Levels of Medium-Chain Triglycerides and Their Energy Value

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ABSTRACT

This study examined the effect of the level of dietary intake of medium-chain triglycerides (MCTs) on their energy value. The MCT oil tested for the purpose replaced baker's shortening in a traditional muffin formula and provided, through muffins added to the diet of the rats, 20 or 30% of total energy. Changes in body composition of the rats due to MCTs fed over a three-week period formed the basis of calculating energy value. Rats fed MCTs deposited significantly ($P < 0.05$) less fat in their carcasses than did rats fed shortening. Calculations showed the MCT oil tested to contained 7.0 cal/g at both levels (20 and 30%) of energy intake. In an earlier study, this MCT showed an energy value of 6.8 cal/g when fed at a 40% energy level. Thus, the level of feeding MCTs, unless quite excessive, may have a limited effect on the energy level of MCTs, which appears to be about one-fourth lower than that of conventional fats.

In food products, medium-chain triglycerides (MCTs) are currently used as solvents for colors and flavors, as antistick or release agents for bakery products and candies, and as ingredients in gloss-enhancing coatings. They may also be a good substitute for tropical oils as a spray oil for use in cereals, crackers, and other snacks. MCT oil can also serve as the fat ingredient in reduced-calorie bakery products.

For use in reduced-calorie bakery and other products, MCT oils are likely to find application if they show a caloric value appreciably lower than that of regular fats. In a study we recently reported (Ranhotra et al 1994a), three commercial MCT oils showed an average energy value of 6.9 cal/g, a value about one-fourth lower than that of regular fats. In that study, MCTs (through MCT-containing muffins) provided 40% of total energy in the diet of the test animals.

For humans, 40% of energy as fat may be considered excessive. Excessive inclusion of MCTs in the diet (overfeeding) has been suggested (Baba et al 1982, Geliebter et al 1983) as causing a reduction in body fat deposition, and hence in MCTs' observed lower energy values. This study was undertaken to evaluate the effect of level of MCTs consumed as a factor affecting MCTs' energy value. The study protocol was essentially the same as followed in the earlier study (Ranhotra et al 1994a) except that MCTs now provided 20%, a low level, and 30%, a medium level, of the dietary energy as compared to 40% (considered a high level) provided in the earlier experiment.

MATERIALS AND METHODS

Test Fats

Baker's shortening (partially hydrogenated soybean oil), a commercial USP-grade heavy mineral oil, and a commercial source of MCT oil were tested. MCT oil (Neobee M-5) was obtained from Stepan Co., Maywood, NJ. It contained 71.1% caprylic acid, 26.9% capric acid, and 2% other acids (supplier's data).

Muffins Prepared with Test Fats

Test fats were used at the 11.2% (low) or 16.5% (medium) levels in muffin formulas; in the earlier study (Ranhotra et al 1994a), they were used at the 22.3% (high) level. Other formula ingredients were the same as used in the earlier study except that their use levels were somewhat adjusted to accommodate the lower formula levels of the test fats.

Test Diets

Air-dried and finely ground muffins (Table I) were used to prepare two sets (LSH-LMT and MSH-MMT) of experimental diets (Table II). Each set contained two control diets and one test diet. Control diets were shortening-based (LSH or MSH) and mineral oil-based (LMO or MMO) diets, while the test diets contained MCT (diets LMT or MMT) (Table II). Except for a minor contribution from flour, test fats were the only source of fat in the muffins. One percent soybean oil was added to the diets as a source of essential fatty acids. Calories from fat were 20% in diets LSH-LMT and 30% in diets MSH-MMT (Table II).

Experimental

Sixty-four 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 climate-controlled environment. They were randomly assigned to six groups (10 rats/group) for the three-week study period. A group of four rats was sacrificed at day 0 to obtain baseline carcass energy values. As the study progressed, all rats were allowed to consume increasingly higher, but otherwise identical, amounts of the diets. Deionized water was offered ad libitum. All diets were complete in nutrients required by the rat (NRC 1978). Total fecal collection was made on each rat fed experimental diets except in the rats fed mineral oil-based diets. Mineral oil-fed rats showed anal leakage of the oil, which made fecal collection impractical; anal leakage also required occasional washing of the rats. Anal leakage was not observed on other diets.

At the end of the study, all rats were sacrificed under ether, and their gut contents were removed and discarded. The carcasses were weighed, individually autoclaved in excess water (121°C, 15 psi, 1.5 hr), freeze-dried, and then finely ground. Aliquots of the ground carcasses were taken for analysis.

Analytical

Standard methods (AACC 1983) were used to analyze muffins and carcasses for moisture, protein (Kjeldahl), ash, and fat (muffins by ether extract method, carcasses by acid hydrolysis method). Body weight was considered in calculating total moisture in the carcass. Feces were analyzed only for fat (ether extraction). Dietary fiber in muffins was determined by the method of Prosky et al (1992). Carbohydrate (muffins) and glycogen (carcasses) values were calculated as the remainder of the sum of analyzed components subtracted from 100. Data were analyzed statistically using the multiple range test (SAS 1982).

RESULTS AND DISCUSSION

Test Fats and Diets

As in our earlier studies (Ranhotra et al 1994a,b), baker's shortening and mineral oil were used as the positive and negative con-

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trols, respectively, to assess the caloric value of a test fat. Shortening, like most other fats, provides about 9 cal/g (Reeves and Weihrauch 1979), whereas mineral oil, a petroleum-derived product, provides no energy.

Air-dried muffins contained 11.5–11.7% (low level) or 17.2–17.5% fat (medium level) (Table I). They were incorporated in diets to provide, respectively, 20 or 30% energy as fat (Table II), in contrast to the 40% level they provided in the earlier study (Ranhotra et al 1994a).

Growth Response and Body Composition

All rats were fed 214 g of total diet during the three-week study period (Table III). By week 3, their body weights differed significantly ($P < 0.05$) due to the low caloric density of the mineral oil-based diets (LMO and MMO) (Table III). Rats fed the MCT-based diets (LMT and MMT) showed only slightly lower weights than rats fed shortening-based diets (LSH and MSH). This may suggest that MCT oil contains only a slightly lower energy value than shortening, a conclusion not supported, however, by the more sensitive parameter, i.e., body composition (Table III).

Body composition data revealed that carcass fat deposition was significantly higher ($P < 0.05$) in rats fed shortening-based diets than the corresponding MCT-based diets (LSH vs. LMT and MSH vs. MMT). Besides fat, protein represents the other major component of energy gained. However, in rats fed shortening or MCT oil, differences in carcass protein content were minimal.

Fat digestibility did not contribute to lower fat deposits in MCT-fed rats. At both levels of energy intake (20 and 30%), MCT oil was even slightly better digested than shortening (Table III). Most likely, MCT was rapidly oxidized (higher thermogenesis) and, consequently, less fat was deposited. In humans, this stimulatory effect of MCT on thermogenesis has been documented, especially when caloric intake from fat is excessive (Hill et al 1989, Mascioli 1991). The body's limited ability to incorporate medium-chain fatty acids into tissue lipids and their capacity to inhibit de novo synthesis of fatty acids (Bach and Babayan 1982) may have contributed to differences observed between MCT and shortening.

Carcasses were also analyzed for other components (Table III), but differences noted in values for these components carry limited nutritional significance because they contribute little or no energy.

Energy Value of MCT

Body composition data (Table III) and standard conversion factors of 4, 9, and 4 cal/g of protein, fat, and glycogen, respectively, were used to calculate carcass energy values (Table IV). This energy represents the day 0 carcass energy (48 cal) plus energy gained during the three-week study period, with differences between the two representing a net increase in carcass energy. The net increase occurred due to the feeding of 214 g of total diet containing 18.6 (diets LSH-LMT) or 29.7 g (diets MSH-MMT) of fat.

As mineral oil, 18.6 or 29.7 g fat provided no energy. However, corresponding amounts of shortening and MCT provided energy that resulted in rats with a relative increase of 88 (shortening) and 68 cal (MCT) at the 18.6-g fat intake, and 124 (shortening) and 97 cal (MCT) at the 29.7-g fat intake. For shortening, this

TABLE I
Percent Composition of Air-Dried Muffins

	Low Level[a]			Medium Level[a]		
Component	**Shortening**	**Mineral Oil**	**MCT[b]**	**Shortening**	**Mineral Oil**	**MCT[b]**
Moisture	7.6	6.2	4.6	4.6	6.4	4.2
Protein	7.1	7.3	7.4	7.0	6.5	7.0
Ash	2.0	2.0	2.0	1.9	1.8	1.9
Fat	11.5	11.5	11.8	17.5	17.2	17.3
Dietary fiber	1.7	1.7	1.7	1.8	1.8	1.8
Carbohydrates[c]	70.1	71.3	72.5	67.2	66.3	67.8

[a]Compared to the high level in the earlier study.
[b]Medium-chain triglycerides.
[c]Calculated by difference.

TABLE II
Composition of Test Diets[a]

Composition, %	LSH	LMO	LMT	MSH	MMO	MMT
Shortening (SH)[b]	67.0	...	...	73.7	...	...
Mineral oil (MO)[b]	...	67.0	...	...	75.0	...
MCT (MT)[b]	...	...	65.8	...	...	74.6
Casein	5.5	5.5	5.5	5.3	5.5	5.3
Gluten	6.6	6.5	6.5	6.3	6.5	6.3
Starch	14.8	14.9	16.1	8.8	7.2	7.9
Cellulose	0.3	0.3	0.3	0.1	...	0.1
Constants[c]	5.8	5.8	5.8	5.8	5.8	5.8
Percent fat	8.7	8.7	8.7	13.9	13.9	13.9
Percent calories from fat	20	20	20	30	30	30

[a]LSH = low shortening, LMO = low mineral oil, LMT = low MCT (medium-chain triglycerides), MSH = medium shortening, MMO = medium mineral oil, MMT = medium MCT.
[b]As finely ground muffins.
[c]Included (%): vitamin mix, 1; mineral mix, 3.5; soybean oil, 1; and dl-methionine, 0.3.

TABLE III
Body Weight, Body Composition, and Fat Digestibility Responses in Rats (Week 3)[a]

	Diet[b]					
Factor	**LSH**	**LMO**	**LMT**	**MSH**	**MMO**	**MMT**
Diet intake, g	214	214	214	214	214	214
Body weight, g[c]	117 ± 5 a	98 ± 5 b	114 ± 5 a	118 ± 6 a	92 ± 6 c	117 ± 6 a
Body composition, g[d]						
Fat	13.4 ± 1.7 b	4.5 ± 0.6 d	11.2 ± 1.3 c	15.7 ± 2.7 a	3.4 ± 0.6 d	12.5 ± 2.1 bc
Protein	20.9 ± 0.9 a	19.2 ± 0.9 b	21.0 ± 1.1 a	20.9 ± 1.3 a	17.8 ± 1.4 c	21.1 ± 1.3 a
Ash	3.4 ± 0.2 a	3.2 ± 0.2 b	3.5 ± 0.2 a	3.5 ± 0.2 a	3.1 ± 0.2 b	3.5 ± 0.3 a
Water	78.4 ± 3.4 a	71.1 ± 3.8 b	78.3 ± 3.4 a	77.9 ± 4.2 a	67.7 ± 4.2 b	78.9 ± 4.5 a
Glycogen	0.5 ± 0.4 a	0.2 ± 0.2 ab	0.4 ± 0.2 ab	0.4 ± 0.2 ab	0.2 ± 0.2 b	0.5 ± 0.2 a
Apparent fat digestibility						
Fat intake, g	18.6	18.6	18.6	29.7	29.7	29.7
Fat excreted, g	0.3 ± 0.1	...	0.2 ± 0.0	0.4 ± 0.1	...	0.1 ± 0.1
Fat digested, %	98.2 ± 0.2	...	99.2 ± 0.1	98.5 ± 0.1	...	99.5 ± 0.1

[a]Values are averages ± standard deviation for 9–10 rats per diet. Within a line, averages not sharing a common letter are significantly different ($P < 0.05$).
[b]LSH = low shortening, LMO = low mineral oil, LMT = low MCT (medium-chain triglycerides), MSH = medium shortening, MMO = medium mineral oil, MMT = medium MCT.
[c]Ingesta free. Initial (day 0) body weight: 34 ± 10 g.
[d]Body composition of rats sacrificed at day 0: fat, 2.3 ± 1.1 g; protein, 6.2 ± 1.7 g; ash, 1.1 ± 0.3 g; water, 23.7 ± 6.4 g; and glycogen, 0.6 ± 0.4 g (carcass energy, 48 cal).

TABLE IV
Calculating Energy Value of Medium-Chain Triglycerides[a]

Factor	Diet[b]					
	LSH	LMO	LMT	MSH	MMO	MMT
Fat consumed, g	18.6	18.6	18.6	29.7	29.7	29.7
Total carcass energy, cal[c]	206 ± 17 b	118 ± 8 d	186 ± 14 c	226 ± 24 a	102 ± 9 e	199 ± 19 bc
Increase in carcass energy						
Net increase, cal[d]	158 b	70 d	138 c	178 a	54 e	151 bc
Relative increase, cal[e]	88	...	68	124	...	97
Energy value, cal/g[f]	...	...	7.0	...	...	7.0

[a]Values are averages ± standard deviation for 9–10 rats per diet. Within a line, averages not sharing a common letter are significantly different ($P < 0.05$). Calculations based on data from Tables II and III.
[b]LSH = low shortening, LMO = low mineral oil, LMT = low MCT (medium-chain triglycerides), MSH = medium shortening, MMO = medium mineral oil, MMT = medium MCT.
[c]Based on compositional data in Table III.
[d]Total carcass energy minus baseline (day 0) carcass energy (48 cal).
[e]Relative to diet LMO or MMO.
[f]Energy value = $A/B \times C/D$, where A = shortening consumed (g) × calories (9) per gram of shortening; B = relative increase in carcass energy (cal) due to shortening; C = relative increase in carcass energy (cal) due to MCT; D = MCT consumed (g).

represents a diet energy ($18.6 \times 9 = 167.4$ cal) to carcass energy (88 cal) ratio of 1.9:1 at the 18.6-g fat intake, and a diet energy ($29.7 \times 9 = 267.3$ cal) to carcass energy (124 cal) ratio of 2.2:1 at the 29.7-g fat intake. An equation based on this ratio (Table IV) revealed that the MCT oil tested contains 7.0 cal/g at both levels (20 and 30%) of energy intake. In our previous work (Ranhotra et al 1994a) where rats were fed the same MCT but at a 40% energy level, the energy value determined was 6.8 cal/g.

CONCLUSIONS

It appears that the level of feeding MCTs, unless highly excessive (not tested), may have a limited effect on the energy level of MCTs, which appears to be about one-fourth lower than that of regular fats. Additional studies incorporating different experimental methods should, however, be conducted to confirm this.

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