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Influence of carbohydrate source on digesta kinetics and postprandial glucose responses of broiler chicks

O.O. Adeleye *, A.D. Ologhobo, B.T. Oje-Adetule

Agricultural Biochemistry and Nutrition Unit, Department of Animal Science, University of Ibadan, Ibadan, Nigeria

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ABSTRACT

This study was conducted to investigate the effect of different carbohydrates included in the diets of broiler chicks on digesta kinetics and postprandial plasma glucose responses. Starch extracted from different energy feedstuffs, maize, wheat, millet, sweet potato, and cassava, was used as the main energy source in each diet. Ninety 1-d-old broiler chicks were assigned to 5 diets containing 45 ± 3% of each starch with 3 replicates and 6 broiler chicks per replicate. The digesta kinetics study involved administering 50 mg chromic oxide orally to each broiler chick before feeding. Excreta produced was collected hourly for the first 8 h and 10, 12, 24, 36, and 48 h, and their Cr^{2+} content determined. Cumulative Cr^{2+} excretion, times at 1 (T1) and 50% (T50) Cr^{2+} excretion, time at peak Cr^{2+} excretion, and mean retention time (MRT) were estimated. Two broiler chicks per replicate were used for the plasma glucose response study where glucose concentration was measured from blood collected from the wing vein of each broiler chick up to 480 min postprandial. Postprandial glucose responses, as well as hydrolysis indices were calculated. Digesta transit time variables, T1, T50, time at peak Cr^{2+} excretion, and MRT varied and were greatest for cassava starch diet at 0.2, 6.20, 8.00, and 19.45 h, respectively, and least for the sweet potato starch diet at 0.1, 4.2, 5.0, and 17.20 h, respectively. Plasma glucose response variables also varied considerably ($P < 0.05$) between treatments and were attributed to starch granule size and dimensions. However, no relationship was observed between digesta kinetics and postprandial glucose responses of broiler chicks fed the experimental diets.

1. Introduction

Starch is found as a storage carbohydrate in feedstuffs like cereal grains, legume seeds, tubers, and roots, and is the main source of energy in domestic animal diets providing more than 50% of the apparent metabolizable energy content of common diets for broiler chickens (van der Aar, 2003). Starch digestibility is often considered as 100%, however, several authors have reported incomplete starch digestion in broiler chickens (Hasselman and Aman, 1986; Weurding et al., 2001; Yutste et al., 1991) for cereals and legume grains. The rate and extent of starch digestion have been reported to be affected by physicochemical properties of the starch such as starch structure, granule shape, size and dimension, surface area, degree of crystallinity, association with protein and lipid matrices, and antinutrients (Giuberti et al., 2012; Singh et al., 2010). Other animal related factors such as age, physiological status, feed intake, passage rate, and absorptive capacity of the gastrointestinal tract also affect rate and extent of starch digestion.

Relative opportunities for contact between ingested food, digestive enzymes, and bile salts and the time available for contact between digested particles and absorptive surfaces are likely to influence nutrient utilization. Therefore, differences in starch properties as well as differences in accessibility of the starch granules, determine the susceptibility of starch to enzymatic degradation in the small intestine (Eastwood, 1992).

Digesta passage rate through the gastrointestinal tract provides information on the extent to which feed is exposed to digestion and fermentation and is influenced by feed related factors such as type of diet, feeding levels, or frequency of diet (van Weyenberg et al., 2006), and viscosity of diet within the gastrointestinal tract (Lazaro et al., 2003).

On the other hand, postprandial plasma glucose studies have been used to assay different starch sources with various physicochemical characteristics in humans (Englyst et al., 1996), pigs (Li et al., 2008, Regmi et al., 2010, van Kempen et al., 2010), and cats (de-Oliviera et al., 2008), on the premise that enzymatic starch digestion produces glucose as a final product for absorption.

Therefore, this experiment was conducted to study the rate and extent of starch digestion in broiler chicks fed diets containing starch from different carbohydrate sources based on postprandial

* Corresponding author.
E-mail address: ooadeleye@rocketmail.com (O.O. Adeleye).

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glucose responses and digesta transit time. It was hypothesized that the inclusion of different carbohydrates as energy source in broiler diets will result in substantial variations in digesta transit time and postprandial glucose responses observed in broiler chicks.

2. Material and methods

2.1. Broiler chicks, housing and diets

One hundred 1d-old unsexed Arbor Acre broiler chicks were obtained from a commercial hatchery, housed on deep litter and fed a commercial broiler starter diet (containing (g/100 g): maize, 61; soybean meal, 30; fish meal, 4; soy oil, 2; dicalcium phosphate, 0.8; limestone, 1.5; vitamin-mineral premix, 0.2; Lys · HCl, 0.1; DL-Met, 0.2, and salt, 0.2) for the first 7 d of the study. At 8 d of age, 90 of the broiler chicks were selected according to body weight and randomly allocated to 15 experimental battery brooder units, 6 broiler chicks per replicate. Temperature within the brooder units was maintained at 32 °C for the first 3 d and decreased gradually to 30 °C at d 7. Thereafter, temperature ranged between 24 and 29 °C throughout the experimental period. The experimental design was completely randomized with 5 dietary treatments based on wheat, millet, maize, cassava and sweetpotato starch. Starch was obtained by subjecting each cereal or tuber through the process of wet milling (Singh and Eckhoff, 1996) which involved milling, steeping for 6–12 h and sieving through a double layer cheese cloth to separate the crude starch. Thereafter, all liquid was decanted and the starch air dried before incorporation in the experimental diets at 45 ± 3% of the diets (Table 1). Diets were formulated to meet the requirements for broiler starter chicks (NRC, 1994) and a lignocellulosic fibre concentrate (Arbocel, J. Rettenmaier & Sohne GmbH + Co KG, Rosenberg, Germany) was added to the diet to furnish fibre requirement of broiler chicks. Diets were pelletized with the aid of a 6 mm die and thereafter crushed into starter crumbles. Feed was offered ad libitum and water freely available from a low pressure drinking nipple. The routine animal care and experimental protocol used in this study was approved by the Department of Animal Science at the University of Ibadan, and conformed to the NIH (1978) guidelines for the care and use of laboratory animals.

2.2. Digesta transit time study

At 21 d of age, each broiler chick was orally administered a gelatin capsule containing 50 mg of chromic oxide and the time of marker administration for each replicate was recorded, after a 12 h feed withdrawal period only allowing access to drinking water. Thereafter, all broiler chicks were allowed access to their corresponding experimental diet ad libitum, and all excreta voided were collected hourly for the first 8 h and thereafter at 10, 12, 24, 36, and 48 h. Excreta collected was oven dried at 50 °C till constant weight was attained. The excreta was ground through a 1 mm sieve, and kept in air tight sample bottles until analyzed.

2.3. Postprandial glucose response study

For the postprandial glucose response study, 2 twenty eight-d-old broiler chicks per replicate were used with an additional treatment serving as the reference treatment. All the broiler chicks were fasted for 12 h preceding the study. Basal blood glucose was measured before the experimental diets were offered to the broiler chicks for 30 min and thereafter withdrawn. Blood was collected from the wing vein of each broiler chick by puncturing the vein with a needle and collecting a sample of blood using a heparinized capillary tube at 15, 30, 60, 90, 120, 180, 240, and 360 min postprandial and glucose concentration measured immediately using a glucometer (ACCUCHEK active, Roche Diagnostics GmbH, Mammheim, Germany). The broiler chicks in the reference treatment were offered a diet consisting of (g/100 g): maize, 16.0; milled white bread, 45.0; soybean meal, 24.8; fishmeal, 6.5; soy oil, 5.0; dicalcium phosphate, 0.9; limestone, 1.1; vitamin-mineral premix, 0.2; Lys · HCl, 0.1; DL-Met, 0.2, and salt, 0.2. The mean concentration of glucose (mg/dL), maximum concentration of glucose (mg/dL), mean incremental concentration of glucose (mg/dL), maximal incremental concentration of glucose (mg/dL), time to peak (min), area under the curve (AUC, $mg \cdot dL^{-1} \cdot 360\ min^{-1}$), area under incremental curve (AUIC, $mg \cdot dL^{-1} \cdot 360\ min^{-1}$), hydrolysis index (HI) as well as the rate of increment and decrement of glucose absorption were estimated for each broiler chick.

Table 1
Composition of experimental diets containing carbohydrate from different sources on as fed basis.

	Maize	Wheat	Millet	Sweet potato	Cassava
Ingredients (g/100 g)					
Maize grain	10.64	10.64	10.64	10.64	10.64
Starch	47.4	46.80	44.60	45.00	45.00
Soybean meal	31.00	31.00	31.00	32.60	32.00
Fibre concentrate[a]	0.80	0.80	1.00	1.00	0.60
Fish meal (72% CP)	6.50	7.00	8.00	8.00	8.00
Soy oil	1.00	1.00	2.00	–	1.00
Anticoccidial premix[b]	0.06	0.06	0.06	0.06	0.06
Dicalcium phosphate	0.80	0.90	0.90	0.90	0.90
Limestone	1.10	1.10	1.10	1.10	1.10
Vitamin – mineral premix[c]	0.20	0.20	0.20	0.20	0.20
Lys · HCl	0.10	0.10	0.10	0.10	0.10
DL-Met	0.20	0.20	0.20	0.20	0.20
Salt	0.20	0.20	0.20	0.20	0.20
Total	100	100	100	100	100
Calculated nutrients of experimental diets[d]					
Apparent metabolizable energy, kcal/kg	3093	3026	3061	3112	3161
Crude protein (%)	22.00	21.30	20.50	21.60	21.40
Total Lys (%)	1.30	1.30	1.30	1.30	1.30
Total Sulphur amino acids (%)	0.80	0.80	0.80	0.80	0.90
Calcium (%)	1.00	1.00	1.10	1.10	1.10
Phosphorus (%)	0.60	0.50	0.50	0.60	0.50
Fibre (%)	3.40	3.50	3.50	3.60	3.80
Starch (%)	55.10	50.40	53.80	52.90	52.50
Chemical composition of test starch[e]					
Dry matter, DM (%)	92.7	88.3	85.8	91.3	90.5
Crude protein (%)	0.4	4.8	0.7	1.8	0.7
Ash (%)	0.8	0.8	0.1	1.7	0.2
Fat (%)	0.4	0.5	0.1	0.4	0.2
Crude fibre (%)	0.3	3.0	2.5	0.8	1.1
Amylose (%)[f]	26.0	29.1	nd	24.2	23.4
Total starch (%)[g]	50.7	50.4	64.3	54.3	60.7

nd: not determined.

[a] Arbocel; a fibrillated lignocellulosic fibre concentrate, J. Rettenmaier & Sohne GmbH + Co KG, Rosenberg, Germany.

[b] Amprolium 20S; VM.D Livestock Pharma, Arendock, Belgium (60g/100kg diet).

[c] Optimix poultry chick nourisher, Animal Care, Nigeria. Provided the following per kg/diet: vitamin A, 20,000 IU; vitamin D_3, 4,000 IU; vitamin E, 20 mg; vitamin K_3, 4 mg, vitamin B_1, 3 mg; vitamin B_2, 10 mg; niacin 16 mg; calpan 16 mg; vitamin B_6, 6 mg; vitamin B_{12}, 0.03 mg; choline chloride, 200 mg; folic acid, 2 mg; biotin, 0.1 mg; manganese, 120 mg; iron, 40 mg; zinc, 100 mg, copper, 10 mg; iodine, 2 mg; cobalt, 0.4 mg; selenium, 0.4 mg; antioxidant, 250 mg.

[d] Calculated analysis based on values for feed ingredient (NRC, 1994).

[e] Chemical analysis, on dry matter-basis.

[f] Adeleye et al., 2014; Megazyme amylose/amylopectin assay kit (K-AMYL 07/11), Megazyme Int, Wicklow, Ireland.

[g] Megazyme total starch procedure (Vasanthan, 2001) after enzymatic hydrolysis of the starch present in the sample with amylase and amyloglucosidase.