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Influence of Dietary Fat and Carbohydrate on Food Intake, Body Weight and Body Fat of Adult Dogs[1] (40037)

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Certain strains of rodents become fatter when fed high-fat rather than high-carbohydrate diets while other strains are able to consume a high-fat diet without an appreciable increase in body fat content (1-4). The obesity prone rodents are less able to regulate their food intake when fed a high-fat diet; additionally, consumption of a high-fat diet has also been shown to increase the efficiency of energy utilization in pair-fed rodents (5, 6). Less attention has focused on the interrelationship of the dietary fat to carbohydrate ratio and the development of obesity in other species.

The influence of the dietary fat to carbohydrate ratio on body weight and body fat has been studied in young growing dogs (7). The fat-free body weight gain was not influenced, but accumulation of body fat tended to be elevated in dogs fed high-fat diets. Body fat averaged 29% of body weight in the young dogs fed diets with more than 50% of energy from fat while the body fat content averaged 23% in dogs fed the diets which contained less than 50% of energy from fat. The dogs were only 10-months-old at the end of the 8-month study; had the diets been fed to adult dogs, body fat content might have been altered to a greater extent.

The purpose of the present study was to examine the influence of a high-fat diet (51% of energy from fat) and a high-carbohydrate diet (59% of energy from carbohydrate) on food intake and on body weight and body fat changes in adult dogs. Dogs were fed these diets for 25 weeks.

Materials and methods. Three-year old female beagle dogs[2] were housed in individual cages with raised floors. Lights in the temperature-controlled (22-23°) room were on from 7 AM to 7 PM and off from 7 PM to 7 AM. Prior to the present study the dogs were fed approximately 750 kcal daily for 110 days. The composition of this nutritionally adequate (8) canned diet has been described previously (Table I, Diet 6 in Ref. 7). The dogs approximately maintained their weight during this 110-day period. Food and water were offered *ad lib.* during the present study. Dogs were fed once daily. Body weights were recorded weekly.

Two semipurified diets were prepared; one diet was high-fat and the other high-carbohydrate. Each diet was formulated to contain 20% of energy from protein. Approximately 50% of the protein in the diets were derived from isolated soybean protein and 50% from beef kidneys. Corn oil (7% of energy) was added to provide a source of essential fatty acids. Corn starch and tallow were added to provide the desired carbohydrate to fat ratio. A mineral and vitamin supplement[3] and cellulose (6% of dry matter) were added to each diet. The diets were canned.

At monthly intervals samples of each diet were obtained and analyzed for moisture by drying to a constant weight at 50°, for gross energy with a bomb calorimeter and for nitrogen by the Kjeldahl procedure. Protein was determined by multiplying the

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[2] Laboratory Research Enterprises, Inc., Kalamazoo, MI.

[3] Vitamin premix was added at the level of 550 mg/kg diet. The vitamin premix contained per g: vitamin A-5344 IU; vitamin D_3 = 132 IU; vitamin E-27 IU; vitamin B_{12}-5.8 mg; thiamin-741 mg; riboflavin-1760 mg; pyridoxine-88 mg and choline chloride-253 mg. A mineral premix was added at the level of 465 mg per kg diet. The mineral premix contained in mg per g: potassium chloride-933; magnesium oxide-43; copper sulfate-10; cobalt sulfate-9; potassium iodate-3 and manganese sulfate-2. Additionally, dicalcium phosphate, iodized salt and potassium chloride were added at the levels of 1.4, 1.0 and 0.36% of the diet.

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TABLE I. COMPOSITION AND DIGESTIBILITY OF DIETS FED TO ADULT DOGS.

	Diet	
	1	2
Dry matter, g/g diet	25.4	25.4
Gross energy, kcal/g diet	1.43	1.16
Energy digestibility, %	85.7 ± 0.4[a]	89.5 ± 0.6[b]
Metabolizable energy, %[c]		
Protein	20	18
Fat	51	23
Carbohydrate	29	59

[a] Mean ± SEM for 7 dogs.
[b] Significantly different from values obtained when dogs were fed diet 1 ($P < 0.05$).
[c] See Materials and Methods for method of calculation.

nitrogen content of the diet by 6.25. The percentage of metabolizable energy from protein, fat and carbohydrate in each diet was then determined as previously described (7).

The body water content of each dog was determined at the start and again at the end of the study. Each dog was fasted overnight and then injected intravenously with 2 ml of saline containing 50 μCi ^3H_2O. A blood sample was obtained 3 h later and the specific activity of the plasma was determined. The body water content and fat-free body mass were then calculated as previously described (7). Body fat content was calculated by subtracting the fat-free mass from the body weight of the dog.

The apparent digestible energy value of each diet was determined during the 20th week of the study. Total fecal collections from each dog were continued for 5 days. Feces were dried at 50°. A bomb calorimeter was then utilized to determine total fecal energy. The difference between the gross energy intake and the fecal energy output during the 5 day period represented the apparent energy digestibility of the diets.

The data were treated statistically by the student's *t* test.

Results and Discussion. The composition and energy digestibility of the diets are presented in Table I. Both diets contained 25% dry matter. The gross energy content of diet 1, the high-fat diet, was 23% higher than diet 2, the high-carbohydrate diet. Digestibility of energy in the high-carbohydrate diet was 4% greater than observed when the high-fat diet was fed. This difference in digestibility was unexpected. In a previous study with growing dogs a high-carbohydrate diet of similar composition to diet 2 exhibited slightly lower digestibility than did diets higher in fat (7). Differences in energy intake may influence digestible energy values; however, dogs in both groups consumed similar amounts of food during the digestion trial. Gross energy intake of diet 1 and 2 averaged 4185 ± 271 and 4506 ± 157 kcal, respectively, for the 5-day period. Based on the analyzed composition, diet 1 was slightly higher in protein than was diet 2. Dogs fed diet 2 consumed an adequate quantity of protein (40 g per day), thus it is unlikely that the small difference in protein content of the diets influenced the results.

The dogs had been fed a restricted amount of food prior to this study; consequently, food intake was high during the first several weeks of the study (Fig. 1). Dogs fed the high-fat diet consumed more energy than did dogs fed the high-carbohydrate diet during this period; however, the differences were not significant. After approximately 6 weeks, energy intake stabilized and remained rather constant during the remainder of the study. The average daily energy intake of the dogs during the first 12 weeks and during the last 13 weeks of the study is presented in Table II. None of the differences in energy intake were statistically significant.

Body weight changes of the dogs are presented in Fig. 1. Both groups of dogs increased their body weights during the study; but by 10 weeks the increase in body weight of dogs fed the high-fat diet was significantly greater than observed when the high-carbohydrate diet was fed. The increase in body weight of dogs fed the high-fat diet during the first 12 weeks was twice the increase observed when the high-carbohydrate diet was fed (Table II). During the last half of the study the rate of body weight gain decreased in both groups of dogs, but dogs fed the high-fat diet still gained more than did dogs fed the high-carbohydrate diet. This greater body weight gain in dogs fed the high-fat diet occurred even though

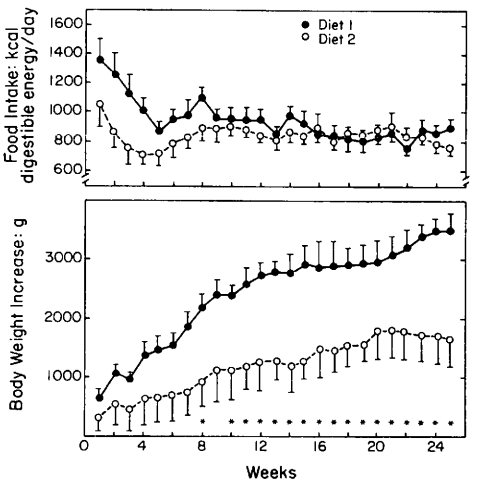

FIG. 1. Influence of diet composition on daily food intake and body weight changes of adult dogs. Each point represents the mean ± SEM for seven dogs. * indicates significant differences ($P < 0.05$).

TABLE II. INFLUENCE OF DIET COMPOSITION ON FOOD INTAKE, BODY WEIGHT AND BODY FAT OF ADULT DOGS.[a]

Parameter	Diet 1	Diet 2
Initial body wt, kg	10.26 ± 0.43	10.22 ± 0.33
Initial body fat, kg	2.98 ± 0.50	3.10 ± 0.36
Food intake, kcal digestible energy/day		
Weeks 0-12	1038 ± 59	841 ± 66
Weeks 13-25	855 ± 42	832 ± 41
Body weight gain, kg		
Weeks 0-12	2.75 ± 0.24	1.25 ± 0.45[b]
Weeks 13-25	0.74 ± 0.12	0.36 ± 0.08[b]
Body fat gain, kg	2.78 ± 0.44	1.26 ± 0.41[b]

[a] Results expressed as Mean ± SEM for seven dogs.

[b] Significantly different from values obtained when dogs were fed diet 1 ($P < 0.05$).

energy intake of the two groups of dogs during the last half of the study was virtually identical (Table II). Dogs fed the high-fat diet consumed less than 3% more energy than did dogs fed the high-carbohydrate diet during this period. Body fat gain averaged 78-80% of body weight gain (Table II). This observation indicates that the increase in body weight observed in these adult dogs could be accounted for by gain in adipose tissue as adipose tissue from mature animals contains approximately 85% fat (9).

Dogs fed the high-fat diet consumed only 13% more energy during the study, but gained 117% more energy (assumed that the body weight gain was adipose tissue and that the adipose tissue contained 7700 kcal/kg). Dogs fed the high-fat diet retained approximately 16% of the digestible energy consumed, whereas dogs fed the high-carbohydrate diet retained only 8% of the digestible energy consumed. These results agree with the suggestion that the energy cost of fat deposition is greater when high-carbohydrate diets are fed than when high-fat diets are fed (5, 6, 10). However, as discussed in the next paragraph, an alternative explanation of the results is also plausible.

The metabolizable energy requirement of these adult, relatively inactive, dogs was estimated to average 840 kcal per dog per day (8). This value closely approximates the actual energy intake of the dogs (Table II). Consequently, even when the dogs were in positive energy balance, only a small fraction of the energy consumed by the dogs would be available for body fat gain. This small increment in daily energy intake, which might be practically nonmeasurable, could if allowed to accumulate for months, result in significant increases in body fat. The difference in energy intake between dogs fed diet 1 and diet 2 during the first 12 weeks averaged 197 kcal per day; during the last 13 weeks the difference was 23 kcal per day. If it is assumed that this additional energy consumed by the dogs fed the high-fat diet was deposited as adipose tissue (assume 7700 kcal/kg adipose tissue), then it would be possible to explain the entire difference in weight gain of the dogs on the basis of the small nonstatistically significant difference in food intake. The increased energy intake of the dogs fed the high-fat diet, if deposited as adipose tissue, would account for 2.42 kg adipose tissue gain. The observed difference in gain was 1.88 kg, suggesting that the increased energy intake in dogs fed the high-fat diet was utilized for adipose tissue gain with an efficiency of 78%.

It would be necessary to pair-feed the

dogs to determine whether the increased fat deposition observed in the dogs fed the high-fat diet resulted from an increased efficiency of energy utilization or from the small difference in energy intake. Possibly both factors contributed to the results obtained in the present study.

Summary. Adult female dogs were fed ad libitum for 25 weeks a high-fat diet (51% of energy from fat) or a high-carbohydrate diet (59% of energy from carbohydrate). Dogs fed the high-fat diet gained more body weight than did dogs fed the high-carbohydrate diet. In both groups of dogs 78–80% of the increase in body weight was fat. The high-fat diet may have been utilized more efficiently for body fat gain than the high-carbohydrate diet; alternatively, it is possible to explain the increased body fat accumulation in dogs fed the high-fat diet on the basis of the small observed difference in energy intake. Dogs fed the high-fat diet consumed slightly more energy (13%) which resulted in the accumulation of more than twice the amount of fat accumulated in dogs fed the high-carbohydrate diet during the 25 week study.

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1. Schemmel, R., Mickelsen, O., and Gill, J. L., J. Nutrition **100,** 1041 (1970).
2. Lemonnier, D., Winand, J., Furnelle, J., and Christope, J., Diabetology **7,** 328 (1971).
3. Genuth, S. M., Diabetology **12,** 155 (1976).
4. Lin, P. Y., Romsos, D. R., and Leveille, G. A., J. Nutrition **107,** 1715 (1977).
5. Forbes, E. B., Swift, R. W., James, W. H., Bratzler, J. W., and Black, A., J. Nutr. **32,** 387 (1946).
6. Wood, J. D., and Reid, J. T., Brit. J. Nutrition **34,** 15 (1975).
7. Romsos, D. R., Belo, P. S., Bennink, M. R., Bergen, W. G., and Leveille, G. A. J. Nutrition **106,** 1452 (1976).
8. Anonymous. Nutrient requirements of dogs. National Academy of Sciences-National Research Council. Washington, D.C. (1974).
9. Jeanrenaud, B. "Adipose tissue regulation and metabolic functions," p. 181, Academic Press, New York (1970).
10. ARC/MRC Committee. Food and Nutrition Research Report of ARC/MRC Committee, p. 30, H. M. Stationary Office, London (1974).

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