THE SIGNIFICANCE OF FATS IN THE DIET.

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From the beginning of the science of dietetics it has been recognized that a diet must include representatives of the three classes of foodstuffs—proteins, carbohydrates, and fats. An enormous amount of work and controversy has been devoted to the questions of the minimum and optimum requirements of the average man for proteins, and the influence of the quality of proteins. Since, however, every mixed diet of sufficient energy value contains more than the minimum amount of proteins necessary for the maintenance of health, the question is more academic than practical, and does not, therefore, present itself in considering the requirements of the individual man or of a nation. With regard to carbohydrates, it has been established that a certain quantity is essential. Sugar is the form in which carbohydrates are put into currency in the system, and a certain amount of this substance appears to be necessary for the normal functioning of the cells of the body. In the absence of carbohydrates the proteins are attacked and carbohydrate is split off from the protein molecule, or synthesized from the oxy-fatty acids resulting from the primary decomposition of the amino acids. A diet in which fat takes the whole place of carbohydrates produces acidosis, the oxidation of the fats being defective in the absence of carbohydrates.

The question as to the requirements of the body for fats and the significance of these substances in ordinary metabolism has, however, been practically neglected, and it has needed the restriction of food supplies throughout Europe, which is the immediate consequence of the war, to bring into prominence the great practical importance of the fat supply. Indeed, after having provided the necessary calories for the maintenance of a population the only important question remaining is the provision of a proper amount of fat. Is it possible to arrive at a minimum figure for fat, or even a minimum desirable amount, which science can lay down for the guidance of those responsible for the feeding of the nation?

Scientific evidence for the indispensability of fat in the diet is indeed very scanty. We have been accustomed to believe that fat and carbohydrate are convertible isodynamically. We know that carbohydrate can be easily converted into fat in the body, and is the main source of fat in the raising of animals for food. But in the case of carbohydrates this isodynamism is limited. Some carbohydrate is necessary for the health of man unless he is to be reduced to partake of an abnormally large diet of protein for the sake of obtaining the necessary carbohydrate (as, for example, among the Esquimaux).

Is there any evidence of a similar limit in the case of fat? For the adult man we have a mass experiment in Germany, where the population has suffered for the last two years or more from a marked shortage of fat, which has been reduced in the towns to about 20 grams a head a day. In this case certain diseases have occurred which have been ascribed to the deficiency in fat and have been cured by increasing the fat in the diet. These morbid conditions are marked by a generalized dropsy. It has long been known that a sudden change from a mainly fat to a mainly carbohydrate diet causes an immediate increase in weight, due not to the putting on of fat but to the retention of water in the body, and the dropsical condition occurring in Germany would seem to be due to the same factor in an exaggerated form. Similar cases occurred in some asylums in this country during the mild fat shortage from which we suffered during the early part of this year. The pathological effects of fat shortage are especially marked when there is a reduction of the total food supply, so that there is general deprivation of food as well as the special deprivation of fat. According to Hindhede, it is possible to maintain health, in the almost entire absence of fat, on a full diet in which potatoes and green foods are predominant features. But a deficiency of fat in the diet will almost always be associated with and due to a shortage of food supplies generally.

In babies rickets is associated by some with deficiency of fat in the diet. In this case a more important factor seems, however, to be an absence of some food hormone or vitamin associated with butter, cod liver oil, and many other kinds of fat, and, according to Mellanby, it cannot be cured except by giving a fat containing the substances in question.

The absolute physiological need of the cells of the body for fat supplied as such seems, therefore, to be unproven in view of the capacity of the body for manufacturing fat out of carbohydrates given in excess of the physiological requirements for energy. This conclusion, however, does not mean that fat is unnecessary in a normal diet; several other points have to be taken into consideration.

In the first place, fat is highly assimilable and is almost entirely absorbed from the alimentary canal. But it is digested and absorbed more slowly than carbohydrate. Whereas the greater part of the latter is absorbed three hours after food has been taken, the most intense absorption of fat occurs between five and six hours after a meal. On this account a meal lacking in fat is deficient in staying power. Man is unaccustomed to working with the alimentary canal entirely at rest. When digestion of the last meal is finished hunger recurs and affects the efficiency of work. Thus Major Ewing relates how on a railway job in Canada the Italian workmen were found to become inefficient at about 11 o'clock in the morning. These workmen were only spending 7 to 8 dollars for food at the canteen as against 15 dollars expended by the Canadian workmen. The chief difference in the diet conditioned by this economy was in the meat. The company then insisted on the Italians spending 15 dollars a month. With the extra money they bought fat beef, and it was then found that their work was entirely satisfactory. It may be objected that in this case it was the lean of meat, that is, the extra protein rather than the fat, which was responsible for the difference; but examination of the diets of very heavy workers—for example, lumbermen in Sweden and in Canada, who were consuming food with a calorie value of 4,000 to 8,000 calories a day—shows that this great increase in food related not to the protein but to the fat. The Canadian lumbermen live largely on fat pork and beans. In this country, too, there have been complaints from the Welsh miners during the first half of this year that the food had not enabled them to work their normal shifts. They are used to taking with them to their work pies made of fat pastry with a little meat, and it was impossible to make the pastry in consequence of the absence of fat. Premature hunger was also a universal experience in this country during the first five months of this year.

In the second place, the bulk of food must be of considerable importance, especially when the total food required by the energy needs of the body is very large. Weight for weight fat has more than double the calorie value of starch and sugar. But the difference in bulk is still greater, since fat is taken without admixture in a pure form, whereas the other foods are all mixed with a considerable proportion of water. The proteins in meat only form 15 to 20 per cent. of the total bulk. Starch cannot be taken except mixed with large quantities of saliva. When ordinarily cooked it is swollen up with probably five to ten times its amount of water. Even after absorption the same necessity for increasing the bulk of carbohydrates with water persists. Even glycogen does not occur to a larger amount in the liver than 12 per cent., a figure which may be largely surpassed by fat, and in adipose tissue there may be as much as 80 per cent. of fat. When carbohydrate goes into the circulation it is changed into sugar, and as sugar it needs twenty times its weight of water to carry it. It acts, therefore, to some extent in the same way as common salt. Just as an extensive diet of salt may produce dropsy, so a diet of carbohydrate increases in the first place the water content of the body, and this factor, when associated with inanition and fat shortage, may itself produce actual dropsy.

The question of bulk is probably one of the most important factors in determining the need for fat. The human alimentary canal has been developed so as to cope with a diet in which 20 to 25 per cent. of the energy is presented in the form of fat. In order to get the same energy from carbohydrates the alimentary canal

would have to be much larger. Theoretically, then, the absence of fat can be made up by an increased supply of carbohydrates. But this can only be carried out in a certain number of individuals and under certain conditions. The ordinary individual deprived of fat diminishes his total intake of food and exists on a lower metabolic level. It is a notable fact that during the recent shortage of fat in this country there was no appreciable increase in the consumption of cereals. It was easier to live on the stored-up fat of the body than to adopt a stuffing process with carbohydrates.

In the third place, it seems that carbohydrates are more subject to fermentative changes in the intestines than fats. Overloading the intestines with carbohydrates in many individuals leads to abnormal fermentation, the production of gases, and general discomfort. We may conclude, then, that fat is an essential ingredient of the diet of man, and that there must be some relation between the quantity of fat necessary and the total energy requirements of the individual. So great are the powers of adaptation in the animal body and so retarded are the effects of a fat shortage that ordinary laboratory experiments of short duration do not seem suitable for deciding the question as to the relation of the fat ration to the energy requirements of the body. We shall arrive at more reliable results by the statistical method, that is, by studying the proportion of fat to the whole diet taken by a number of individuals of different energy requirements, living under conditions in which they can choose the quality of their diet.

It is necessary, however, to recognize the limitations of this method. It tells us how much fat a man eats ordinarily and how much he can take under certain conditions. It gives us no information as to the minimum fat requirements, nor can we assert that the proportions which are habitual are necessarily the optimum proportions. It will, however, give us some clue in arriving at what we may call the *minimum desirable ration* of fat, and from the practical standpoint—that is, as guidance for those concerned in controlling the food supplies of the country—it is this minimum desirable ration which is of chief importance.

Food Requirements of the Child.

In the breast-nourished infant the proportion of food energy represented by the fat of the diet is given by the composition of human milk. Thus, in some estimates by E. Feer, quoted by Bunge, a boy 30 weeks old took 951 grams of milk daily. This contained:

Proteins	...	...	15.2 grams = 62.3 calories
Fat	...	...	32.3 " = 300.4 "
Sugar	...	...	58.0 " = 237.8 "
Ash	...	...	1.9 " = —
Total calories	...	...	600.5

The suckling thus takes 50 per cent. of its nourishment in the form of fat. At weaning we should expect the proportion of fat to diminish considerably, since the food of the young child is composed chiefly by adding foods rich in carbohydrates to milk. It is not easy, however, to find any definite and ideal proportion between the fat and the total diet in young children up to 6 or 8 years of age. The following figures are given by Camerer as the average diet of children from 2 to 14 years of age, in relation to body weight:

TABLE I.—Food of Children per Body Weight.

Age.	Fat.	Fat Calories.	Total Calories.	Percentage of Total Calories.
2—4	3.1	28.8	75.3	38
5—7 (boys) ...	1.9	17.9	69.0	25
7—10 (boys) ...	1.3	12.1	59.2	20
11—14 (boys) ...	1.4	13.0	51.4	25

If we may regard these diets as adequate we may perhaps conclude that, after weaning, the proportion of energy yielded by fat drops to about 35 per cent. during the first five years of life, and then drops further to about 25 per cent. during the rest of childhood. It would be

interesting to see how far these conclusions are borne out by other dietetic studies on children. A series of diets for young children by Steffen, quoted by Pfaundler and Schlossmann, give from 41 per cent. to 50 per cent. of fat, but in this case each child receives a litre of milk a day, besides one egg and some meat. In view of the universal distaste of children for fat and the difficulty which has been found in persuading them to take all the milk which is available for them in well-to-do families, I am inclined to think that this figure is too high, and that the figures deduced above from Camerer's results represent more nearly the usual diet compatible with the maintenance of health and growth. It seems very probable that the great value of milk in the child's dietary is due in the first place to the presence of the growth hormones in the fat of milk, and to the high biological value of the milk protein. Given a sufficiency of milk, there seems no reason why the child's natural taste for carbohydrates should not be indulged in preference to forcing upon it an excess of fats.

Fat Requirements of the Adult.

Some light is thrown upon the proportion of fat in the adult diet by the tables given by Tigerstedt in Nagel's *Handbuch*, which represent the results of the analysis of diets in a number of individuals of different occupations and requirements.

TABLE II.

Continental.					American.				
	Total Calories.	Total Fat. Grams.	Calories in Fat.	Percentage Fat Calories of Total Calories.		Total Calories.	Total Fat. Grams.	Calories in Fat.	Percentage Fat Calories of Total Calories.
1	2229	44	409.2	18.4	1	2135	81	753.3	35.3
2	2889	60	558.0	19.3	2	2779	108	1006.4	36.2
3	3222	85	790.5	24.5	3	3262	125	1162.5	35.6
4	3702	93	864.9	23.4	4	3738	137	1274.1	34.0
5	4252	135	1255.5	29.5	5	4180	158	1469.4	35.2
6	4752	106	985.8	20.7	6	4692	195	1813.5	38.7
7	6037	156	1450.8	24.0	7	5511	215	2185.5	39.7

The first half of Table II is taken from analyses of European observers. The individuals are sorted into seven classes according to the average number of total calories taken per day. In these individuals the proportion of the total energy represented by fat varied from 18.4 per cent. to 29 per cent. The percentage shows a tendency to increase with increase in the total calories.

In the second half of Table II is given a similar series of observations by American observers. It will be noted that in this series the proportion of energy furnished by the fat is throughout much larger than in the European series, varying from 34 per cent. to 39.4 per cent. Since the individuals who were subjected to observation could be regarded as normal in both sets of observations, the difference between the two series must be ascribed to the greater abundance of food of animal origin in the American continent, and is evidence at any rate that, given a sufficient supply of fats, a man with free choice of diets will increase his consumption of this foodstuff until it will give over one-third of the total energy of his food. But in searching for the desirable minimum ration we are justified in using the first series, and we shall probably not be far wrong in assuming that in a normal diet the fat should account for 20 per cent. to 25 per cent. of the energy of the whole diet.

The Inter-Allied Scientific Food Commission laid down 75 grams of fat a day as the minimum desirable ration for the average man working eight hours a day and utilizing 3,000 calories, or, allowing for waste, taking 3,300 calories in food as purchased. This figure is midway between 20 per cent. and 25 per cent.—20 per cent. would give a daily ration of 70 grams of fat, 25 per cent. a ration of 88 grams of fat. For purposes of comparison we may give here (Table III) the fat content of various standard

TABLE III.

	Protein.	Fat.	Carbo- hydrate.	Total Calories.	Fat Cals. per cent. of Total Cals.
VOIT:	Grm.	Grm.	Grm.		
Medium work ...	118	56*	500	3,055	17.0
Hard work ...	145	100	500	3,574	26.0
RUBNER:					
Light work ...	123	46	377	2,445	17.5
Medium work ...	127	52	509	2,868	17.0
Hard work ...	165	70	565	3,362	19.4
ROYAL SOCIETY:					
Food War Committee	100	100	500	3,400	27.4

* The fat in this diet is regarded by Voit as minimal.

TABLE IV.—Food Consumption per Head per Day in European Cities, based on Municipal Statistics of Gross Consumption. (Rubner, quoted by Lusk.)

City.	Protein.	Fat.	Carbo- hydrate.	Total Calories.	Fat Cals. per cent. of Total Cals.
	Grm.	Grm.	Grm.		
Königsberg ...	84	31	414	2,394	12.0
Munich ...	96	65	492	3,014	20.4
Paris ...	98	64	465	2,903	20.5
London ...	98	60	416	2,665	21.0

This ratio of fat energy to total energy, 20 per cent. to 25 per cent., should only be applied to the diet of the ordinary individual—that is, the sedentary man, the woman, and the ordinary labourer. When the energy requirements of the individual become excessive—for example, 4,000 calories and more per day—we find that in almost all cases the proportion borne by the fat energy to the total energy is considerably larger than 25 per cent.

Table V gives the diet of woodcutters in the winter in northern Sweden. The total calories varies from 4,600 to 8,500 a day. The fat calories in each case form thus over

TABLE V.—Winter Diet of Woodcutters in Northern Sweden, and of American Lumbermen.

	Total Calories.	Total Fat.	Calories in Fat.	Percentage Cals. of Total Cals.
Swedish woodcutters:		Grm.		
5 and 6 ...	4,606	210	1953.0	42.4
7a ...	5,500	251	2334.3	42.4
7b ...	6,502	296	2752.8	42.3
7c ...	7,487	349	3245.7	43.4
7d ...	8,506	390	3627.0	42.6
American lumbermen..	8,083	388	3608.0	45.0

42 per cent. of the total calories. In American lumbermen, with a total intake of over 8,000 calories a day, the fat energy amounted to 45 per cent. of the total energy. This is, however, what one would expect. If a man is called upon for an extreme expenditure of energy, either in performance of work or in order to maintain his body temperature in excessive cold, he must take more food; and since his alimentary tract does not constantly increase in extent in proportion to the augmented demand upon it, it is necessary that the large increase in the food be taken in the most concentrated form—namely, as fat. The preponderatingly fat diet of the arctic and antarctic regions is, therefore, dictated not only by the nature of the food available in these regions, but also by the size of the human alimentary canal in relation to the energy demands of the body as a whole.

CONCLUSIONS.

So far as the evidence goes, and bearing in mind the limitations of the methods employed, we are, I think, justified in formulating the following conclusions:

1. Strictly speaking, there is no evidence for an absolute physiological minimum of fat in the diet, provided that the calorie value of the whole diet is sufficient to meet the total energy needs of the body, and to provide a surplus for fat formation in the body.

2. Practically a certain amount of fat is necessary in the diet, the alimentary canal of man having been developed to deal with a diet in which a considerable proportion of the energy is presented in the shape of fat.

3. In the diet of the infant at the breast fat gives over 50 per cent. of the total energy.

4. After weaning and for the next few years of life, up to 6 years of age, the main source of fat in the diet should be milk and butter. This fat should probably represent about 35 per cent. of the total energy of the diet.

5. From 6 years onwards the fat of the diet should represent from 20 per cent. to 25 per cent. of the total energy, provided that there are no excessive demands on the energy output of the body. This proportion can be increased considerably—for example, up to 35 per cent.—without any deleterious effects. The proportion of 20 per cent. may be regarded as a minimum. Any increase upon this would be determined by the supplies available, it being borne in mind that fat is not only the most concentrated but also an expensive form of energy to the body. Animal fat is probably at least three times as expensive a source of energy as carbohydrates derived from vegetable sources.

6. As soon as the demands of the body become excessive—for example, 3,600 calories to 5,000 calories or more—it is unprofitable to attempt to meet the increased demands by means of carbohydrates alone, the limiting factor being probably the size and digestive powers of the alimentary tract. The proportion of fat in the diet in these circumstances should, therefore, be increased up to 30 or 40 per cent. It is a question requiring further consideration whether the energy requirements of a rapidly growing, active lad should be met in the same way by an increased proportion of fat in the diet.

These conclusions may be interpreted in terms of grams of fat for the different classes of the community in accordance with their energy requirements as follows, it being borne in mind (1) that the fat figures represent what I have called the minimum desirable ration, (2) that, given an otherwise adequate diet, these figures can be diminished without serious detriment to the health of the individual, though probably not without inconvenience and diminution of efficiency, and (3) that they can be considerably augmented without interfering with efficiency or with health.

In the following table the total calories are those proposed by Lusk and adopted by the Inter-Allied Scientific Food Commission. The gross figures refer to calorie value of food as purchased, and allow for a total wastage of 10 per cent.

TABLE VI.

Age in Years.	Total Calories per Day.		Fat in Grams.	Fat Calories per Cent. of Total.
	Gross.	Net.		
0-6 ...	1,650	1,500	62	35
6-10 ...	2,310	2,100	62	25
10-13 ...	2,750	2,500	74	25
13-20—				
Males ...	3,300	3,000	88	25
Females ...	2,750	2,500	74	25
Adult average bodily workers:				
Males ...	3,300	3,000	70-88	20-25
Females ...	2,750	2,500	60-74	20-25
Adult sedentary workers:				
Males ...	2,750	2,500	60-74	20-25
Females ...	2,200	2,000	47-60	20-25
Adult very heavy bodily workers*	3,900 to 5,000		12-160	30

* For example, lumbermen, puddlers, etc.