addition of XOS and xylanase.

Table 1. Caeca weights and performance results.

Treatment	D21 Caeca weight (g)	D42 Caeca Weight (g)	D0-42 BWG	D42 FI	D42 FCR
Control	7.11 (0.751)	6.32 (1.286)^{b}	3021 (31.0)	4938 (49.3)	1.64 (0.019)
Corn XOS	6.41 (0.393)	6.01 (1.196)^{b}	3007 (40.2)	4864 (68.7)	1.62 (0.019)
Novel XOS	7.07 (1.033)	9.19 (1.258)^{ab}	2996 (61.5)	4967 (63.9)	1.66 (0.031)
Control + Xyl	6.62 (0.698)	9.80 (1.025)^{ab}	3003 (58.9)	5055 (95.6)	1.69 (0.052)
Corn XOS+Xyl	7.20 (1.146)	12.20 (1.146)^{a}	2985 (68.6)	4940 (85.2)	1.66 (0.049)
Novel XOS + Xyl	5.67 (0.581)	10.96 (0.869)^{ab}	3076 (58.1)	5076 (85.2)	1.65 (0.026)
XOS	0.826	0.222	0.341	0.186	0.341
Xyl	0.615	0.000	0.639	0.251	0.639
XOS*Xyl P Value	0.471	0.161	0.980	0.904	0.980

Superscript letters denote differences within columns at $P < 0.05$.

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Determining the most appropriate bones for measuring skeletal development and integrity

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Application

Researchers and practitioners assessing skeletal development via bone strength should be consistent in selecting left or right bones, noting the right tibia showed the largest differences in this study of young broilers.

Introduction

Due to their rapid growth, many birds are prone to leg disorders which reduce welfare and profits. Maintaining skeletal integrity requires careful monitoring which can be done in a number of ways (Shastak & Rodehutscord, 2013). The tibia is the most commonly used bone in broilers but may be less useful in layers (Toscano et al., 2015). The aim of this study was to investigate which is the optimal bone to use for assessing skeletal integrity in broilers.

Materials and methods

Thirty-two Ross 308 broiler chickens were fed one of two diets: 'LO PHY': 500 FTU of phytase and 'HI PHY': 1500 FTU phytase (Quantum Blue, AB Vista). A wheat-soya based basal diet meeting the requirements of the age and strain of birds was used throughout in two phases, starter crumb (d0-14) and grower pellet (d14-21). This study was approved by the NTU college ethics committee. Each treatment was fed to 8 pens each containing 10 birds. One bird per pen was euthanised at D14 and D21 and the following bones were dissected out; keel, humerus, ulna, radius, femur and tibia. Left and right bones were taken in all bones except keel, producing 11 bones in total which were stored at -20°C. Bones were de-fleshed prior to recording length, width, weight and strength. Length was measured at the greatest distance between each end of the bone and width was measured at the midpoint. Weight was measured using a 4 d.p scale. A texture analyser (TA.XT; Stable Micro Systems, Guildford) with a 3-point bend rig attachment (HDP/3PB; Stable Micro Systems, Guildford) was used to break the bones at the midpoint and record-breaking strength. Independent T-tests (IBM SPSS 24) were used to compare diets for each bone type; $p < 0.05$ was considered significant.

Results

Birds fed the HI PHY diet consistently had greater bone breaking strength than the LO PHY diet (Table 1). There were no significant differences in strength between the LO PHY and HI PHY diets in the left bones. Interestingly, while there were no significant differences at D14, there were significant differences in strength between the two diets at D21 in the right bones (Radius P = 0.003, Humerus P = 0.004, Tibia P = 0.000).

As would be expected, supplementing birds with higher doses of phytase had a significant effect on bone strength. It was an unexpected finding that the HI PHY diet showed more significant differences over the LO PHY diet in the right bones than the left bones. It may be suggested that due to biological mechanisms, the same bone at different orientations may grow at different capacities. As the birds used were of a young age, differences were more notable and at an older age, differences in growth of bone orientation become less obvious. It is a recommendation from this study to take right bones opposed to left as more significant differences were shown. Overall, the right tibia showed the largest differences.

Table 1. Comparison of bone strength in birds fed high and low phytase diets.

	LO PHY	HI PHY	P value	LO SEM	HI SEM	LO PHY	HI PHY	P value	LO SEM	HI SEM
Bone			Left					Right		
Radius	16.4309	20.8463	0.113	0.886	0.997	23.4138	33.3196	0.003	1.537	1.169
Ulna	54.4874	65.3698	0.320	2.991	2.948	62.3270	69.9396	0.484	4.476	4.032
Humerus	129.2789	137.8111	0.434	8.272	5.961	124.2333	169.2289	0.004	6.749	7.811
Femur	108.8105	139.1008	0.055	8.461	7.669	114.7480	139.4208	0.150	8.052	8.135
Tibia	68.1522	87.7808	0.086	4.075	5.356	58.5273	122.0477	0.000	3.125	4.931

p-Values show differences between diets for each bone and orientation at D21.

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Effect of two rapeseed meals with and without exogenous phytase and/or xylanase on growth performance, metabolisable energy and nutrient retention when fed to broiler chickens

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Application

Samples of rapeseed meals exposed to more heat during production tend to be more responsive to exogenous phytase supplementation compared to samples receiving less heat treatment.

Introduction

Rapeseed meal (RSM) is a potentially attractive protein source for poultry. During the standard process of RSM production, the meal is exposed to a high temperature for over an hour. Research by Newkirk, Classen, Scott, and Edney (2003) showed that reducing the heat applied during RSM production improves metabolisable energy (ME), crude protein (CP) and amino acid digestibility in broilers. The aim of the study was to compare the feeding value of two RSM produced either under standard industry conditions (ST) or processed under lower temperature (approximately 50°C) for a shorter period (approximately 30 min; M), with and without exogenous phytase and/or xylanase, when fed to broiler chickens.

Material and methods

The experiment was approved by the Harper Adams University Research Ethics Committee. Ninety-six male Ross 308 chicks were reared from 7 to 21 days of age in 48 pens (2 birds in each). Eight diets in total were fed; a basal diet (Control; C) with adequate levels of CP and ME, but lower in available P compered to breeder's recommendations (2.5 vs 4.7 g/kg diet). The C was then split into two parts and each of the two RSM samples was incorporated into a diet in mash form at 200 g/kg and fed as they were, or supplemented either with phytase (1500 FTU/kg; Quantum Blue^{TM}, AB Vista, UK; QB), xylanase (16,000 BXU/kg; Econase®, AB Vista, UK; XYL), or with both QB and XYL. Each diet was fed to six pens following randomisation. Daily feed intake (FI), weight gain (WG), feed conversion efficiency (FCE), dietary nitrogen-corrected ME (AMEn), nitrogen (NR) and fat (FR) retention coefficients were determined. The data were analysed with ANOVA, and in all instances, differences were reported as significant at $P < 0.05$.

Results

Feeding XYL improved overall FCE by 5.8% ($P < 0.01$) compared to C. There was an RSM × QB interaction as the QB

Table 1. Effect of RSM type (ST or M), Phytase (QB) and Xylanase (XYL) on feed intake (FI), weight gain (WG), feed conversion efficiency (FCE), N-corrected apparent metabolisable energy (AMEn), nitrogen (NR) and fat (FR) retention coefficients when fed to chickens from 7 to 21 days of age.

RSM	Enzyme (units/kg diet)	FI (g/b/d)	WG (g/b/d)	FCE (kg/kg)	AMEn (MJ/kg)	NR	FR
ST		65.3	42.3	0.651	12.85	0.626	0.720
M		66.9	41.7	0.631	13.05	0.650	0.720
QB	0	67.6	42.3	0.629	12.98	0.633	0.727
	1500	64.6	41.8	0.652	12.92	0.643	0.714
XYL	0	66.9	41.2	0.623	12.94	0.638	0.722
	16,000	65.2	42.9	0.659	12.96	0.638	0.718
SEM		1.28	0.68	0.0088	0.120	0.009	0.010
RSM x QB							
ST	0	64.3	41.7	0.649	12.72	0.608	0.721
ST+QB	1500	66.2	43.0	0.652	12.98	0.645	0.719
M	0	66.9	42.9	0.610	13.24	0.658	0.732
M+ QB	1500	63.0	40.5	0.652	12.86	0.641	0.709
SEM		1.81	0.96	0.0125	0.170	0.012	0.015
Probabilities							
RSM		0.195	0.511	0.125	0.244	0.059	0.988
QB		0.025	0.590	0.075	0.710	0.393	0.394
XYL		0.187	0.085	0.006	0.935	0.967	0.763
RSM x QB		<0.001	0.062	0.131	0.067	0.031	0.482

improved the FI of ST but not of the M sample ($P < 0.001$), and QB improved the NR of the ST but not of the M sample ($P < 0.05$). There were no ($P > 0.05$) QB x XYL, RSM x XYL or interactions on any parameter (not presented).

Conclusion

Although the two RSM samples were not significant in their AME or effect on growth performance in broilers, there was an interaction with added phytase that improved nitrogen retention in the high temperature produced RSM sample.

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Newkirk, R. W., Classen, H. L., Scott, T. A., & Edney, M. J. (2003). *Canadian Journal of Animal Science*, *83*, 131–139.

Xylanase, β-glucanase or xylo-oligosaccharide supplementation may improve the utilisation of carbohydrate fractions in the ileum of broilers challenged with sub-clinical coccidiosis

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Application

Xylanase, β-glucanase and xylo-oligosaccharide (XOS) may act to reduce the impact of sub-clinical coccidiosis in broilers.

Introduction

Xylanase, β-glucanase and prebiotics have been shown to reduce the lesions caused by coccidiosis (Elmusharaf, Peek, Nollet, & Beynen, 2007) and improve the growth performance of broilers infected with coccidiosis (Bozkurt et al., 2014). The aim of the current study was to investigate the effect of supplementing mixed cereal diets with xylanase, β-glucanase or XOS on growth performance, immune parameters and the flow of carbohydrate fractions in broilers challenged with coccidia.

Materials and methods

Nine hundred and sixty 1-d old male broilers (Ross 308) were allocated to 64 pens following a randomised complete block design and a 4 × 2 factorial arrangement. There were four additives (control (CON), 16,000 XU/kg xylanase (XY), 16,000 XU/kg xylanase and 16,000 BXU/kg β-glucanase (XY+BG) or 0.025% XOS) with or without coccidian challenge. All of the diets were marginally deficient in energy and protein containing 11.56MJ/kg DM of apparent metabolisable energy and 200g/kg DM of protein. This study was approved by SRUC's Animal Experiment Committee. Birds and feed were weighed on d0 and d21. On d14, the challenged group was given 12× the normal dose of coccidia vaccine and the non-challenged group was given distilled water by oral administration. On d21, two birds per pen were euthanised, caeca content and tissue samples from caecal tonsil and bursa of fabricius were collected for short-chain fatty acid (SCFA) and gene expression analysis. A further six birds per pen were euthanised and ileal digesta collected to determine the flow of carbohydrate fractions.

Results

Table 1 shows the effect of XY, XY+BG or XOS supplementation on growth performance, carbohydrate fraction flow and parameters associated with immune function. Body weight gain (BWG) was greater ($P < 0.05$) following XOS supplementation compared to CON but there were no other effects on performance. Arabinose and xylose flow were lower ($P \leq 0.001$) following XY+BG or XOS supplementation compared to CON. Propionic acid concentration was greater ($P < 0.05$) and butyric acid concentration tended to be greater ($P < 0.1$) following XOS supplementation

Table 1. The effect of additives with and without coccidian challenge on d21 BWG (g/bird), ileal flow of carbohydrate fractions (g/100g ileal digesta), caecal SCFA concentrations and the expression profile of immune-related genes.

	Challenged				Non-challenged					P-Values		
	CON	XY	XY+BG	XOS	CON	XY	XY+BG	XOS	SEM	Chal.	Add	Chal×Add
BWG	656	691	691	698	655	674	704	717	16.18	NS	0.013	NS
Ara	3.15	2.79	2.82	2.54	3.23	2.97	2.72	2.71	0.130	NS	0.001	NS
Xyl	5.54	4.35	4.58	4.37	5.26	4.87	4.40	4.63	0.215	NS	<0.001	NS
Pro (%)	1.58	1.68	2.45	2.53	1.68	1.68	1.70	2.25	0.27	NS	0.023	NS
But (%)	12.82	13.77	13.45	17.77	13.75	13.75	16.22	15.13	1.32	NS	0.096	NS
TLR21	0.63	18.67	2.33	0.39	0.92	7.57	0.65	4.96	5.86	0.043	0.005	NS
TLR4	1.70	11.39	0.82	1.17	1.40	21.45	0.79	6.42	6.93	0.049	NS	NS
IL1β	1.93	2.14	14.13	0.87	0.57	37.32	1.95	21.75	12.574	0.004	0.005	NS

CON: control; XY: xylanase alone; XY+BG: xylanase and β-glucanase; XOS: xylo-oligosaccharide; Chal: coccidia challenge; Add: additive type; Ara: arabinose flow; Xyl: xylose flow; Pro: propionic acid; But: butyric acid.

compared to CON. TLR 21 expression was upregulated ($P < 0.05$) while TLR4 expression was downregulated ($P < 0.05$) in the challenged group. TLR21 expression was upregulated ($P < 0.05$) following XY supplementation compared to the CON or XY+BG treatment. Il1β expression was downregulated ($P < 0.05$) in birds challenged with coccidiosis and upregulated ($P < 0.05$) following XY supplementation compared to CON.

Conclusion

Although the coccidia challenge had no detrimental effects, supplementing broiler diets with XY, XY+BG or XOS had similar effects on weight gain, ileal flow of carbohydrate fractions, caecal SCFA concentration and, despite the high variation, the expression profile of immune-related genes. This could suggest an increase in the fermentation of carbohydrate fractions and SCFA production by beneficial microbiota which could influence the immune system.

Acknowledgements

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The rate of starch digestion in broilers fed wheat-based diets

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Application

The rate of starch digestion differs between different wheat samples and is important in determining feeding value of wheat for broiler chickens.

Introduction

The nutritional value of wheat and variations in feeding quality have significant commercial importance as it influences efficiency and rate of broiler chicken growth. The lack of clear relationship between growth performance and characteristics of wheat such as apparent metabolisable energy (AME) indicates the need to investigate new ways of determining its nutritive value. The rate of nutrient assimilation in broilers could be an important variable in this regard. The aim of this study was to investigate whether there are differences in *in vivo* rate of starch digestion in broilers fed two wheat samples, with and without supplementation of xylanase. A previous experiment at Harper Adams University showed differences ($P < 0.05$) in growth performance of broilers (feed intake (FI), weight gain (WG)) when fed these wheat samples. A follow-up experiment was designed from the results to investigate the rate of starch digestion in broilers fed two wheat samples with similar proximate nutrients and starch contents.

Table 1. Digestion time and rate of starch digestion between different wheat-based diets[a].

	Digestion time (min)	Starch digestion rate (k_d $^{h-1}$)
Wheat		
High growth performance (Diego)	149.0	3.18
Low growth performance (Lili)	164.5	2.54
Xylanase		
–	156.8	2.85
+	156.7	2.87
SEM[b]	4.45	0.158
Significance		
Wheat	0.021	0.008
Xylanase	0.990	0.934
Wheat x Xylanase	0.330	0.138

[a]Each value represents mean of 10 replicates. [b]Standard error of the means.

Materials and methods

All procedures were approved by the Harper Adams University Research Ethics Committee. In the present experiment, two samples with the lowest (61.4, 46.7 g/b/d) and highest (68.3, 52.6 g/b/d) FI and WG, respectively, from the previous experiment were chosen to formulate diets including 670 g/kg wheat, 172 g/kg soybean meal, 99 g/kg full fat soya, and contained 19.89% CP and 12.76 AME. The diets were split into two and half of the diets were supplemented with xylanase at 16,000 BXU/kg of diet (AB Vista, Marlborough, UK), resulting in four diets. Two hundred and forty Ross 308 broilers (d 21 age) were allocated randomly to 40 raised floor pens (six birds per pen). Each diet was replicated 10 times, in a randomised complete block design and fed from 21 to 28 days. At d28, digesta from four segments of intestine (proximal jejunum (PJ), distal jejunum (DJ), proximal ileum (PI), distal ileum (DI)) were collected for starch digestion and mean retention time (MRT). Mean retention time in four segments was determined to calculate rate of starch digestion (k_d) (Weurding, Veldman, Veen, van der Aar, & Verstegen, 2001). The digestion time (t) was calculated from the sum of MRT determined in each intestinal segment. Data were statistically analysed by ANOVA using a 2 × 2 factorial design in GenStat.

Results

The digestion time varied ($P < 0.05$) from 149 to 164.5 min for the wheat with highest and lowest FI and WG, respectively (Table 1). The addition of xylanase did not influence ($P > 0.05$)

digestion time between the two wheat samples. Broilers fed the wheat sample which stimulated the higher FI had a faster (P = 0.008) rate of starch digestion (3.18 k_d $^{h-1}$) than the sample with lower FI (2.54 k_d $^{h-1}$). No interaction (P > 0.05) of xylanase with wheat was observed for rate of starch digestion.

Conclusion

In the current study, the results indicate that there were large differences (25%) in the rate of starch digestion in wheat samples, which previously varied in growth performance. In addition, the digestion time was 10% lower in broilers fed the wheat which promoted better growth rates. This *in vivo* measurement of starch digestion rate indicates one potential reason why wheat samples vary in growth performance in broiler chickens.

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Effect of graded levels of dietary *myo*-inositol and phytase supplementation on growth performance and plasma *myo*-inositol concentrations in broilers

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Application

It is important to establish the effects of supplementing broilers with free *myo*-inositol (MI) and MI released by dietary phytase on growth performance and blood plasma concentration as supplemented MI is not always positively associated with growth performance.

Introduction

The beneficial effect of dietary phytase (PHY) is not only releasing additional phosphorus but simultaneously degrading phytate, which is considered an anti-nutrient due to its negative effect on digestion and nutrient absorption in poultry. In a recent study by Sommerfeld, Künzel, Schollenberger, Kühn, and Rodehutscord (2018) it was demonstrated that feeding PHY or MI increases MI concentrations in the digesta, blood of poultry and improves gain: feed ratio, thus suggesting that MI may be a part of the beneficial effect of dietary PHY. Research by Pirgozliev, Brearley, Rose, and Mansbridge (2018), however, did not find a relationship between blood MI and growth performance of broilers. The aim of the study was to quantify the response to feeding three levels of MI and two levels of PHY to broilers on growth performance and MI concentration of blood plasma.

Table 1. The effect of dietary phytase and *myo*-inositol (MI) supplementation on feed intake (FI), average daily gain (ADG), feed conversion ratio (FCR) from day 0–21 and concentration of MI in blood plasma of broiler chickens.

Treatment factor	FI g/bird/d	ADG g/bird/d	FCR g/g	MI in plasma (nmol/mL)
Control	47.92^{b}	33.14^{bc}	1.44^{bc}	219.1^{c}
1,500 FTU/kg	47.78^{b}	33.84^{b}	1.41^{bc}	340.6^{bc}
4,500 FTU/kg	50.77^{a}	36.21^{a}	1.40^{c}	490.9^{b}
1.5 g/kg MI	47.93^{b}	32.69^{bc}	1.46^{ab}	435.5^{bc}
3.0 g/kg MI	46.96^{b}	32.39^{bc}	1.43^{bc}	490.9^{b}
30.0 g/kg MI	46.51^{b}	30.85^{c}	1.50^{a}	1933.3^{a}
SEM	0.719	0.776	0.0185	75.3
P value	0.003	<0.001	0.005	<0.001
CV %	4.7	7.4	4.1	36.5

Values with different superscripts are statistically different within columns (P < 0.05).

Materials and methods

Four hundred and eighty male Ross 308 chicks were reared from 0 to 21 days of age in 60 raised floor pens (eight birds in each). A mash basal diet, following breeder's recommendations (Aviagen Ltd, Edinburgh, UK) was produced. The study was approved by Harper Adams University Research Ethics Committee. The basal diet was then split into six parts, with each part supplemented either with two levels of PHY (1,500 or 4,500 FTU/kg; Quantum® Blue, ABVista, UK), or with three levels of MI at 1.5 g/kg, 3 g/kg or 30 g/kg, with one part left un-supplemented as a control (C), resulting in six diets in total. Each diet was fed to 10 pens following randomisation. Feed intake (FI) and daily weight gain (ADG) were determined on a pen basis and adjusted for mortality. At day 21, one bird per pen was stunned and blood collected from vena jugularis in lithium heparinised tubes. Concentration of MI in blood plasma was determined by HPLC. Data were analyzed using analysis of variance in GenStat® (18th edition), differences were reported as significant at P < 0.05.

Results

The performance level, in general, was below the breed standard which might be explained by the feeding of mash diets. Feeding the highest dosage of PHY improved FI (P < 0.01) and ADG (P < 0.01) compared to other treatments. The feed efficiency of birds fed 30 g/kg MI was the poorest although blood MI concentration was the highest (P < 0.001) compared to the other treatments. Blood plasma MI was increased by MI at 30 g/kg and PHY at 4,500 FTU.

Conclusion

Supplementing diets with a high dosage of PHY but not MI improved the growth performance of the birds. Blood plasma MI concentration did not correlate with growth performance in this study. It may be that MI levels in plasma vary with basal diet formulation and with time and that there is a threshold beyond which performance suffers, all of which warrants further investigation.

Acknowledgements

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Sensitivity of resilience to amino acid nutrition: reassessing the ideal protein concept?

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Application

Whilst existing evidence supports the view that selected amino acid supplementation improves the performance of broiler under sub-clinical challenge, data available from 11 published papers on the effect of amino acid supplementation to broiler performance with or without challenges cannot yet conclude that this necessitates reassessment of the ideal protein concept.

Introduction

The ideal protein (IP) concept, where a fix ratio between digestible lysine and other amino acids (AA) is assumed, results in rations in which AA supply more closely match AA demand. Together with synthetic AA, this allows dietary crude protein (CP) levels to reduce, and nitrogen efficiency to increase. The IP concept derived from studies where disease would have been carefully avoided. However, if sub-clinical disease selectively reduces AA digestibility and/or increase AA demand, for e.g immune responses, then different dietary AA ratios may be required for optimised performance under challenge (resilience). A literature review was undertaken for evidence that broiler resilience is sensitive to AA supply, i.e. that the magnitude of production response to AA supplementation is greater in challenged than in non-challenged birds.

Materials and methods

We identified 11 papers where broilers were either challenged or remained unchallenged and fed varying levels of selected AA. Data from four representative studies are summarized here. Impact on body weight gain (BWG) and feed efficiency (FE) shown relative to that of unchallenged birds at the lowest AA level used, and their original values shown as footnote.

Results

Table 1 shows that increasing dietary threonine (Thr) in the presence of challenge resulted in greater improvement of both BGW and FE than in the absence of challenge (Kidd et al., 2003; Star, Rovers, Corrent, & Van der Klis, 2012). Arginine (Arg) is the sole source for nitric oxide synthesis in immune responses, and an increase dietary Arg during disease challenge resulted in greater response in BWG than in unchallenged birds (Tan, Guo, Applegate, Du, & Zhao, 2015). The conditionally essential AA glutamine (Gln) has been implicated in ameliorating bacterial infections, and an increase in dietary Gln similarly improved performance of both unchallenged birds and birds challenged with *Salmonella* (Fasina, Bowers, Hess, & McKee, 2010).

Conclusion

This literature review indicates that supplementation of selected AA has variable effects on resilience. However, none of the 11 available studies support the view that supplementation of such AA in isolation or combination to rations already formulated to IP would have similar outcomes. Therefore, AA supplementation studies to unchallenged and challenged birds using IP as the starting point are

Table 1. Relative impact of AA supply on resilience (body weight gain (BWG) and feed efficiency (FE) under challenge).

		Amino acid		BWG (%)		FE (%)		
Challenge	Age (d)	Type	Level (%)	UNC	C	UNC	C	References
Re-used litter	42–56	Thr	0.45	100[a]	95	100[b]	87	Kidd et al. (2003)
			0.80	132	154	122	134	
Eimeria and *C. perfringens*	9–37	Thr	0.63	100[c]	83	100[d]	100	Star et al. (2012)
			0.67	99	89	99	102	Star et al. (2012)
Infectious bursal disease virus	1–42	Arg	0.95	100[e]	104	100[f]	100	Tan et al. (2015)
			2.36	104	115	112	110	
Salmonellosis	1-14	Gln	3.33	100[g]	94	100[h]	100	Fasina et al. (2010)
			4.19	110	97	103	105	

UNC: unchallenged; C: challenged; [a]59 g, [b]0.32 g/g, [c]2129 g, [d]0.596 g/g, [e]1690 g, [f]0.49 g/g, [g]319 g, [h]0.77 g/g.

required to assess whether the IP concept indeed needs to be adapted to account for the impact of sub-clinical challenge on broiler performance.

Acknowledgements

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Comparison of genetic and feed induced differences in growth rate on the expression of growth hormone and thyroid-stimulating hormone beta genes in the chicken pituitary

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Application

Understanding the physiology of the control of growth and food intake in broiler breeders is required in order to tackle the broiler breeder paradox and understand the factors controlling the efficiency of meat production. The study aims to help explain how growth and food intake is regulated in chickens and how food restriction and genetic sex affect the signals from the feeding centre in the brain.

Introduction

To increase feed conversion efficiency and profit margins, broiler chickens are selected for fast muscle growth and have a high voluntary feed intake. These traits, however, are problematic in broiler breeders (Decuypere et al., 2010). The broiler breeder paradox occurs because the necessary practices to ensure acceptable reproduction and health may impair animal welfare. In this study, the hypothesis that the expression of Growth Hormone (GH) and Thyroid Stimulating Hormone Beta (TSHβ), genes known to have effects on metabolism and growth, is regulated in situations where the growth rate of animals is changed, either due to feed restriction or genetics is tested.

Materials and methods

Complementary DNA (cDNA) from two experiments was analysed. In experiment 1, pituitary tissue was obtained from two groups (n = 21 per group) of broiler breeder hens (Ross 308 line). At 6 weeks of age, one group continued on the recommended restricted diet (R) while the other was given *ad libitum* access to food (AL). All hens were killed at 12 weeks of age. In experiment 2, pituitary tissue from 12-week-old males and females (Ross 308) subjected for the final 2.5 days to AL, R and AL feeding with 15% w/w ispaghula husk (IH) (n ≈ 24 per group) was obtained. Gene expression of pituitary GH and TSHβ was measured using real-time PCR. A weighted mean of three housekeeping genes was used for normalisation. Data were analysed by unbalanced ANOVA (Genstat v13.0) and replication was achieved over time. Experiments were carried out under the Animals (Scientific Procedures) Act 1986, project license 70/7909.

Results

For experiment 1, there was no significant difference between treatment groups in the expression of pituitary GH. Expression of TSHβ was greater in AL than R birds (11.4 fold, $P = 0.016$) but the difference was not significant ($P = 0.186$) when the data were normalised. There was a clear difference in GH expression in experiment 2 ($P < 0.001$) with GH expression higher in the FR group whether normalised or not (2 and 2.7 fold for FR and IH groups, respectively, compared to AL). TSHβ expression was again significantly higher in the AL group (1.37 and 1.7 fold of FR and IH, respectively) without normalisation, but not when normalised. A pronounced sex difference in gene expression was observed in experiment 2; GH expression was significantly higher (2 fold) in males compared with females ($P < 0.001$) while TSHβ was significantly higher (1.4 fold) in females compared with males ($P = 0.004$). Housekeeping genes differed significantly with higher expression in AL groups reflecting overall increased expression.

Conclusion

Although the results show that GH expression was lower after acute removal of feed restriction, the most striking result is that GH and TSHβ gene expression was sexually dimorphic. Males grow faster than females and the authors have also shown in the same experiment that they have a higher hypothalamic expression of orexigenic AGRP (Caughey et al., 2018) which mediates

control of metabolism. In this study, males had higher GH expression with lower TSHβ gene expression while the opposite occurred in females. GH expression may well reflect the genetic potential of the male and its AGRP levels. The decrease in TSHβ may be explained by the increase in GH causing an increase in T3, so reducing TSHβ due to negative feedback (Buonomo & Baile, 1986). Research investigating the relationship between AGRP and pituitary hormone expression is required to better understand how genetic factors including sex differences affect signals from the feeding centre in the brain to control growth.

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Relationship between dietary wheat characteristics and jejunal gene expression in broilers

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Application

Wheat characteristics affect gut function of broilers and this information informs plant breeders for future feed wheat cultivars selection.

Introduction

Wheat is the main cereal in broiler grower and finisher diets in the UK and many European countries. Understanding the reasons why the growth response of broilers differs with different wheat samples is commercially important and subject of ongoing research. The gastrointestinal tract of broilers plays a key role in the digestion and absorption of nutrients and understanding of its proper function is essential for efficient broiler growth. The satiety signals are generated in response to nutrient contents and physical presence of feed or specific feed component in the gut. The literature on the expression of genes associated with gut function (occludin, mucin) and appetite regulation (peptide YY) in broilers fed wheat-based diets is limited. The aim of this study was to investigate the relationship between wheat characteristics and jejunal gene expressions in broilers fed wheat-based diets.

Materials and methods

All procedures were approved by the Harper Adams University Research Ethics Committee. Seventeen wheat samples were analysed for chemical composition and quality characteristics. Seventeen iso-nitrogenous diets were formulated, all of which included the wheat sample at 670 g/kg and 330 g/kg of a balancer. Six hundred and eighty Ross 308 male chicks at day one were allocated to 136 floor pens (5 birds in each pen). Each diet was replicated eight times, in a randomised complete block design. Birds were fed *ad libitum* one of the 17 experimental mash diets from 0 to 7d and pelleted diets from 7 to 21d of age. At 21d of age, one bird from each pen, with a body weight nearest to the pen average weight, was stunned and killed by cervical dislocation and a sample from the mid-jejunal section of the small intestine was excised for determination of gene expression. The relative expression (copies/reaction) of occludin (OCLN), mucin 2 (MUC2) and peptide YY (PYY) genes were quantified in 10 µl reactions (containing 2 µl cDNA) by RT-qPCR. Data were statistically compared by randomised block ANOVA. Pearson correlation coefficients were determined between wheat characteristics, broiler growth performance and log10 values of studied genes.

Table 1. Relationship between wheat characteristics, growth and jejunal gene expression in broilers.

	Ash	NSPins*	HFN**	FCR	AME	OCLN	MUC2
Ash	1						
NSPins	0.425	1					
HFN	−0.032	−0.487	1				
FCR	0.044	−0.128	0.294	1			
AME	−0.512	−0.466	0.091	0.164	1		
OCLN	**0.518**	**0.542**	**−0.672**	−0.070	−0.458	1	
MUC2	0.446	0.387	**−0.617**	−0.090	−0.292	**0.877**	1
PYY	0.061	0.189	−0.315	0.436	−0.188	0.339	0.114

*Insoluble NSP, **Hagberg falling number. Significant correlations are highlighted in bold.

Results

The content of insoluble NSP and ash in wheat samples ranged from 63.7 to 80.2 g/kg DM (CV = 5.3%) and 12.8 to 19.6 g/kg DM (CV = 9.9%), respectively. There were differences ($P < 0.05$) in expression of OCLN, MUC2 and PYY between different wheat samples. There was a positive correlation ($P < 0.05$; $r = 0.542$) between OCLN and insoluble NSP (Table 1). The log10 expression of OCLN and MUC2 was negatively correlated ($P < 0.01$, $r = -0.672$, -0.617, respectively) with Hagberg falling number (HFN) of wheat samples. The expression of OCLN was positively correlated ($P < 0.05$, $r = 0.518$) with ash content of wheat. There was a tendency of positive correlation ($P < 0.10$, $r = 0.436$) between PYY and FCR.

Conclusion

It is apparent from the results of this study that a complex and dynamic response of jejunal gene expression in broilers fed different wheat samples may be due to variation in wheat characteristics. Significant relationship between insoluble NSP, ash content and tight junction protein occludin in broilers may be due to variation between wheat samples. Further research is warranted to investigate the wheat characteristics and its relationship with the genes associated with gut function in broilers.

Is pathogen-induced anorexia in *Eimeria maxima* infected broilers influenced by dietary crude protein content?

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Application

The experiment has implications on what kind of feeds birds infected with coccidia, the most common poultry parasite, should be given access to. This may allow more effective control of the consequences of parasitism.

Introduction

Pathogen-induced anorexia (a voluntary reduction in feed intake; FI) is a common consequence of parasitic infection. The hypothesis that coccidia induced anorexia is sensitive to dietary crude protein (CP) supply was addressed in this study. Resistance to gastrointestinal parasitic infections has been shown to increase with dietary CP level (Coop & Kyriazakis, 1999). We hypothesised that the duration and extent of anorexia (the greatest reduction in FI) would be reduced at increasing levels of CP supply, due to improved resistance to coccidiosis.

Materials and methods

Procedures were conducted under the UK Animals (Scientific Procedures) Act 1986, EU Directive for animal experiments, and Home Office. Four-hundred and eighty male Ross 308 D-old broilers were distributed into 48 pens and offered a common starter diet until D8 of age. Four iso-energetic, fine mash diets were formulated with graded levels of CP (12%, 16%, 20%, 24%) and similar essential amino acid ratios to CP content. Feeds were gradually changed over from D8 until D10, when birds were switched from a common starter diet to the experimental feeds. At D13 (D0 post-infection; pi) half of the pens were orally inoculated with 0 (C), or 7,000 sporulated *E. maxima* oocysts (I). FI was measured daily and BW every 3 days until D15pi. Faeces were collected from D5pi until D11pi to measure oocysts per gram of faeces (OPG) to assess resistance. Daily CP intake (CPI) and FI were expressed relative to the estimated daily BW (rCPI and rFI, respectively). Daily absolute and relative FI and

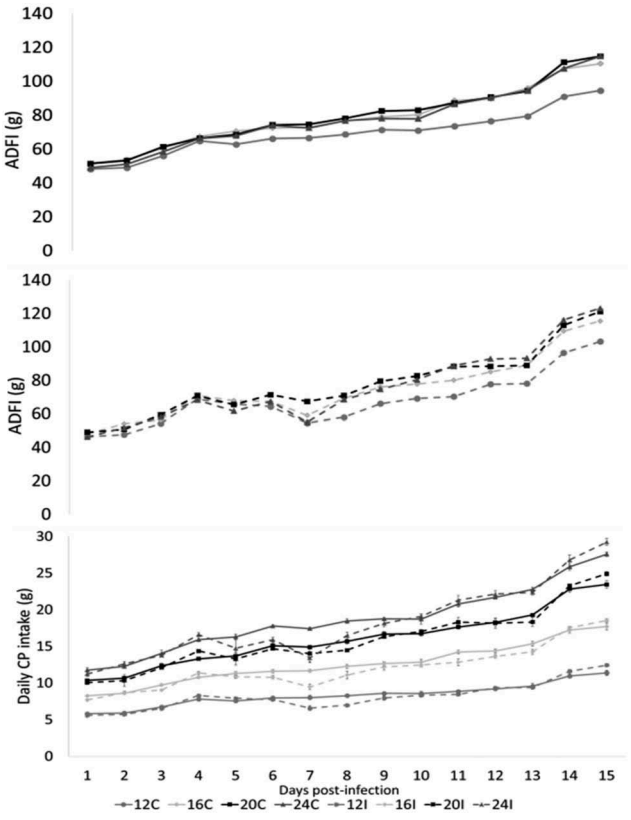

Figure 1. ADFI (g/d) over the post-infection period of uninfected (C) broilers (Figure 1a), or broilers infected with (I) 7 × 103 sporulated *E. maxima* oocysts (Figure 1b) fed one of four feeds differing in CP (d0-15pi). Figure 1c. CPI (g/d) over the post-infection period of C and I broilers fed one of four feeds differing in CP (d0-15pi).

CPI data were analysed by an ANOVA, with feed and infection as factors and their interaction.

Results

Reducing dietary CP level in the feed significantly reduced average daily gain (ADG) throughout the experiment ($P < 0.05$). At increasing levels of dietary CP supply, both absolute and rCPI increased throughout the trial ($P < 0.05$). FI gradually increased at increasing dietary CP up to 20%, whilst it was significantly lower at 24% ($P < 0.05$). However, rFI decreased as dietary CP was increased ($P < 0.05$). Infection significantly reduced both FI (Figure 1a, 1b) and CPI (Figure 1c) and rFI and rCPI over D5-8pi ($P < 0.05$). Feed and infection did not interact for FI, rFI or rCPI throughout the experiment ($P < 0.05$), but significantly interacted for CPI on D6pi ($P < 0.05$); the extent of anorexia was highest for birds on the 24% treatment. Furthermore, on D9pi birds offered 12% CP produced significantly more OPG, compared with birds offered 20% ($P < 0.05$). However, there were no significant differences in OPG excretion during the rest of the experiment ($P < 0.05$).

Conclusions

Contrary to our hypothesis, the duration of anorexia was not sensitive to dietary CP content. However, when comparing CPI, the results suggest that birds fed high CP diets suffered a greater extent of anorexia. OPG results showed that resistance is reduced at low CP levels, but this was unrelated to the characteristics of anorexia.

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Salmonella Typhimurium exposure improves growth and performance of male Ross 308 broilers

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Application

Salmonella Typhimurium orally administered to 8-day-old broilers initially depressed growth performance; however, weight gain and FCR were superior in the infected birds from day 28 onwards.

Introduction

Salmonella in poultry is of significant interest to producers due to the potential negative impacts on human health. Much of the published work has investigated methods to reduce exposure, colonisation and spread of *Salmonella* sp with little published on the effects on bird performance. This experiment measured the impact of *Salmonella* Typhimurium serotype 135A exposure on the performance of Ross 308 male broilers as well as the levels of the bacteria in the caeca of the birds at 7 and 27 days post-exposure in a controlled environment.

Materials and methods

A total of 1200 Ross 308 male broilers were obtained from a commercial hatchery (Turiosi, Fiveways, VIC, Australia), weighed and randomly allocated to deep litter pens at the Ridley Poultry Research Centre (Tyabb, VIC, Australia). Treatments (± *Salmonella* exposure) were allocated in two blocks to prevent *Salmonella* cross-contamination containing 24 replicates per block, as per a previous protocol study. Feed and water were provided *ad-libitum* and the birds were housed according to the recommended Aviagen guidelines for temperature and humidity throughout the experiment. Diets were formulated to meet or exceed the nutrient recommendations. Mortality was recorded daily; individual body weights and feed consumption were recorded weekly. One block of birds was orally administered *Salmonella* Typhimurium serotype 135A at a rate of 10^9 cfu/mL*0.5 mL per bird at day 8, the *Salmonella* negative treatments were administered 0.5 mL of a *Salmonella* negative control broth. Pooled caecal content samples were taken from two birds per pen at day 7 (pre-treatment), day 15 (7 days post-treatment) and day 34 (27 days post-treatment) for *Salmonella* quantification through qPCR analysis.

Results

Birds exposed to *S.* Typhimurium serotype 135A at day 8 showed depressed growth at day 14 compared to the control group (Table 1) with no significant differences in mortality. However, birds exposed to S. Typhimurium 135A showed no difference in body weight gain or FCR at day 21. The birds exposed to *S.* Typhimurium serotype 135A showed improved

Table 1. Broiler performance data post *Salmonella* exposure.

	Age	*Salmonella* Control	*Salmonella* Challenge	P-Value
Body Weight Gain (grams)	Day 14	473[a]	443[b]	0.002
	Day 21	1058	1076	N.S.
	Day 28	1819[b]	1879[a]	0.002
	Day 34	2568[b]	2630[a]	0.004
Feed Conversion Ratio	Day 14	1.281[b]	1.373[a]	0.006
	Day 21	1.319	1.305	N.S.
	Day 28	1.392[a]	1.355[b]	0.01
	Day 34	1.445[a]	1.413[b]	0.016

performance from day 28 onwards. *Salmonella* exposure was successful as measured through qPCR. No *S.* Typhimurium serotype 135A was detected in the caeca at day 7. Birds exposed to *Salmonella* had a significantly higher level of 5.84 Log_{10} 16S copies/g compared to the control group at 0.34 Log_{10} 16S copies/g 7 days post-exposure. Both treatment groups displayed decreased *Salmonella* numbers to nearly 0 at day 34, a finding similar to those of Marcq, Cox, Szalo, Théwis, and Beckers (2011). Low positive results in control group likely due to cross-contamination between treatments; however, this does not impact on result significance for analysis.

Conclusion

The oral administration of *S.* Typhimurium serotype 135A at day 8 improved feed efficiency and final weight at day 28 and 34 after an initial depression in the first 6 days. This indicates that despite an initial setback in post-exposure performance there is the potential for broiler chickens to exhibit compensatory growth post-recovery from the infection.

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Industry-level training-programme design requires inputs from research findings that deliver both novel technologies and innovative husbandry approaches

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Application

Production level training programmes will benefit from improved targeting of science research toward training needs.

Introduction

Training and career development courses are a major route for technology and knowledge transfer in the animal and poultry industries. Livestock production training courses delivered by the industry sectors themselves crave a flow of *relevant* new ideas from the research and development communities. However, funding streams rarely target this need directly and are inherently unsympathetic to the needs of training course providers whose purpose is to improve production efficiency and profit.

Materials and methods

Feedback from 713 attendees at 29 international training courses delivered to the poultry industry over the period of 2013–2018 by a major breeding company (Aviagen Ltd, UK), whilst confirming the satisfactory nature of the courses themselves, has highlighted problems in the transfer from the research base of usable messages appropriate for the wide spectrum of technology through to husbandry that is required for industry training courses.

Results

The author's team has experienced a clear tendency for training course appreciation in the advanced livestock industries to relate more to up-skilling in the new hard technologies such as systems control, rather than to re-skilling in the (equally as important) traditional softer sciences such as the understanding of human/animal interactions (or stockmanship) for optimum animal care. Unfortunately, animal behaviour and welfare research is often perceived by industry practitioners as the driver for legislative imposition of regulations, constraining new technologies as they are seen as instrumental in prejudicing proper animal care. For industry-level operatives on production units to deliver the appropriate synthesis of new ideas, training courses must simultaneously deliver *all* the interacting elements. This has been found to be a particularly taxing concept for trainers because both knowledge flow coming forward and trainee interest are skewed toward novel hard technologies (often product-based), and skewed away from the more difficult (usually experience and knowledge-based) concepts of animal care. In brief, those that are being trained tend to give more enthusiastic feedback to their training when it delivers new systems, products and management tools. Trainees are less enthusiastic to receive exhortations to commit to improvements in husbandry skill levels. As trainers are judged on feedback, there is a likelihood of a reduction in the intensity of training in the essential elements of animal care. Genetic progress and advances in management technologies (such as in poultry house environmental monitoring systems, feeding, and processing) tend to make livestock carers less aware of the basics of good bird husbandry. Those parts of training programmes that are involved in human/animal interactions are more difficult to deliver than those transferring novel technologies. Trainers find it is inherently more difficult to convince trainees that improvements in husbandry are relevant, exciting and rewarding both personally and to the animals being managed. Different trainer approaches and different trainee attitudes are required if a clear understanding is to be obtained of the two different sorts of training; up-skilling (usually of exciting new technologies) and re-skilling (usually of already known – albeit inadequately applied – elements of animal care). Guidances as to how this may be achieved are scarce. While efficiency improvements at

industry production level through the implementation of new technological systems are readily measured, there is little hard empirical evidence on the profit benefits of improved husbandry; were such available, research funding into farm animal husbanding might be more forthcoming.

Conclusion

The importance of hard technologies in the operation of the poultry industry over recent years has resulted in a reduction in the traditional emphasis upon husbandry skills, as a vital component of an efficient and profitable business. Materials presented in training courses have reflected this trend which has been exacerbated by the difficulty of sourcing from the science base exciting new pro-farming messages that address the human/animal interface (animal husbandry). There remains the underlying issue for trainers that up-skilling in the more effective use of purchasable products yields not only profit rewards, but also trainer popularity. Neither case applies for course content dealing with re-skilling through the re-visiting of existing husbandry knowledge. There is a need for a balanced flow from research science of both new technologies and exciting novel methodologies toward better husbandry. This can only be achieved by a joint approach, from both industry and research.

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Is there a difference in the brain centres controlling feed intake between qualitative and quantitative feed restriction in the broiler breeder?

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Application

Qualitative feed restriction for broiler breeders has apparent benefits in reducing the need for quantitative feed restriction. Whilst qualitatively restricted diets clearly produce gut fill and achieve the desired growth curve, there is no evidence that they change the central neurons that drive feed intake. Alternative methods than measuring the central drivers of feed intake will be required to assess if these diets deliver the welfare improvements expected.

Introduction

In broiler breeder hens, food restriction improves reproduction and health but increases hunger. We are interested in understanding the way that food intake is controlled to try to tackle this 'broiler breeder paradox'. One approach has been diets diluted with fibre that are believed to have behavioural benefits. AGRP neurones in the hypothalamus of broiler breeder chickens are sensitive to feeding history, the expression of AGRP and NPY increasing when feed intake is reduced (Dunn et al., 2013). We hypothesised that when diets were diluted with fibre and fed iso-energetic with the usual ration to maintain the target growth curves, the expression of orexigenic AGRP and the anorectic gene, POMC would not differ from quantitatively restricted hens, despite the fact that the hens 'voluntarily' grew to a growth trajectory the same as quantitatively fed hens. In other words, although the hens were eating *ad libitum*, the orexigenic neurones in the brain would not be 'fooled'.

Materials and methods

Broiler breeder hens were reared on a standard restriction to 6 weeks of age when they were assigned randomly to four replicated treatment groups (n = 24 per group): continued standard restriction on a typical commercial diet (R), the same diet with 20% (OH20) or 40% oat hulls (OH40) added to attain the usual growth curve combined with an increase in quantity, finally one treatment was released to *ad-libitum* feeding with the commercial diet (AL). Hens were killed at 12 weeks of age and the hypothalamus containing the orexigenic and anorectic peptide expressing neurones was collected for measurement of gene expression by RT-PCR. Experiments were carried out under the Animals (Scientific Procedures) Act 1986, project license 70/7909. Statistics were performed using linear mixed models (Genstat).

Results

The body mass on the quantitatively (R) and qualitatively restricted diets (OH20&40) were similar ($P > 0.05$) whilst as expected the AL hens had a higher mass ($P < 0.001$, R, 1324 ± 20 g; OH20, 1312 ± 22 g; OH40, 1349 ± 16 g; AL, 2851 ± 75 g). As anticipated, there was a highly significant ($P < 0.001$) effect of diet on AGRP expression with R, OH20 and OH40 being ~10 fold greater than AL hens. There was no significant difference within the restricted hens ($P > 0.970$, R, 0.50 ± 0.05; OH20, 0.55 ± 0.06; OH40, 0.47 ± 0.06; AL, 0.05 ± 0.01). In contrast, but as observed previously, there was no statistically significant effect of diet on POMC expression ($P = 0.330$, R, 165 ± 49; OH20, 157 ± 29; OH40, 137 ± 24; AL, 204 ± 38; $P = 0.324$).

Conclusion

The results indicate that although the OH20 and OH40 diet allowed physically larger rations to be fed, there were no differences compared to the quantitatively restricted animals in the orexigenic gene expression in the brain. A similar result was observed in an acute comparison of qualitative and quantitative restrictions. As has been observed previously, the anorexigenic gene expression does not change with diet treatment. The diets do show benefits in allowing closer to *ad-libitum* feeding. However, different methods, including behavioural assessment and measurements of how gut fill inhibits intake, will be required to understand the mechanism of their welfare benefits.

Acknowledgements

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Phytogenic benefits on growth performance on clean and re-used litter for broilers

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Application

Phytogenic additives have great potential to increase broiler resilience to litter derived sub-clinical challenges.

Introduction

A number of phytogenic feed additives are being developed as alternatives to in-feed antibiotics (Upadhaya & Kim, 2017; Yitbarek, 2015), and aim to improve host resilience, which can be defined as the ability to perform under challenge. Such phytogenic includes Biostrong 510®, which contains a proprietary blend of plant extracts such as essential oils, bitter substances, pungent substances, and saponins (Buchanan et al., 2008). To quantify the impact on resilience, interventions ought to be tested in the presence and absence of challenge, where it is then hypothesised that the magnitude of response to the intervention is greater in the presence of challenge. Here we tested the effect of Biostrong 510® on resilience of broilers to challenge arising from re-used litter, as a model to mimic the generally greater level of challenge under field situations.

Material and methods

As part of a larger investigation, a total of 576 Ross 308 day-old male broilers were allocated to wheat-soybean meal-based rations with per tonne 150 g Biostrong 510® via 1 kg carrier premix added or carrier only (control), and were placed on fresh bedding without (clean) or with 2 kg one-month-old litter from a previous flock (re-used). Each diet-litter treatment combination had 12 pens and 12 birds per pen in a randomized block design. Birds were fed *ad libitum* starter (0-10d; crumbs), grower (10-25d; pellets) and finisher (25-35d; pellets) rations, formulated to meet Ross 308 requirements. Body weight, feed offered and feed refusals were recorded at post-hatch (d0), d10, d25 and d35. Mortality was recorded as and when occurred, bird body weight gain (WG), and hen-day-corrected average feed intake (FI) and feed conversion ratio (FI/WG). Mortality was arc-sin transformed prior to statistical analysis. Data were analysed via analysis of variance, with orthogonal contrast locating Biostrong 510®, litter and interaction effects.

Results

Table 1 shows that the treatments did not affect feed intake but that diet and litter interacted for weight gain and FCR. An additional set of contrast statements showed that the addition of Biostrong 510® increased weight gain by 7.8% and reduced FCR by 4.3% in the presence of re-used litter ($P < 0.001$), whilst these figures

Table 1. Effects of phytogenics (Biostrong 510®) on growth performance and mortality of broilers placed on clean or re-used litter.

Treatments		Growth performance			Mortality	
Litter	Diet	FI (g)	WG (g)	FCR (g/g)	Arc-sin transformed	Arithmetic mean (%)
Clean	Control	3,078	2,173	1.417	0.181	5.56
	Biostrong 510®	3,091	2,230	1.386	0.133	4.17
Re-used	Control	3,035	2,123	1.430	0.049	1.39
	Biostrong 510®	3,133	2,289	1.368	0.141	4.86
	s.e.d.	61	41	0.012	0.069	-
P-values						
Diet		0.202	<.001	<.001	0.656	-
Litter		0.993	0.882	0.793	0.207	-
Diet × litter		0.336	0.059	0.071	0.151	-

averaged 2.6% (P = 0.164) and 2.2% (P = 0.010) for broilers placed on clean litter. Both diet and litter treatments did not impact on mortality, suggesting challenge from re-used litter was sub-clinical at best.

Conclusions

This data demonstrates the principle of testing nutritional interventions for their impact on broiler resilience, and as such support the view that the expected benefits of phytogenic feed additives on broiler performance, as demonstrated here for Biostrong 510®, are greater when birds are exposed to some degree of (sub-clinical) challenge.

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Smarter systems for livestock production: challenges and opportunities for integrating technology into practice

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Technological innovations in agriculture have opened up a range of capabilities that help to increase production and efficiency in everyday processes through the observation and recording of data. A vast array of developed and developing sensor and response technologies continue to advance our monitoring capabilities, with robotics moving us towards a more automated and semi-automated future for agricultural practice. The advent of greater connectivity and integration technologies through Internet of Things (IoT) opens up the capacity to achieve greater oversight, control and potential efficiency savings through the generation of large-scale databanks for data analytics, machine intelligence, forecasting and intervention. The application of advances from the financial technology sector (such as blockchain) offers enormous potential for food safety and traceability.

Forecasted Compound Annual Growth Rates (CAGR) 2014–2020 for precision farming are 15% in Europe, 5% in USA, 20% in South America and 21% in Asia and the rest of the world (Statista.com), and expected global market size is predicted to grow from 13.74 billion US dollars to 26.74 billion US dollars by 2020 (Statista.com). Despite this, the integration of technology into practice in livestock production is patchy. This is likely to be linked to a number of specific issues that face the livestock industries that make technology development and integration more challenging. These challenges are both biological and non-biological in nature. For instance, different environmental challenges exist in both indoor and outdoor systems; the focal target for measurement – the animal – is generally not stationary. Socially, the culture for innovation plays a large role and end-user co-development is critical to later phase translation.

In this presentation, the key challenges and future opportunities from up-and-coming technologies currently in development with potential for application to the livestock sector will be explored. The broad range of technologies developed to date, what makes a success story for technology integration, and what the main pitfalls to avoid are for an early phase development project will also be discussed. Finally, how the integration of technology could potentially allow a more intimate understanding of the complex systems in which farming takes place will be considered, with deliberation on the broader social and natural landscapes.

Single- and multi-tier housing systems for free-range laying hens: effects on production and welfare

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Application

Internal housing structures for laying hens vary, but multi-tier is growing in popularity in the free-range sector. This work showcases the pros and cons of multi-tier and single-tier sheds, both in terms of production and welfare, which may help egg producers with decision-making during investment in new or refurbished poultry sheds.

Introduction

The UK has a large free-range egg market, with 52% of eggs produced in free-range systems in the third quarter of 2018 (Defra, 2018). To meet this demand, many producers are installing multi-tier internal structures to free-range sheds, which can house more hens than an equivalently sized shed using a single-tier structure (also known as 'flat deck'). However, production and welfare between these two shed types may differ. This study examined egg production, mortality, and a range of welfare measures in commercial free-range flocks of laying hens in Wales, Scotland, Northern Ireland and England that were housed in either multi-tier (MT) or flat-deck (FD) sheds.

Materials and methods

Flocks of free-range hens housed in either MT (n = 17) or FD (n = 25) sheds were visited once at 69–90 weeks (mean 74 weeks). Replicate numbers were based on previous research in which similar measures were taken. Some farms provided more than one shed for the study. Historical data on egg production, floor eggs, seconds, and mortality were gathered for 30, 50, 60 and 70 (or 69) weeks of age. During the visit, feather scores (as a proxy measure for feather pecking, scored on an ordinal scale, 0–5, where 0 is perfect, 5 is denuded), keel bone damage (bone fracture and shape deviations) and foot pad dermatitis (both binary scored as absent = 0 or present = 1) data were collected from up to five hens, each at four zones (1–4) within the house and two zones (5–6) on the range (≤5 m and >5 m from shed). Data were transformed where necessary to produce normal distributions. Flock-level data and feather score data were analysed by linear mixed models (LMMs); keel damage and foot score data were analysed by generalised LMMs, all in Genstat v16.1. Fixed effects included shed type (MT or FD), zone, shed age, hen breed, flock size, and bird age (where relevant); random effects included farm and shed i.d., and individual bird (where relevant). Results shown are original mean values and standard deviation (SD). This survey-style study was approved by the Scottish Government and by SRUC's AWERB.

Results

Egg production was marginally insignificant (P = 0.057) between the two systems (at 70 weeks: MT 83.7%, 3.8% SD; FD 79.4%, 7.5% SD) but could be financially important. Floor eggs and seconds did not differ (P > 0.05) with system either (means across ages, floor eggs: MT 2.3%, 2.7% SD; FD 1.9%, 2.4% SD, seconds: MT 2.2%, 1.7% SD; FD 2.4%, 2.1% SD). Variation in mortality figures was high (range at 70 weeks, MT 1.9–10.1%; FD 1–27.5%) so although mean mortality at 70 weeks was 1.5 times higher in FD than MT, there was no significant difference (P = 0.19, MT 4.8%, 2.3% SD; FD 7.5%, 6.4% SD) between shed types. Feather scores were low in hens from either shed type (MT 0.89, SD 0.40; FD 0.74, SD 0.49) and did not differ (P = 0.53), but were affected by zone, with hens furthest from the house (zone 6) having better feather cover than those inside (zones 1–4) (P < 0.001) (data not shown). Both keel bone fracture (MT 0.48, 0.50 SD; FD 0.28, 0.45 SD) and deviation (MT 0.07, 0.26 SD; FD 0.03, 0.18 SD) prevalence were significantly higher in hens housed in MT than FD sheds (P < 0.001; P = 0.014, respectively). Foot pad dermatitis prevalence was low in hens from both shed types (MT 0.04, 0.22 SD; FD 0.03, 0.17 SD) and did not differ (P = 0.63).

Conclusion

Due to high variation, many measures did not differ significantly. However, there may be financial implications to slightly better egg production and lower mortality in MT sheds. The main welfare outcome was that hens housed in MT sheds have a higher risk of keel bone damage, which agrees with other studies (e.g. Riber & Hinrichsen, 2016).

Acknowledgements

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Associations between production traits and egg quality of individually caged ISA brown hens

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Application

In a flock of commercial hybrid hens, there are important associations between some production and egg quality traits. An understanding of these relationships is important to develop nutritional and physiological strategies, which will aim at improving egg quality and safety, optimizing production efficiency and maximizing profits.

Table 1. Correlation (*r*) between production performance and egg quality parameters of ISA Brown hens (*n*= 45).

	EWt	YoC	Alb. Ht	Yo %	Alb. Wt	HU	YoHt	Alb: Yo	SBS	ST
BWt	0.09	0.22	−0.09	0.14	−0.05	−0.11	0.01	−0.06	0.03	0.1
ADFI	0.06	0.38*	0.18	0.14	−0.04	0.18	0.15	−0.19	0.09	0.09
% lay	−0.08	0.05	0.09	0.06	−0.08	0.11	0.23	−0.08	0.03	0.06
EWt	1.00***	−0.18	0.34*	−0.55***	0.94***	0.2	0.42**	0.53**	−0.12	−0.14
EM	0.75***	−0.08	0.32*	−0.43**	0.70***	0.22	0.44**	0.40**	−0.07	−0.07
FCR	−0.43**	0.38*	−0.03	0.41**	−0.50**	0.03	−0.09	−0.44**	0.11	0.13

*coefficients with a P value of ≤0.05; **P <0.01; ***P < 0.001; BWt: body weight; EWt: egg weight; EM: egg mass; FCR: feed conversion ratio; ADFI: average daily feed intake; YoC: yolk colour; Alb.Ht: albumen height; Alb.Wt: albumen weight; Alb:Yo: albumen:yolk ratio; SBS: shell breaking strength; ST: shell thickness; HU: Haugh unit; YoHt: yolk height; %: percentage.

Introduction

The profitability of the commercial egg industry is influenced by key production traits such as feed consumption, feed efficiency and egg quality. For production efficiency and profits to be maximised, these production traits must be optimised to maintain consistent and quality egg production. However, there is a lack of information on the relationship between production traits and egg quality in commercial hybrid laying hens. The objective of this study was to evaluate variation in production traits in a group of individually caged hens and its associations with internal and external quality of eggs produced.

Material and methods

Forty-five individually caged ISA Brown hens, aged 25 weeks, were randomly selected from a flock of 450 birds and monitored for production traits and egg quality characteristics. Hens were observed for 6 weeks and managed according to the ISA Brown management guide. A wheat-soybean meal-based diet was offered *ad libitum*. Egg production and egg weights were recorded daily, FCR and average daily feed intake (ADFI) were computed weekly, and eggs were assessed for quality once weekly, following procedures as reported by (Yenice, Kaynar, Ileriturk, Hira, & Hayirli, 2016). Descriptive statistics, Pearson correlation and Spearman coefficients were generated for production traits and egg quality measurements, using the proc univariate procedure in SAS. Coefficient values were considered significant at $P \leq 0.05$.

Results

The average production rate (98% ± 1.99; CV 2.0%) and average egg weight (61.21 g ± 3.11; CV 5.4%) of the hens were consistent with the ISA brown management guide for hens between 25 and 30 weeks of age; however, the average values for ADFI (123 g; CV 9.2%), FCR (2.05; CV 9.8), and week 30 average body weight (1965 g ± 145.4; CV 7.4%) were not in line with the ISA Brown breed recommendation. Pearson and Spearman correlations are presented in Table 1. FCR was positively related with yolk % and yolk colour, and negatively correlated with albumen weight and the albumen:yolk weight ratio. There was no significant relationship between body weight and egg weight, nor between FCR and eggshell breaking strength.

Conclusion

The smaller egg weights observed in hens having a higher FCR value could be linked to the reduced albumen weight characteristic to hens, which have poor feed efficiencies. This finding may potentially influence egg quality. Further, the deeper yolk colour seen in eggs from high FCR hens could be associated to the increased feed intake observed in hens with a high feed conversion ratio. Body weight does not relate to egg weight. The findings of this study show that there are important variations in production traits and significant relationships between some production and egg quality traits in 25-week-old individually caged ISA Brown hens. It will be useful to explore the extent and depth of these relationships with increased sample size and across different hen laying periods, as well as the effect of albumen weight characteristics on egg quality and safety.

Acknowledgements

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The effect of high levels of whole wheat with enzyme supplementation on laying hen performance

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Application

The use of a combination of enzymes may allow the replacement of corn with whole grain wheat.

Introduction

Using wheat in poultry feed is somewhat limited due to its low energy and the presence of anti-nutritional non-starch

Table 1. The effect of wheat (ground and whole) with and without enzyme on layer performances.

Experimental treatments	Egg weight	Egg production ((eggs/hen/day	Egg mass (g/d)	Feed intake (g/d)	Feed conversion ratio	Shell weight (g)	Shell thickness (mm)	Yolk colour	Haugh unit
Control	62.41^{ab}	0.71^{b}	44.84^{b}	92.2	2.18^{b}	6.21	0.31	5.14^{a}	89.52
Whole wheat + Enzyme	64.48^{a}	0.76^{a}	48.57^{a}	94.7	1.91^{c}	5.74	0.30	4.57^{b}	87.67
Whole wheat	58.07^{c}	0.65^{c}	39.86^{c}	92.6	2.42^{a}	6.04	0.30	4.42^{b}	88.13
Ground wheat + Enzyme	62.16^{a}	0.70^{b}	43.82^{b}	92.2	2.20^{b}	6.07	0.31	4.14^{b}	90.43
Ground wheat	58.12^{c}	0.66^{c}	39.11^{c}	90.9	2.39^{a}	6.07	0.31	4.14^{b}	86.31
SEM	0.25	0.03	0.41	1.94	0.06	0.19	0.79	0.22	1.92
p-value	0.02	0.04	0.01	0.53	0.004	0.49	0.89	0.02	0.79

Values with different superscript letters within columns are significant (P > 0.05). SEM = standard error of the mean.

polysaccharides. On the other hand, it has been shown that enzyme supplements reduce the restricting impact of non-starch polysaccharides (Jeroch & Danicke, 1995). The addition of enzymes to the diet can improve nutrient digestibility and reduces fluctuations in feed nutritional value (Hartini, Choct, Hinch, Kocher, & Nolan, 2002). Furthermore, it has been suggested that replacing ground cereals with whole grain is beneficial (Singh, Amerah, & Ravindran, 2014).

Material and methods

In this study 105 laying hens (Hy-line W-36) aged 40 weeks old were randomly allocated to 5 treatments, with 7 replicates of 3 birds. The experimental treatments included a control mash diet containing 660g/kg corn, a diet replacing corn with whole wheat-without enzymes, a diet replacing corn with whole wheat with enzymes, a diet replacing corn with ground wheat-without enzymes, and a diet replacing corn with ground wheat with enzymes. The enzyme supplement consisted of a combination of xylanase, β–glucanase and protease (giving 6258, 172 and 274 units/g measured activity, respectively). Feed and water were offered *ad libitum* throughout 12 weeks of experiment. Egg production criteria were measured weekly. At the end of the experiment, eggs were analysed for egg quality. A total of 70 eggs from each treatment were broken to measure internal egg quality and shell thickness using Egg Multi Tester EMT-5200, Ultrasonic Thickness Gauge (Echometer 1062) and Digital Egg Shell Force Gauge (model-II), respectively. Data were analysed using the General Linear Model procedure within SAS. Treatment means were compared using the Duncan's Multiple Range Test, and values were considered statistically different at P < 0.05. This experiment was approved by the Animal Ethics Committee of the Tarbiat Modares University.

Results

Replacing corn with either whole or ground wheat reduced egg weight, egg production and egg mass and increased feed conversion (P < 0.05). However, when fed whole wheat with the enzyme the birds had higher egg production, egg weight and consequently egg mass than other treatments. The egg quality parameters were not significantly affected by the dietary treatments with the exception of yolk colour (P < 0.05) that was paler as compared with control. The Haugh unit of the egg was not affected by either type of wheat inclusion or enzyme addition.

Conclusion

In general, the addition of a combination of xylanase, β–glucanase and protease with whole grain wheat in the diet improved laying hens' performances. Whole grain wheat + enzyme could replace corn by 100% without having a negative effect on the performance of laying hens.

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Effect of different feeding program on performance, carcass and skin quality of broilers

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Application

This experiment was conducted to investigate the effect of different feeding program on broiler chicken performances. This experiment indicates that phase feeding program could have beneficial effect on broilers performances and thus presented to enhance broilers performances further.

Introduction

Constant improvements in nutrition and genetic selection over the last two decades have led to a fast growth rate in modern broiler strains, to the extent that the average time required to grow a broiler chicken to 2 kg has reduced nearly by half (Zubair & Leeson, 1999). However, the classical/

Table 1. Effect of feeding program on various criteria of broiler chickens.

Treatment	Weight gain (g)	FCR	Protein conversion ratio	Production index	Carcass yield (%)	Visceral fat (%)	Degree of foot pad dermatitis	Degree of hock burn
Control	2723[b]	1.96	0.393	364.5[c]	78.43[ab]	1.32	1.5	2.05
Phase	2973[a]	1.85	0.387	419.5[a]	77.55[b]	1.35	1.65	2.2
Alternate	2773[ab]	1.88	0.427	390.1[b]	80.85[a]	1.56	1.42	2.05
Choice	2697[b]	1.99	0.401	367.1[c]	76.23[b]	1.51	1.5	2.05
P-Value	0.02	0.36	0.45	0.01	0.02	0.50	0.25	0.16
MSE	167.5	0.25	0.08	2.54	1.84	0.34	0.51	0.35

[a,b,c]Means values within a column with no common superscript differ significantly (P ≤ 0.05). SEM: Standard error of mean.

universal 3(4) fixed phases feeding program has been around for many decades. The logic of applying a fixed period for traditional dietary phased feeding programs has been challenged by many researchers (Shariatmadari, 2012). Thus, broiler feeding planners have also come up with new innovations such as feeding phase program to boost broiler performance efficiency further.

Materials and methods

Three hundred and sixty male broiler chickens of Cobb 500 strain were randomly assigned to four treatments with five replications (each pen 18 chickens). Treatments include (1) control (receiving starter (0–14 days), grower (14–26 days) and finisher (26–38 days) diet ever 2 weeks respectively); (2) phase feeding (having five different ratios of starter and finisher that changes every week); (3) alternate feeding (starter for 12 h and finisher for 12 h) and (4) choice feeding (allowed starter and finisher throughout the experiment). The diet mainly consisted of soya, corn, vitamin and mineral supplements. The diet content of starter, grower and finisher for protein was 22% 20% and 18% and for energy was 2900, 3000 and 3100 kcal/kg, respectively. The duration of the experiment was 42 days. The experimental protocol was approved by the animal welfare committee of Tarbiat Modares University, and the animals were handled and treated in a humane manner.

Results

Choice feeding treatment and phase feeding birds had lower and higher body weight (P < 0.05), respectively, at the end of the experiment. There was no effect of feeding program on feed conversion ratio. Protein conversion ratio was not affected by feeding programme. The higher production index ((liveability x weight gain)/(feed efficiency x age of bird)) of broiler fed phase feeding plan shows a better performance of this group when all main criteria of production were taken into consideration. The birds fed control or choice feeding had a lower production index ratio. Broilers fed alternative feeding programme had a higher carcass ratio. There was no effect of feeding program on fat content of broilers. The feeding plan did not affect the skin quality (degree of foot pad dermatitis and degree of hock burn) of broilers on different feeding program.

Conclusion

As a result of this study, broilers allowed access to phase feeding plan had a better preference as compared to other feeding programmes. Phase feeding with five feeding time changes is an advanced feeding programme as to that of traditional three feeding plan. As such it looks as if this extra feeding time changes, or that shorter duration of feeding period matches more the ever-changing nutrient requirement of broiler chicken and thus improves its performances.

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Assessment of residual feed intake in two varieties of Japanese quail (*Coturnix coturnix japonica*) under high environmental temperature

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Application

Feed expenses represent almost 70% of the gross cost of poultry production. Lowering costs of maintenance processes would leave more energy remaining for higher output. Minimizing residual feed intake (RFI) and, in turn improving feed efficiency would be beneficial for more efficient quail hens particularly under high environmental temperatures.

Introduction

Birds' ability to convert consumed feed to produce eggs and/or meat is greatly influenced by genotype and environmental

Table 1. Productive performance for two varieties of Japanese quail under high environmental temperature.

	Strain			
Parameter	Grey	White	SEM	P-value
Body weight gain, g	9.8	10.4	1.32	0.84
Egg mass, g	289.5[a]	277.8 [b]	2.43	0.02
FI, g	713.6	720.3	8.6	0.70
FCR	2.6	2.7	0.07	0.11
Egg production, %	89.9[a]	86.4[b]	0.73	0.02
Broken eggs, %	1.13[b]	2.06[a]	0.02	0.05
EFI, g	719.9	722.6	3.75	0.72

Values with different superscript letters across columns are significant (P > 0.05).

Table 2. Partial regression coefficients of factors affecting expected feed intake for two varieties of Japanese.

	Partial regression coefficient		Prob.	
Parameter estimate	Grey	White	Grey	White
Intercept	914.6	396.2	<0.001	0.02
Δ BWT	−0.96	−0.36	0.08	0.63
$(BWT)^{0.75}$	5.21	11.84	0.04	<0.001
Egg mass (EM)	−1.64	−1.11	<0.001	<0.001

factors. Birds that require less feed than expected for maintenance and production requirements have a negative RFI and are desirable in poultry breeding programs to reduce feed costs. Traditionally, feed efficiency has been improved by selection for increased egg mass and decreased body weight and getting a correlated response in feed efficiency (Altan, Oguz, Akbas, & Aksit, 2004). However, selection for feed conversion ratio can lead to unfavorable changes in the component traits. Additional criteria for feed utilization should be involved. To present, there are no reports available on RFI traits in varied varieties of Japanese quail (Varkoohi et al., 2010). Due to adjusting pattern of feed consumption according to ambient temperature, the present study was carried out to estimate RFI and their partial regression coefficients in two varieties of Japanese quails under high environmental temperature.

Materials and methods

A total of 310 laying quails of two varieties (grey and white) (155 each) were randomly selected from an initial population of 800-day olds that were reared to point of lay and transferred to individual battery cages. The average high and low ambient temperatures recorded during the experimental period were 39°C and 24°C, respectively. Egg production (weight and number), feed intake (FI) and body weight (initial and final) were determined for each hen over a four-week experimental period. Expected feed intake was computed using mid-metabolic body weight ($BW^{0.75}$), body weight gain (ΔBW) and total egg mass (EM) for a given time considered by multiple regression analysis. Residual feed intake (RFI) was calculated as the difference between observed (OFI) and expected feed intake (EFI) for each experimental hen using the PROC REG procedure, SAS® (2013). The proposed protocol was approved by the animal care committee of Qassim University.

Results

Grey quails had significantly higher (P < 0.02) egg mass and egg production percentage than white quails (Table 1). No significant difference for FI, FCR and EFI was identified between varieties. A significant decrease (P < 0.05) in broken eggs was noticed in grey quails compared to white quails. As shown in Table 2, the partial regression coefficients for metabolic body weight and egg mass had a significant effect in computing expected feed intake in both quail varieties.

Conclusion

In conclusion, these results indicate that egg mass significantly increased in grey variety compared to white one. Additionally, grey quails had a significantly lower percentage of broken eggs. Metabolic body weight and egg mass significantly affect expected feed intake rather than body weight gain in both varieties of Japanese quails under high environmental temperature.

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Antioxidant status and gut microbial population of broilers fed different dietary levels of ginger root powder (*Zingiber officinale*)

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Application

Ginger root powder may be used in broiler diets as both an antioxidant and inhibitor of pathogenic gut microbes at a suggested inclusion rate of 1%.

Introduction

Recently, use of medicinal plants as natural growth promoters and antioxidants has gained increasing interest because of the global trend of restriction in the use of

antibiotics and synthetic substances (Ahn, Grun, & Fernando, 2002). Ginger rhizome (ginger root) is widely used as a spice or condiment and medical treatment for certain diseases (Tapsell, Hemphill, Cobiac, & Patch et al., 2006). Furthermore, antibacterial properties of ginger powder have been established in poultry production. The objective of the present study was to evaluate the effect of different feeding levels of ginger root powder on the final body weight, antioxidant profile and gut microbial properties of broiler chickens.

Materials and methods

A total of 400 one-day-old unsexed broiler chicks (Ross 308) were grown over a period of 42 days. Chicks were individually weighed and randomly divided into four different dietary treatments. Ginger root powder was added to the diet in different levels (0%, 1%, 2%, 3%). Each dietary group had five replicates (20 chicks each). Feed and water were supplied *ad libitum*. All birds were raised under similar husbandry and environmental conditions. Body weight and feed consumption were determined weekly. On day 42, ten birds were randomly selected and sacrificed from each dietary group. The contents of ileum section were collected for microbial culture evaluation in log cfu/g. Also, 10 chicks/dietary group were randomly chosen for bleeding to evaluate antioxidant status in blood plasma. The proposed protocol was approved by the animal care committee of Qassim University. Data were subjected to a one-way analysis of variance using SAS® software.

Results

Table 1. Effect of dietary supplementation of ginger on antioxidant status and gut microbial population of broilers.

	Ginger level					
Item	0%	1%	2%	3%	SEM	*P*-value
Body weight at 6 weeks, g	1977.7	1953.0	1919.2	1965.2	29.14	NS
TAC. mmol/L	3.18^{b}	5.08 ^{a}	4.51 ^{b}	4.26 ^{b}	0.26	0.03
CAT, U/mL	2.08 ^{b}	4.19 ^{a}	3.42 ^{a}	2.16 ^{b}	0.25	<0.01
MDA, nmol/mL	8.33 ^{b}	9.75 ^{a}	6.81 ^{c}	8.45 ^{b}	0.25	<0.01
Total count	6.29^{a}	4.57^{b}	4.36^{b}	3.84^{c}	0.06	<0.01
Campylobacter	5.44 ^{a}	2.72 ^{b}	2.48 ^{b}	2.17 ^{b}	0.04	<0.01
Coliform- E. Coli	4.50^{a}	2.21^{b}	1.98^{bc}	1.64^{c}	0.08	<0.01
Salmonella	5.40^{a}	3.65^{b}	3.59^{b}	3.51^{b}	0.08	<0.01
Staphylococcus	5.51^{a}	3.56^{b}	3.42^{b}	3.24^{b}	0.07	<0.01

^{a,b,c}Means within each row with no common superscript letters are significantly different.

TAC: total antioxidant capacity, CAT: catalase, MDA: malondialdehyde.

Conclusion

Ginger root powder can be used as an antioxidant supplement for broilers. Additionally, it acts as a considerable inhabitation factor for the growth of pathogenic microbes without penalizing growth performance. The recommended dosage of ginger powder in broiler diet must not exceed 1.0%.

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Enzyme supplementation of diets having palm kernel cake on performance and intestinal morphometry of 42-day-old broilers

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Application

Palm kernel cake (PKC) can be used in the diets of broiler chickens with enzyme supplementation as it produces better results than when diets were fed without enzyme supplementation to the animals.

Introduction

Incorporation of PKC in livestock and poultry diet is limited due to high fibre level, gritty nature, unpalatability, relatively low availability of amino acids and copper content (Hassan, Teck, Hooi, Samsudin, & Alshelmani, 2017), and PKC could be a readily available substitute for Soybean meal (SBM) giving rise to a reduction in the cost of feeding poultry animals. A study was designed to evaluate the impact of replacing SBM with PKC at 0%, 7.5% and 15% with or without enzyme supplementation, on performance and intestinal morphometry of broiler chickens.

Material and methods

The study protocol was conducted in accordance with the Animal Care and Use Review Committee guidelines of the College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta, Nigeria. A total of 720 one-day-old Marshall Strain of broiler chicks were randomly distributed into 6 dietary treatments having 6 replicates of 20 birds each. The birds were housed in fabricated battery cages made of galvanized steel (30″) length, (18″) width and (19″) height, throughout the experiment (42 days). The experiment was in a 2 × 3 factorial arrangement, having two levels of enzyme supplementation (0 and 500g/ton) containing Xylanase (5000U/g), β-glucanase (1500U/g), β-mannanase (3000U/g), α-galactosidase (3000U/g), amylase (1500U/g), protease (4000U/g) and three levels of PKC addition (0%, 7.5% and 15%). Final weight (FW), weight gain (WG), feed intake (FI)

Table 1. Performance (0-42d), and gut morphometry of broiler chickens. Values with different superscript letters across columns are significant (P > 0.05).

Diets	FW (g/bird)	WG (g/bird)	FI (g)	FCR	DL (mm)	JL (mm)	IL (mm)
0 % PKC	1352.12^{c}	1000.39^{cd}	2749.29^{c}	2.75^{b}	2.86	5.28	6.08
7.5 % PKC	1331.14^{c}	989.27^{d}	2774.54^{b}	2.80^{ab}	3.31	5.25	5.95
15% PKC	1330.76^{c}	996.32^{d}	2813.37^{a}	2.82^{a}	3.43	5.17	5.68
0 % PKC+ E	1502.47^{a}	1129.00^{a}	2648.73^{e}	2.34^{e}	2.92	4.83	5.57
7.5 % PKC+ E	1469.08^{b}	1069.19^{b}	2712.91^{d}	2.54^{d}	3.00	4.42	5.45
15% PKC+ E	1455.07^{b}	1021.93^{c}	2728.65^{d}	2.67^{c}	3.57	4.17	4.76
SEM	12.123	8.725	8.792	0.029	0.15	0.17	0.16
P value	0.0001	0.0001	0.0001	0.0001	0.7618	0.2614	0.2358

PKC: palm kernel cake, E: enzyme, SEM: standard error of mean, FW: final weight, WG: weight gain, FI: feed intake, FCR: feed conversion ratio, DL: duodenum length, JL: jejunum length, IL: ileum length.

and feed conversion ratio (FCR) were recorded weekly for each replicate. On day 42, the chickens were fasted for 24 h, killed and their gastrointestinal tract (GIT) was excised in its different sections, the GIT lengths were measured using a measure. The ileum, duodenum and jejunum lengths were taken using the tape. Data were analysed by ANOVA using SAS® software and the mean was separated using a Tukey.

Results

The result of the experiment is presented in table 1. Increasing the inclusion of PKC in the diet resulted in reduced FW, WG Jejunum length (JL) and Ileum length (IL).

Conclusion

The use of PKC and enzyme in diets of broiler chickens on weight for weight basis influenced the growth parameters but did not significantly influence the GIT measurements. Duodenum length increased with increasing levels of PKC, but Jejunum and Ileum length reduced as the PKC level increased. The inclusion of PKC at the three levels did not affect the morphometry significantly suggesting that the amount of inclusion on this basis could have been too small for such effects to be evidently seen. The use of enzyme increased weight gain and resulted in better utilization. Palm kernel cake could be used in diets of broiler chickens with enzyme supplementation, without an adverse effect on the intestinal morphometry of the animals. Further studies are required to investigate the effect of these inclusion levels on a protein for protein basis on its impact on gut microbiology and microflora of the animals.

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Application of a high-density distiller's protein product in turkey poult diets from 0 to 42 days of age

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Application

Conventional distillery co-products (distillers dried grains and solids; DDGS) have limited application in neonate nutrition. High-density distillers protein (HDDP) is an excellent alternative protein in diets for turkey poults.

Introduction

Europe is heavily dependent on imported soya bean meal and there is an urgent need to source alternative supplies of home-produced protein for feed (European Commission, 2018). The distilling industry is a major processor of grain but the current high fibre co-product (DDGS), has limited application in monogastric nutrition. However, as a co-product from the distilling industry, the protein cannot be used for food and is therefore not in competition with human food. In the dry-grind bioethanol process simple mechanical processing downstream of fermentation produces a high density (>50% protein on a dry matter basis), highly digestible protein (HDDP) suitable for monogastric nutrition.

Material and methods

HDDP is a high protein (52.4% DM) low crude fibre (4.4% DM) product physically extracted from bioethanol whole stillage. The study received ethical approval prior to commencement from the University's School Ethical Review

Table 1. Performance data of turkey poults 0–21 and 0–42 days of age.

Diet	d0-21 BWG (g/bird)	FI d0-21 (g/b/d)	d0-42 BWG (g/bird)	d42 BW (g/bird)	FI d0-42 (g/bird)	FCR d0-42
Control	550	50.2	2262	2328	3741	1.66
HDDP 4%	556	48.9	2357	2423	3850	1.64
HDDP 8%	590	50.2	2452	2518	3743	1.61
HDDP Sy	571	49.7	2292	2357	3756	1.64
Soy isolate	586	52.4	2365	2430	3842	1.63
p value	0.062	0.751	0.116	0.122	0.363	0.797

Table 2. Comparison of performance data between controls and poults receiving HDDP.

Diet	BW d42 (g)	BWG 0–42 (g)	FI 0–42 (g)	FCR 0-42
Control	2328	2262	3741	1.66
HDDP diets	2470	2405	3897	1.62
P value	0.032	0.03	0.111	0.349

group. 250-day-old male BUT6 turkey poults were weighed and randomly allocated to treatments. Feed and water were available *ad libitum*. A standard commercial-practice temperature, ventilation and lighting regime were used. There were 50 pens of poults; one replicate consisted of a pen containing 5 poults with 10 replicates for each dietary treatment. Test diets were manufactured as crumbs for the starter period (0-21days) and pellets for the grower period (21–42 days). Five dietary treatments were formulated based on a commercial formulation: A) control containing standard hi pro soya; B) 4% HDDP; C) 8% HDDP; D) low-quality soy plus 4% HDDP; E) Soy protein isolate. Diets were formulated to be iso-proteic in terms of ileal digestible amino acids and isoenergetic. HDDP was included at levels of either 4 or 8% essentially replacing soya bean meal in the ratio 1.55:1, respectively. In the controls compared with the 8% HDDP diet, dietary inclusion of soya bean meal was reduced from 47.3% to 41.9% in the starter diets and from 40.5% to 35.1% in the grower diets, respectively. Feed intake was recorded on a per pen basis for each phase of the trial. Birds were weighed by pen on arrival, on d0, d7, d14, d21, d28, d35 and at the end of the trial on d42. Statistical analysis was carried out using SPSS v.24. After KS testing to confirm normality, data were analysed using one-way ANOVA to investigate the effect of dietary treatment on FCR, feed intake (per bird) and individual bodyweight gain for each weight period of the study, and cumulatively (Table 1). Where appropriate, Bonferroni post hoc testing was used to elucidate differences between diets/treatments. Data were then pooled across HDDP treatments and compared with the control in an unbalanced t-test (Table 2).

Results

There were no significant differences during either the starter or the grower period between treatments in feed intake, live weight gain or feed conversion efficiency (Table 1). When data were pooled and treatments with or without HDDP (Table 2) compared, the partial replacement of soya bean meal with HDDP significantly increased weight gain and tended to increase feed intake. Inclusion of HDDP in the diet had no effect on litter moisture content.

Conclusion

Partial replacement of soya protein by HDDP in diets for turkey poults had no effect in the starter period but improved growth at 42 days of age. This new alternative protein showed a significant advantage in terms of partial replacement of soya bean meal in diets for turkey poults.

Dietary means to improve the antioxidant status of broiler chickens grown in high-temperature conditions

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Application

Dietary antioxidants may improve the overall antioxidant status of birds, thus protecting them from oxidative damage.

Introduction

The popularity of natural antioxidants to protect human and animal health and to increase the shelf life of products from animal origin has increased during the past decade. Flavonoids, being a major sub-group representing plant polyphenols, are antioxidants from natural sources and as such, have been attracting attention for use in animal nutrition. Dihydroquercetin (DHQ), a flavonoid extracted from various conifers, has been widely applied as an antioxidant for the surface treatment of fresh meat and been included in animal diets in order to enhance production performance. However, results in animal studies are contradictive (Fomichev, Nikanova, & Lashin, 2016; Pirgozliev et al., 2018) and suggest that the impact of DHQ on performance may be more noticeable during hot summer months. The aim of the study was to assess the impact of DHQ and vitamin E, alone or in a combination, on daily feed intake (FI), weight gain (WG) and feed conversion efficiency (FCE) when fed to broiler chickens reared in high-temperature conditions from 7 to 28 days of age. Dietary apparent

Table 1. The daily feed intake, weight gain and feed conversion efficiency (FCE), dietary apparent metabolisable energy (AME), AME intake and glutathione peroxidase (GPx) in blood of 28-day-old chickens fed the experimental diets.

Treatment factor	Feed intake (g/b/d)	Weight gain (g/b/d)	FCE (g:g)	AME (MJ/kg)	AME intake (MJ/b/d)	GP x (u/ml RBC)
Standard temperature	81	51	0.632	12.47	1.01	62
35*C	51	30	0.593	13.34	0.68	53
SEM	3.1	3.0	0.0126	0.334	0.049	1.4
DHQ no	66	41	0.615	12.86	0.84	53
DHQ yes	66	40	0.610	12.95	0.85	61
vit E no	67	41	0.613	12.86	0.86	57
vit E yes	66	40	0.612	12.95	0.84	57
SEM	0.9	1.1	0.0070	0.088	0.013	2.4
Probabilities						
Temp	<0.05	<0.05	NS	NS	<0.05	0.05
DHQ	NS	NS	NS	NS	NS	<0.05
vit E	NS	NS	NS	NS	NS	NS
Temp x DHQ interaction	NS	NS	NS	NS	NS	NS
Temp x vit E interaction	NS	NS	NS	NS	NS	NS

metabolisable energy (AME), AME intake and glutathione peroxidase (GPx) concentration in blood were also determined.

Material and methods

The Harper Adams University Research Ethics Committee approved the study. Three hundred and twenty 7-day-old male 308 Ross broiler chickens were used in the study. The birds were reared from 7 to 28 days of age in 64 raised floor pens (5 birds in each) allocated in four rooms. The temperature in two rooms was increased to a constant 35°C, and in the other two rooms, the temperature was gradually reduced from 27°C to 21°C. Within each room four diets were offered to the birds; these were a control wheat-based diet that was adequate for energy and nutrients (C; containing 0.1g/kg vitamin E), C + 0.3 g/kg vitamin E (Merck, Cramlington, UK), C + 0.5 g/kg DHQ (Flavit, Pushchino, Russian Federation) and C + 0.3 g/kg vitamin E + 0.5 g/kg DHQ. The diets were provided in mash form *ad libitum* throughout the experiment, and each diet was given to four pens in each room following randomisation. All pens were bedded with wooden shavings. Between 24 and 28 days of age, the solid floor was replaced with wire mesh and excreta were collected for AME determination. Data on daily WG and FI were obtained from 7 to 28 days of age. At 28 days, one randomly chosen bird from each pen was euthanized and blood was collected for GPx determination. The results were compared by 2x2x2 factorial ANOVA (using a split-plot design).

Results

Rearing birds at high temperature reduced daily FI and WG ($P < 0.05$) although FCE was not affected ($P > 0.05$). Birds reared in high temperature had lower GPx concentration in blood ($P = 0.05$). Dietary AME was not affected by any of the treatments ($P > 0.05$). However, birds reared in high temperature had lower AME intake ($P < 0.05$). Feeding DHQ increased GPx concentration in blood ($P < 0.05$), although dietary vitamin E did not have any impact ($P > 0.05$). Glutathione peroxidase is an enzyme which main biological role is to protect the organism from oxidative damage, thus potentially improving the health of the birds reared in hot temperature.

Conclusions

Rearing chickens in high temperature reduced their feed and AME intake, weight gain and GP x in blood. Feeding DHQ increased GP x in blood. There was no diet by temperature interaction in any of the studied variables.

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The effect of different selenium sources on the growth performance and antioxidant status of broiler chickens reared in two different temperatures

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Application

Dietary supplementation with Se improves the antioxidant status of the birds, which may potentially advance bird health and resistance to disease and other challenging conditions.

Introduction

High temperature is an environmental factor that may lead to oxidative stress, disrupting the equilibrium between antioxidants and reactive oxygen species (ROS) (Surai, 2002). Dietary selenium (Se) may improve the antioxidant status of

Table 1. The effects of rearing temperature and supplementary Se sources on broilers feed intake (FI), weight gain (WG), feed conversion efficiency (FCE), Se in liver, total antioxidant status (TAS) and glutathione peroxidase (GSH-Px) in blood.

Diet	FI 14–35 (g/b/d)	WG 14–35 (g/b/d)	FCE 14–35 d	Se liver (mg/kg) DM	TAS blood (mmol/l)	GSH-Px blood (U/ml RBC)
Temperature °C						
21	115	76	0.666	2.23	1.10	66
35	90	57	0.639	1.80	1.43	76
SEM	2.1	1.1	0.0063	0.107	0.213	4.1
Diets						
NC	103[a]	67	0.653	1.66[a]	1.19	47[a]
SS	104[a]	68	0.655	2.17[b]	1.22	88[b]
BT	104[a]	67	0.658	2.08[b]	1.39	74[b]
SY	99[b]	64	0.644	2.16[b]	1.25	75[b]
SEM	1.4	1.1	0.0064	0.073	0.070	8.3
Probabilities						
Temperature	0.074	0.054	0.098	0.106	NS	NS
Diets	<0.05	0.063	NS	<0.001	NS	<0.001
Temperature*Diets	NS	NS	NS	NS	NS	NS

birds, although different supplements may have different bioavailability (Woods et al., 2018). In the majority of the studies, the effectiveness of dietary Se supplements was compared under the same temperature conditions, and there is a lack of experiments that compare supplements used in normal and high temperature simultaneously. This study evaluated the effect of various sources of dietary Se on growth performance and antioxidant capacity (determined as glutathione peroxidase (GSH-Px) activity, total antioxidant status (TAS) in blood and Se contents in liver) in broilers reared in two temperature conditions, normal and high.

Materials and methods

The study was approved by the Harper Adams University Research Ethics Committee. Three-hundred-twenty 14 d old male Ross 308 chicks were allocated to 64 raised solid floor pens (0.6 m x 0.6 m) with 5 birds in each. Half were raised under normal temperatures (21°C) and the other half were heat stressed (35°C). Broilers were fed one of the four wheat soybean-based mash diets: negative control containing only background selenium (NC); NC + 0.15 g/t of Se as sodium selenite (SS); NC + 0.15 g/t Se as B-Traxim ^{Se}, an organic selenium in the form of a Se proteinate (Pancosma SA, Switzerland) (BT); NC + 0.15 g/t Se as selenized yeast (SY). Birds had free access to feed and water. Growth performance was measured from 14 to 34 days old. At 34 days old one bird per pen was stunned and its blood and liver were collected. TAS and GSH-Px levels were measured in the blood and Se levels analyzed in liver. The results were statistically compared with ANOVA using a 2 × 4 factorial structure.

Results

Broilers reared at high temperature tended ($P > 0.05$) to have low growth performance and Se in liver. Birds fed SY had lower feed intake ($P < 0.05$) and tended ($P = 0.063$) to have lower weight gain. The NC fed birds had the lowest Se content in liver ($P < 0.001$). The Se fed birds had high GSH-Px ($P < 0.001$) and numerically higher ($P > 0.05$) TAS in blood compared to NC. There was no dietary treatment by rearing temperature interactions ($P > 0.05$).

Conclusion

Dietary Se can be provided in different forms that may influence its bioavailability. The lack of statistically significant difference in antioxidant status between the two temperature treatments was surprising; however, these birds were kept in hygienic conditions with proper ventilation, low stocking density, and provided with balanced feed and water. The mode of action of dietary Se supplements for broilers requires further investigation.

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Studies on broiler growth and economics in response to steroid supplementation

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Application

Poultry production, specifically broiler production and consumer awareness.

Introduction

The progress in broiler production, especially in terms of weight gain and overall feed efficiency, is the result of

decades of genetic selection (Hunton, 2006), but some misconceptions exist particularly about steroid and hormonal usage (Schumacher, Barrantes, Alpízar, & Corella, 2010). The perception of hormonal usage in poultry, which is being encouraged by the media, is misleading consumers. Several authors have reported that the application of steroids is not appropriate in broilers for many justifiable reasons. Most prominently, growth performance is not dependent on exogenous hormones (Schumacher et al., 2010), and secondly, in many countries using hormonal products for any such purpose is banned. Although muscle production can be increased with supplementation of anabolic steroids, such as anabol, this improvement is associated with regular physical activity. Since broilers have a relatively low physical activity, it is difficult to predict any potential benefit of steroid use in broilers. Therefore, a study was planned to investigate the possibility of steroid supplementation in broilers and to assess the growth performance, meat yield, immune status and overall economics in response to supplementation.

Materials and methods

The study was conducted at the Department of Poultry Production, University of Veterinary and Animal Sciences Lahore. Before the start of the experiment, ethical approval was taken from the Animal Ethics Committee at the University. Anabol (methandrostenolone) at 1.5mg/kg body weight was supplemented to drinking water during different phases of the 35-day trial. Straight run broilers of Cobb-500 strain were divided into four groups in such an arrangement that group A was not offered the steroid at any stage of life, group B received steroids from day one to day 17, group C received steroids from day 18 to 35, while, group D received steroids from day 1 to day 35. Each group was replicated six times with ten birds in each replicate; hence, a total of 240 broilers were subjected to experimentation. Broiler starter, grower and finisher rations were offered as per specific strain standards. The collected data were analysed by ANOVA using SAS® (9.2), with significance accepted at $P < 0.05$ and significant means compared by Duncan's Multiple Range test.

Results

Statistical analysis showed significant treatment differences in growth performance and feed intake. Higher ($P < 0.05$) body weights of broilers at 5 weeks of age were observed in control group (A), while group D had the lowest body weights, highest feed intake and hence significantly poorer ($P < 0.05$) feed conversion ratio. Overall liveability and carcass yield did not show any significant variation with treatment. Antibody titer against Newcastle disease was unaffected by treatment, while, infectious bronchitis resulted in significant differences, with the lowest titers detected in group D ($P < 0.05$). In terms of overall economics, a loss of PKR Rs. 121/- per bird (0.9 US$) was observed in group D.

Conclusion

It can be concluded that, in the current scenario, the use of steroids is not suitable in terms of cost-effectiveness. Secondly, their use did not show any positive effect on growth performance, but rather, poor growth and higher feed intake, resulting in a poorer FCR.

Acknowledgements

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The *in vitro* antibacterial effect of botanicals against *Campylobacter jejuni*, *Listeria monocytogenes*, *Escherichia coli* and *Salmonella enterica*

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Application

This research aims to determine the antimicrobial activity of a range of natural botanical supplements (phytogenics). Phytogenics which exhibit antimicrobial activity can potentially be used as sustainable alternatives to antibiotics to promote poultry health and performance. This could lead to a reduction in the use of antibiotics in agriculture.

Introduction

Governments worldwide are seeking alternatives to antibiotics in poultry feed such as phytogenics. These might reduce antibiotic resistance in poultry while maintaining health and performance (O'Neill, 2016). Phytogenics have antimicrobial properties exhibiting multiple modes of action to inhibit pathogens and target antibiotic resistant phenotypes (Chitemerere & Mukanganyama, 2014). The

Table 1. MIC and MBC values for three phytogenics with greatest antibacterial activity against 20 isolates.

	Phytogenic					
	Agrimonia pilosa		*Allium macrostemon bunge*		*Smilax china*	
Strain	MIC (mg/L)	MBC (mg/L)	MIC (mg/L)	MBC (mg/L)	MIC (mg/L)	MBC (mg/L)
C. jejuni NCTC 11,322	31.25	500	125	>1000	250	1000
C. jejuni (n = 3)	31.25–125	500 – >1000	125–250	>1000	250	1000
L. monocytogenes NCTC 11,994	31.25	250	62.5	>1000	62.5	250
L. monocytogenes (n = 5)	31.25–125	250–1000	31.25–1000	1000 – >1000	31.25–125	250–1000
S. enterica NCTC 00074	500	1000	62.5	>1000	250	>1000
S. enterica (n = 3)	125	1000	62.5	>1000	125–250	>1000
E. coli ATCC 25,922	7.8125	31.25	31.25	500	125	500
E. coli (n = 5)	7.81–15.62	31.25–62.5	31.25–62.5	250–500	125	500

purpose of this research was to develop a screening process to select phytogenics for *in vivo* study by testing the *in vitro* efficacy of plant extracts against pathogenic poultry bacteria.

Materials and methods

The broth microdilution method (CLSI, 2009) was used to measure *in vitro* antibacterial activity of 36 phytogenics against reference clinical isolates of *C. jejuni, E. coli, S. enterica* and *L. monocytogenes*. A range of concentrations (0.98 mg/L to 1000 mg/L) of each phytogenic was added to a series of tubes with broth. Media used to support pathogen growth included: Mueller-Hinton broth (MHB) for *E. coli* and *S. enterica*; Tryptone Soya broth with 5% lysed horse blood for *L. monocytogenes*; and MHB with 5% lysed horse blood and 20 mg/L β-NAD for *C. jejuni* growth. Broths that supported pathogens' growth and reproducibility were chosen to improve the reliability of results. Tubes were inoculated with a standardised suspension of test pathogen. The experiment was set up in triplicate. A negative control included inoculated broth with no phytogenic – growth was expected. A positive control included inoculated broth with an antibiotic – no growth was expected. The well with the lowest concentration of phytogenic with no visible bacterial growth across three repeats was recorded as the minimum inhibitory concentration (MIC) of the phytogenic. The minimum bactericidal concentration (MBC) was determined by plating 10 µL from each well and determining the lowest concentration that reduced the initial viability of bacteria by ≥99.9%.

Results

The results are shown in Table 1.

Conclusion

Fifty-eight percent of phytogenics showed antimicrobial activity. *A. pilosa* and *A. m. bunge* showed broad spectrum activity. These were selected for use in an *in vitro* poultry digest model to examine their effect on inhibition of pathogenic poultry gut bacteria and on their modulation of the composition of poultry gut microbiota (see Diaz-Sanchez, D'Souza, Biswas, & Hanning, 2015).

Acknowledgements

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Performance characteristics of laying hens fed diets supplemented with inorganic or chelated blends of copper, zinc and manganese in late lay

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Application

Copper, zinc and manganese supplementation, regardless of source, improved Hen-day egg production. Furthermore, chelated trace mineral supplementation led to better laying performance and feed conversion ratio.

Introduction

Egg production and eggshell quality decrease with hen age. This cannot be overlooked in poultry production as it can increase the incidence of cracked eggs and other malformations. Minerals are important components of egg and could be effective against this if supplemented

Table 1. Performance characteristics and serum mineral concentration of experimental laying chickens fed diet supplemented with Cu, Zn and Mn.

Parameters	Control diet	100% ITM	100% CTM	50% CTM	25% CTM	SEM	P value
Hen-day egg production (%)	73.16^{d}	80.63^{bc}	85.14^{ab}	86.03^{a}	79.31^{c}	0.99	0.0001
Feed intake (g/bird/day)	118.63^{b}	120.04^{a}	116.18^{d}	117.29^{c}	118.81^{b}	0.18	0.0001
FCR (kg feed/kg egg)	2.65^{a}	2.47^{ab}	2.06^{c}	2.17^{c}	2.44^{b}	0.04	0.0001
Eggshell thickness (mm)	0.49^{c}	0.52^{b}	0.55^{a}	0.52^{b}	0.50^{c}	0.00	0.0001
Initial weight (g/bird)	1669.0	1735.4	1698.0	1696.4	1735.4	12.69	0.4700
Cu (µg/dL)	1.84^{e}	2.08^{c}	2.41^{a}	2.22^{b}	1.95^{d}	0.05	0.0001
Zn (µg/dL)	8.48^{d}	12.18^{b}	15.29^{a}	12.14^{b}	11.77^{c}	0.59	0.0001
Mn (µg/dL)	1.85^{c}	2.16^{ab}	2.24^{a}	2.07^{b}	1.93^{c}	0.04	0.0001

^{a,b,c,d,e} Means with different superscripts in a row are significantly different ($P < 0.05$).

appropriately. Chelates are usually formed with two moles of organic ligands to one mole of metal ion held together by covalent bond (Yi et al., 2007). They remain electrically neutral in the acidic gastric pH and as such gets to site of absorption without suffering ionic dissolution. As a result, they are protected from chemical reactions with other molecules in the intestinal lumen (Liu et al., 2016). This gives CTM a comparative advantage over inorganic trace mineral (ITM) sources as it may increase mineral bioavailability and subsequently improve performance in poultry (Nollet, Van Der Klis, Lensing, & Spring, 2007). This study aimed to determine the performance of layers in late lay to supplemental inorganic and proprietary chelated blends of copper, zinc and manganese.

Material and methods

This study was carried out according to the research ethics and guidelines of the College of Animal Science and Livestock Production of the Federal University of Agriculture, Abeokuta, Nigeria. A total of 540 Nera Black laying chickens at 58 weeks of age were randomly assigned to 5 dietary treatments. Each treatment consisted of 108 randomly allocated layers housed in colony cages. The cages were equipped with nipple drinkers and trough feeders. Each dietary treatment was randomly replicated 12 times. Each replicate consisted of three cage units at three birds per cage (40 cm long x 30 cm wide x 45 cm high) making nine birds per replicate. Diets consisted of a control containing 0, 0, 0 mg/kg of Cu, Zn and Mn, respectively; 16, 64, 64 mg/kg of inorganic Cu, Zn and Mn (100% ITM supplementation); 16, 64, 64 mg/kg of Cu, Zn and Mn (100% CTM supplementation); 8, 32, 32 mg/kg of Cu, Zn and Mn (50% CTM supplementation) and 4, 16, 16 mg/kg of Cu, Zn and Mn (25% CTM supplementation) in that order. The diets were introduced to the birds when daily egg production was 69%. The duration of the experiment was 77 days which was divided into 5 periods of 14 days each and a 7-day adaptation period. Feed consumption for each replicate was determined at the end of each period and was used to calculate average daily feed intake per bird. Eggs for the determination of eggshell thickness were sampled after each period. On day 77 of the experiment, 2.5 mL of blood was collected individually from 12 birds per treatment and concentration of copper, zinc and manganese in serum samples were determined using flame atomic absorption spectrometer. The experiment was arranged in a completely randomized design and data collected were subjected to Analysis of Variance using SAS® (2007). Significant means were compared using Tukey's test of the software.

Results

Feed intake increased with ITM supplementation while it decreased as the concentrations of CTM supplementation increased. Egg production increased with supplemental trace minerals with 50% CTM supplementation recording the best hen-day egg production. Chelated trace minerals improved ($P < 0.05$) the feed conversion ratio (kg feed/kg egg) compared to ITM and control diet. Supplementation with 100% CTM, 100% ITM and 50% CTM elicited higher ($P < 0.05$) eggshell thickness than control and 25% CTM. Supplementation of trace minerals increased ($P < 0.05$) serum Cu, Zn and Mn.

Conclusion

Trace mineral supplementation improved the performance of layers in late lay. Additional methionine from the ligands, resulting in a balanced amino acid profile, could be responsible for reduced feed intake and improved FCR in CTM groups. More bioavailability of zinc which is a component of uterine carbonic anhydrase that supports eggshell formation led to improved eggshell thickness. Trace mineral supplementation increased the concentration of sera Cu, Zn and Mn.

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Growth performance and nutrient digestibility of Japanese quails fed diets containing graded levels of sundried cassava peel meal supplemented with molasses as replacement for maize

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Application

Sundried cassava peel meal supplemented with molasses replaced maize at 50% as a major energy source in the diets of growing Japanese quails.

Introduction

The cassava (*Manihot esculenta crantz*) is cultivated mainly in the tropic and sub-tropic regions of the world, over a wide range of environmental and soil conditions. It is very tolerant of drought, heat stress and produces well on marginal soils. It is an important dietary staple in many countries within the tropical regions of the world (Perez & Villamayor, 1984). The cassava and its by-products that are used in feeding livestock have to undergo some processing to make it acceptable to livestock (Salami & Odunsi, 2003). The aim of this research is to investigate the growth performance and nutrients digestibility of Japanese quails fed diets containing graded levels of sundried cassava peel meal supplemented with molasses as a replacement for maize.

Materials and methods

The ethical implications of conducting these trials were considered under the Nigeria Institute of Animal Science (NIAS) code of conducts and the studies deemed fit to be undertaken by the Department of Animal Production Federal University of Technology Minna Nigeria. A total of 500 two-week-old Japanese quails were randomly allotted to four dietary treatments in which sundried cassava peel meal supplemented with 6% molasses replaced maize at 0%, 50%, 75% and 100% in T1, T2, T3 and T4, respectively, in a completely randomized design, each treatment had five replicates with 20 birds per replicate. The crude protein was set at 24% with feed and water given *ad libitum*. The parameters measured were initial weight, daily feed intake, average daily weight gain, feed conversion ratio, nutrient digestibility and final weight. All data collected were subjected to one-way analysis of variance using SPSS 2007 and where differences occurred Duncan Multiple Range Test was used to separate means.

Results

There were no significant ($P > 0.05$) differences in initial weight, daily feed intake, daily weight gain and feed conversion ratio among treatments. There were no significant ($P > 0.05$) differences in nutrient digestibility among treatments except crude protein which showed significant ($P < 0.05$) difference among treatments where birds on 0% and 50% had higher protein digestibility values of 82.69% and 82.54%, respectively (Table 1).

Conclusion

Replacing maize with sundried cassava peel meal supplemented with 6% molasses can maintain growth, FCR and nutrient digestibility at up to 50% inclusion without any adverse effect on the Japanese quail birds.

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Table 1. The effect of sundried cassava peel meal supplemented with molasses on the growth performance and nutrients digestibility of Japanese quails as a substitute for maize.

Parameters	T1	T2	T3	T4	SEM	LS
Initial weight (g)	49.80	50.70	50.30	50.80	0.32	NS
Feed intake/bird/week (g)	11.00	10.71	11.69	11.05	1.56	NS
Weight gain/bird/day (g)	3.40	3.60	3.60	3.45	0.09	NS
Final weight (g)	110.40^{a}	113.40^{a}	104.49^{b}	96.04^{c}	1.26	*
Feed Conversion Ratio	1.25	1.27	1.33	1.30	0.04	NS
Crude protein Digestibility (%)	82.69^{a}	82.54^{a}	79.94^{c}	80.69^{b}	0.36	*
Dry matter Digestibility (%)	76.90	77.12	74.69	77.19	0.32	NS
NFE Digestibility (%)	75.42	72.12	70.32	71.24	0.58	NS

Values with different superscript letters across columns are significant (*$P > 0.05$).

Discovering genes and pathways in the shell gland which may be involved in egg cuticle formation by gland shell RNA-seq data analyses

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Application

Unveiling genes involved in cuticle deposition give us a better understanding of this unexploited egg quality trait that has advantages for the industry.

Introduction

The cuticle of an egg is formed in the shell gland and we know there is a considerable genetic variation in cuticle deposition. We can use hormonal treatments to produce eggs without cuticles (Bain, McDade, Burchmore, Law, & Wilson et al., 2013; Wilson, Suther, Bain, Icken, & Jones et al., 2017). In an effort to try to understand more about the molecular mechanisms and biological pathways involved in cuticle deposition, we have analysed global gene expression in the shell gland.

Materials and methods

For the first experimental condition, an injection of chicken gonadotropin-releasing hormone 1 (GNRH1) was administered 10 h before a normal oviposition at a dose of 28.9×10^{-6} mol/kg body weight in PBS (17.3×10^{-6} mol/m^3). For the second experimental condition, neurohypophyseal arginine vasotocin (AVT) was administered i.v. at 1.05×10^{-6} mol/kg body weight in PBS (initially dissolved in 25% v/v acetic acid to 4.76×10^{-6} mol/m^{3}then diluted to 3.8×10^{-9} mol/m^3 with PBS for injection).

We have sequenced RNA from eight biological replicate samples of chicken shell gland in each of the two experimental conditions; GnRH and AVT, this resulted in hens laying eggs with and without cuticle, respectively, but at the same chronological time. After sequencing, samples were analysed with EdgeR. Selected genes from our data analysis were studied further in all samples from the previous experiment by RT-qPCR.

Results

Quality control and data processing steps resulted in rejection of one replicate from the AVT group resulting in eight GnRH and seven AVT biological replicates of 'clean' data totalling ~889M aligned sequence reads. Of a total of 18,346 genes present in the chicken genome, our sequencing reads were assembled onto 17,108 genes (genes with reads per count per million (RCPM) $\geqslant 1$ in at least two samples). After fitting gene-wise generalized linear models and performing likelihood ratio test, a total of 12,248 genes are differentially expressed between the shell gland of the two conditions. After correcting for False Discovery Rate (FDR) we obtained a list of 3431 DE genes (representing around 18,7% of the total number of annotated genes in the chicken genome) of which 46 are up-regulated (fold change $\geqslant 1.5$) and 115 are down-regulated (fold change $\leqslant -1.5$). The set of down-regulated genes was particularly enriched with genes annotated with GO terms related to glycosaminoglycan binding.

Then, selected genes were studied further by RT-qPCR. Gene expressions were normalized using the housekeeping genes LBR and NFUDA. Genes from the down-regulated set (fold change $\leqslant -1.5$) included: Proto-oncogene c-Fos (FOS); Jun proto-oncogene AP-1 transcription factor subunit (JUN); Heparin-binding EGF like growth factor (HBEGF); Regenerating family member 4 (REG4); Secreted phosphoprotein 1 (SPP1; Osteopontin); Thrombospondin-1 precursor (THBS1); Nuclear receptor subfamily 4 group A member 3 (NR4A3), and Heat shock protein family B member 9 (HSPB9). Genes from the up-regulated set (fold change $\geqslant 1.5$) included Gastrokine 2 (GKN2) and TNF superfamily member 10 (TNFSF10). Genes that are highly expressed and are selected because of their biological importance included: Period circadian protein homolog 2 (PER2), and Cryptochrome circadian clock 1 and 2 (CRY1 and CRY2).

Conclusion

The results of these studies have expanded our knowledge of important genes and pathways involved in the final stages of egg formation including the deposition of the cuticle. We are further examining the expression of genes discovered by these experiments and believe it will lead to greater understanding of the function of the shell gland.

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Feeding exogenous xylanase to young broiler chickens

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Application

Commercially available xylanase gave important improvements in the rate of growth of broiler chickens and in the metabolisable energy (ME) of their diets.

Introduction

Non-starch polysaccharides (NSP) in grains are responsible for several anti-nutritive effects in young broilers. To alleviate the negative impact of NSP the inclusion of NSP degrading enzymes (NSPases) is a common practice in poultry production. For NSPases, there are three principal modes of action, including digesta viscosity reduction, grain cell wall destruction and generation of prebiotics (Bedford, 2018). Exogenous xylanases are being constantly improved and upgraded so there is a continued need to evaluate their efficacy and mode of action. Therefore, the aim of the experiment was to study the effect of a commercially available xylanase on growth performance variables, including daily feed intake (FI), weight gain (WG) and feed conversion ratio (FCR), gastrointestinal tract (GIT) development, measured as the weight of the GIT, dietary ME and dry matter retention (DMR) coefficient, when fed to broilers from 0 to 21d age.

Materials and methods

The experiment was conducted at the National Institute of Poultry Husbandry and approved by the Harper Adams University Research Ethics Committee. Six-hundred-day-old male Ross 308 chicks were obtained from a commercial hatchery and were distributed into 30 floor pens (20 birds each). The pens had a solid floor with an area of 2.1 m^2 that was covered with wood shavings. From 0 to 21d age, birds were fed one of the 2 diets with 15 replicates per treatment. The control diet (CTR) contained 300 g/kg maize, 320 g/kg wheat and 330 g/kg soybean meal and satisfied breeder's recommendations. The second diet was based on the CTR plus 16 000 BXU/kg xylanase (XYL; Econase XT, ABVista, UK) on the top. The xylanase used was a preparation of endo-1,4-beta-xylanase produced by a strain of *Trichoderma reesei*. Both diets contained acid insoluble ash (AIA) as indigestible marker. At 15d age, one bird per pen was stunned and killed, and the development of the GIT determined. When birds were 17d old, five chickens from each pen were placed in pens (0.36 m^2) and excreta were collected for three consecutive days, until 19d age. Excreta were collected daily and kept in a fridge. After the last collection, all excreta from each pen were well mixed and a representative sample was taken and oven dried at 60°C. Feed and excreta were then milled to pass 0.50 mm mesh. The gross energy (GE) of feed and excreta was determined using an adiabatic bomb calorimeter and dietary ME and DMR were determined following standard procedures.

Table 1. The effect of dietary xylanase on daily feed intake (FI), daily weight gain (WG), feed conversion ratio (FCR), apparent metabolisable energy (AME), dry matter retention (DMR) coefficient and the relative weight of the gastrointestinal tract of broiler chickens.

Diets	FI	WG	FCR	AME	DMR	GIT%
CTR	47.1	25.5	1.703	11.55	0.706	10.5
XYL	48.4	26.9	1.665	11.75	0.721	10.3
SED	0.89	0.54	0.0261	0.072	0.0046	0.26
P	NS	<0.05	NS	<0.05	<0.05	NS

Results

Birds fed XYL had an improved WG ($P < 0.05$), but FI and FCR did not differ ($P > 0.05$). Feeding XYL improved ($P < 0.05$) dietary AME and DMR by 1.7% and 2.1%, respectively. There were no differences in the total weight of the GIT of birds fed either diet. The results showed that dietary XYL was able to release more nutrients compared to the CTR, thus suggesting that NSP in grains may have been degraded.

Conclusion

The benefits of feeding xylanase were evident even in maize-based diets. The size of the improvements in rate of growth and in metabolisable energy of the feeds are commercially important.

Acknowledgements

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Re-used litter impacts on post-hatch broiler performance, litter quality and caecal morphology

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Applications

The gut microbiota of birds exposed to fresh litter are recognised to harbour more bacteria of litter material origin than those reared on re-used litter which are largely colonised with bacteria of intestinal origin mainly excreted from the previous flocks. The results of this study show that cycling of different bacteria between litter and gut may have an age-dependent impact on broiler performance.

Introduction

Litter quality and composition have a significant impact on broiler growth performance. It has been demonstrated that litter-induced changes in the gut microbiota may be partially responsible for the significant differences in the growth rate of broilers (Saleem, Sparks, Pirzgoliev, & Houdijk, 2012; Torok, Hughes, Ophel-Keller, Ali, & MacAlpine, 2009). Lee et al. (2011) reported that broilers reared on fresh litter had gut microbiota dominated by *Lactobacillaceae* family, whereas members of Clostridiaceae family predominated in birds raised on re-used litter, obtained from gangrenous dermatitis endemic farms. This study was conducted to investigate the growth performance, litter quality, foot pad dermatitis and caecal histomorphology of birds reared on fresh and re-used litter during 6 weeks post-hatch.

Material and methods

A total of 288 Ross 308 day-old male broilers were allocated to fresh or re-used litter in a randomised complete block design, each litter treatment having 12 pens and 12 birds per pen. Fresh soft wood shavings were used as fresh litter material whereas, one-month-old litter from a previous flock that was positive for *E. coli* and coccidia was used as re-used litter. All pens with re-used litter were topped up with a thin layer of fresh litter to reduce early age mortality. Birds were fed *ad libitum* with a wheat-soybean meal-based diets manufactured as a starter (0-21d) and grower (21-42d) phase. Body weight and feed intake (FI) were recorded at post-hatch (d0), d21 and d42. All birds were examined for foot and hock pad dermatitis on d42, when litter samples were collected from each pen to determine moisture content, *E. coli* and cocci enumerations and one bird/pen was euthanised for caecal morphology assessment.

Results

Table 1 shows the effect of fresh or re-used litter on broiler growth performance, litter quality and caecal morphology. Birds reared on re-used litter had lower (5.6%) body weight gain and FI (6.6%) than those on fresh litter from d0 to 21 with similar feed conversion ratio. The growth performance during 21 to 42 days and during the overall period (0 to 42 days) was similar and showed no differences between birds reared on fresh or re-used litter. Litter moisture tended to be greater for re-used litter pens. Coccidia in broilers is ubiquitous however, it was interesting to note that litter coccidial oocyst counts were 1.6 log higher in fresh litter than re-used litter ($P < 0.05$). Speciation data showed that the coccidian oocyst found in both fresh and re-used litter was primarily *Eimeria acervulina*. Caecal surface area, caecal total mucosal thickness and foot and hock pad dermatitis values (data not presented here) were similar between treatments ($P > 0.05$).

Conclusions

The study suggests that the use of re-used litter instigates a mild challenge in birds up to 21 days posthatch and this could be probably due to disrupting gut microbiota homeostasis through the ingestion of litter-borne bacteria and protozoa and thus results in depressed body weight and FI. However, the disappearance of these differences in growth response after day 21 and no differences in caecal morphology may suggest improved resilience and/or resistance arising from early exposure. It cannot be excluded that this contributed to the reduced cocci counts from re-used litter pens. No differences in foot and hock pad scores could be

Table 1. Effects of fresh and re-used litter on growth performance, litter quality and caecal morphology.

	Posthatch d 0-21			Posthatch d 21-42			Litter Analysis d 42			Morphology d42	
	Gain	FI		Gain	FI		Moisture	*E.coli*	Cocci	CSA	CTMT
Treatment	kg/bird/period		FCR	kg/bird/period		FCR	%	log_{10} cfu/g	log_{10} oocysts	(µm2)	
Fresh litter	0.784	1.044	1.334	2.361	3.789	1.607	40.28	7.796	4.75	3,080,969	1409
Re-used litter	0.740	0.975	1.317	2.343	3.847	1.650	43.28	7.717	3.17	3,199,826	1429
P-value	0.035	0.014	0.170	0.701	0.465	0.182	0.101	0.173	<.001	0.726	0.837
SED	0.018	0.024	0.011	0.045	0.078	0.031	1.585	0.056	0.383	325,807	91.3

SED: standard error of deviation; FI: feed intake; FCR: feed conversion ratio (FI/Gain); CSA: caecal surface area; CTMT: caecal total mucosal thickness.

due to small differences in end of trial litter moisture content between fresh and re-used litter.

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Comparative investigation of the phytate susceptibility of feed ingredients from Australia and the UK

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Application

The variation in phytate susceptibility is substantial in different raw materials and a rapid test would allow for more accurate feed formulation to account for this.

Introduction

Phytase is routinely added to broiler diets to denature phytate, an indigestible compound in grains. Phytase has the capacity to release phytate bound phosphorous so has reduced inorganic phosphate additive use in broiler diets (Humer, Schwarz, & Schedle, 2015).

Nutritionists can use the total phytate of a grain to calculate the potential organic phosphorous levels when formulating (with the addition of phytase) and adjust inorganic phosphate levels as required. However, only around 35% of dietary phytate is hydrolysed by exogenous phytase at the ileal level in broilers (Selle & Ravindran, 2007). Therefore, it is important to quantify not only the total phytate of feed ingredients but also the level of susceptible phytate under normal gastrointestinal tract (GIT) conditions.

Materials and methods

Five samples of wheat, soybean meal, rapeseed meal, barley, maize and sorghum were collected from multiple sites across Australia. Free phosphorous and phytic acid concentrations were determined using the Megazyme™ method for determination of total phytate. Susceptible phytate content was determined by warming samples in acetate buffer (pH 4.5) for 10 min to mimic GIT as a preparatory step for the Megazyme™ kit. (Morgan et al., 2016a,b).

Results

The total phytic acid P concentrations of all the feed ingredients were higher in the samples from Australia compared to UK samples of the same ingredient (Table 1). The Australian feed ingredients also showed a greater range of susceptible phytic acid P between different ingredients, with barley and wheat showing 38.97% and 34.89% range of susceptible phytate-P, respectively. In the Australian ingredients, phytase more readily hydrolysed phytate in maize, soybean meal and sorghum in GIT conditions although the highest total phytate was found in rapeseed meal. The UK samples, however, show less than a 14% difference in the range of susceptible phytate for individual ingredients. Sorghum was unfortunately only tested from Australia, as less common in the UK, but interestingly its levels of phytate are relatively low compared to soybean and rapeseed meals and its susceptibility to exogenous phytase averages 94.45% (Table 1).

Conclusion

It is more accurate to formulate diets with consideration of the known susceptible phytate level of the raw materials used, and this would give a more accurate level of organic P available, reducing the need for excess inorganic P addition. There are, however, large variations

Table 1. Susceptible phytic acid P content of feed ingredients from the UK (Morgan et al., 2016a,b) and Australia (2018).

	UK			AU		
Ingredient	Phytate P g/100g	Sus. Phytate (%)	Range	Phytate P (g/100g)	Sus. Phytate (%)	Range
Barley	0.122	55.82	52.68–61.45	0.184	33.36	17.29–56.26
Rapeseed meal	0.235	50.81	46.84–56.16	0.674	18.23	14.25–24.57
Maize	0.141	57.44	51.82–60.78	0.207	64.92	59.16–71.90
Soybean meal	0.096	48.55	43.62–53.34	0.545	70.55	56.10–85.98
Sorghum*	-	-	-	0.197	94.45	75.95–102.72
Wheat	0.069	57.45	49.51–63.45	0.211	39.62	29.84–64.73

* No sorghum was analysed for UK samples.

between both the total and susceptible phytate levels between crops of feed ingredients both between different countries and between and within crops. The need for a rapid phytate measure going forward is clear.

Acknowledgements

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Use of a bio-emulsifier mitigates the detrimental effect of feeding lecithin oil in young broilers

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Application

Addition of a bio-emulsifier in starter diets can bring the performance of birds fed diets with lecithin oil up to soya oil levels.

Introduction

Lecithin oils are claimed to have a similar energy to soya oil, but anecdotally can reduce bird performance. Bio-emulsifiers based on lysophospholipids have been shown to improve emulsification of lipids and thereby improve nutrient absorption (Brautigan, Li, Kubicka, Turner, & Garcia et al., 2016; Papadopoulos, Poutahidis, Chalvatzi, Di Benedetto, & Hardas et al., 2018). Therefore, the use of bio-emulsifiers may improve the digestibility of lecithin oils for young broilers, thereby making their use more cost-effective. The aim of this study was to investigate the effect of a bio-emulsifier on diets made with lecithin oil on the performance of young broilers.

Materials and methods

A total of 480 male Ross 308s were placed in 48, 0.64 m^2 pens on day of hatch and randomly allocated to one of the four diets as follows: Control, Control with lecithin oil – Lecioil (C+ LE), Control plus a bio-emulsifier – Lysoforte EXTEND (C+ BE), or a control with both lecithin oil and bio-emulsifier (C+ LE+BE). Ten birds were placed per pen at d0, with 12 replicate pens per treatment. Birds were fed diets formulated for age and strain of the bird in two phases, starter crumb (d0-10) and grower pellet (d11-21), using a wheat-soya bean meal base. Analysis prior to the trial showed lecithin oil used had higher saturated fat compared with soya (20.5% to 17.2%) and lower AME (33.7 MJ/kg compared with 36.6 MJ/kg for soya oil). However, as the oil is claimed to be equal energy to soya oil, diets were formulated as if this were the case. Feed and water were available *ad libitum*. Birds and feed were weighed by pen on d0, d10 and d21 and FCR calculated. Data were analysed using Univariate GLM in a 2 × 2 factorial to compare the effects of LE and BE using SPSS (v24). This study was approved prior to starting by the NTU ARES school ethical review committee.

Results

Bird weights at d10 and d21 are shown in Table 1 for each treatment and average daily gain (ADG) and feed conversion ratio (FCR) from d0-21. The diets containing both LE oil and the bio-emulsifier tended to significantly improve bird weights and average daily gain over the starter period when compared with the diet with LE oil alone. The addition of LE to the starter diet reduced body weight at day 10, but addition of BE to this diet restored this back to the control diet level. BE improved bird weight up to d21. There were no significant differences in FCR between treatments.

Table 1. Performance data from d0-21, body weight (BW), average daily gain (ADG) and feed conversion ratio (FCR).

Treatment	BW d10 (g)	BW d21 (g)	ADG 0–10 (g/d)	ADG d0-21 (g/d)	FCR d0-21
Control	256^{ab}	934^{ab}	21.2	42.5^{ab}	1.33
Control+LE	249^{b}	907^{b}	20.8	41.3^{b}	1.40
Control+BE	259^{ab}	942^{ab}	21.5	42.8^{ab}	1.35
Control+LE+BE	264^{a}	962^{a}	22.0	43.9^{a}	1.34
SEM	3.2	1.4	0.41	0.50	0.024
LE p value	0.713	0.797	0.963	0.0.858	0.127
BE p value	0.009	0.029	0.064	0.024	0.385
LE*PE p value	0.064	0.093	0.302	0.074	0.322

Values with different superscript letters across columns are significant (P > 0.05).

Conclusion

Diets containing lecithin oil reduce bird weight compared with soya oil to day 10. However, the addition of a bio-emulsifier into starter diets with lecithin oil significantly improves bird performance in the starter period, back to the level of the control. This supplementation can mitigate any detrimental effects of incorporating this type of oil into starter diets for broilers.

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The effect of the host nutritional status and coccidiosis infection on chicken productivity

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Application

Challenging poultry with 10 times the recommended dose of a live coccidiosis (*Eimeria*) vaccine did not have an impact on any of the studied variables.

Introduction

Coccidiosis is a protozoan disease, which is caused by *Eimeria* species. Coccidiosis can lead to widespread deaths and severe weight loss (Chapman, 2014). Trial was designed to characterise the relationships between nutritional status, genetic and immune response. The aim of the study was to evaluate that the resilience to coccidiosis is not only dependent upon the genetic status of the birds but also on its nutritional status.

Material and methods

Seventy-two each of Hy-Line Brown pullets, Ross 308 broiler and H & N Nick Brown layer were used in a 35-day study. Each commercial line was randomly distributed into four treatment groups using a 2 × 2 factorial design with three replicates and six birds/pen. The factors were two feeds (*ad lib* or restricted) and two challenge (with and without coccidia challenge) groups. The wheat soya-based coccidiostats free diet was used. The *ad lib* group had free access to feed and the restricted group had a 10% reduction out of their daily intake as per breed specifications. On d28, all birds in the challenge group were gavaged with 1 ml of Paracox live vaccine (10 times the recommended dose). On d35, four chickens/pen were humanely euthanised and blood and gut samples collected. Feed and birds were weighed on d0, d28 and d35. Faecal samples were also collected from each pen at d35. Data were analysed by ANOVA using GenStat with significance level determined at $P < 0.05$.

Results

Table 1 shows the effect of feed and coccidia challenge on growth performance and faecal oocysts counts in three commercial lines tested. Feed restriction had a significant effect ($P < 0.05$) on body weight gain, whereas, coccidian challenge had no effect ($P > 0.05$). Improved FCR values

Table 1. Effect of feed and challenge on chicken performance over 35-day period.

	Broiler (day 0 to 35)				Pullet (week 14 to 19)			Laying hens (week 22 to 27)			
	AWG	AFI		Faecal	AWG	AFI	Faecal	AWG	AFI		Faecal
Treatment	g/bird/period		FCR g/g	oocysts/g	g/bird/day		oocysts/g	g/bird/day		EP %	oocysts/g
Feed											
Ad lib	2350	3143	1.34	22,714	477	103.4	757	−79	134.8	82.7	146
Restricted	1946	2987	1.54	37,800	180	67.5	214	7	100.8	77.5	615
SED	76.3	100.8	0.031	16,197	41.5	4.36	525.3	27.9	5.092	1.89	362.1
Challenge											
No	2144	3125	1.46	26,854	346	86.9	311	−44	121.6	81.2	559
Yes	2152	3005	1.41	33,660	312	84	659	−29	114	78.9	202
SED	76.3	100.8	0.031	16,197	41.5	4.36	525.3	27.9	5.092	1.89	362.1
P-values											
Feed (F)	<0.001	0.159	<.001	0.379	<.001	<.001	0.331	0.016	<.001	0.03	0.232
Challenge (C)	0.916	0.268	0.12	0.685	0.436	0.529	0.526	0.605	0.177	0.27	0.354
F * C	0.816	0.268	0.082	0.134	0.903	0.529	0.406	0.028	0.177	0.55	0.292

AWG: average weight gain; AFI: average feed Intake; FCR: feed to gain ratio; EP: egg production.

($P < 0.05$) were observed in broilers with *ad lib* access to feed. Faecal oocyst counts were considerably higher in broilers compared to both pullets and laying hens in both challenged and non-challenged groups. Similarly, gut lesion scores were only observed in broilers and blood interleukin 10 cytokine values tended ($P = 0.09$) to show feed * challenge interaction (data not presented here). In laying hens, egg production was affected ($P < 0.05$) by feed.

Conclusion

This experiment shows that feed restriction had a significant effect on the body weights of all commercial lines tested. However, coccidial infection using X10 Paracox live vaccine (which has a mixture of cocci strains) did not have an effect ($P > 0.05$) on productivity and survival fitness of the birds at the measured phenotypes. Further studies are required to investigate if challenging birds using specific pathogenic strains of coccidian will result in significant differences between challenged and unchallenged birds.

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In-feed larvacide produces toxic histopathological effect on liver and kidney of broiler chickens

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Application

In-feed larvacide is not recommended for use in poultry production practice due to its negative effect on animals and public health.

Introduction

Larvacides are commonly used in poultry feed to alter the moulting stage of houseflies (*Musca domestica*) which hatch on droppings, hence reducing the population of flies and smell nuisance in poultry houses. Cyromazine an active ingredient in larvacides has melamine as a metabolite which became a public health concern after the death of 9 infants and hospitalisation of 294,000 others after taking melamine tainted infant formula (World Health Organization, 2008). However, cyromazine is widely used to reduce smell from poultry litter and to increase nitrogen content which usually translates to higher weight gains in broilers without the knowledge of its toxic effect on organs of animals. In this study, toxic effect of in-feed larvacide in broiler organs was investigated.

Materials and methods

All protocols used in this study were approved by the Animal Care and Use Review Committee guidelines of Centre of Excellence in Agricultural Development and Sustainable Environment, Federal University of Agriculture, Abeokuta, Nigeria. A total of 160-day-old Arbor Acre broilers of approximately 40 g body weight were used in the study. Four diets were formulated to contain cyromazine at 0, 0.25, 0.50 and 0.75 g/kg and were assigned to four dietary groups consisting of four replicates per treatment of ten birds

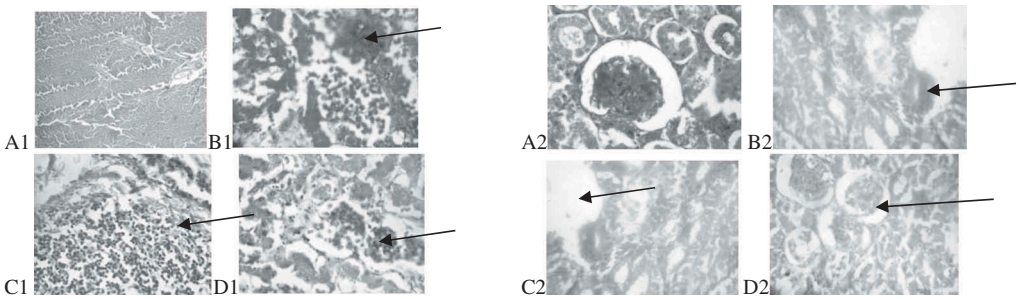

Figure 1. A histopathological view of liver (1) and kidney (2) tissues taken from broilers fed diets containing (A) 0 g/kg cyromazine, (B) 0.25 g/kg cyromazine, (C) 0.50 g/kg cyromazine and (D) 0.75 g/kg cyromazine. Arrows indicate necrosis of hepatocyte of the liver (A1-D1) and tubular necrosis and desquamation of kidney (A2-D2). Magnification x400.

each. At the end of the 42-d feeding trial, one bird per replicate (4 birds/treatment) was sacrificed, the liver and kidney were harvested and stored in sample bottles containing 10% formalin. The tissues were dehydrated in 70% absolute ethanol for 2 h and in another 95% absolute ethanol for 2 h. Impregnation of tissue was done and embedded in molten paraffin wax, blocked after solidification and sectioned on microtone at four-micrometer thickness. The sections were stained with haematoxylin and eosine and then moulted on permanent slides which was observed under high power (x400) microscope lens.

Results

The liver of birds fed diets containing cyromazine was characterised by a focal area of lymphoid aggregates with disseminated necrosis of the hepatocytes and inflammatory cells (Figure 1B1-D1). Additionally, when cyromazine was added to the diet, the kidney was characterised by an interstitial infiltration of cells with tubular necrosis and desquamation (Figure 1B2-D2), which could cause increased renal pressure and subsequent failure. However, this was not observed in the kidney of control birds (Figure 1A2).

Conclusion

It was concluded that in-feed larvacide dosed at 0.25 to 0.75 g/kg resulted in a toxic effect on liver and kidney of broiler chickens. Therefore, the potential risk to both animal and human health should be considered and controlled when using larvacides.

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