LX. A NOTE ON THE DIGESTION OF FATS BY PANCREATIC LIPASE

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FATS have for some time been recognized as basal dietary constituents, though even now it is not definitely established whether or not these constituents should be regarded as essential food factors. That animals eat a variety of fats, both of animal and vegetable origin, is widely recognized and there is evidence that man can digest a number of fats other than those which are normally included in his diet.

Special consideration was given to this type of food when a Committee of the Royal Society [1918-19] considered the possibility of utilizing fatty acids as food. Burns & Sharpe [1918-19] concluded that the fatty acids of whale oil were as thoroughly digested and absorbed as was the hardened oil from which they were prepared. Gardner & Fox [1919] found that cocoabutter could be satisfactorily utilized by man. Barbour [1934], working with rats, showed that peanut oil or cottonseed oil could be effectively metabolized when it constituted 20% of the diet. Langworthy & Holmes [1917, 1], from experiments on man, found that olive oil, cottonseed oil, peanut oil, coconut oil, sesame oil and cocoabutter could safely be included in his diet, but concluded that the limit of tolerance was less for cocoabutter than for the other fats studied. With animal fats these observers [1915] found the coefficient of digestibility of butter to be 97.1%, of lard 97.3%, of beef fat 93.1% and of mutton fat slightly less, 87.6%; for cream the figure was 96.9% [1917, 2].

In the experiments just quoted the subjects were left entirely free as to the amount of food they consumed and wide variations were noted. For instance, with beef fat the average amount taken per day was 100 g. and with mutton fat only 53 g. This work demonstrated that various fats could be adequately digested and assimilated by man, but afforded no information as to the respective rates of digestion of the fats. Weber & King [1935] found that the α - and β -monoglycerides of lauric, myristic, palmitic and stearic acids were hydrolysed with equal facility by pancreatic lipase, but on the whole there appears to be little experimental evidence as to the comparative rates of digestion of different fats.

EXPERIMENTAL

Various methods for emulsifying fats have been used by different workers. A method in general use involves the use of alcohol, but other methods have been suggested such as the use of gum acacia or neutral sodium oleate as emulsifying agents [Weinskin & Wynne, 1935-36]. Such methods have no direct application to digestion in man and it was desirable to use the fat in a form in which it could be taken as food. At first an emulsion in water [Plimmer, 1933] was tried, but this method could not be used because it was applicable only to some and not to all fats. Reconstituted creams in which various fats were substituted for butter were next tried and this method proved satisfactory.

Preparation of creams

The creams used in these experiments were made with a well-known type of machine and it was found that once the machine was "run in" a standard product could always be obtained. It had been shown previously [Hartwell, 1937] that the best emulsification was obtained with the proportion of 57 g. butter to 105 ml. milk; the cream so made contains approximately 33 % of fat. With other fats which contained little or no water, 47 g. fat were added to 105 ml. milk and 10 ml. water. When creams were kept overnight they were placed in a refrigerator, previous experiments [Hartwell, 1937] having shown that keeping them in this way made no difference to their rate of digestion. Such creams were allowed to stand for half an hour after being made, so that the layer of air bubbles which came to the top could be removed. If this precaution were not taken, a thick crust formed which rendered an even mixing of the cream impossible.

Beef, mutton and bacon fats were prepared in the following way. Any lean was removed and the fat was cut into small pieces and heated in a gas oven for $\frac{1}{2}$ – $\frac{3}{4}$ hr., after which the liquid fat was poured off, allowed to cool and used for the experiments.

In making the creams the fat was melted and the milk was heated to boiling point; the machine was also heated.

Butter cream was made by pumping the mixture once through the machine. With all the other fats the mixture was pumped through three times to ensure complete emulsification, because it was found that some fats (especially olive oil and lard) were apt to oil out on top if only put through once. Some preliminary experiments were made with creams which had been put through the machine six and nine times. These creams, however, digested at the same rate as those which had been put through only three times, therefore it seemed unnecessary to take this extra precaution. Microscopic examination showed that all the creams consisted of very small fat globules, and no differences in the sizes of the fat droplets could be detected.

Method of experiment

The commercial form of pancreatic substance used as a source of lipase was that found by Clifford [1934] to be suitable for this type of work. In a typical experiment 50 ml. cream, 175 ml. distilled water and 25 ml. of 2–4 % pancreatic substance (the exact strength depending on the activity of the sample) were used.

The cream was measured in a 50 ml. graduated cylinder, and washed into a flask with the distilled water, the pancreatic substance being added last. The reagents were mixed cold, not warmed separately as is usual in digestion experiments.

The sample of lipase used was active at room temperature (19–19.5°), and in some cases digestion started so rapidly that the initial stages would not have been recorded had the reagents been at 38° when mixed.

Immediately after mixing 20 ml. were taken for titration, further 20 ml. samples being removed every 15 min. To the 20 ml. digestion mixture were added approximately 150 ml. boiling distilled water and 2 ml. phenolphthalein and the whole was titrated hot with 0.1 *N* NaOH. The flasks were placed in a large water bath and the temperature was maintained at 38–39°.

Butter cream was used as a standard for comparison and control experiments were made with milk and with boiled pancreas substance and cream. The fats

used were almond oil, arachis oil, bacon fat, beef fat, beef oleo, beef stearin, castor oil, cocoabutter, coconut oil, cod liver oil, cottonseed oil, lard, mutton fat, olive oil, palm oil, palm kernel oil, premier jus, soya bean oil, hardened whale oil and hardened arachis oil.

Blank titrations of the creams alone gave 0.25–0.3 ml. of 0.1 *N* NaOH for butter. The other creams ranged from 0.2 to 0.3 ml. except beef oleo, premier jus and castor oil which gave slightly higher values, 0.4–0.45 ml. The slightly higher figure for the first titrations of some creams is due to the rapid start of digestion. Palm oil had an appreciably higher value, 1.8 ml., and owing to its yellow colour, it was difficult to judge the end point of the titration.

RESULTS AND COMMENTS

Butter cream was taken as a standard for comparison and each experiment included three or four of the other creams. These were arranged in different combinations and at least three experiments were made with each.

A comparison of lard, fat from smoked bacon and fat from green bacon showed that there was no difference in the rates of digestion of these three fats. Fat prepared from beef suet and from scrap beef fat also gave similar digestion curves, as did mutton suet fat and scrap mutton fat, so it was concluded that it was unnecessary to use more than one type of fat from any animal.

When it was found that beef and mutton fats were digested so slowly when compared with butter fat, it was thought possible that heating the fats might have had some detrimental effect. In order to see if this supposition were true two samples of butter were heated in a gas oven, one sample at the same time as some beef suet, and the other sample with some mutton suet. The digestion of the fat in creams made from these heated butters showed no alteration in rate, therefore it was unlikely that heating the beef and mutton fats was the cause of the slower digestion.

The majority of the fats used were digested by lipase much more slowly than was butter fat, three only showing a more rapid rate of digestion. Coconut oil was digested more rapidly than any other fat; three separate samples were used and all gave similar digestion curves. Palm kernel oil also showed a rapid rate of digestion, but not so rapid as the coconut oil. Castor oil was digested more rapidly than butter, but the curve obtained with this fat was of rather a different type from the other curves.

Almond oil, arachis oil, bacon fat, beef fat, beef oleo, beef stearin, cocoa-butter, cod liver oil, cottonseed oil, lard, mutton fat, olive oil, premier jus, soya bean oil, hardened whale oil and hardened arachis oil were digested at a much slower rate than butter and all at approximately the same rate. This is in agreement with the experiments of Gardner & Fox [1919] who found that cocoabutter was rather less digestible than butter. Palm oil digested slowly, but could hardly be compared with the others, owing to the difficulty in judging the end point because of the orange colour of the fat itself. The experiments, however, served to demonstrate that palm kernel oil belongs to the group of fats which are digested slowly by pancreatic lipase.

That coconut oil is digested so much more quickly than butter may be of dietetic interest in that this oil is said to be used for the making of cream buns. It seems possible that if margarines contain this fat they may be more rapidly digested than butter. Except in the case of castor oil, the rate of digestion runs parallel with the saponification value of the fats. Thus of the fats used, coconut oil has the highest saponification value [Bolton, 1928] and is the most rapidly

digested. According to Lewkowitsch [1923] palm kernel oil is very nearly related in its chemical composition to coconut oil and its digestion curve (Fig. 1) is nearer to that of coconut oil than that of any other fat. Wright & Mitchell [1921] state that in butter and coconut oil fatty acids of low molecular weight

Fig. 1.

are present "to some notable extent", while as a general rule natural oils and fats rarely yield fatty acids of that description. It is possible that this may be correlated with the more rapid rate of digestion of coconut oil and butter fat by lipase. Evans *et al.* [1934] put coconut oil first in order of fats able to spare vitamin B. If, as suggested by Burr *et al.* [1932] linoleic is an essential fatty

acid, then coconut oil which contains 1% [Chemists' Year Book 1934] and is rapidly digested, may prove a more valuable food than has hitherto been supposed.

SUMMARY

1. Coconut oil was digested by pancreatic lipase more rapidly than any other fat.

2. Palm kernel oil and castor oil were digested more rapidly than butter fat, while almond oil, arachis oil, bacon fat, beef fat, beef oleo, beef stearin, cocoabutter, cod liver oil, cottonseed oil, lard, mutton fat, olive oil, palm oil, premier jus, soya bean oil, hardened whale oil and hardened arachis oil were digested appreciably more slowly, and at approximately equal rates.

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