rator was installed on the 5,000-gal. slurry storage tank as shown in Figure 2.

With the exception of the wet separator, the pneumatic system operates on the same principle as others that are in common use. Air is admitted and controlled through ports in the unloading hopper attachment. This attachment is an extension of the railroad-car hopper and provides a controlled outlet for the soda ash. Air fluidizes soda ash and carries it into the top of the separator. Recycle solution is pumped from the tank into the nozzle of the separator. Here the solution forms a curtain through which air and soda ash must pass. The solution scrubs soda ash from the air stream and washes the soda ash down the tail pipe into the tank. The direction of the air stream is then changed 180° as air is pulled into the disengaging chamber of the separator. The air velocity is reduced considerably in this chamber allowing soda ash dust and entrained solution to drop from suspension. The dust-free air is then pulled through the vacuum pump and discharged along with the seal water.

The pneumatic system operates at 10 in. of mercury and is capable of unloading approximately 0.7 lbs. of soda ash per minute for each cubic foot of air. The air velocity in the unloading line should be 90 to 110 ft. per second. The velocity is decreased to approximately 10 ft. per scond in the disengaging chamber of the separator. Velocity of the solution is maintained at approximately 15 ft. per second at the nozzle of the separator.

The wet separator (patent rights held by Diamond Alkali Company) is a fabricated piece of equipment which replaces costly bag-cyclone type of filters, thereby materially reducing the capital cost of a pneumatic system.

Many commercial units have been designed, utilizing the data obtained from pilot-plant operation. The completed installations vary in storage capacity from 70 to 1,200 tons of soda ash. The unloading systems have been designed and operated at rates of 5 to 20 tons of soda ash per hour.

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Nutritional Properties of the Triglycerides of Saturated Fatty Acids of Medium Chain-Length[1]

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NUTRITIONAL STUDIES with rats have revealed that the inclusion in the diet of autoxidized fats or their polymeric fractions increases the amount of food which the animal needs to maintain its weight and that this effect does not result from poor absorption (7). This observation suggested the search for other fats which might also boost the maintenance requirements and, at the the same time, be atoxic and more palatable.

This report will describe some of the biological properties of the saturated, medium chain-length (6 to 12 carbons) triglycerides (MCT) derived from coconut oil. Such triglycerides, which occur mainly in coconut and other palm kernel oils and in butter, have received the attention of several nutritionists (8, 10).

In the studies reported below MCT was compared with natural fats and fat-free diets as to growth, weight maintenance requirements, serum cholesterol, and relation to unsaturated fatty acids.

Present Study

The MCT which was used throughout these experiments was a clear, thin oil containing the triglycerides of saturated fatty acids of 6 to 12 carbons. It was derived from coconut oil by fractionation of the split fatty acids and reconstitution of the desired fraction into triglycerides and represented 15% of the original coconut oil. It had a melting point below 0°C. and an iodine number less than 1.

The experiments were carried out on albino rats from a homogeneous colony of the Sherman strain. Until such time as they were placed on the experimental diets (usually at about five weeks), the rats were fed an adequate diet containing 30% lactalbumin and 10% lard. The procedure used in this laboratory for making up well-matched groups has been previously described in detail (6).

The experimental diets were composed of 30% casein (G.B.I. vitamin-free, test casein), 4% salt mixture (U.S.P. XIII), 2% cellulose (Alphacel), the desired percentage of fat and dextrose (Cerelose) to make 100%. To this were added, per kilogram of diet, 1 g. choline chloride, 1 g. inositol, 300 mg. PABA, 100 mg. nicotinic acid, 2 mg. thiamin chloride, 4 mg. riboflavin, 4 mg. pyridoxine, 10 mg. calcium pantothenate, 2.5 mg. folic acid, .025 mg. biotin, 5 mg. 0.1% trituration of vitamin B_{12} in mannose, and 25 mg. ascorbic acid. Fat-soluble vitamins were added in the form of a linoleic acid[2] suspension at the rate of 1 cc. per kilogram of diet to supply the diet with, per kilo, 5 mg. beta-carotene, 50 mg. alpha tocopherol acetate, 10 mg. free alpha tocopherol, and 0.5 mg. vitamin D_2. The basic diet contained no linoleic acid other than the 900 mg. per kilogram of diet used as the carrier of the vitamins. Inasmuch as the rats fed this diet ate approximately 12 g. per day, their linoleic acid intake was about 10 mg. per day. In certain experiments the linoleic acid supplement was increased to 2% of the total diet; the daily intake of rats eating this diet was more than

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[2] A concentrate prepared from safflower oil and containing 95% of unoxidized linoleic acid.

200 mg. For the linoleic acid-free diet the fat-soluble vitamins were suspended in MCT.

For the determinations of weight-maintenance requirements, groups of eight animals were housed in single-unit cages and given each day a measured amount of food just sufficient to enable them to keep their weight constant at 100 g. for several weeks. The requirements are expressed as calories per gram of body weight per week. For this calculation, natural fats were assumed to yield 9.2 calories per gram, and protein and carbohydrate 4.0 calories. Bomb calorimetry indicated a value of 8.3 for MCT. At the end of the period of food restriction the animals were permitted to eat freely of their diets for three days, and their weights and food consumptions were recorded. From these data and the maintenance requirements for the last week of food restriction the amount of food necessary for growth could be calculated, as has been previously reported in detail (3).

TABLE I

Influence of Purified Diets Containing 20% Lard or Medium Chain-Length Triglycerides (MCT) on Survival and Body Weight of Male Rats

Series	Age	Fat	Original number in group	Surviv-ors	Average body wt.	Proba-bility factor [a]
	months				*g.*	
C 56	12	Lard MCT	8 8	6 6	442 363	5.4
D 56	11	Lard MCT	7 7	5 7	453 384	2.4
E 56	10	Lard MCT	8 8	6 6	477 402	3.1

[a] The probability factor was derived in the usual manner from standard deviations and probable errors. A factor greater than 2 means probable significance and one greater than 3, high significance.

Fecal fat analyses to determine the absorption of MCT were carried out according to a modification of the method of Hoagland and Snider (5). Serum cholesterol was assayed according to Schoenheimer and Sperry (9).

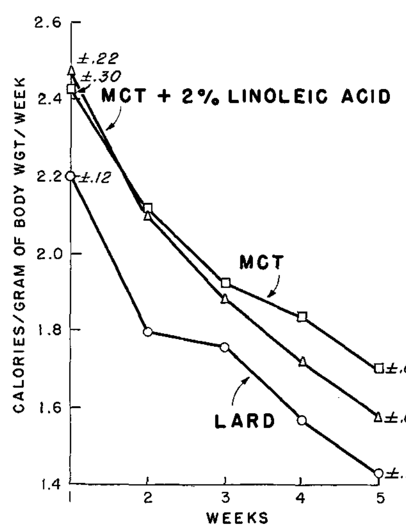

FIG. 1. Average caloric weight-maintenance requirements of groups of 8 male rats (average weight, 100 g.) on purified diets containing 20% lard or MCT. The standard deviations for the first and last weeks are next to the corresponding points. Probability factors for the last week (see footnote to Table I) are as follows:

Lard vs. MCT 5.1
Lard vs. MCT + 2% linoleic acid 2.7
MCT vs. MCT + 2% linoleic acid 3.2

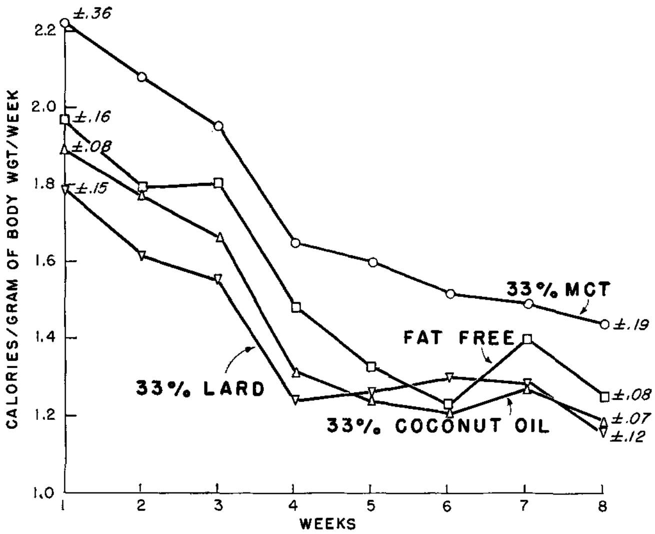

FIG. 2. Average caloric weight-maintenance requirements of groups of 8 male rats (average weight, 100 g.) fed purified diets containing 33% fat or no fat + 2% linoleic acid. Standard deviations are given next to the average values for the first and last weeks. Probability factors for the last week (see footnote to Table I) are as follows:

Lard vs. MCT 3.6
MCT vs. fat-free 2.4
Lard vs. fat-free 1.6
Lard vs. coconut oil 0.4

Results and Discussion

In Table I are given body weights and survival rates of male rats after 10 to 12 months on diets containing 20% of either lard or MCT + .09% linoleic acid. There was no difference in the survival rates, but the average body weights of the comparable groups differed by 69 to 79 g., and each difference was statistically significant. When the logarithms of the average weights of the groups were plotted against the reciprocal values of the ages according to Zucker and Zucker (11), straight-line relationships without plateaus resulted.

When these rats were mated, at nine months of age, with normal females, all males were equally fertile, and the litters were normal as to number and weight. At the age of 18 months mating tests showed that 9 of the 13 survivors on the lard diet and 13 of the 15 survivors on the diet containing MCT + .09% linoleic acid were fertile.

Some of the data dealing with the weight-maintenance requirements of rats kept at constant weight by restricted feeding are given in Figure 1. Either 20% lard or MCT was used. The latter regimen was supplemented by either 2% linoleic acid or only the .09% used as the carrier for the vitamins. As the experiment progressed, the requirements of all groups declined steeply, but the group fed MCT + .09% linoleic acid required about 25% more calories than that fed lard. Addition of 2% linoleic acid to the diet resulted eventually in the reduction, but not the obliteration, of the difference in caloric requirements of the groups fed lard and MCT. Inasmuch as these differences existed from the beginning when the animals must have had reserves and when the daily intake of the group on the diet containing 2% linoleic acid was between 100 and 200 mg., it is highly unlikely that the increased caloric requirements were caused by linoleic acid deficiency. This experiment was repeated four times with similar significant results.

Fetal fat analyses showed that the animals on lard absorbed 97.7% and those on MCT 98.5% of the dietary fat. Thus the difference in maintenance requirements on the two diets did not result from fecal fat losses.

In Figure 2 are given the results of weight-maintenance experiments in which were used fat levels of 33% + .09% linoleic acid or a fat-free diet supplemented by 2% linoleic acid. With lard and coconut oil the maintenance requirements were similar and were lower than on the fat-free diet. With MCT the animals required more calories than did the animals on the fat-free diet. This latter difference, although small, was observed in three experimental series.

After termination of the food restriction the requirement for weight increase above the maintenance requirement was determined and was found to be .9 g. of diet regardless of whether the diet contained lard or MCT. This may be evidence that MCT leaves unimpaired the capacity of the animal to build new body tissue.

The possibility had to be considered that the small size of the animals fed MCT and their increased weight-maintenance requirements were caused by a toxic effect of MCT similar to the one exerted by autoxidized fats. In previous studies the fats which brought about an increase in the weight maintenance, even if they did not contain appreciable amounts of polymers, gave evidence of toxicity in the appearance of the animals, their inability to grow, or in pathological changes in the organs. The only exception was MCT. This could also be seen in studies of the relation of the weights of the liver, adrenals, and kidneys to the body weight. All fats which increased the maintenance requirements led to increased organ size, with the exception of MCT, with which the organ weights were normal.

One aspect of the biological activity of fat is its relation to unspecific stress conditions. Certain fats are capable of counteracting various stresses, which makes them desirable for the human diet. The deleterious effects of highly autoxidized fats or their polymeric fractions can be counteracted by the addition of fresh lard or cottonseed oil to diets containing the autoxidized fats. The effect can be demonstrated in various ways, among them the improved growth of the animals receiving the added fresh fat (4). MCT exhibited remarkable properties in this respect.

In Figure 3 are shown growth curves as evidence of the relative protective effects of lard and MCT against the toxicity of highly autoxidized cottonseed oil and the polymeric fraction of autoxidized lard. The protective effect of the fresh fats made it possible for the animals fed 20% of these fats together with 10% of the toxic materials to grow whereas the groups without fresh fats died. As can be seen from the graphs, the animals receiving MCT with the toxic materials grew better than those fed lard and these substances. This was true although the animals on lard not given the autoxidized fat or the polymeric residue grew better than those fed only MCT.

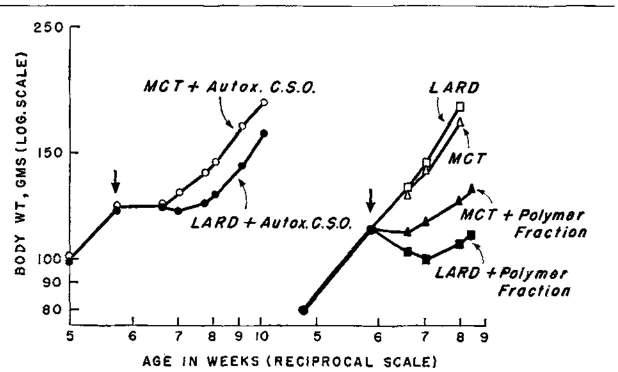

FIG. 3. Influence of addition of 20% lard or MCT upon the average growth of male rats on a purified diet containing 10% highly oxidized cottonseed oil or the residue of highly oxidized lard obtained after molecular distillation. In the right drawing growth of control groups receiving no oxidized fat is included.

Another biological activity of fats is their influence on serum cholesterol. Therefore it seemed desirable to measure serum cholesterol in rats maintained for verying periods of time on diets containing 20% lard or 20% MCT with different supplements of linoleic acid. The results are given in Table II. The cholesterol levels of the rats on MCT varied from 55 to 76 mg. %, and those of the animals fed lard from 83 to 129 mg. %.[3] In all parallel groups the levels of the MCT animals were substantially below those of their lard controls; and the latter had the same levels as animals fed cocoa butter, the values for which are not included in the table. Linoleic acid supplements had hardly any effect on the serum cholesterol levels of the rats fed MCT.

TABLE II

Influence of Purified Diets Containing 20% Lard or MCT and Various Linoleic Acid Supplements Upon the Serum Cholesterol Levels of Rats

Experimental series	Age	Body wt.	Dietary fat	Serum cholesterol	Remarks
	months	*g.*		*mgs. %*	
C 56	12½	430	Lard	129	Freely eating
		396	MCT+.09% Lin. A.	55	
D 56	11	440	Lard	92	Freely eating
		410	MCT+.09% Lin. A.	59	
E 56	10½	496	Lard	99	Freely eating
		320	MCT+.09% Lin. A.	63	
A 57	2½	276	Lard	83	Freely eating (2 animals pooled)
		240	MCT+2% Lin. A.	59	
A 57	3	283	Lard	83	Freely eating (6 animals pooled)
		216	MCT+No Lin. A.	61	(8 animals pooled)
		272	MCT+2% Lin. A.	57	(6 animals pooled)
A 57	2	91	Lard	118	Restricted feeding (7 animals pooled)
		91	MCT+No Lin. A.	76	(6 animals pooled)
		91	MCT+2% Lin. A.	88	(8 animals pooled)

It was recently reaffirmed by Anderson *et al.* (2) that the degree of saturation of fats is one of the important factors involved in the effect of diet on serum cholesterol. It had earlier been assumed that saturation contributes to the increase of serum cholesterol, but the authors have emphasized that the chain length of the fatty acids in food fats can not be overlooked. The MCT experiments support the view that chain length plays a part because the cholesterol levels on the saturated MCT are significantly lower than on lard, which contains a high amount of long-chain, saturated fatty acids. Linoleic acid deficiency hardly plays a part in this because the addition of linoleic acid does not change the levels. This observation is significant because it has been found that serum cholesterol levels of rats decreased when they were placed on a low-fat diet, an effect which was assumed to be an expression of unsaturated fatty acid deficiency (1).

[3] Preliminary results of liver cholesterol studies have shown that, in two parallel groups, the cholesterol levels were lower in the group fed MCT than in the group fed lard.

The part played by a deficiency of essential fatty acids in the effects observed with MCT is not clear. There is evidence to suggest that such a deficiency is at work and other evidence to show that it is minimized by MCT.

The very fact that the MCT diet contained little (.09%) or no linoleic acid (in some experiments) is presumptive evidence of a deficiency. It would explain the weight-depressing effect of MCT shown in Table I, especially if there is coupled with it the observation that the addition of 2% linoleic acid to a diet containing 20% MCT or the incorporation into MCT molecules of 5% linoleic acid obliterated the difference in weight between animals fed MCT and lard.

However the existence of an unsaturated fatty acid deficiency does not seem compatible with the observation that the rats maintained for 18 months did not, at any time, show any of the typical signs of a more severe deficiency, such as a plateau in growth, skin changes (tail lesions, in particular), renal damage, and lack of fertility. Also pertinent here is the observation that linoleic acid had no effect on the serum cholesterol levels.

Linoleic acid deficiency did play a part in the performance of the second generation of animals maintained on MCT. When female rats which had been kept on the MCT diet supplemented with either .09 or 2% linoleic acid were mated with the old males described in Table I, birth of normal litters occurred in 90% of the cases, a high percentage for any colony. The young born from mothers on the two levels of linoleic acid supplement soon showed a difference in weight, and some of the young on the lower linoleic acid supplement died. Thus linoleic acid deficiency played a part in the lactation performance of the animals.

Young from mothers on the low linoleic supplement were used at weaning for the formation of three well-matched groups which were placed on MCT without linoleic acid or with .09% or 2% of the substance. The animals had, after weaning, characteristic tail lesions, which later disappeared regardless of the presence or absence of linoleic acid. Table III summarizes the survival rate and average body weights of the various second generation groups at three months of age. As can be seen from the table, half of the group of males receiving no supplement had died; but those which survived, as well as all other groups, male and female, eventually grew without a plateau. However their growth (of the males especially) varied with amount of linoleic acid given.[4] Taken all together, all evidence points to the conclusion that the absence of linoleic acid is a limiting factor in the over-all growth of rats maintained on a diet containing MCT. The fact that none of the animals showed signs of a more severe deficiency suggests that the requirements for unsaturated acids are low in the presence of MCT, especially in older animals.

TABLE III

Influence of Linoleic Acid Supplements on Survival Rate and Body Weight of Second-Generation Rats Reared on a Purified Diet Containing 20% MCT

Supplement	Original number in group	Survivors	Average body wt.
	♂♂		
No linoleic acid	8	4	190
.09% linoleic acid	8	8	236
2% linoleic acid	8	8	269
	♀♀		
No linoleic acid	8	8	161
2% linoleic acid	8	7	185

[4] At the age of nine months all second-generation rats were still growing, including those which had never received any linoleic acid. All males of the latter group were fertile, and six of the eight females became pregnant when mated.

Summary

The influence of a purified rat diet containing 20 or 33% of the saturated medium chain-length triglycerides (MCT) with and without linoleic acid supplements on growth, caloric requirements for weight maintenance and weight increase, fertility, lactation performance, and serum cholesterol levels was compared with that of similar diets containing lard, coconut oil, or no fat.

Among male rats maintained on diets containing 20% lard or 20% MCT and .09% linoleic acid for 18 months no differences were observed between the groups other than the depressed body weight and lowered serum cholesterol levels of the group fed MCT. When groups of male rats were kept at constant weight by the daily restricted feeding of diets containing lard, MCT, or coconut oil or no fat plus 2% linoleic acid, the weight-maintenance requirements of the group fed MCT were higher than of those on lard and coconut oil and even somewhat higher than the requirements of the animals fed the fat-free diet. The requirements for weight increase over those for maintenance were 0.9 g. per gram increase for all diets. Additional linoleic acid in the MCT diet decreased the weight and maintenance differences between groups fed MCT and lard.

The lactation performance of mothers on MCT plus .09% linoleic acid was poor. The second generation animals initially showed signs of more severe linoleic acid deficiency which however disappeared without linoleic acid supplements.

Some cholesterol levels of animals on MCT were significantly below those of groups on lard. Addition of linoleic acid to the MCT diet did not change the results.

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