THE RATE OF PASSAGE OF DIGESTA INFLUENCES ENERGY METABOLISM IN BROILER CHICKENS

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Summary

This study examined the relationship between digestion of energy and transit time of digesta in chickens given a wheat-based diet, with and without feed enzymes. There was a significant (P<0.05) positive correlation between apparent metabolisable energy (AME) value and whole tract transit time (WTTT) determined with ferric oxide marker administered in a gelatine capsule. That is, chickens with longer transit times had higher AME values. Despite genetic selection for liveweight gain and feed efficiency over many generations, the modern broiler chicken exhibits relatively wide variation in both energy metabolism and rate of passage of digesta. However, rate of passage of digesta appears not to be the reason for previously observed differences between males and females in the digestion of energy. Nevertheless, it is possible that underlying sex-dependent differences were not expressed in this particular study due to the high AME value (15.6 MJ/kg DM) of the wheat. Likewise, the high AME value also explains why there were no responses to the feed enzymes.

I. INTRODUCTION

Modern broilers have a prodigious capacity to eat (Mahagna and Nir 1996), a relatively short retention time for ingested food, and greater absorptive capacity (Mitchell and Smith 1991) compared with layers. Iskander and Pym (1987) reported that broiler chickens selected for improved feed efficiency had a slower digesta transit time and improved retention of dietary energy and protein compared with broiler chickens selected for increased feed intake. Hence it is possible that the different selection objectives and strategies used over the years to produce the current commercial lines of broiler chickens may well have produced differences between the lines in transit time, and consequently in energy metabolism. There is a lack of published data on the variation that may exist between strains and between individual birds within a strain in the relationship between rate of passage of digesta and digestion of energy. If large differences exist, it would help explain, at least in part, the wide between-bird variability in AME observed by Hughes and Choct (1997). Similarly, differences may exist between males and females in transit time, as observed in gut structure (Hughes 2003).

The following experiment tested the hypotheses that (a) AME values and digest transit time were related, and (b) the relationship between AME and transit time differed between males and females.

II. MATERIALS AND METHODS

Ross broiler chickens were raised from hatch in two rearing pens in a controlled temperature room. Male and female chickens were reared separately, and maintained on commercial starter crumbles. At 17 days of age, a total of 32 chickens were transferred in single-sex pairs to 16 metabolism cages located in a controlled-temperature room set at 25-27°C initially, and given starter crumbles. The temperature setting in the room was reduced daily until it was 22°C at the end of the experiment. Birds had free access to feed and water prior to and during the experimental period. Chickens were placed one per cage in 24 cages for the experiment when they were 19 days old, and continued to receive the starter crumbles.

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The basal diet comprised (in g/kg), 800 wheat (variety Oxley grown at Narrabri, NSW in 2000), 155 casein, 20 dicalcium phosphate, 11 limestone, 7 DL-methionine, 2 vitamin and mineral premix, 3 salt, and 2 choline chloride (60%). Enzyme products with xylanase activity were added to the basal diet to provide four dietary treatments comprising control (no enzyme), Avizyme 1300 (1kg/tonne), Kemzyme W1 (1kg/tonne), and Bio-Feed Wheat CT (200g/tonne). In addition to xylanase activity, Avizyme 1300 had protease activity and Kemzyme W1 had β-glucanase, protease, amylase, cellulase and lipase activities. The four experimental dietary treatments were replicated six times (three female and three male chickens) in a randomised complete block layout. Experimental diets were pelleted (4 mm diameter and 6 mm length) in a cold-press to avoid selective feeding.

On day 6 of the experiment, chickens were administered with a gelatine capsule containing ferric oxide (Fe₂O₃ 200 mg/kg live-weight) as per the method of Iskander and Pym (1987). Excreta trays were examined frequently for signs of red colouration from ferric oxide in voided droppings. Whole-tract transit time (WTTT) for each chicken was taken as the time elapsed (in minutes) from time of administration of ferric oxide in a gelatine capsule to time of first observation of red colouration in droppings.

AME values for diets were determined by measurements of total feed intake and total excreta output and subsequent measurement of gross energy values of feed and excreta by bomb calorimetry. The values for AME of wheat were calculated by subtraction of energy contributed by casein (assumed to be 20.1 MJ/kg dry matter).

III. RESULTS

Effects of diet, and the interaction between diet and sex, were not significant (P>0.05) for any measurement. Males were significantly greater in live weight (in g/bird) than females at the start (948 vs 831), and at end of the experiment (1425 vs 1217), gained more weight (476 vs 386) and ate more feed (99.1 vs 84.6 g/bird/d), respectively. The mean AME value for the wheat was extremely high (15.6 MJ/kg dry matter) and ranged from 14.4 to 16.3 MJ/kg DM for individual birds. The relationship between AME of the wheat and whole tract transit time is shown in Figure 1.

AME wheat (MJ/kg dry matter)

![](Figure 1: Plots of values for AME of wheat and whole tract transit time (WTTT) for individual chickens (n = 24). Males are represented by □ and females by ♦. Data shown here are untransformed values for WTTT. Similar statistical results were obtained for log e transformed WTTT

64
Analysis of covariance indicated that the linear relationship between AME and WTTT was the same for males and females. The omission of data from one female bird with the lowest AME value (14.4 MJ/kg DM) did not alter the overall result. The two chickens with longest transit time were females and are shown in Figure 2 as the points with lowest energy excretion values. The chicken with the lowest AME value in Figure 1 was also a female and had a higher energy excretion value than any other female (Figure 2).

![Energy excreted (MJ per bird)](image)

**Figure 2.** Relationships between energy excreted and gross energy intake for male (□) and female (◆) chickens.

Analysis of covariance indicated that the linear relationship between energy intake and energy excretion shown in Figure 2 was the same for males and females. Estimated endogenous energy loss was 22 kJ/bird/day, which is considerably less than 46 and 101 kJ/bird/day estimated for females and males, respectively, by Hughes (2003).

**IV. DISCUSSION**

AME increased linearly with whole tract transit time. This relationship was unaffected by the sex of the chicken. The lack of response to enzymes by chickens given the wheat-based diet was probably due to the unusually high AME value of the wheat. An AME value of 15.6 MJ/kg DM is at the high end of the ranges for Australian wheats (Hughes and Choct 1999). Repeated measurements of AME values for this wheat in subsequent experiments (data not shown) confirmed this high value.

In this experiment, chickens were given cold-pressed pellets containing 800 g/kg wheat which was not milled prior to pelleting. The resulting pellets were easily broken during feeding activity by the chickens. Svihus and Hetland (2001) pointed out that ileal starch digestibility was increased when cold-pressed pellets were crushed to mash prior to feeding, and when some of the wheat component of the diet was fed as whole grain. Hence, it is possible that the physical form of the feed contributed to the high AME value.

Although not measured, it is highly likely that this particular wheat had a relatively low concentration of soluble NSP given its very high AME value. This could explain why energy excretion by both males and females in this experiment increased linearly with increasing energy intake, and why it was comparatively lower than that for most of the chickens fed a diet based on low AME wheat as used by Hughes (2003). Svihus and Hetland...
(2001) showed that overloading the digestive tract of male chickens with starch can result in incomplete digestion of starch, and impaired feed conversion, with the possibility that microbial fermentation in the hindgut could result in large losses of energy. There was no indication in the present study that a high starch intake overloaded the digestive tract of either sex in contrast to the observations made on male chickens by Svihus and Hetland (2001). This tends to suggest that it is the soluble NSP component of a high grain intake rather than the starch content per se that causes the impairment in starch digestion and leaves the chickens vulnerable to microbial overgrowth of the small intestine (Choct et al., 1996).

The relatively long WTTT of 206 minutes observed here with a wheat diet compared with WTTT of 165 minutes for a commercial broiler feed reported by Hughes et al. (2002) is difficult to explain on the basis of what is known about the effects of soluble NSP and addition of enzyme to the diet on digesta viscosity and transit time. The commercial broiler diet used previously and the experimental wheat diets used here all contained recommended dosages of enzymes so it seems unlikely that digesta viscosity would contribute to a difference in transit time. Similarly, it seems unlikely that soluble NSP was the cause because this would require the wheat diet to contain a higher concentration of soluble NSP than the commercial diet, which is not consistent with the very high AME value of the wheat. Perhaps the difference in transit time was associated with the physical form of the feed offered (relatively hard, steam-treated starter crumbles compared with soft cold-pressed pellets used in the present experiment), or the physical and chemical attributes of the different diets. A further possibility is the insoluble NSP content of the respective diets. Hetland and Svihus (2001) recently pointed out that inclusion of oat hulls in the diet shortened digesta transit time but did not affect nutrient digestibility. Insoluble NSP in flourmill offal added to the commercial broiler diet may have reduced the transit time.

V. CONCLUSIONS

The positive correlation between digesta transit time and retention of dietary energy in broiler chickens observed in this study is consistent with the report by Iskander and Pym (1987) on broilers selected for feed efficiency. Because the AME value of wheat was high, the work ought to be repeated with wheat of lower energy value (e.g., in the range 13 to 14 MJ/kg DM) in order to determine the relative importance of rate of passage of digesta on digestion and absorption of nutrients in individual chickens of both sexes.

REFERENCES