The Role of Fat in Human Nutrition

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Introduction

IN these days of food shortages there are a number of questions which come to mind in relation to the role of fat in the diet. How necessary is it to include this foodstuff in our diet? Is any one fat specifically required or will vegetable and animal fats serve equally well? What are the optimum quantities of fat in the diet?

Inasmuch as fat can readily be synthesized in abundant amounts from carbohydrate and protein, it was earlier considered to be a dispensable component of the diet. Osborne and Mendel (1) stated in 1920 that "if true fats are essential for nutrition during growth, the minimum necessary must be exceedingly small" although it was later found in the Yale laboratories that better growth was obtained in rats receiving adequate fat-soluble vitamins when fats were also present in the diet (2).

The experiments of Evans and Burr (3) and later of Burr and Burr (4) gave definite proof that certain unsaturated fatty acids are required for growth. The symptoms which accompany this failure in growth are a scaly skin, an incrustation of the tail, and finally a hematuria. These all can be prevented by linoleic acid, linolenic acid, arachidonic acid or by natural fats and oils containing these fatty acids. One must consider fats essential to the extent that they furnish these unsaturated fatty acids.

Another function of fat is as a carrier of the fat-soluble vitamins. They also aid in the absorption of such vitamins. Being the most concentrated foodstuff from the caloric standpoint, fats may serve effectively where the bulk of the diet is limited. Finally, fats contribute much to the palatability of the diet. Diets which are fat-free are generally quite unappetizing.

The first basis for the comparison of the nutritive value of animal and vegetable fats is on their composition. Vegetable fats (particularly the seed oils) are especially rich in the unsaturated fatty acids while the animal fats contain only minimal quantities of these components. However, the linolate content of lard can be increased somewhat by feeding a high content of unsaturated fats to the hogs over a period of days.

Vitamin E (alpha-tocopherol) is another necessary component of the diet which is present in much larger proportion in the vegetable fats than in the animal fats. In fact, this vitamin is almost completely absent in most animal fats. Because of the antioxidant properties of alpha-tocopherol the vegetable oils in general are much more resistant to rancidity than are the animal fats.

Vitamin A, on the other hand, is found in a few animal fats as butter, egg yolk fat, and fish liver oils but in no case as such in the vegetable fats. However, beta-carotene, the most potent of the provitamins A, is present not only in such animal fats as butter but also such vegetable fats as palm oil.

With the exception of fish liver oils none of the animal or vegetable fats contain any appreciable concentration of vitamin D although butter may contain minimal quantities. This vitamin can be synthesized both in animal and vegetable fats by irradiation with ultraviolet light; under such treatment very high concentrations of the vitamin D can be produced.

The ultimate test which must be applied in the evaluation of nutritive value of different fats is their ability to serve adequately in promoting various physiological processes.

The first of these criteria is the extent of digestibility of various fats. In an extensive series of experiments on human subjects carried on over a number of years in the Office of Home Economics of the United States Department of Agriculture practically all animal and vegetable fats were found to be digested to the extent of 95% or better (see Langworthy (5) for a summary of these tests). Thus, the high digestibility of butter and lard was matched by an almost complete digestibility of such vegetable oils as cottonseed, corn, peanut, and soybean. The only exceptions to the almost complete digestibility of the fats were the somewhat lower values reported for fats having melting points considerably above body temperature, especially those melting above 50° F. (6). This included such animal fats as oleostearine, beef tallow, and deer fat as well as some almost completely hydrogenated vegetable fats. The lower rate of digestibility in these cases according to Mattil (7) is believed to be related to their tristearin content rather than directly to their melting point. Margarine fat of the types on the market in 1915 were found to be highly digestible in spite of the fact that one type, at least, contained oleostearine (8). A more recent study of the author has indicated that a similar high digestibility obtains for the modern type of margarine made up of hydrogenated domestic oils (9). Although the hydrogenated oils having melting points somewhat above 50° C. are less efficiently utilized than fats with lower melting points, blended hydrogenated fats having melting points of 50° C. or below are as digestible as fats melting in the same range where the whole fat has been subjected to the hydrogenation process although these blended fats contain considerable proportions of the less readily digestible higher fractions (10). It is interesting also that a species difference is known to exist in the utilization of fats. Guinea pigs (11) and sheep and rabbits (12) are able to digest castor oil almost com-

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pletely but the guinea pig is less efficient in digesting high melting fats than are most of the other animals (11). One is forced to conclude that on the basis of digestibility animal and vegetable fats have similar nutritive properties.

A second method of evaluation which has not usually been applied is the rate of absorption. A number of common vegetable fats including margarine fat were shown to have a digestibility similar to butter fat although rape-seed oil was found to be considerably more slowly absorbed (13). Lard and Crisco also have a comparable rate of absorption in the rat although hydrogenated cottonseed oil melting at 47 and 53 show a marked retardation in absorption rate as well as digestibility. However, a similar decrease in absorption rate and digestibility also obtains with a lard hydrogen to 50° C. (14). The rate of absorption is most constant where the dose of fat is varied or where rats of widely varying size are employed, when estimations are based upon surface area. Only poor correlation was obtained between the percentage of fat absorbed or amount absorbed per 100 grams body weight unless rigid restriction as to size of the animals and dosage fed were employed (13). Adrenalectomy is another factor which lowers absorption rate of the C_{16} and C_{18} triglycerides but not of the short-chain ones (15). Cortin administration restored absorption rates to normal. Another interesting variation, of little practical importance, however, is the marked retardation in absorption rate of odd-chain fatty acids as contrasted with those triglycerides with even-chain fatty acids (16). Although the experimental evidence on absorption rates is quite scanty, it would appear that a retardation in absorption rate occurs before a decrease in digestibility results. There is no evidence that any differences in behavior of animal and vegetable fats occur at this stage of metabolism.

There is little positive evidence of any variations in the intermediary metabolism of animal and vegetable fats. Fat deposits may to some extent be altered when large amounts of a foreign fatty acid are present in the diet. This was demonstrated to be the case with triarachidin when excessive amounts of peanuts were fed (17); Lebedeff (18) demonstrated the production of a much harder adipose tissue in the dog when mutton fat was administered. The most remarkable demonstration of the deposition of an unusual fat was the recent proof that triundecylin can be deposited in the fat storage depots of the rat when fed in large excess (19). This is the first instance as far as known to the author where any odd-chain fat has been found in animal fat. Short chain triglycerides as the tributyrin and tricaproin of butter cannot be stored (20).

Such intermediary changes as are involved in oxidation of the fats apparently are not related to the source of the fats. All even-chain fatty acids from butyric acid through stearic acid are precursors of the acetone bodies (21, 22); odd chain acids which are not present either in animal or vegetable fat are converted to glycogen and not to the acetone bodies (23, 24). The preliminary oxidation of stearic acid to palmitic acid occurs irrespective of whether the stearic acid originates from an animal or vegetable source (25). From such isolated examples of known intermediary reactions it is evident that animal and vegetable fats share a similar fate.

The most widely employed criterion for establishing the nutritive value of a food is its effect on growth. If the requirement for fat-soluble vitamins is satisfied, it has generally been considered that any of the common edible fats can serve equally well in satisfying any need for this foodstuff. However, it has recently been stated by Schantz *et al.* (26) that butter fat was unique in supporting the growth of young rats when added to a skim milk diet while vegetable fats were less satisfactory in promoting growth even though the fat-soluble vitamins were furnished in adequate amounts. However, a number of workers have failed to confirm the above observations. Results from the author's laboratory (27) have indicated that the growth of weanling rats on diets containing mineralized skim milk powder and vitamin-fortified fats was similar irrespective of whether the fat employed was a butter, a margarine, or corn, cottonseed, olive, peanut or soybean oil. That the body weights were a true picture of growth was indicated by the identity in bone growth as well as in the similarity in body composition between the animals in the different groups (28). The lower growth in the Wisconsin tests may in part be due to lower food consumption which to some extent could be remedied by the addition of butter flavor or diacetyl (29).

There has also been no confirmation to the statement of Boutwell *et al.* that the prematurely weaned animal is especially sensitive to the requirement for butter fat (30). Zialciti and Mitchell (31) were able to raise rats weaned at 7 days on synthetic diets containing corn oil or butter fat without observing any variation in growth rate. Similar results were obtained in our own laboratory (32) where the growth of rats weaned at 14 days (instead of the usual 21-day period) was uniform irrespective of the type of fat employed. No differences in the rate of growth as related to the type of dietary fat could be observed when the calories were limited or when growth was accelerated by the intraperitoneal injection of growth hormone (33). Euler, Euler, and Säberg (34) have reported a better growth on margarine than on butter. The evidence from growth tests would seem to be that butter and vegetable fats are equally satisfactory in promoting growth under a variety of conditions.

A still more critical proof as to nutritional behavior is obtained by ascertaining the effect of the substance to be investigated on fertility and especially on lactation. No differences were noted in the fertility of female rats raised from weaning on diets of mineralized skimmed milk powder and a butter fat, a margarine fat, corn, cottonseed, olive, peanut or soybean oil (35). That lactation was promoted equally well by the different fats is indicated by the fact that practically all the young rats survived the 21-day period and the average weight of the 3-week-old rats was essentially the same on all diets. Using reproduction as a measure of the nutritive value of fat, Euler, Euler, and Ronnestäm-Säberg (36) have recently presented figures indicating the decided superiority of margarine over butter fat. In their first series of tests the total weight at 28 days of all rats raised over an 18-month period from females on a diet containing butter was 8,508 grams compared with a total of 15,956 grams for the progeny of a similar number of females which had received a similar diet where margarine fat replaced the butter. The results were essentially similar on a second series of tests; however, the results both on the butter and margarine diets were improved by the addition of vitamin E. However, the total weight of the progeny from the rats receiving the butter diet fortified with vitamin E was less than that obtained on the margarine diet which had not been supplemented with additional vitamin E.

It is also well known that slight dietary deficiencies may not be immediately reflected by failure in growth, reproduction, and lactation but may require several generations to become evident. We have recently reported (37) that satisfactory growth, reproduction, and lactation were obtained over 10 generations on rats which received a diet similar to that used by Sherman and Campbell (38) where the whole milk powder had been replaced by skimmed milk powder and a proportionate amount of margarine fat. This experiment, at present, has progressed satisfactorily to the fifteenth generation and there is no indication of any approaching dietary deficiency. It should be pointed out that an experiment on man covering 15 generations would require 450 years.

Finally, the more recent studies on the various fractions of butter fat have failed to confirm the report that there is a specific growth-promoting activity in certain long chain saturated fatty acids of butter (39, 40). Henry, Kon, Meara, and Hilditch (41) in England as well as Jack, Henderson, Reid, and Lepkovsky (42) in this country are in agreement that the saturated fatty acid fraction of butter has no specific growth-promoting properties. The results of Hilditch and Meara (43) as well as of Baldwin and Longenecker (44, 45) have emphasized the dissimilarity of fatty acid make-up of cow's milk fat and human milk fat. In fact, it was stated that "the composition of human milk fat more nearly approaches that of a margarine blend than it does that of cow's milk fat" (43). In the basis of such studies one can hardly argue that cow's milk fat has a composition especially adapted for the human infant.

The last of the three questions to be considered is the optimum level of fat in the diet. The results on this subject are in need of amplification. On the basis of dietary studies the average fat intake before the war was 125 grams daily in this country (46) which would account for 33% of the total calories. It has been somewhat reduced since that time due to the shortages of fat. This contrasts with the low intake of the Japanese prior to 1930 (29 grams) or of the Southern Chinese troops where fat comprised only 3% of the calories (47). In contrast with these figures, the calculated average intake of the American soldier in World War II was 193 grams or 40% of the total calories. Such dietary studies, however, cannot be considered necessarily as optimum levels since not only dietary preference but also the actual availability of the foodstuff would enter into the amount consumed.

Another method of approaching the problem is to compare the growth of animals on diets containing various fat levels. In the tests of Hoagland and Snider (49), greater growth was usually associated with diets containing the higher levels of fat. In recent tests in our laboratory (50) it was found that on an adequate diet optimum growth resulted on a diet containing 20% of cottonseed oil (or 33% of the caloric intake). Moreover, when the maximum physical capacity of the male rats was determined by duration over which they could continue swimming, it was found that those receiving the 40% fat diet gave the best performance (51). Thus, the optimum level of fat for growth and physical performance may vary and it is altogether possible that the most satisfactory level of intake for different fats may vary.

In conclusion, I hope you will agree that the digestible animal and vegetable fats are largely interchangeable in nutrition according to individual fat preference, provided, of cource, that the intake of the fat-soluble vitamins is assured. There also would seem to be some evidence that better nutrition is to be expected if at least one-third of the calories are derived from fat.

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