Journal of Animal and Feed Sciences, 22, 2013, 366–370
The Kielanowski Institute of Animal Physiology and Nutrition, PAS, Jabłonna

Short communication

A note on the particle size distribution of intestinal digesta and nutrient digestibility in growing turkeys fed diets with different whole-grain wheat contents

J. Jankowski[1], D. Mikulski[1], Z. Zduńczyk[2,3] and J. Juśkiewicz[2]

[1] University of Warmia and Mazury, Department of Poultry Science, Oczapowskiego 5, 10-718 Olsztyn, Poland
[2]Institute of Animal Reproduction and Food Research, Polish Academy of Sciences, Tuwima 10, 10-747 Olsztyn, Poland

KEY WORDS: wheat, particle size, duodenal digesta, nutrient digestibility, turkey

Received: 26 September 2013
Revised: 28 October 2013
Accepted: 7 December 2013

[3] Corresponding author: e-mail: z.zdunczyk@pan.olsztyn.pl

ABSTRACT. The aim of the present study was to investigate the effect of varying levels of whole-grain wheat in the diet (12.5%, 25%, 37.5% and 50%) on the particle size spectra of duodenal digesta and nutrient digestibility in young turkeys. After feeding from 4 to 8 weeks of age, a linear increase in particles larger than 2 mm (P = 0.002) and a linear decrease in particles ranging in size from 1 to 2 mm and smaller than 0.071 mm (P = 0.001; excluding particles ranging in size from 0.106 to 0.071 mm) were noted in the duodenal digesta of turkeys. No differences were observed in the digestibility coefficients of dry matter and crude fibre or in nitrogen retention. Our findings indicate that the inclusion of whole wheat in the diet increased the proportion of coarse particles in the digesta leaving the gizzard, which did not reduce the apparent digestibility of dry matter and crude fibre, or nitrogen retention. Nonetheless, both the weight gain and feed conversion ratio worsened linearly with increasing amounts of whole wheat in the diet (linear contrast P = 0.002 and P = 0.001, respectively).

Introduction

Feed particle size can significantly affect gastrointestinal tract development and function in poultry through feed intake, activity of exogenous and endogenous enzymes, and changes in intestinal morphology (Engberg et al., 2002; Svihus et al., 2004; Amerah et al., 2007). An important role is played by both the degree of milling of the dietary components (fine or coarse) and the physical form of the diet (mash or pellet). Fine grinding of cereal grains does not contribute to improved performance in broiler chickens compared with feeding whole grain (Rodgers et al., 2012).

Mash diets with a large particle size increase gizzard weight relative to total body weight, while such an effect is not observed in pelleted feed (Engberg et al., 2002; Amerah et al., 2007). Feeding larger particle size and whole grain to poultry has gained popularity as it is believed to improve gizzard function and bird health (Amerah et al., 2008; Gabriel et al., 2008; Biggs and Parsons, 2009).

An increase in gizzard size may improve nutrient digestibility (Nahas and Lefrancois, 2001), exert an antimicrobial effect (Hetland et al., 2002), improve the morphology of the intestinal tract through increased peristaltic movement (Taylor and Jones, 2004) and improve bird performance (Ravindran et al., 2006). It is generally assumed that in broilers, the gizzard reduces particulate material to a uniform size (Hetland et al., 2004). Little is known about the effectiveness of the turkey gizzard in grinding whole grains.

The aim of the present study was to investigate the effect of varying levels of whole-grain wheat in the diet (12.5%, 25%, 37.5% and 50%) on the particle size spectra of duodenal digesta and nutrient digestibility in young turkeys.

Material and methods

Birds, management and diets

The experiment was carried out at the Research Laboratory of the Department of Poultry Science, University of Warmia and Mazury in Olsztyn (Poland), on 350 four-week-old heavy-type Hybrid Converter turkey males randomly assigned to five dietary treatments comprised of 70 male turkeys (seven replicates of 10 birds each).

During the first four weeks of rearing, all birds were fed a commercial diet formulated to meet their nutrient requirements. From 5 to 8 weeks of age, the turkeys were fed *ad libitum* diets composed of protein-fat-mineral-vitamin concentrate (50%) and wheat added as ground-pelleted or whole grain (50%). The control diet (W_0) contained only ground and pelleted wheat. Diets $W_{12.5}$, W_{25}, $W_{37.5}$ contained whole grain in the amount of 12.5%, 25% and 37.5% of the diet, respectively, and diet W_{50} contained only whole wheat. Wheat grain from the same batch was used in all dietary treatments, and its chemical composition was estimated based on crude protein (CP) content (120.0 g · kg^{-1}) and Polish feedstuff analysis tables (Smulikowska and Rutkowski, 2005). Wheat grain was ground in a hammer mill with a screen diameter of 4 mm, at 3000 rpm. The diameter and length of concentrate and wheat pellets were 3 × 2 mm and 4 × 2 mm, respectively. The composition and nutritional value of the concentrate, as a supplement to ground-pelleted or whole wheat, ensured adequate nutrition of turkeys aged 5 to 8 weeks with respect to CP, amino acids and AME. In addition to wheat, the diets contained the same amounts of soyabean meal (38.8%), rapeseed meal (4%), soyabean oil (3%), mineral supplements, mineral-vitamin premix, as well as crystalline methionine, lysine and threonine. The calculated nutritional value of the daily diet was as follows: AME, 2.870 kcal · kg^{-1}; crude protein, 250 g · kg^{-1}; lysine, 15.5 g · kg^{-1}; methionine, 5.2 g · kg^{-1}; Ca, 11.0 g · kg^{-1}; available P, 5.5 g · kg^{-1}.

At eight weeks of age, seven birds were randomly selected from each treatment and transferred to battery cages for a balance trial. The cages were thermostatically controlled, and the turkeys had free access to water from nipple drinkers. Each cage was equipped with excreta collection trays. The birds received the experimental diets in an amount corresponding to 80% *ad libitum* feed intake, to ensure that all feed is consumed. Digestibility was evaluated using the total collection method. After a three-day preliminary period, a collection period was continued for 5 days; the excreta were collected 4 times daily, stored at –20°C, freeze-dried and ground through a 0.5 mm screen. Feed and dried excreta samples were analysed in triplicate for dry matter (DM), nitrogen (N), crude fat and crude fibre (AOAC, 2005).

Determination of particle size distribution in the diet and duodenal digesta

After digestibility assays, seven birds per treatment were sacrificed by cervical dislocation. The duodenum, with the digesta, was removed. The particle size distributions of diets and duodenal digesta were determined by wet sieving using the method described by Lentle et al. (2006). Each sample of diet and digesta was weighed and divided into two subsamples. One subsample was oven dried at 90°C in a forced-draft oven to determine its DM content, and the other was suspended in 50 ml of distilled water prior to sieving. Diet samples were left to stand for 30 min at room temperature prior to sieving to ensure adequate hydration. Each sample was washed through a nest of Retsch (F. Kurt Retsch GmbH & Co. KG, Haan, Germany) sieves of decreasing size (2, 1, 0.5, 0.25, 0.106 and 0.071 mm opening diameter) and the eluate was stored for determination of soluble matter. The contents of each of the sieves were subsequently washed onto dried, pre-weighed filter papers. Filter papers and eluate samples of known volume were dried in a forced-draft oven at 90°C before re-weighing. The weight of particles from each sieve was expressed as a percentage of total dry matter recovered, including solubles.

Calculations and statistical analysis

Relative proportions (on a dry-weight basis) of particle size classes in the duodenal digesta samples of turkeys were calculated as: (feed particle fraction – duodenal digesta particle fraction)/feed particle fraction. For performance parameters, a pen was considered a replicate experimental unit in the statistical analysis. Other results were analysed with each turkey as a replicate. Linear, quadratic and cubic polynomial contrasts were used to evaluate the effects of different dietary levels of whole-grain wheat (Statistica 8.0 software, StatSoft Inc., 2007). The effects were considered to be significant at $P \leq 0.05$, and were expressed as mean values with pooled SE.

Results and discussion

The sieve analysis revealed that the particle size in the duodenal digesta was determined by the composition of diets administered to the turkeys (Table 1). It was found that an increased amount of whole grains in the diet resulted in a linear increase in particles larger than 2 mm ($P = 0.002$) and a linear decrease in particles ranging in size from 1 to 2 mm and smaller than 0.071 mm ($P = 0.001$ excluding particles ranging in size from 0.106 to 0.071 mm) in the duodenal digesta. The observed trends are consistent with the findings of other authors who analysed diets with a different content of coarse particles (Lentle et al., 2006), and mash or pelleted diets (Amerah et al., 2007).

Amerah et al. (2007) demonstrated that passing through the stomach decreases the number of feed residue particles larger than 0.500 mm in the intestinal contents, however, when coarser feed is administered, a high number of particles larger than 0.500 mm transited the duodenum without comminution. The findings of Amerah et al. (2007) do not support previous research conducted by Hetland et al. (2002), who reported that the gizzard was able to grind all organic constituents of feed to a very fine consistent particle size regardless of the original size of feed. Our results are consistent with those of Amerah et al. (2007) and differ from the conclusion of Hetland et al. (2002).

In the present study, no differences were observed in the coefficients of apparent digestibility of dry matter and crude fibre, or in nitrogen retention (Table 2). In another experiment (Amerah et al., 2007), the intestinal digestibility of lupine protein was lowest for coarse seeds, higher for fine seeds, and highest for medium-sized seeds. In a study by Peron et al. (2005), fine grinding of wheat before pelleting of chicken diets increased starch digestibility, but did not increase protein or fat digestibility as compared with chickens fed a diet containing wheat that was coarsely ground before pelleting. In one of the few experiments concerning the nutrient digestibility of diets containing whole grain, Biggs and Parsons (2009) found that feeding 10% to 20% whole wheat increased amino acid digestibility. In our experiment, whole wheat contained in turkey diets had no effect on the digestibility of dry matter, crude fibre and crude fat or on nitrogen retention – neither the expected beneficial effect of a low inclusion rate of wheat nor the potential adverse impact of a high inclusion level of whole grain were noted.

Table 1. The proportions (on a dry weight basis) of various particle size classes in the diets contained different levels of whole grain and duodenal digesta samples of turkeys[1]

Treatment[2]	Particle size class, mm						
	> 2.0	1.0–2.0	0.5–1.0	0.25–0.5	0.106–0.25	0.071–0.106	< 0.071
W_0	0.770	0.622	0.444	0.032	-0.025	0.146	-0.690
$W_{12.5}$	0.764	0.603	0.129	-0.025	0.131	0.268	-0.836
W_{25}	0.777	0.500	-0.006	-0.490	-0.293	0.162	-0.976
$W_{37.5}$	0.831	0.559	0.136	-0.793	-0.632	-0.256	-1.814
W_{50}	0.842	0.323	-0.191	-0.770	-0.358	0.217	-1.763
SEM	0.010	0.024	0.041	0.073	0.067	0.100	0.083
Contrast							
linear	0.002	<0.001	<0.001	<0.001	<0.001	0.594	<0.001
quadratic	0.300	0.058	0.187	0.423	0.481	0.641	0.148
cubic	0.339	0.090	<0.001	0.042	0.005	0.135	<0.001

[1]relative proportion (on a dry weight basis) of particle size classes in the duodenal digesta samples of turkeys was calculated as: (feed particle fraction – duodenal digesta particle fraction)/feed particle fraction. [2]W_0, W_{25}, $W_{37.5}$, W_{50} – whole grain in the amount of 0, 12.5, 25, 37.5 and 50% diet, respectively. Data represent mean values of 7 turkeys per treatment. SEM – standard error of the mean

Table 2. Coefficients of nutrient digestibility[1], %

Treatment[2]	Coefficients of apparent total tract digestibility			Apparent nitrogen retention
	dry matter	crude fat	crude fibre	
W_0	58.8	91.0	17.3	51.7
$W_{12.5}$	56.0	90.8	19.1	52.1
W_{25}	56.4	91.1	18.2	51.1
$W_{37.5}$	56.2	90.8	16.7	50.4
W_{50}	55.5	91.0	18.0	50.8
SEM	0.589	0.245	0.639	0.385
Contrast				
linear	0.133	0.935	0.828	0.218
quadratic	0.479	0.986	0.758	0.939
cubic	0.386	0.953	0.253	0.405

[1]data represent mean values of 7 turkeys per treatment. SEM – standard error of the mean. [2]W_0, W_{25}, $W_{37.5}$, W_{50} – whole grain in the amount of 0, 12.5, 25, 37.5 and 50% diet, respectively

Different physical forms of wheat in the diet did not decrease feed intake, however, they affected body weight gains and feed conversion in the turkeys (Table 3). Statistical analysis revealed that weight gains decreased linearly and feed conversion deteriorated with increasing amounts of grain in the diet (both $P = 0.001$). In comparison with the control group, distinctly worse results were noted in groups $W_{37.5}$ and W_{50}. The present results of growth performance, observed over 5 to 8 weeks of age, were confirmed in another study in turkeys fed the experimental diets to 12 weeks of age (Jankowski et al., 2012). In that experiment, a low inclusion level of whole wheat (18% on average between 4 and 18 wk of age) had no influence on the body weights of birds, but it improved feed conversion.

In the current experiment, a reduction in weight gain due to a high grain content contrasted

Table 3. Growth performance, feed consumption and feed conversion ratio of turkeys from 5 to 8 wk of age[1]

Treatment[2]	Initial body weight, kg	Daily feed intake, g · bird	Body weight gain, kg	Feed conversion ratio, kg · kg^{-1}
W_0	0.96	184.3	2.66	2.01
$W_{12.5}$	0.96	181.5	2.62	2.02
W_{25}	0.96	182.6	2.57	2.07
$W_{37.5}$	0.96	184.1	2.47	2.16
W_{50}	0.96	176.1	2.35	2.18
SEM	0.006	1.636	0.036	0.016
Contras				
linear	-	0.254	0.002	0.001
quadratic	-	0.476	0.455	0.716
cubic	-	0.256	0.901	0.188

[1]data represent mean values of 7 replications per treatment. SEM – standard error of the mean.[2]W_0, W_{25}, $W_{37.5}$, W_{50} – whole grain in the amount of 0, 12.5, 25, 37.5 and 50% diet, respectively.

with similar coefficients of dry matter and fibre digestibility, and nitrogen retention in all groups.

This discrepancy can be explained by the fact that the coefficients of total tract apparent digestibility of nutrients less digested in the small intestine can be realigned by fermentation processes in the lower gastrointestinal tract. This could be also related to the carbohydrate fraction, including starch grains, which provides more than 50% of the apparent metabolizable energy of the diet for poultry (Weurding et al., 2003). Such a possibility is supported by the linear increase in the amount of caecal content and production of short-chain fatty acids in turkeys fed diets with a higher content of whole grain, as shown in another paper with a similar experimental procedure (Jankowski et al., 2013; Zduńcyk et al., 2013). It is known that carbohydrates fermented in the caeca are energetically less efficient than those digested by endogenous enzymes in the small intestine (Weurding et al., 2001). Therefore, the true energetic value of the diet with an enhanced whole grain level may be lower, thus reducing body weight gain by poultry.

It can be concluded that the inclusion of whole wheat in the diet increased the proportion of coarse particles in the digesta leaving the gizzard, which did not reduce nitrogen retention or the apparent digestibility of dry matter, crude fat and crude fibre assessed for the whole gastrointestinal tract. Both weight gain and feed conversion worsened linearly, however, with increasing amounts of grain in the diet.

Acknowledgements

This work was supported by the Polish Committee for Scientific Research, Project No. NN311 400 339.

References

Amerah A.M., Ravindran V., Lantle R.G., Thomas D.G., 2007. Performance and digestive tract characteristics of broilers as influenced by particle size and feed form. In: Poultry Research Foundation (Editor). Proceedings of 19th Annual Australian Poultry Science Symposium. Sydney, New South Wales, pp. 85–88

Amerah A.M., Ravindran V., 2008. Influence of method of whole-wheat feeding on the performance, digestive tract development and carcass traits of broiler chickens. Anim. Feed Sci. Tech. 147, 326–339

AOAC, 2005. Association of Official Analytical Chemists, Official Methods of Analysis. 15th Edition. Arlington, VA

Biggs P., Parsons C.M., 2009. The effect of whole grains on nutrient digestibilities, growth performance, and cecal short-chain fatty acid concentrations in young chicks fed ground corn-soybean meal diets. Poultry Sci. 88, 1893–1905

Engberg R.M., Hedemann M.S., Jensen B.B., 2002. Influence of grinding and pelleting of feed on the microbial composition and activity in the digestive tract of broiler chickens. Brit. Poultry Sci. 44, 569–579

Gabriel I., Mallet S., Leconte M., Travel A., Lalles J.P., 2008. Effect of whole wheat feeding on the digestive tract of broiler chickens. Anim. Feed Sci. Tech. 142, 144–162

Hetland H., Svihus B., Olaisen V., 2002. Effect of feeding whole cereals on performance, starch digestibility and duodenal particle size distribution in broiler chickens. Brit. Poultry Sci. 43, 416–423

Jankowski J., Mikulski D., Zdunczyk Z., Mikulska M., Juskiewicz J., 2012. The effect of diluting diets with ground and pelleted or with whole wheat on the performance of growing turkeys. J. Anim. Feed Sci. 21, 735–747

Jankowski J., Zdunczyk Z., Mikulski D., Przybylska-Gornowicz., Sosnowska E., Juskiewicz J., 2013. Effect of whole wheat feeding on gastrointestinal tract development and performance of growing turkeys. Anim. Feed Sci. Tech. 185, 150–159

Lentle R.G., Ravindran V., Ravindran G., Thomas D.V., 2006. Influence of feed particle size on the efficiency of broiler chickens fed wheat-based diet. J. Poultry Sci. 43, 135–142

Nahas J., Lefrancois M.R., 2001. Effect of feeding locally grown whole barley with or without enzyme addition and whole wheat on broiler performance and carcass traits. Poultry Sci. 80, 195–202Peron A., Bastianelli D., Oury F.X., Gomez J., Carre B., 2005. Effect of food deprivation and particle size of wheat on digestibility of food components in broilers feed on a pelleted diet. Brit. Poultry Sci. 46, 223–230

Ravindran V., Wu Y.B., Thomas D.G., Morel P.C.H., 2006. Influence of whole wheat feeding on the development of gastrointestinal tract and performance of broiler chickens. Aust. J. Agr. Res. 57, 21–26

Rodgers N.J., Choct M., Hetland H., Sundby F., Svihus B., 2012. Extent and method of grinding of sorghum prior to inclusion in complete pelleted broiler chicken diets affects broiler gut development and performance. Anim. Feed Sci. Tech. 171, 60–67

Smulikowska S., Rutkowski A., 2005. Nutrient Requirements of Poultry (in Polish). 4th revised Edition. The Kielanowski Institute of Animal Physiology and Nutrition, PAS, Jabłonna (Poland), pp. 117–119

StatSoft Inc., 2007. Statistica (data analysis software system), version 8.0. Accessed Jan. 16, 2011. http://www.statsoft.com

Svihus B., Juvik E., Hetland H., Krogdahl A., 2004. Causes for improvement in nutritive value of broiler chicken diets with whole wheat instead of ground wheat. Brit. Poultry Sci. 45, 55–60

Taylor R.D., Jones G.P.D., 2004. The incorporation of whole grain into pelleted broiler chicken diets. II. Gastrointestinal and digesta characteristics. Brit. Poultry Sci. 45, 237–246

Weurding R.E., Enting H., Verstegen M.W.A., 2003. The relation between starch digestion rate and amino acid level for broiler chickens. Poultry Sci. 82, 279–284

Weurding R.E., Veldman A., Veen W.A.G., van der Aar P.J., Verstegen M.W.A., 2001. Starch digestion rate in the small intestine of broiler chickens differs among feedstuffs. J. Nutr. 131, 2329–2335

Zdunczyk Z., Jankowski J., Mikulski D., Przybylska-Gornowicz B., Sosnowska E., Juskiewicz J., 2013. Gastrointestinal morphology and function in turkeys fed diets diluted with whole grain wheat. Poultry Sci. 92, 1799–1811