APRW -63

Influence of Whole Grain Diets on Glycemic Response Indices and Whole Tract Transit Time in Broiler Chicken

O. O. Adeleye
Agricultural Biochemistry and Nutrition Unit, Department of Animal Science, University of Ibadan, Nigeria
Corresponding author: O. O. Adeleye; E-mail: ooadeleye@rocketmail.com; Tel: +2348037074723

Abstract
The influence of whole millet grain feeding on (a) starch digestion and glucose absorption, (b) digesta residence time in the gastrointestinal tract, and (c) relationship between glycemic response and digesta residence time in broiler chicken was assessed in this study. A total of 360 1-day-old broiler chicks of a commercial breed (Arbor-acre) were randomly allotted to 6 treatment groups of 5 replicates, 12 chicks per replicate. Chicks were fed diets containing 0, 20, 40, 60, 80, or 100% whole millet replacement for milled millet in broiler starter diets with supplemental phytase for 28 days. On d-21, blood was drawn from fasted chicken (2 per replicate) before feeding and at intervals up to 4.5 hours postprandial to assess glycemic response. On d-28, whole tract transit time was assessed by feeding the experimental diets containing 1% chromic oxide to fasted chicken and observing time lapse until coloured excreta was observed. Whole millet in the diets had no effect on mean glucose concentration; mean incremental glucose concentration, time at peak glucose concentration and whole tract transit time. Higher whole millet inclusions i.e. W80 and W100, recorded lower area under the curve (AUC) values (1103.76 ± 67.85 and 1111.98 ± 78.20 mg dL^{-1}. h^{-1} respectively) with highest AUC observed in W0 (1190.40 ± 79.42 mg dL^{-1}. h^{-1}). However area under the incremental curve was not influenced by whole millet inclusion in the diets. In conclusion, whole millet inclusion in the diets of broiler chickens did not affect starch digestion, glucose absorption or digesta residence within the gastrointestinal tract.

Keywords: Plasma glucose, starch digestion, glucose absorption, whole grain feeding

Introduction
Feed represent 60 to 70% of production costs in any poultry enterprise, hence the adoption of whole grain feeding (WGF) regimes such as free choice feeding- *ad libitum* choice of whole grain with another feed in separate feeders, mixed feeding- whole grain mixed with another compound feed, and sequential feeding- whole grain and another feed in the same feeder at different times (Singh et al. 2014) geared at improved feed utilization, lowered production costs and increased profits by lowering/eliminating milling costs.

Although the practice of WGF contradicts the conventional practice of finely grinding the grain components of the diet in a bid to increase surface area of the feed and facilitate digestion, WGF improves functionality and development of the gizzard (Fernandes et al. 2013; Pacheco et al. 2015), colonization of the hindgut by commensal bacteria (Santos et al. 2007, 2008) and prevention of coccidiosis and other enteric diseases in the lower gut (Cumming, 1992). WGF affects gizzard function by enhancing the initiation of protein digestion by pepsin and HCl, as well as amylase-induced starch digestion in the small intestine by prior physical disruption of starch granules (Liu et al. 2015).

However, WGF may increase residence time in the gastrointestinal tract as a result of retention of whole grain particles in the gizzard for further grinding to a consistent fine size (Clemens et al. 1975). The retention of whole grain particles in the gizzard also increases interaction between HCl, digestive enzymes and the feed. The resultant effect of this phenomenon on starch digestion and absorption in chickens remains unclear.

Against this backdrop the following hypotheses were assessed in broiler chicken:

1. Rate of starch digestion and glucose absorption in the small intestine as reflected in glycemic response indices, is influenced by WGF,
2. Digesta residence time in the gastrointestinal tract is affected by WGF
3. A relationship exists between glycemic response and digesta residence time in broiler chicken

Materials and Methods
Six experimental broiler starter diets (crude protein 22.03%; metabolizable energy 3182.91 kcal/kg ME) containing (g/100g): millet 50, soya bean meal 25.5, maize starch 8, fish meal 7, soya oil 5.5, di-calcium phosphate 1.7, limestone 1.5, vitamin-mineral premix 0.2, lysine-HCl 0.2, DL-methionine 0.2 and sodium chloride 0.2, with 0, 20, 40, 60, 80 and 100% of its milled millet content replaced with whole millet grain were assigned W0,W20, W40, W60, W80 and W100 respectively. Diets were supplemented with a commercial phytase at

0.4g/kg diet. Three hundred and sixty 1-day-old unsexed broiler chicks (Arbor acre) were obtained from a reputable commercial hatchery and randomly allotted to the dietary treatment groups in 5 replicates, 12 chicks per replicate. The experimental diets were offered *ad libitum* as a mash in a mixed feeding regime. The chicks were raised on deep litter, and their management was as reported by Adeleye et al. (2016).

At d-21, two broiler chicks per replicate were fasted for ~ 12 hours (only allowing access to drinking water) prior to the onset of the glycemic response study. Blood was drawn from each chick before the feed was offered for 30 minutes, thereafter blood was drawn at 0.25, 0.5. 1.0. 1.5, 2.0, 2.5 and 4.5 hours postprandial. Glucose concentration was measured in each blood sample immediately after collection using a glucometer (ACCU-CHEK active, Roche Diagnostics GmbH, Mammheim, Germany). Glycemic response indicators; mean glucose concentration (mg/dL), maximum glucose concentration, mean incremental glucose concentration, maximum incremental glucose concentration, time to peak glucose concentration, area under the curve and area under the incremental curve, were estimated for each chicken.

At d-28, whole tract transit time (WTTT) study was carried out on 3 chickens per replicate. Chickens were fasted for ~ 12 hours (only allowing access to drinking water). Experimental diets containing 1% chromic oxide were offered, and time lapse before coloured (green) excreta was observed, was noted. Incremental glucose concentration was obtained from concentration of glucose at every time point minus the baseline glucose concentration (fasting glucose concentration), and area under each curve was estimated using the trapezoidal method.

Statistical analysis of data was performed using SPSS v 20, and means separated using DMRT ($p \leq 0.05$). The relationship between whole tract transit time and area under the curve, area under the incremental curve was also assessed by linear regression.

Results and Discussion

Replacement of milled millet by whole millet grains in the diet of broiler chicken did not influence glycemic response indices: mean glucose concentration, maximum glucose concentration, mean incremental glucose concentration, maximum incremental glucose concentration, and time to peak glucose concentration. However, the area under the curve was highest in chicken on the control (W0) diet (1190.40 ± 79.42 mg dL^{-1}. 270 min $^{-1}$) and least in chicken on the W80 and W100 diets (1103.76 ± 67.85 and 1111.98 ± 78.20 mg dL^{-1}. 270 min $^{-1}$ respectively). On the other hand, the area under the incremental curve (obtained by correcting glucose concentration observed at each time point with the baseline glucose concentration (fasting blood glucose concentration)) remained unaffected by whole millet grain inclusion at all levels. Whole tract transit time was also unaffected by whole millet grain inclusion in the diets and ranged from 122.40 ± 38.48 to 158.40 ± 58.61 minutes.

While there exists no known published work that studied the effect of whole millet grain inclusion in the diet of broiler chicken on glycemic indices as a measure of rate of starch digestion and absorption, numerical increase in ileal starch digestibility by 15.2% (Svihus and Hetland 2001) and significant improvement in excreta starch digestibility (Svihus et al. 2010) have been reported in broiler chicken fed whole wheat diets. The possibility of WGF promoting starch digestion and glucose absorption in the posterior ileum has also been argued (Liu *et al.,* 2015).

Table 1. Glycemic response indices of 21-d-old broiler chicken as affected by whole millet inclusion in their diets

Glycemic response indices	W0	W20	W40	W60	W80	W100
Mean glucose conc.(mg/dL)	254.66±18.2	250.44±14.0	256.58±15.1	248.76±14.7	241.98±11.45	242.38±15.1
Max. glucose conc.(mg/dL)	286.40±21.0	290.10±22.7	295.60±22.2	284.11±22.9	274.00±19.4	277.30±26.2
Mean incremental glucose conc. (mg/dL)	49.46±12.5	38.54±18.5	43.63±28.0	36.13±24.9	35.28±15.6	39.88±32.3
Max. incremental glucose conc. (mg/dL)	81.20±23.0	78.20±27.9	82.20±39.0	71.44±34.1	67.30±24.2	74.80±39.3
Time at peak glucose conc. (hours)	2.15±1.6	1.55±1.7	1.65±1.3	1.38±1.3	1.90±1.2	1.60±1.2
AUC (mg dL^{-1}. h^{-1})	1190.40±79.4^{a}	1166.18±64.3^{ab}	1174.20±65.7^{ab}	1123.47±78.0^{ab}	1103.76±67.9^{b}	1111.98±78.2^{b}
AUIC (mg dL^{-1}. h^{-1})	267.00±67.9	212.63±95.0	225.14±143.5	175.71±129.4	173.61±82.48	200.73±166.4
WTTT (mins)	122.40±38.5	124.60±44.0	120.80±41.7	137.20±37.7	144.20±54.2	158.40±58.6

[a] Values are presented as Means ± Standard deviation

[b] Means with different superscript are significantly different at $p < 0.05$

[c] AUC Area under the curve; AUIC Area under the incremental curve; WTTT Whole tract transit time

While provision of whole grain in the diet of broiler chicken increases the average particle size of the diet, increased gizzard activity is expected to reduce the digesta particle size ahead of digestion and absorption in the small intestine resulting in prolonged residence of digesta in the gastrointestinal tract. This trend was however not observed in this study as well as other published work (Amerah and Ravindran, 2008). Hetland et al.

(2005) opined that rapid dissolution of starch granules from whole grains when retained in the acidic environment of the gizzard resulted in rapid reduction of particle size and could be responsible for the observed trend. A weak relationship was shown to exists between whole tract transit time (R^2 = 0.037, P = 0.31) and area under the incremental curve (R^2 = 0.047, P = 0.25), suggesting a lack of dependence of one on the other.

Conclusion and Recommendations

Glycemic response indices (excluding area under the curve) as a reflection of starch digestion and glucose absorption in broiler chickens was not influenced by whole millet grain inclusion in their diets. Digesta residence time was not affected by whole millet grain feeding and a weak relationship was seen to exist between glycemic response indices and digesta residence time in broiler chicken. Varied interpretations in the area under the curve and area under the incremental curve values could be screened in future studies.

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