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The effect of incremental inclusion of whole grain wheat in the diet of growing turkeys on growth performance, feed conversion ratio, cecal health, and digesta characteristics

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A B S T R A C T

This study was conducted to determine the effects of adding incremental amounts of whole grain wheat (0, 100, and 200 g per kilogram of feed) to the diet of growing turkey poults on growth performance, feed efficiency, digesta pH, and the incidence of cecal distension. Seventy two, 6-wk-old commercial line turkeys were blocked by live weight and randomly allocated to 1 of 3 dietary treatment (n = 4 pens/treatment). Turkeys were offered their respective treatments for the duration of the study. Feed offered and refused and body weights were determined weekly. At 63 d of age 12 turkeys from each treatment were euthanized and crop contents were collected and weighed, pH of gizzard and cecal digesta measured, and ceca and cecal contents visually scored. At 84 d of age, all remaining turkeys were euthanized and the same sampling procedure repeated. Feed conversion ratio was poorer in those turkeys offered diets containing whole grain wheat ($P < 0.05$), declining quadratically ($P < 0.005$) as the proportion of whole grain wheat (**WGW**) in the diet increased. The proportion of WGW found in the crop post-mortem reflected whole wheat inclusion rates of the diets. The pH of gizzard contents at 63 d was lower in turkeys receiving diets supplemented with WGW, declining quadratically ($P = 0.005$) as the proportion of WGW in the diet increased. However, this difference in gizzard pH was not apparent at 84 d of age. Cecal content pH, cecal visual appearance scores, and cecal content visual appearance scores were not affected by the inclusion of WGW to the diet. The inclusion of WGW to the diets of growing turkeys reduces growth performance and feed efficiency suggesting that the addition of whole wheat may have reduced the nutritional quality of the diet as a whole.

Keywords

Turkey, Wheat, Gizzard, Ceca, Digesta

1. Introduction

The feeding of whole grains to poultry has been shown as a means of improving poultry gut health whilst reducing feed processing costs (Forbes and Covasa, 1995, Singh et al., 2014). As a consequence there has been renewed attention by the commercial poultry industry to the feeding of whole grains, not only as a way of reducing feeding costs, but as a means of improving gut health and subsequent litter quality, which could impact negatively on performance, welfare, and carcase quality (Amerah and Ravindran, 2008).

The feeding of whole grains to poultry has been associated with a number of effects on performance, although responses seem to be variable and to some extent dependent upon the species of bird and the way in which whole grains were offered. Munt et al. (1995) reported reduced growth rates in broilers offered free choice diets, whereas Erener et al. (2006) reported improved rates of gain in turkeys using a free choice system. Both Husveth et al. (2015) and Singh and Ravindran (2015) reported improved feed conversion ratio (**FCR**) in broilers fed wholegrains that had been incorporated into the pellet, whereas Taylor and Jones (2001) reported no improvement. Jankowski et al. (2014) reported no improvement in turkey performance when whole grains were incorporated into the pellet, but did report an improvement in FCR when whole grains were added to the diet post-pelleting (Jankowski et al., 2012).

During the past 50 years poultry nutrition, structure of the diet and nutrient requirements have changed noticeably due to improvements in nutritional knowledge and advances in poultry genetics (Havenstein et al., 2003). There is considerable research showing that physical structure of feed (type and form) can affect the development of the digestive tract (Amerah et al., 2007b, Engberg et al., 2002, Svihus et al., 2004), which in turn has been shown to influence subsequent nutrient digestibility (Amerah et al., 2007a, Gabriel et al., 2008, Hetland et al., 2002, Svihus et al., 2010), and digesta characteristics (e.g., pH) (Zdunczyk et al., 2013). Changes in the composition of digesta arriving at the cecum may result in changes in excreta consistency that may in turn impact litter quality (Zdunczyk et al., 2013); both Engberg et al. (2004) and Taylor and Jones (2004) have reported increased digesta viscosity in turkeys fed diets containing whole wheat.

A previous study conducted by this research group investigating the effects that whole grain wheat (**WGW**) had on turkey gut health had noted that consumption of WGW, when offered through a free choice feeding system, was highly variable and that a number of turkeys consumed very little, if any, WGW when given free choice. The aim of this study was to determine whether the feeding of pelleted diets that had been mixed with the graded addition of WGW resulted in selective feeding, and to determine the effects that wheat inclusion, and subsequent nutrient dilution had on turkey growth performance, aspects of gut health, and digesta pH.

2. Materials and methods

The study was subject to local review and conducted in accordance with the University of Reading's current animal research policy and conformed to the United Kingdom's Animal (Scientific Procedures) Act 1986.

A total of seventy two 6-wk-old commercial line turkeys were used in this study. Wing tagged turkey poults were provided by Aviagen (Aviagen Turkeys Ltd, Tattenhall, Cheshire, UK), and were all of the same age, breed, and sourced from a single unit. After arrival turkeys were individually, weighed, blocked by live weight and then randomly allocated to 1 of 3 dietary treatments. Treatments included an unsupplemented control that comprised a pelleted diet that contained no supplementary WGW, a group that received the pelleted diet supplemented with 100g WGW per kilogram of feed and a group that received the pelleted diet supplemented with 200g WGW per kilogram of feed. The pelleted diet comprised of a commercial grower diet (ingredient composition of pelleted diets not disclosed); Grower 1 (F66503, GLW-Feeds Leicestershire, UK) was offered from 42 days of age to 63 d of age, and Grower 2 (F66504, GLW-Feeds) from 63 d to 84 d of age. The change from Grower 1 to Grower 2 was abrupt and occurred in all pens at the same time. The whole grain wheat was mixed with pelleted feed using a mechanical mixer.

The study was conducted in an open pole barn between January and March 2015. The building provided natural ventilation and natural lighting. There were 4 pen replicates per treatment with 6 turkeys in each pen. Each pen provided approximately 0.5 m^2/turkey, was bedded with white wood shavings and equipped with a single bell type drinker, a single suspended feed hopper, and a suspended halogen heat lamp that remained on for the duration of the study.

Turkeys received their experimental diets throughout the entire study period. All feed offered and refused were weighed and recorded weekly on a per pen basis throughout the study. Turkeys were weighed weekly on an individual basis and weights recorded. Laboratory analysis of Grower1 and Grower 2 pelleted diets and whole wheat used in the study are shown in Table 1.

At 63 d of age, three turkeys were randomly selected from each pen and euthanized by captive bolt followed by abrupt exsanguination. The crop was removed intact after which the contents were emptied and sorted to determine the proportion of WGW within the crop. The viscera were exposed and the ceca scored in-situ in terms of appearance using a numerical system adapted from (Raman et al., 2011; Table 2). Cecal contents were emptied from the cecal sac into an Eppendorf tube, scored for their appearance using a system proposed by Saif (2011; Table 2), and cecal digesta pH measured. The gizzard was removed, the contents emptied into a container, and gizzard digesta pH measured. At 84 d of age, all remaining turkeys were euthanized by captive bolt followed by abrupt exsanguination. The viscera were exposed and the ceca scored in-situ in terms of appearance using a numerical system adapted from (Raman et al., 2011; Table 2). Cecal contents were emptied from the cecal sac into an Eppendorf tube, scored for their appearance using a system proposed by Saif (2011; Table 2), and cecal digesta pH measured. The gizzard was removed, the contents emptied into a container, and gizzard digesta pH measured.

Digesta pH (both gizzard and cecal contents) were determined immediately post-sample harvesting. 50 mL of distilled water was added to 5 g of digesta material, mixed thoroughly, and pH measured using a calibrated digital pH probe (Hannah Instruments, HI 110, Bedfordshire, UK). The probe was cleaned with distilled water and calibration checked between samples.

Data pertaining to turkey performance includes feed intake (calculated average feed intake per turkey based on group pen intake), live weight gain (calculated within pen individual daily live weight gain), and feed conversion ratio (calculated from total pen feed intake and total weight gained within pen with respect to age). Growth data, and digesta pH (gizzard and ceca), were analysed by analysis of variance (ANOVA) using a general linear model (GLM) using the Genstat 17th edition statistical software package (VSN International Ltd, Hemel Hempstead, UK). Sources of variation included wheat inclusion rate (2 df). Results are presented as least square means with the standard error of the mean with orthogonal polynomials. Data pertaining to cecal external visual appearance scores and cecal content visual scores were analysed by Pearson Chi-Square. Data are presented graphically with the Chi Square value, degrees of freedom, and *P*-value.

3. Results

3.1 Growth performance

There were no effects of WGW inclusion on rates of feed intake at 63 d of age, although there were effects on growth rate and feed conversion ratio (Table 3). Growth rates were greatest in those turkeys receiving the 0 g WGW per kilogram of feed diet (P = 0.036) and decreased quadratically (P = 0.028) as the proportion of whole wheat inclusion increased. Feed conversion ratios were better in those turkeys receiving the 0 g WGW per kilogram of feed diet (P = 0.009) with feed efficiency declining quadratically (P = 0.004) as the proportion of whole wheat included in the diet increased. The effects of wheat inclusion on feed conversion ratio seen at 63 d of age was still apparent at 84 d with turkeys receiving the 0 g WGW per kilogram of feed diet having better feed conversion ratios (P = 0.004) than those supplemented with WGW with feed efficiency declining quadratically (P = 0.002) as the proportion of whole wheat in the diet increased.

3.2 Proportion of wheat in the crop

As anticipated there was an effect of dietary treatment ($P < 0.001$) on the proportion of wheat found in the crop post-mortem; the proportion of wheat found in the crop mirrored that of the study structure (Table 4), indicating that inclusion and increasing the proportion of wheat in the diet did not appear to result in selective feeding. However, proportions of wheat found in the crop ranged markedly within treatment; 70 to 223 g/kg in turkeys receiving the 100 g per kilogram of feed diet and 104 to 683 g/kg in those receiving the 200 g per kilogram of feed. This would suggest that there was a degree of selection between individual turkeys.

3.3 Gizzard and ceca digesta pH

At 63 d of age, the pH of gizzard digesta from turkeys receiving whole grain wheat was lower than when compared to those receiving the 0 g WGW per kilogram of feed diet (P = 0.006), with pH declining quadratically (P = 0.005) as the proportion of WGW in the diet increased (Table 4). However, this difference was not evident at 84 d of age. There were no effects of treatment on cecal content pH.

3.4 Cecal appearance and content scores

There were no effects of treatment on cecal appearance scores (Figure 1; Pearson Chi square = 4.878, P = 0.570) or cecal content scores (Figure 2; Pearson Chi square = 5.764; P = 0.450).

4. Discussion

The dilution of poultry feed by the use of WGW has been practiced for a number of years using a number of different feeding strategies and inclusion rates of WGW into the base diet. Feeding strategies that have been used include pre-pelleting (pelleted mixture of WGW and other dietary components), post-pelleting inclusion resulting in nutrient dilution, post-pelleting inclusion with dietary adjustment (use of protein concentrate to compensate for nutrient dilution), and free choice feeding (WGW offered in separate feeders to standard diet) (Jankowski et al., 2016). The current study used post-pelleting inclusion that when compared to the 0 g WGW per kilogram of feed diet, resulted in a calculated graded dilution of crude protein content (≈ 15 and 30 g/kg for 100 and 200 g WGW per kilogram of feed, respectively), sugar content (≈ 5 and 10 g/kg for 100 and 200 g WGW per kilogram of feed, respectively) and an increase in starch content (≈ 25 and 55 g/kg for 100 and 200 g WGW per kilogram of feed, respectively). However, the inclusion of WGW did not appreciably affect the calculated energy density of the diets.

Studies investigating the effects of whole grain inclusion and its subsequent effects on turkey performance are limited, although there are a number of studies conducted on broilers. The findings of the current study are similar to those of (Bennett and Classen, 2003); the current study found that although there were no effects of treatment on intake behaviour there were effects with respect to rates of weight gain and subsequent feed conversion efficiency, with rates of gain and efficiency of feed use being poorer in turkeys offered diets containing WGW. Bennett and Classen (2003) reported that the inclusion of WGW reduced both weight gain and feed conversion efficiency as WGW inclusion increased (150-350 g/kg). In contrast, (Jankowski et al., 2012) reported that the feeding of WGW up to 225 g per kilogram did not adversely affect feed intake or body weight gain but improved feed conversion ratio (FCR) when compared to comparable inclusions of ground wheat. The changes in turkey growth performance seen in the current study and that of Bennett and Classen (2003) may be a consequence of the dilution of crude protein; in the current study crude protein contents of the diets, when compared to the control, were reduced by 15 to 30 g/kg with a metabolisable energy (**ME**) content across diets of 13.5 MJ/kg, and that of Bennett and Classen (2003) were reduced by 15 to 25 g/kg with an ME content across diets of 12.6 MJ/kg. However, the study of Jankowski et al. (2012) had similar levels of crude protein dilution as seen in the current study but in contrast had reported improvements in feed conversion efficiency with the addition of WGW to the diet. These differences in responses between studies are difficult to reconcile and may reflect differences in turkey management and/or environmental conditions (stocking rate, temperature, etc.).

There are a number of studies reporting on improvements in gizzard development and associated digestive health in poultry fed whole grains; increases in gizzard weights in both turkeys (Jankowski et al., 2014, Zdunczyk et al., 2013) and broilers (Bennett et al., 2002a, Gabriel et al., 2003, Preston et al., 2000, Williams et al., 2008) have been reported when fed diets containing whole grains. The current study did not assess gizzard weight but instead determined the pH of digesta within the gizzard. The reduction in pH of gizzard contents has been reported in both turkeys (Bennett et al., 2002b, Zdunczyk et al., 2013), and broilers (Engberg et al., 2004, Gabriel et al., 2003). Svihus (2011) proposed that this reduction in pH was most likely due to increased gizzard volume leading to increased digesta retention time resulting in a stimulatory effect on gizzard activity and hydrochloric acid secretion. Benefits of this acidic environment may include reduced pathogenic bacteria (Engberg et al., 2004), and improved gastric digestion (Gabriel et al., 2003, Zdunczyk et al., 2013).

The inclusion of WGW did reduce gizzard digesta pH at 63 d of age in the current study but responses followed a quadratic ($P = 0.005$) rather than linear ($P = 0.116$) response. It could be hypothesised that as the proportion of WGW increased linearly in the diet there would be a commensurate increases in retention time resulting in reductions in gizzard digesta pH. However, this was not the case and reflects the findings of Zydunczyk et al. (2013) who showed that there was no dose dependent change in gizzard digesta pH when the level of whole wheat inclusion in the diet of turkeys was increased. However, it should also be noted that in the current study fibrous bedding material (wood shavings) was found in both the crop and gizzards of all birds sampled. This accumulation of fibrous material may well have increased digesta retention time within the gizzard and as such may have influenced subsequent gizzard digesta pH. A similar observation was made at 84 d of age, whereby bedding material was present in gizzard digesta, irrespective of treatment. This too may have influenced retention time and subsequent digesta pH values thus masking any effect of whole wheat inclusion on gizzard digesta pH resulting in what appeared to be a time dependent response in gizzard digesta pH. Unfortunately only the quantity of feed pellets and whole wheat found in the crop were quantified whereas the presence of bedding material was only noted but not measured. As a consequence it is not possible to confirm this hypothesis in the current study.

Zdunczyk et al. (2013) reported that cecal content pH was lower in turkeys fed diets containing high levels of whole wheat (225 g per kilogram of feed) and this was associated with increases in the concentrations of acetic and butyric acids found in cecal digesta. The findings of the current study were unable to establish any effects of treatment on cecal pH. However, the associated reductions in cecal pH reported by Zdunczyk et al. (2013) were quite small and it could be that any small pH difference seen between treatments in the current study may have been masked by individual bird variation. Short chain fatty acids (**SCFA**) were not determined in the current study but it would have been interesting to note whether SCFA concentrations were influenced by the ingestion of whole wheat; the findings of Zdunczyk et al. (2013) indicated that SCFA concentrations in cecal digesta were altered in both low and high whole wheat fed birds, although cecal digesta pH was only lower in those receiving the highest quantity of whole wheat in their diet. Furthermore Zdunczyk et al. (2013) reported that butyrate concentrations were greater in the digesta of birds receiving whole wheat; butyrate is the preferred energy source for enterocytes and has been shown to positively affect cellular differentiation and proliferation resulting in an increase in epithelial surface area and absorptive capacity (Guilloteau et al., 2010).

Turkeys remained healthy throughout the current study, although there was evidence of mildly distended ceca (cecal scores 2 and above). These were not treatment related suggesting that the provision of whole wheat to the diet did little to reduce the incidence of cecal distention. Similarly, cecal content scores indicated that the majority of ceca contained foamy/liquid content, but this too was not related to treatment, although the foaming was most probably indicative of some form of fermentation activity.

5. Conclusion

The inclusion of whole wheat in the diets of growing turkeys resulted in lower growth rates in the earlier part of the study and poorer rates of feed conversion throughout the entire study period, suggesting that the addition of whole wheat may have reduced the nutritional quality of the diet as a whole. Lower gizzard pH has been related to improved gizzard function and improved digestion, and the findings of this study would suggest that as the consumption of whole wheat increases there is a commensurate reduction in gizzard pH, although the consumption of fibrous bedding material may affect this response. Whole wheat inclusion in the current study did not appear to affect visual cecal health. Although the current study did not evaluate the economic benefit of feeding whole wheat there is a need to evaluate whether improvements in digestive health, and any subsequent improvements in litter and carcase quality, outweigh the associated reductions in turkey growth and feed efficiency.

Conflict of interest statement

The authors declare that they have no conflict of interest.

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Fig 1. Effect of whole grain wheat (WGW) inclusion (g/kg of feed) on cecal external appearance score (adapted from Raman et al., 2011) (Pearson Chi-Square = 4.878, df = 6, P = 0.570)

Fig 2. Effect of whole grain wheat (WGW) inclusion (g/kg of feed) on cecal content score (adapted by Saif, 2011) (Pearson Chi-Square = 5.764, df = 6, P = 0.450)

Table 1

Laboratory analysis of Grower 1, Grower 2 pelleted diets and whole wheat (g/kg DM[1] unless otherwise stated)

Calculated analysis	Grower 1	Grower 2	Whole wheat
Crude protein	257	237	124
Starch	343	286	607
Sugar (sucrose)	67	42	21
Ether extract	85	90	19
Ca	15	9.9	0.7
Mg	2.2	2.1	1.1
P	8.8	6.6	3.2
Metabolisable energy (MJ/kg DM[1])	13.5	13.7	13.4

[1] DM = Dry matter

Table 2

Scoring systems used for the assessment of cecal appearance and content.

Score	Description
Appearance	
0	No pathological changes
1	Mild distension with no colour change
2	Moderate distension with pale colour change
3	Complete distension with blood present in the wall
4	Complete distension with severe cell necrosis
Content	
0	No pathological changes - light brown, smooth consistency
1	Thick and viscous, brown/dark brown in colour
2	Foamy/liquid content, pale yellow in colour
3	Foamy/liquid content, pale yellow in colour with blood present
4	Thick coagulated blood present

(Adapted from Saif, 2011, and Raman et al., 2011)

Table 3

Effect of whole grain wheat inclusion on turkey growth performance.

Item	Whole wheat (g/kg of pelleted diet)			SEM	*P*-values		
	0	100	200		Treatment	Linear	Quadratic
63 d of age							
Feed intake (g/d)	360	346	365	9.0	0.352	0.668	0.181
Growth rate (g/d)	140	124	131	3.2	0.036	0.101	0.028
FCR (g/g)[1]	2.68	2.91	2.76	0.04	0.009	0.180	0.004
84 d of age							
Feed intake (g/d)	473	468	484	13.8	0.705	0.590	0.542
Growth rate (g/d)	200	183	199	6.6	0.186	0.958	0.078
FCR (g/g)[1]	2.37	2.57	2.46	0.03	0.004	0.053	0.002

[1] Feed conversion ratio

Table 4 Effect of whole grain wheat inclusion on crop content and digesta pH

Item	Whole wheat (g/kg of pelleted diet)			SEM	*P*-Values		
	0	100	200		Treatment	Linear	Quadratic
63 d of age							
Crop whole wheat content (g/kg DM)	0	120	239	35	< 0.001	< 0.001	0.927
Gizzard pH	3.45	2.60	3.05	0.18	0.006	0.116	0.005
Cecal pH	5.78	5.78	5.49	0.21	0.535	0.332	0.583
84 d of age							
Gizzard pH	3.23	3.47	3.08	0.13	0.130	0.452	0.061
Cecal pH	5.77	5.54	5.79	0.14	0.397	0.938	0.178