Rate of Food Passage (Transit Time) as Influenced by Level of Supplemental Fat[1]

GONZALO G. MATEOS, JERRY L. SELL, and JENNIFER A. EASTWOOD

Department of Animal Science, Iowa State University, Ames, Iowa 50011

(Received for publication December 5, 1980)

ABSTRACT An experiment involving 35 White Leghorn hens was conducted to study the influence of graded levels of supplemental yellow grease on rate of food passage (transit time). Seven experimental diets (0, 5, 10, 15, 20, 25, and 30% supplemental fat) were formulated. Transit time was determined by utilizing either Cr_2O_3 or ^{144}Ce as indicators. First appearance of the markers in the excreta and percentages of the markers ingested that were recovered in excreta 10 hr after feeding were criteria used to determine transit time. There was a significant ($P<.01$) linear effect of fat on transit time of Cr_2O_3 whereby the time required for the marker to appear in the excreta increased with increments of supplemental fat. Average first appearance time of Cr_2O_3 was 193, 219, 214, 227, 251, 250, and 270 min for the diets containing 0, 5, 10, 15, 20, 25, and 30% supplemental fat, respectively. Transit time of ^{144}Ce also was increased slightly ($P<.10$) by fat supplementation. Transit time, measured as percentage of marker recovered in excreta 10 hr after feeding, was faster for the control than for the fat-supplemented diets, although the linear effects of fat were not statistically significant ($P>.10$). The results show that supplemental fat increased transit time of ingesta in chickens. This observation may be helpful in understanding the nature of the extrametabolic effect of fat in poultry diets. By increasing transit time, supplemental fats may improve digestibility of other dietary constituents and thereby increase the utilization of dietary energy.

(Key words: food passage, dietary fat, laying hens)

1982 Poultry Science 61:94–100

INTRODUCTION

Rate of food passage (ROP) through the digestive tract may influence the amount of energy derived from diets (Maner *et al.*, 1962; Kass *et al.*, 1980) by changing the length of time during which ingesta is exposed to the digestive enzymes and to the absorptive surfaces. Several management and environmental factors, such as temperature (Wilson *et al.*, 1980), age (Hillerman *et al.*, 1953), genetic background (Cherry and Siegel, 1978), excitement (Henry *et al.*, 1933), amount of feed intake (Rice *et al.*, 1967; Wilson *et al.*, 1980), and pelleting of the ration (Seerley *et al.*, 1962) have been shown to modify ROP. There is a lack of information, however, concerning the influence of diet composition on ROP. Monson *et al.* (1950) and Mateos and Sell (1981a) observed that sucrose-containing diets had a faster rate of passage than did starch-containing diets. Stokstad *et al.* (1953) reported that the growth response of chicks to aureomycin was greater with sucrose-containing than with starch-containing diets. Also, they observed that in the absence of the antibiotic, the sucrose diet had a faster ROP than the starch diet. In the presence of the antibiotic, however, both diets had a similar ROP.

Recently, Mateos and Sell (1981a) observed that supplemental fat decreased the ROP of semipurified, laying-hen diets containing either sucrose or starch. The research reported herein was conducted to examine the influence of graded levels of yellow grease supplementation on the ROP of practical diets for laying hens. First appearance in excreta of two markers (Cr_2O_3 and ^{144}Ce) fed to laying hens and the percentage of the marker recovered in feces 10 hr after feeding were used as criteria for ROP.

MATERIALS AND METHODS

Single Comb White Leghorn hens in egg production were used. The birds were kept in wire laying cages equipped with trays for collection of excreta.

Seven experimental groups were used, and five individually caged hens were assigned

[1] Journal Paper No. J-10110 of the Iowa Agriculture and Home Economics Experiment Station, Ames IA. Project 2240.

randomly to each group. Control hens received a corn-soybean meal, sunflower meal diet with no added fat, and increments of 5% yellow grease were included in the formulas to obtain six additional test diets (Table 1). Appropriate adjustments were made in the formulas so that the metabolizable energy:major nutrient ratios remained constant. After a 6-day adaptation period in which the hens received their respective diet without a marker, the transit time of the marker through the digestive tract was measured in three periods. Chromic oxide (Cr_2O_3, MW = 149.98) was used as a fecal marker in the three periods. In addition, ^{144}Ce was used as a marker in period 3. The methods used to estimate transit time were developed in our laboratory as slight modifications of the procedure used by Mateos and Sell (1981a).

In period 1, the hens were fasted for .5 hr before they were fed their respective diets supplemented with .3% Cr_2O_3. Fasting was done to encourage immediate and uniform feed intake when the marked diets were offered. Time of first appearance of the marker in the excreta, as detected visually by two observers, was recorded for each hen. The average time obtained by the two observers for each hen was used as time of first appearance of Cr_2O_3 in excreta. The marked diets were fed for 5 days in period 1 to facilitate metabolizable energy determination by the total collection technique and feed intake was recorded for this time interval.

In period 2, the hens were fasted for 1.25 hr before Cr_2O_3-marked diets were fed. Marked feed was supplied for 4.5 hr, and then all birds were switched to the original diets without indicator. Time of first appearance was recorded as in period 1. In addition, the percentage was determined of the total marker ingested that was recovered in excreta 10 hr after the start of feeding. Chromium contents of diets and excreta were determined by atomic absorption spectrophotometry (Perkin-Elmer, 1973).

In period 3, the hens were fasted for 9 hr, and both Cr_2O_3 and ^{144}Ce were used as indicators. This extended fasting interval was used to determine whether the effects of fat supplementation on transit time would be

TABLE 1. *Composition of the experimental diets, %*

Ingredient	Supplemental fat, %						
	0	5	10	15	20	25	30
Sunflower meal	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Soybean meal, 48.5% protein	4.60	8.32	11.87	15.55	19.18	22.87	26.51
Yellow corn	61.28	52.13	43.10	33.90	24.80	15.70	6.55
Yellow grease[a]	...	5.00	10.00	15.00	20.00	25.00	30.00
Dl-methionine	.01	.03	.03	.05	.07	.08	.09
L-lysine	.06	.02	...	...	...	...	...
Salt	.30	.30	.30	.30	.30	.30	.30
Dicalcium phosphate	1.30	1.40	1.60	1.70	1.85	1.90	2.00
Calcium carbonate	6.65	7.00	7.30	7.70	8.00	8.35	8.75
Chromic oxide	.30	.30	.30	.30	.30	.30	.30
Vitamin premix[b]	.50	.50	.50	.50	.50	.50	.50
Calculated analysis:							
ME (kcal/kg)[c]	2600	2772	2944	3113	3285	3457	3628
Crude protein, %	14.62	15.62	16.55	17.52	18.48	19.47	20.44
Methionine, %	.28	.31	.32	.35	.38	.39	.41
Lysine, %	.61	.65	.73	.82	.92	1.02	1.11

[a]Yellow grease (National Byproducts Co., Des Moines, IA) had by analysis the following fatty acid composition: myristic, 1.8%; palmitic, 24.7%; palmitoleic, 2.6%; stearic, 15.8%; oleic, 44%; linolenic, .6%; others, .4%.

[b]Supplied the following per kilogram of diet: Vitamin A, 8000 I.U.; Vitamin D_3, 2400 I.U.; Vitamin B_{12}, 5 μg; riboflavin, 6.6 mg; calcium pantothenate, 6.6 mg; niacin, 2.2 mg; choline, 440 mg; and ethoxyquin, 11 mg.

[c]On the basis of National Research Council (1977) values for soybean meal and corn. ME's of 7900 and 1540 kcal/kg were used for yellow grease and high-fiber sunflower meal, respectively.

changed by duration of feed withdrawal. The ^{144}Ce was added to the diet by absorbing the isotope on 40 g of an anion exchange resin (Amberlite IRA-400, Mallinckrodt) and mixing this premix with 500 g of feed (Chandler and Cragle, 1962; Mateos and Sell, 1981a). The final concentration of ^{144}Ce in each test diet was about 50 μCi/kg of diet. The radioactive feed, also marked with .3% of Cr_2O_3, was offered to the birds for 3.5 hr, and then the hens were changed to the original, unmarked diets. First appearance of Cr_2O_3 in excreta was determined by continuous visual observation. Also, excreta from the hens were collected as produced from the beginning of feeding, and each sample was monitored for ^{144}Ce activity by using a Tracor Model 1197 gamma counter. Excreta collection was continued until ^{144}Ce had appeared in the excreta of each hen for at least four successive collections. First appearance of ^{144}Ce in excreta was calculated by two methods. In method 1, the time after feeding required for the radioactivity level of the excreta to reach 2000 disintegrations per min (dpm) was used as an estimator of first appearance. In method 2, first appearance of the marker in excreta was calculated by regressing total ^{144}Ce excreted *vs.* time of excreta sampling and extrapolating to zero ^{144}Ce excretion. Also, excreta were collected for 10 hr after start of feeding, and the percentage of ingested ^{144}Ce recovered in the total excreta was calculated for each hen.

Analysis of variance was used to statistically analyze the data (Snedecor and Cochran, 1967). To evaluate the results further, the data were regressed on level of fat in diet, and the linear and quadratic components of the regression equations were studied.

RESULTS AND DISCUSSION

The data presented in Table 2 show that supplementation of diets with yellow grease increased the time required after feeding for Cr_2O_3 to first appear in excreta. The length of fasting before feeding of the marked diet resulted in some inconsistencies in the magnitudes of fat's effect on transit time. The greatest and most consistent increases in transit time were observed when hens were fasted for only .5 hr before feeding (Period 1). Regression analysis showed that fat supplementation had a highly significant ($P \leq .01$) linear effect on transit time in periods 1 and 2, and the linear effect of fat approached significance ($P \leq .06$) in period 3 (Table 3). The quadratic effects of fat supplementation on first appearance of Cr_2O_3 in excreta were not significant ($P > .10$) for data of any period.

The reasons for the differences in transit time, among the three periods, cannot be determined from the data obtained. There was a trend toward reduced transit time from periods 1 to 3, and the use of different lengths of fast may have been a contributing factor. Generally, the longer the fasting period, the shorter the transit time.

Regardless of fasting time, however, the linear effect of supplemental fat on transit time was statistically similar for all periods. Data obtained in periods 2 and 3 indicate that feed intake *per se* did not contribute greatly to differences among periods in transit time (Table 2). Generally, feed intakes during the 4.5 hr feeding interval of period 2 were similar to those during the 3.5 hr interval of period 3 but transit times during period 3 (hens fasted 9 hr) were noticeably shorter than those of period 2 (hens fasted 1.25 hr). Unfortunately, feed consumption during the early portion of period 1 was not recorded.

Sibbald (1979) reported that the rate of dry matter excretion by roosters increased as larger amounts of feed were force-fed, suggesting that transit time was directly related to quantity of feed entering the gastrointestinal tract. Results of the research reported here indicate that changes in transit time of ingesta caused by fat were not entirely due to differences in amounts of feed consumed. Regression analysis of the feed intake data of each period showed that level of fat supplementation had no significant linear or quadratic effect on feed consumption. Also, little correlation was detected between intake of marked diets and first appearance of the marker in the excreta (Table 3). The strongest correlation ($P < .08$) was observed with data of period 3. These findings should not be interpreted to mean that fat's effect on transit time was completely independent of feed intake, dietary fat levels probably altered ingesta transit time *via* other physiological mechanisms as well (Peraino *et al.*, 1959; Duke and Evansen, 1972; Borella and Lippman, 1980).

When ^{144}Ce was used as the marker, fat supplementation again linearly increased the transit time of the diet, although, in this instance, the level of significance was $P < .10$

TABLE 2. *Time of first appearance of Cr_2O_3 in excreta and consumption of Cr_2O_3-containing feed as influenced by supplemental fat*

Supplemental fat (%)	Period				Period		
	1[a]	2[a]	3[b]	Average[a]	1[c]	2[d]	3[d]
	(First appearance of Cr_2O_3 in feces, min)				(Marked feed consumed, g/hen)		
0	201 ± 38[e]	201 ± 17	178 ± 22	193 ± 15	78.7 ± 8.5[e]	22.4 ± 1.5	21.4 ± 2.5
5	271 ± 33	205 ± 13	180 ± 5	219 ± 15	95.4 ± 4.7	24.5 ± 2.0	24.8 ± 2.4
10	273 ± 38	202 ± 17	167 ± 11	214 ± 19	91.2 ± 5.9	24.2 ± 1.7	21.8 ± 2.4
15	286 ± 29	208 ± 13	188 ± 13	227 ± 11	95.6 ± 3.7	22.9 ± 2.5	23.6 ± 3.3
20	342 ± 27	226 ± 15	185 ± 10	251 ± 16	91.4 ± 9.0	22.2 ± 1.8	22.1 ± 2.6
25	325 ± 27	246 ± 11	179 ± 14	250 ± 7	80.6 ± 5.5	20.1 ± 1.5	19.3 ± 3.0
30	348 ± 28	234 ± 9	231 ± 27	271 ± 17	77.8 ± 3.6	17.5 ± .6	16.6 ± .7

[a]Highly significant linear effect ($P<.01$) of level of fat on first appearance of Cr_2O_3 in excreta.

[b]The linear effect of level of fat on first appearance of Cr_2O_3 in excreta was significant at $P<.06$.

[c]Hens were fasted for .5 hr and then fed marked diets for 5 days. The average daily feed intake per hen for the 5 days is presented.

[d]Hens were fasted for 1.25 hr and 9 hr in periods 2 and 3, respectively, and then were fed the marked diets for 4.5 hr and 3.5 hr, respectively, before being switched to the original, unmarked diets. The data represent the average intake of marked diet per hen.

[e]Mean ± SE.

TABLE 3. *Regression equations relating level of supplemental fat to time of first appearance of markers in excreta and correlations between intake of marked feed and time of first appearance*

Period	Regression equations relating transit time to level of supplemental fat[a]	Correlation between intake of marked diets and first appearance	
		r	Significance
	First appearance, Cr_2O_3		
1[b]	Y = 226.3 + 4.4X	.08	NS
2[b]	Y = 195.9 + 1.45X	.14	NS
3[c]	Y = 168.0 + 1.22X	.30	.08
Average[b]	Y = 196.7 + 2.35X	...	...

[a]Where Y = min and X = % fat. There were no significant quadratic effects of fat.

[b]Linear coefficient was significant at P<.01.

[c]Linear coefficient was significant at P<.06.

(Table 4). In general, the time required for ^{144}Ce to appear in excreta was shorter than for Cr_2O_3. When first appearance was obtained by regressing total ^{144}Ce radioactivity excreted on time of excreta production and extrapolating to zero radioactivity, there was a slight decrease in the error of estimate as compared with using the 2000 dpm criterion. But the pattern of treatment effects and level of statistical significance were not changed.

Similar results were observed when ROP was measured as a percentage of the total marker ingested that was recovered in excreta 10 hr after the markers were fed (Table 5). The variability among hens, however, was relatively greater for the total recovery data than for the first-appearance data. Consequently, no significant differences (P<.10) among treatments were observed with the total recovery data. But more marker was recovered from hens fed the control than from the hens fed the fat-supplemented diets. In period 2, the percentage of Cr_2O_3 recovered in the excreta varied from 69.91 to 54.73% for the 0 and 20% fat diets, respectively. Corresponding values for ^{144}Ce recovery in period 3 were 87.44 and 77.47 for the 0 and 30% fat diets, respectively. Irrespective of diet, however, a greater proportion of ^{144}Ce than of Cr_2O_3 was excreted within 10 hr of ingestion of the markers. Evidently, a

TABLE 4. *Influence of increased level of supplemental fat on time of first appearance of Cr_2O_3 and ^{144}Ce in excreta (period 3)*

Supplemental fat (%)	Cr_2O_3[a]	^{144}Ce	
		dpm>2000[b]	Regression equation[b]
0	178 ± 22[c]	154 ± 13	134 ± 12
5	180 ± 5	181 ± 9	153 ± 3
10	167 ± 11	155 ± 13	142 ± 12
15	188 ± 13	172 ± 12	148 ± 12
20	185 ± 10	175 ± 12	144 ± 6
25	179 ± 14	167 ± 18	143 ± 10
30	231 ± 27	211 ± 32	166 ± 13

[a]Significant linear effect (P<.06) of level of fat on first appearance of Cr_2O_3 in excreta.

[b]Linear effect (P<.10) of level of fat on first appearance of ^{144}Ce in excreta (Y = 156.0 + 1.2X, where Y = min and X = % fat).

[c]Mean ± SE.

partial separation of ^{144}Ce from Cr_2O_3 occurred during passage through the GI tract. The question as to which marker best represents the average transit time of the majority of undigested diet residue cannot be answered by the research reported here.

In general, the data reported here for practical-type, laying-hen diets confirm those reported by Mateos and Sell (1981a) with semipurified diets. Also, these results are consistent with those reported by Borella and Lippman (1980), who observed that sesame seed oil inhibited stomach emptying and intestinal propulsion in the rat. But Tuckey *et al.* (1958) reported inconsistencies in the effects of supplemental fat on first appearance of ferric oxide in excreta of broiler chicks.

Our results show that the addition of graded levels of fat to practical diets slows the ROP (transit time) in laying hens. When first appearance of Cr_2O_3 or ^{144}Ce in the excreta was the criterion, transit time increased linearly with increments of supplemental yellow grease. These results also are consistent with the proposal of Mateos and Sell (1980, 1981b) that supplemental fat may enhance the utilization of dietary energy by slowing the ROP of diets and thereby cause an extrametabolic effect.

ACKNOWLEDGMENTS

This research was supported, in part, by a grant by the Fats and Protein Research Foundation, Des Plains, IL.

TABLE 5. *Influence of increased level of supplemental fat on percentage of marker that was recovered in excreta, %*

Supplemental fat (%)	Cr_2O_3[a]	^{144}Ce[b]
0	69.91 ± 9.39[c]	87.44 ± 2.64
5	57.75 ± 6.95	80.53 ± 8.27
10	66.07 ± 5.12	84.03 ± 3.40
15	69.42 ± 6.26	83.02 ± 6.53
20	54.73 ± 8.05	81.47 ± 3.44
25	65.35 ± 4.47	86.74 ± 3.13
30	60.68 ± 2.24	77.47 ± 6.39

[a]Data correspond to period 2 of the experiment. Hens were fasted for 1.25 hr, and the marked diet was fed for 4.5 hr. Excreta were collected for 10 hr after start of feeding.

[b]Data correspond to period 3 of the experiment. Hens were fasted for 9 hr and then fed the marked diet for 3.5 hr. Excreta were collected for 10 hr after start of feeding.

[c]Mean ± SE.

REFERENCES

Borella, L. E., and W. Lippman, 1980. A simple non-radioactive method for the simultaneous quantitative determination of stomach emptying an intestinal propulsion in the intact concious rat. Digestion 20:36–49.

Chandler, P. T., and R. G. Cragle, 1962. Gastrointestinal sites of absorption and endogenous secretion of calcium and phosphorus in dairy calves. Proc. Soc. Exp. Biol. Med. 111:431–434.

Cherry, T. A., and P. B. Siegel, 1978. Selection for body weights at eight weeks of age. 15. Feed passage and intestinal size of normal and dwarf chicks. Poultry Sci. 57:336–340.

Duke, G. E., and O. A. Evanson, 1972. Inhibition of gastric motility by duodenal contents in turkeys. Poultry Sci. 31:1625–1636.

Henry, K. M., A. J. MacDonald, and H. E. Magee, 1933. Observations on the functions of the alimentary canal in fowls. J. Exp. Biol. 10: 153–171.

Hillerman, J. P., F. H. Kratzer, and W. O. Wilson, 1953. Food passage through chickens and turkeys and some regulating factors. Poultry Sci. 32:332–335.

Kass, M. L., P. J. Van Soest, W. G. Pond, B. Lewis, and R. E. McDowell, 1980. Utilization of dietary fiber from alfalfa by growing swine. I. Apparent digestibility of diet components in specific segments of the gastrointestinal tract. J. Anim. Sci. 50:175–191.

Maner, J. H., W. G. Pond, J. K. Loosli, and R. S. Lowery, 1962. Effect of isolated soybean protein and casein on the gastric pH and rate of passage of food residues in baby pigs. J. Anim. Sci. 21:49–52.

Mateos, G. G., and J. L. Sell, 1980. Influence of graded levels of fat on utilization of pure carbohydrate by the laying hen. J. Nutr. 110: 1894–1903.

Mateos, G. G., and J. L. Sell, 1981a. Influence of fat and carbohydrate source on rate of food passage of semipurified diets for laying hens. Poultry Sci. 60:2114–2119.

Mateos, G. G., and J. L. Sell, 1981b. Nature of the extrametabolic effect of supplemental fat used in semipurified diets for laying hens. Poultry Sci. 60:1925–1930.

Monson, W. J., L. S. Dietrich, and C. A. Elvehjem, 1950. Studies on the effect of different carbohydrates on chick growth. Proc. Soc. Exp. Biol. Med. 75:256–259.

National Research Council, 1977. Nutrient requirements of poultry. Nat. Acad. Sci., Washington, DC.

Peraino, C., Q. R. Rogers, M. Yoshida, M. Chen, and A. E. Harper, 1959. Observations on protein digestion in vivo. Can. J. Biochem. Physiol. 37:1475–1491.

Perkin-Elmer, 1973. Analytical methods for atomic absorption spectrophotometry. Perkin-Elmer, Norwalk, CT.

Rice, R. W., J. Matz, and P. Menke, 1967. Passage of food in the alimentary tract of sheep. J. Anim. Sci. 26:938. (Abstr.)

Seerley, R. W., E. R. Miller, and J. A. Hoefer, 1962. Rate of food passage studies with pigs equally and *ad libitum* fed meal and pellets. J. Anim. Sci. 21:834–843.

Sibbald, I. R., 1979. Passage of feed through the adult rooster. Poultry Sci. 58:446–459.

Snedecor, G. W. and W. G. Cochran, 1967. Statistical methods. 6th ed. Iowa State Univ. Press, Ames, IA.

Stokstad, F.L.R., T. M. Jukes, and W. L. Williams, 1953. Growth promoting effect of aureomycin on various types of diets. Poultry Sci. 31:1054–1058.

Tuckey, R., B. E. March, and J. Biely, 1958. Diet and the rate of food passage in the growing chick. Poultry Sci. 37:786–796.

Wilson, E. K., F. W. Pierson, P. Y. Hester, R. L. Adams, and W. J. Stadelman, 1980. The effects of high environmental temperature on feed passage time and performance traits of White Pekin ducks. Poultry Sci. 59:2322–2330.