Energy Value of Blends of Polydextrose and a Synthetic Fat

G. S. RANHOTRA, J. A. GELROTH, and B. K. GLASER[1]

Cereal Chem. 72(1):30–32

ABSTRACT

Polydextrose, now a common ingredient in many bakery products, and a reduced-calorie synthetic fat (caprenin) were blended in ratios of 2:1 (blend A), 1:1 (blend B) and 1:2 (blend C). The blends were evaluated for energy value using young rats as the test model. The evaluation was based on net increase observed in their carcass energy due to blends fed over a three-week period. Compared to a value of 5.7 cal/g for a 2:1 blend of sucrose and a regular fat (baker's shortening), a 2:1 blend of polydextrose and caprenin (blend A) contained 2.0 cal/g. Blends B and C contained 2.2 and 2.4 cal/g, respectively. The corresponding calculated values for blends A, B, and C were: 2.0, 2.5, and 3.1 cal/g. This discrepancy suggests that a higher level of caprenin in the blend may result in further reduction in energy.

In a recent study, we reported a synthetic fat (caprenin) as containing only 4.3 cal/g (Ranhotra et al 1994). In a separate study, we also reported polydextrose, a widely used fat and sugar replacer, as containing only 0.8 cal/g (Ranhotra et al 1993). Blending these two ingredients may yield a fat replacer well suited for use in bakery products. Such blending may also show a further lowering of energy value (due to a possible interaction effect between the two ingredients) as compared to the calculated value. This study was undertaken to examine this latter possibility.

Energy values have been determined using growth curves, balance experiments, and radiolabeling techniques (Figdor and Rennhard 1981, Figdor et al 1987, Grimble et al 1988, Wisker et al 1990). However, such methodologies have often provided contradictory results, since they often lack the necessary precision (Pesti and Ware 1986, Miles et al 1988, Livesey 1991). Determination of energy value based on efficiency of conversion of gross food energy to net (carcass) energy does not require tracking the material ingested and, thus, can be a more precise method. We used this method in two recent studies (Ranhotra et al 1993, Ranhotra et al 1994) and also in the current study. The method uses young rats as the test model because they enable relatively simple whole body analysis.

MATERIALS AND METHODS

Test Materials and Diets

Fine silica (silicon dioxide, Sigma Chemical Co., St. Louis, MO), a commercial USP grade heavy mineral oil (HPC Laboratories, Dallas, TX), sucrose, baker's shortening (Vream, Bunge Foods, Seattle, WA), polydextrose (Litesse, Pfizer Chemical Co., Groton, CT), and caprenin (Procter and Gamble Co., Cincinnati, OH) were the test materials used. Two control and three test diets were prepared using these materials (Table I). The negative control diet (diet A) contained 45% (30% silica and 15% mineral oil) inert material, while the positive control diet (diet B) contained similar levels of the counterpart materials–sucrose and shortening. The test diets contained 45% of polydextrose-caprenin blends, either 2:1 blend (diet C), 1:1 blend (diet D), or 1:2 blend (diet E). Each diet contained 55% constant ingredients. All diets were complete in nutrients required by the rat (NRC 1987).

Animals and Feeding

A total of 53 male, weanling rats of the Sprague-Dawley strain were obtained from Harlan Sprague-Dawley, Indianapolis, IN, and housed individually in mesh-bottomed stainless steel cages in a controlled environment (75°F, 50% rh). Following a two-day adaptation period, rats were randomly assigned to five groups (10 rats per group) for the three-week study period. A control group of three rats was sacrificed at day zero. During the three-week feeding period, each rat was allowed to consume adequate and increasingly higher, but otherwise identical, amounts of diet. Deionized water was offered ad libitum. Diet intake and body weight records were maintained. Feces were quantitatively collected throughout the feeding period and stored frozen.

Carcass Sampling and Analysis

All rats were sacrificed (under ether) at the end of the study, their gut contents removed and discarded, and the carcass weighed and then frozen pending analyses. For compositional analyses, carcasses were individually autoclaved (121°C, 1 kg/cm^2, 1.5 hr) in excess water, thoroughly homogenized in a blender, freeze-dried, and finely ground. Suitable aliquots of the finely ground carcass were taken for analysis.

Analytical and Statistical Data

Carcasses were analyzed for moisture (two-stage), protein (Kjeldahl), fat (acid hydrolysis), and ash using the standard methods of AACC (1983). Ingesta-free body weight was taken into consideration in assessing total moisture content of the carcass. Glycogen values were calculated by difference (100 − [fat + protein + ash + water]). Feces were finely ground and a suitable aliquot was analyzed for fat using the ether extract method of the AACC (1983). Data were subjected to analysis of variance. Mean comparisons were made with Duncan's multiple-range test using the Statistical Analysis System (SAS 1982).

RESULTS AND DISCUSSION

Test Materials

Silica and mineral oil, which provide no energy, served as the inert materials in diet A (Table I). Sucrose and shortening, which

TABLE I
Percent Composition of Diets

	Control Diets		Test Diets		
Component, %	A	B	C	D	E
Silica	30	...	...	...	...
Mineral oil	15	...	...	...	...
Sucrose	...	30	...	...	...
Shortening	...	15	...	...	...
Polydextrose	...	...	30	22.5	15
Caprenin	...	...	15	22.5	30
Constant ingredients[a]	55	55	55	55	55

[a]Contained 1% vitamin mix (American Institute of Nutrition (AIN) mix 76), 3.5% mineral mix (AIN mix 76), 17.2% casein (= 14.3% protein), 0.3% dl-methionine, 2% soybean oil and 31% pregelatinized cornstarch.

[1]Nutrition Research Group, American Institute of Baking, Manhattan, KS.

TABLE II
Body Composition (Three-Week Study)[a]

Diet	Diet Intake (g)	Body Wt. Gain[b] (g)	Body Composition[c] Fat (g)	Protein (g)	Ash (g)	Water (g)	Glycogen (g)
A	221	23 ± 5 e	1.9 ± 0.2 c	12.6 ± 1.2 d	2.5 ± 0.3 c	48.6 ± 4.8 e	0.1 ± 0.1 c
B	221	115 ± 2 a	18.3 ± 1.7 a	29.5 ± 1.3 a	4.5 ± 0.2 a	105.6 ± 3.7 a	0.6 ± 0.2 b
C	221	77 ± 4 d	5.3 ± 1.1 b	23.5 ± 1.1 c	3.8 ± 0.2 b	86.0 ± 3.7 d	1.0 ± 0.1 a
D	221	81 ± 2 c	5.7 ± 1.7 b	23.8 ± 1.0 c	3.7 ± 0.3 b	89.5 ± 2.7 c	1.0 ± 0.3 a
E	221	87 ± 3 b	6.3 ± 1.5 b	25.5 ± 1.2 b	3.8 ± 0.2 b	94.3 ± 3.6 b	0.4 ± 0.4 b

[a]Values are averages ± standard deviation of 10 rats/diet. Within a column, averages not sharing a common letter are significantly different ($P < 0.05$).
[b]Initial body weight: 43 ± 4 g.
[c]Body composition of rats sacrificed at day zero: fat, 2.1 ± 0.9 g; protein, 7.3 ± 1.7 g; ash, 1.3 ± 0.3 g; water, 27.5 ± 5.5 g; and glycogen, 0 g. These values were used to calculate baseline (day zero) carcass energy (48 calories).

TABLE III
Carcass Energy Values at Three Weeks[a]

Diet	Baseline Carcass Energy[b] (cal)	Total Carcass Energy[c] (cal)	Increase in Carcass Energy Net[d] (cal)	Relative[e] (cal)
A	48	68 ± 5 d	20 ± 5 d	...
B	48	285 ± 13 a	237 ± 13 a	217
C	48	146 ± 13 c	98 ± 13 c	78
D	48	151 ± 15 bc	103 ± 15 bc	83
E	48	160 ± 15 b	112 ± 15 b	92

[a]Values are averages ± standard deviation for 10 rats/diet. Within a column, averages not sharing a common letter are significantly different ($P < 0.05$).
[b]At day zero.
[c]Based on compositional data in Table II.
[d]Total carcass energy − baseline carcass energy.
[e]Relative to the control diet A (negative control).

TABLE IV
Calculating Energy Value of Polydextrose and Caprenin Blends

Diet	Test Material Consumed (g)	Increase in Carcass Energy (cal)	Energy Value (cal/g) Calculated[a]	This Study[b]
B	Sucrose, 66.3 Shortening, 33.2	217	5.7	...
C	Polydextrose, 66.3 Caprenin, 33.2	78	...	2.0 (2.0)[c]
D	Polydextrose, 49.7 Caprenin, 49.7	83	...	2.2 (2.5)[c]
E	Polydextrose, 33.2 Caprenin, 66.3	92	...	2.4 (3.1)[c]

[a]Based on energy value of 4 cal/g for sucrose and 9 cal/g for shortening.
[b]Based on equation A/B × C/D where: A = sucrose + shortening consumed (g) × calories per g (= 5.7) of this blend; B = increase in carcass energy (calories) due to sucrose + shortening blend consumed; C = increase in carcass energy (calories) due to a polydextrose and caprenin blend consumed; D = amount (g) of this blend consumed. Example (diet C): $\frac{99.5 \times 5.7}{217} \times \frac{78}{99.5} = 2.0$
[c]Values within parentheses are calculated values; calculated based on 0.8 cal/g for polydextrose and 4.3 cal/g for caprenin.

are fully digested and absorbed in man and monogastric animals, served as the counterpart materials in diet B. Diets A and B, thus, provided the necessary controls to assess energy values of blends of polydextrose and caprenin, which individually do provide some energy (Peters et al 1991, Juhr and Franke 1992, Ranhotra et al 1993, Ranhotra et al 1994), but in combination may show values different from those calculated.

Growth Response

All groups of rats were fed the same amount, 221 g, of diet over the three-week study period (Table II). However, their body weight gains differed ($P < 0.05$), being lowest on diet A (silica and mineral oil) and highest on diet B (sucrose and shortening). Rats fed the three test diets (diets C–E) all showed weight gains higher than rats fed diet A. This suggests that blends of polydextrose and caprenin provided some energy, but evidently less than 5.7 cal/g, the value assigned to the 2:1 blend of sucrose (4 cal/g) and shortening (9 cal/g) used in diet B (Table I).

Where growth response is used as the sole criterion to assess energy value, increasingly higher levels of the control and test materials are normally included in the study. This was not done here, since change in body composition, a more sensitive parameter, was used instead.

Body Composition

In man and animals, fat and protein are the major components of energy gained. In this study, these components closely followed the trend observed for weight gains (Table II). Collectively, the two components averaged 14.5 g in rats fed diet A (silica and mineral oil) and 47.8 g in rats fed diet B (sucrose and shortening). Such values for the test diets (diets C–E) averaged between 28.8 and 31.8 g, suggesting that the three polydextrose and caprenin blends provided energy, and it differed minimally between blends. The ash and water content of the carcasses also closely followed the trend observed for body weight gains.

Calculating Usable Energy Values

Body composition data in Table II were used to calculate total carcass energy. This calculation used standard conversion factors of 4, 9, and 4 cal/g of protein, fat, and glycogen, respectively (Table III). The use of these factors may be in slight variance with factors applicable to carcass energy. However, they are readily understood and universally applied in assessing energy value of food products, including animal-derived foods.

Total energy values represent baseline (rats sacrificed on day zero) carcass energy (48 cal) plus energy gained in three weeks, with the difference between the two representing the net increase in energy (Table III). This net increase resulted in response to constant and test ingredients consumed in three weeks (Table I). Presuming that constant ingredients (starch, casein, etc.) were equally well-utilized by all groups of rats, differences in net energy increases can be viewed as resulting from differences in energy value of the materials tested.

Out of a total diet intake of 221 g per rat (Table II), the test material consumed was 99.5 g (Table IV). In diet A, the test material (silica + mineral oil) obviously provided no energy. In the remaining diets, the test materials provided some energy, which resulted in a relative (to silica + mineral oil) increase of 217 (diet B), 78 (diet C), 83 (diet D), and 92 cal (diet E) (Table III). For the test material sucrose + shortening, this represents a gross energy (99.5 × 5.7 = 567.2 cal) to net energy (217 cal) ratio of 2.6:1. An equation based on this ratio showed that the three blends of polydextrose and caprenin contained between 2.0 and 2.4 cal/g. These values are 58–65% lower as compared to the reference blend of sucrose and shortening (Table IV).

TABLE V
Digestibility of Fat in Test Diets[a]

Diet[b]	Fat Consumed[c] (g)	Fat Excreted (g)	Apparent Digestibility (%)
B	33.2	0.6 ± 0.0 d	98.2 ± 0.1 a
C	33.2	5.4 ± 0.9 c	83.7 ± 2.8 b
D	49.7	10.4 ± 1.4 b	79.1 ± 2.9 c
E	66.3	16.5 ± 1.1 a	75.1 ± 1.7 d

[a]Values are averages ± standard deviation of 10 rats/diet. Within a column, averages not sharing a common letter are significantly different ($P < 0.05$).
[b]Diet A not tested because of anal leakage of mineral oil.
[c]Consumed as shortening (diet B) or caprenin (diets C–E).

Determined vs. Calculated Values

As determined, the three blends of polydextrose and caprenin contained 2.0, 2.2, and 2.4 cal/g (Table IV). Based on an energy value of 0.8 cal/g determined for polydextrose (Ranhotra et al 1993) and 4.3 cal/g determined for caprenin (Ranhotra et al 1994), the corresponding calculated values were: 2.0, 2.5, and 3.1 cal/g (Table IV). The differences noted in determined and calculated values for diet D (2.2 vs. 2.5) and diet E (2.4 vs. 3.1) may suggest a possible interaction between polydextrose and caprenin, or it may be the consequence of our not including corresponding control diets for diets D and E as was done for diet C. The former possibility, however, seems more likely, since the digestibility of caprenin decreased significantly ($P < 0.05$) as the level of caprenin in the blend increased (Table V). Thus, blends of polydextrose and caprenin may actually contain lower energy values than would be determined through calculations.

CONCLUSIONS

The efficiency of conversion of gross energy to net energy is a sensitive method of assessing energy value of food ingredients. However, a variety of influencing factors, e.g., change in diet composition, may slightly alter the energy values determined by this method. Barring a profound effect of these influencing factors, the data obtained in this study suggest a possible interactive effect between polydextrose and caprenin, leading to a further lowering of energy value than obtained through calculations.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC, 8th ed. The Association: St. Paul, MN.

FIGDOR, S. K., and RENNHARD, H. H. 1981. Caloric utilization and disposition of [^{14}C] polydextrose in the rat. J. Agric. Food Chem. 29:1181.

FIGDOR, S. K., ALLINGHAM, R. P., KITA, D. A., and HOBBS, D. C. 1987. Caloric utilization of sorbitol and isomalt in the rats. J. Agric. Food Chem. 35:996.

GRIMBLE, G. K., PATIL, D. K., and SILK, D. B. A. 1988. Assimilation of lactitol, and "unabsorbed" disaccharide, in the normal human colon. Gut 29:1666.

JUHR, N. C., and FRANKE, J. 1992. A method for estimating the available energy of incompletely digested carbohydrates in rats. J. Nutr. 122:1425.

LIVESEY, G. 1991. Calculating the energy value of foods: Towards new emprical formulae based on diets with varied intakes of unavailable complex carbohydrates. Eur. J. Clin. Nutr. 45:1.

MILES, C. W., KELSAY, J. L., and WONG, N. P. 1988. Effect of dietary fiber on the metabolizable energy of human diets. J. Nutr. 118:1075.

NRC. 1987. Nutrient requirements of laboratory animals. Page 23 in: Nutrient Requirements of Domesticated Animals. National Academy of Sciences/National Research Council: Washington, DC.

PESTI, G. M., and WARE, G. O. 1986. Expressing the variability in results of metabolizable energy assays. J. Nutr. 116:1385.

PETERS, J. C., HOLCOMBE, B. N., HILLER, L. K., and WEBB, D. R. 1991. Caprenin 3. Absorption and caloric value in adult humans, J. Am. Coll. Toxicol. 10:357.

RANHOTRA, G. S., GELROTH, J. A., and GLASER B. K. 1993. Usable energy value of selected bulking agents. J. Food Sci. 58:1176.

RANHOTRA, G. S., GELROTH, J. A., and GLASER, B. K. 1994. Usable energy value of a structured fat (caprenin) used in muffins. Cereal Chem. 71:159.

SAS. 1982. SAS User's Guide: Statistics. SAS Institute, Inc.: Cary, NC.

WISKER, E., MALTZ, A., and FELDHEIM, W. 1990. Metabolizable energy of diets low or high in dietary fiber from cereals when eaten by humans. J. Nutr. 118:945.

[Received May 27, 1994. Accepted September 23, 1994.]