Dietary Poultry Fat and Gastrointestinal Transit Time of Feed and Fat Utilization in Broiler Chickens

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ABSTRACT An experiment was conducted with broiler chicks to determine the effect of 0, 5, 10, and 20% supplemental poultry fat and age on gastrointestinal transit time (GTT) and the effect of supplemental fat on fat utilization and growth. Mean GTT, measured with chromic oxide or ferric oxide, was not affected by supplemental fat. There was a curvilinear relationship (rising ogive) between mean GTT and age. It increased from an estimated lower plateau of 170 min to an upper plateau of 211 min with the inflexion point at 3.23 wk. At 6 wk of age, birds receiving supplemental fat consumed more energy and were heavier and more efficient. Total lipid digestibility increased with supplemental poultry fat but digestibility of poultry fat was not altered. The AME of poultry fat ranged from 8.1 to 8.4 kcal/g at 5 to 20% inclusion in the diet.

(*Key words*: dietary poultry fat, fat utilization, gastrointestinal transit time, apparent metabolizable energy, age)

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INTRODUCTION

Numerous factors influence the transit of ingesta through the gastrointestinal tract. Fasting, drugs, ileal obstruction, irradiation, diet composition, and enteric parasitism alter gastrointestinal transit time (GTT) of feed in laboratory animals (Summers *et al.*, 1970; Castro *et al.*, 1976). Factors reported to affect GTT in poultry include excitement (Henry *et al.*, 1933), age (Hillerman *et al.*, 1953; Vergara *et al.*, 1989), temperature (Wilson *et al.*, 1980), genotype (Cherry and Siegel, 1978), amount of feed consumed (Sibbald, 1979; Wilson *et al.*, 1980), and diet composition (Monson *et al.*, 1950; Hillerman *et al.*, 1953; Stokstad *et al.*, 1953; Larbier *et al.*, 1977; Mateos and Sell, 1981).

Diet is the most important factor affecting GTT (Duke, 1989). Food may contain specific cathartics or the qualitative and quantitative differences in carbohydrates, proteins, fats, and additives may alter transit time. Penicillin in feed slowed GTT in chickens and turkeys (Hillerman *et al.*, 1953) and in purified diets aureomycin retarded feed passage in a sucrose-based diet but not in glucose- or starch-based diets (Stokstad *et al.*, 1953). Different carbohydrates have a distinct effect on GTT in chickens. Diets containing sucrose and lactose passed through the tract faster than diets containing either glucose or starch (Monson *et al.*, 1950; Stokstad *et al.*, 1953; Tuckey *et al.*, 1958; Mateos and Sell, 1981).

The effect of supplemental fat on GTT in chickens is equivocal. Yellow grease included at 0 to 30% in the diet delayed transit time of feed in White Leghorn hens in egg production (Mateos *et al.*, 1982). In contrast, neither animal fat supplements at levels up to 12% in the diet of 4-wk-old New Hampshire pullets (Tuckey *et al.*, 1958) nor corn oil at levels up to 10% in the diet of White Leghorn mixed-sex chicks from day old to 3 wk influenced GTT (Golian and Polin, 1984). The slowing in the rate of passage induced by supplemental fat (yellow grease) in laying hens

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TABLE 1. Composition and calculated analysis of experimental diets

Ingredients and analyses	Added fat 0%	5%	10%	20%
	(%)			
Yellow corn	71.30	61.81	52.35	33.50
Soy bean meal (48.5% CP)	25.73	30.00	34.24	42.70
Poultry fat	. . .	5.00	10.00	20.00
DL-methionine	.05	.07	.09	.13
Limestone	.80	.75	.80	.80
Deflourinated phosphate	1.40	1.65	1.75	2.05
Vitamin mix[1]	.25	.25	.25	.25
Salt	.40	.40	.45	.50
Mineral mix[2]	.05	.05	.05	.05
Ethoxyquin	.02	.02	.02	.02
Chemical analysis				
Protein	18.53	19.86	21.17	23.84
Fat	2.08	6.79	10.80	21.49
Calculated analysis				
Energy, kcal AME/g	3.02	3.21	3.41	3.81

[1]Vitamin mix provided per kilogram of diet: retinyl acetate, 2.27 mg; cholecalciferol, .04 mg; DL-α-tocopheryl acetate, 5.5 mg; menadione sodium bisulphite, 1.45 mg; riboflavin, 6.6 mg; pantothenic acid, 11 mg; cyanocobalamin, .01 mg; choline, 550 mg; folic acid, .7 mg; thiamin mononitrate, 1.1 mg; pyridoxine, 1.1 mg; and niacin, 33 mg.

[2]Mineral mix supplied per kilogram of diet: manganese, 65 mg; zinc, 40 mg; copper, 5 mg; and iodine, .5 mg.

fed sucrose-based diets results in more complete digestion (Mateos and Sell, 1980a) and enhanced energy utilization (Mateos and Sell, 1980b). These observations have been extended to all classes of poultry and proposed as an explanation for the extracaloric effect of fat in poultry diets (Summers, 1984).

Supplemental fat is an important component in the diet of broiler chickens. The objectives of the present study were: 1) to determine the effect of supplemental fat on GTT in broiler chickens at different ages using two different markers; and 2) to ascertain the influence of supplemental fat on performance and lipid utilization. The level of supplemental fat (poultry fat) used in the present study ranged from 0 to 20% and the diets were fed from day-old to 6 wk of age.

MATERIALS AND METHODS

Animals and Husbandry

Mixed-sex, day-old broiler chicks (Peterson × Arbor Acres) were obtained from a commercial hatchery. The 120 chicks were identified with wing-bands and allocated at random to 24 pens in an electrically heated, wire-floored, battery brooder. At 3 wk the birds were moved to wire-floored grower cages. In the brooder unit each bird was provided 650 cm^2 of living space with 22 cm of head room, and 6 cm of waterer space. The growing unit provided 1,070 cm^2 of living space in cages 36 cm high, 16 cm of feeder space, and 16 cm of waterer space. These space allowances were in compliance with recommendations for laboratory animals (United States Department of Health, Education, and Welfare, 1980). The units were maintained in a controlled environment and exposed to a 24-h photoperiod and light intensity of about 10 lx. Feed and water were provided for *ad libitum* consumption.

Diets

The experimental diets (Table 1) were introduced at day-old and fed for the duration of the experiment. The diets were designed to evaluate the effect of 0, 5, 10, and 20% supplemental poultry fat in broiler chicken diets. The diets were formulated so that the ratios of major nutrients to AME remained constant. The diets were presented in mash form. Chromic oxide (.4%)

was mixed into a portion of each diet and this was used each week to measure GTT and was also used to measure lipid digestibility in the 3rd wk.

Measurements

Body weight and feed consumption were recorded weekly. Body weight was measured on a pen basis following a feed withdrawal of 12 h. The GTT was measured as the difference between the time of presenting the marked diet or administration of the marker *per os* and the first appearance of the marker in excreta. Time of initial appearance of marker is a superior end-point when compared with final clearance of marker because of greater reproducibility (Lutwak and Burton, 1964). Chromic oxide (.4%) was used in feed (Dansky and Hill, 1952) and ferric oxide (200 mg/kg body weight) in a gelatin capsule given *per os* (Golian and Polin, 1984). Ferric oxide capsules were administered to the same birds each week to reduce variation. In the case of chromic oxide, the birds were starved for 1 h, offered the marked version of the diet until the first appearance of the marker in excreta, and then returned to the equivalent unmarked diet until the next week.

Each week, GTT was first measured with ferric oxide and the next day with chromic oxide. A clean dropping pan was used each time and examined every 10 min during the 2nd h after offering the marker and then almost continuously until the end-point was recorded for each pen. The gross energy of poultry fat, chromic oxide concentration, and fat in feed and excreta were determined (Maurice *et al.*, 1985) between the 3rd and 4th wk. Lipid digestibility and metabolizable energy value of poultry fat were calculated (Young, 1961). Percentage utilization of total fat in the diet (U_f) was calculated as follows: $U_f = 100 - 100$ [(percentage fat in excreta ÷ percentage fat in feed) × (percentage Cr_2O_3 in feed ÷ percentage Cr_2O_3 in excreta)]. Digestibility (D) was calculated as follows. $D = U_f \times$ (percentage total fat ÷ percentage test fat) − percentage utilization of fat in basal × (percentage fat in basal ÷ percentage test fat).

Experimental Design and Statistical Analysis

The four dietary treatments (0, 5, 10, and 20% supplemental fat) were arranged in a randomized block design with six blocks. A pen of five birds constituted the experimental unit for purpose of analysis. The data were subject to analysis of variance (Mead and Curnow, 1983) and least significant difference used to separate means. The relationship between gastrointestinal transit time (y) and age (x) was modeled by a logistic equation of the rising ogive form p(x) with the relationship function y(x) ranging from a lower plateau (d) to an upper plateau (g):

$$p(x) = 1/(1 + \exp)(b \times m - b \times x)$$
$$y(x) = d + (g - d) \times p$$

where b is a rate parameter; and m is the point of inflection (Draper and Smith, 1981). The logistic ogive was fitted by nonlinear least squares method using an iterative process until convergence criteria were met. The criterion (*F* statistic) used throughout for detecting statistically significant effects was based on a level of protection against Type I error set at $P < .05$.

RESULTS

The effect of dietary fat on the performance of broiler chickens is shown in Table 2. An age by diet interaction was detected. Added fat did not affect body weight up to 2 wk, thereafter, birds receiving supplemental fat were heavier. Feed to gain ratio was lower in birds fed diets supplemented with fat. An interaction between age by diet for feed:gain ratio was not evident. The best feed:gain ratio was observed in birds fed the diet containing 20% supplemental fat. The addition of fat to the diet brought about a significant increase in energy intake when compared with the control diet. Mean daily energy intake was not altered as the amount of added fat increased from 5 to 20%.

The average GTT of feed in broiler chickens fed diets with or without supplemental poultry fat was not different (Table 3). The mean GTT measured with chromic oxide were not different from those obtained when ferric oxide was used. The

TABLE 2. Dietary poultry fat and performance of broiler chickens at 6 wk of age[1]

Supplemental fat	Body weight[2]	Feed:gain ratio[3]	AME intake[4]
(%)	(g)	(g:g)	(kcal/day)
0	1,603[c]	2.00[a]	216[b]
5	1,779[b]	1.83[b]	242[a]
10	1,830[ab]	1.81[b]	242[a]
20	1,870[a]	1.76[c]	258[a]
SEM[5]	20.4	.044	6.6

[a–c]Means in a column with no common superscripts are significantly different ($P < .05$).

[1]Data based on six pens of five birds each.

[2]An age by diet interaction was detected ($P < .05$). Added fat did not affect body weight in the first 2 wk. Thereafter, birds receiving supplemental fat were heavier.

[3]A significant interaction of age by diet was not detected.

[4]Added fat did not affect AME intake in the 1st wk, thereafter, birds receiving supplemental fat had higher AME intake.

[5]Pooled SEM.

variation in GTT measurements was lower when chromic oxide was used as marker compared with ferric oxide (SE of 3.7 versus 7.1).

The average with both markers was not different at 1, 2, and 3 wk of age. There was a marked change after 3 wk of age and GTT was increased at 4, 5, and 6 wk of age as compared with the first 3 wk of life. A diet by marker interaction was not detected. The relationship between GTT and age was modelled by a rising ogive (Figure 1). Mean GTT increased from an estimated lower plateau of 170 min to an estimated upper plateau of 211 min at 4 to 6 wk of age with the inflexion point at 3.23 wk.

Total lipid digestibility was improved substantially when poultry fat was added to the diet (Table 4). The addition of 20% fat increased the total fat digestibility as compared with 5% added fat. Total lipid digestibility increased linearly as the level of supplemental fat increased from 5 to 20%. The digestibility of poultry fat, at levels of inclusion of 5, 10, and 20%, was not different and varied from 91 to 94%. The apparent ME of poultry fat was also not affected by the amount of supplemental dietary fat from 5 to 20%.

DISCUSSION

Substitution of 0, 5, 10, and 20% poultry fat at the expense of corn and soybean meal in practical diets did not produce a longer GTT in broiler chicks measured by using either chromic oxide or ferric oxide as markers. This is in agreement with Tuckey *et al.* (1958) and Golian and Polin (1984), who did not observe any increase in GTT with the addition of 10 to 12% fat to the diet of chicks. The present results are at variance with the linear increase in GTT observed by Mateos and Sell (1980a,b) and Mateos *et al.* (1982) when hens in egg production were fed supplemental yellow grease at 0 to 30%. Therefore, the higher body weight and increased feed efficiency in broiler chickens fed fat-supplemented diets must be ascribed to the higher energy concentration and not related to the GTT of feed. Golian and Polin (1984) detected no differences in GTT but detected an extra body weight gain in birds fed diets with 10% supplemental fat when they used equicaloric diets. The current results confirm the report of Washburn (1991) that there is little correlation between rate of passage of feed through the digestive system and feed efficiency.

TABLE 3. Dietary fat and gastrointestinal transit time of feed in broiler chickens[1]

Supplemental fat	Transit time[2]
(%)	(min)
0	195
5	187
10	194
20	192
SEM[3]	4.7

[1]Data are the means of six pens of six birds each measured weekly to six weeks of age. Neither a main effect (diet or marker) nor diet by age interaction was detected ($P > .05$).

[2]Transit time was measured as the difference between the time of giving the marker and the first appearance of the marker in excreta. In the case of chromic oxide (Cr_2O_3) the birds were starved for 1 h prior to offering the marked diet. Ferric oxide (Fe_2O_3) was administered in capsules and the same birds were used each week.

[3]Pooled SEM.

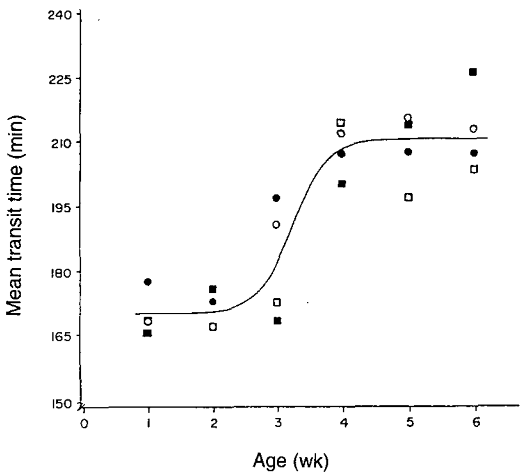

FIGURE 1. The relationship between gastrointestinal transit time and age. The fitted response was obtained from a logistic equation. The parameters of the logistic equation (d = lower plateau; g = upper plateau; b = a rate parameter; and m = point of inflection) and their standard errors were: d = 170 ± 3.1; g = 211 ± 3.0; b = 3.65 ± 2.325; and m = 3.23 ± .195. ● = control (no added fat); □ = 5% fat; ○ = 10% fat; ■ = 20% fat.

TABLE 4. Lipid digestibility and metabolizable energy value of poultry fat

Supplemental fat	Total lipid digestibility[1]	Poultry fat digestibility	AME of fat[2]
	(%)	(%)	(kcal/kg)
0	45.2[c]	. . .	. . .
5	76.9[b]	91.0[a]	8,117
10	83.8[ab]	94.3[a]	8,413
20	88.2[a]	92.8[a]	8,277
SEM[3]	3.13	2.14	191.2

[a–c]Means in a column with no common superscripts are significantly different ($P < .05$).

[1]Total lipid digestibility (percentage) was calculated by the method of Young (1961).

[2]AME = Digestibility of poultry fat × gross energy of poultry fat.

[3]Pooled SEM.

The type of fat may influence the response of GTT to supplemental fat. The current authors used poultry fat, whereas Mateos and Sell (1980a,b, 1981) used yellow grease. However, Tuckey *et al.* (1958) reported an inconsistent effect of saturated fat up to 12% of the diet. The other reason may be the age and type of birds that were used. The present study used broiler chickens at 1 to 6 wk of age but Mateos and Sell (1980b, 1981) used mature hens. The type of bird may not be a determinant because mean retention time of feed in the entire gastrointestinal tract of broiler chicks (338 min) and Leghorns (360 min) are similar (Shires *et al.*, 1987).

The results of the current experiment and others (Golian and Polin, 1984; Tuckey *et al.*, 1958) indicate that in the chick and young broiler chickens, unlike the hen, GTT is not influenced to any great extent by fat in the diet. Therefore, the improved absorption of fats and increased ME of diets detected in chicks (Gomez and Polin, 1974; Polin and Hussein, 1982) cannot be explained by the effect of fat on GTT. Total lipid digestibility increased as the rate of inclusion of supplemental fat increased. There was no evidence that AME of poultry fat declines with increasing rate of inclusion, as reported by Wiseman and Lessire (1987). The digestibility or AME value of poultry fat did not change as the level of fat increased, in agreement with the results of Fedde *et al.* (1960), using chicks, and Hoagland and Snider (1941), using rats. The level of fat did not have any effect on GTT of diet or on digestibility of poultry fat. Hence, an alternative explanation must be sought for the extrametabolic effect of fat in broiler chicken diets.

Age has a definite effect on the GTT of feed (Shires *et al.*, 1987; Vergara *et al.*, 1989). In the current study, GTT exhibited a curvilinear response with age rising from a lower plateau to an upper plateau at 3.23 wk. This may be one of the reasons for the reported improvement in fat digestion with age (Duckworth *et al.*, 1950; Renner and Hill, 1960). Alternatively, development of the digestive tract with age (Kantongole and March, 1980) may promote enhanced digestion, which in turn alters gut motility and transit time.

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