The Fat Soluble Vitamins and Irradiation in Nutrition.

OUR knowledge of the properties and effects of those elusive accessory food factors, usually designated by the term "vitamins," is gradually being extended by the labours of a large number of research workers: a short account of some of the more recent work on the fat soluble vitamins may prove useful, both from its intrinsic scientific interest and also from the influence it may have on the practical problems of human and animal dietetics. No discussion of this subject nowadays would be complete without mention of the effect of irradiation with ultra-violet rays as a substitute for, or a generator of, the fat soluble vitamins, or of the influence of these factors in the prevention and cure of rickets.

The animal organism is dependent for its supply of fat soluble vitamin-A upon the vegetable world: two most important sources are the fresh green leaves of many plants and the liver of fishes, where the vitamin obtained from the food is concentrated in association with the fat (cod liver oil). Now its presence in green leaves and the effects of irradiation to be considered later have suggested that its synthesis may be effected only or chiefly in the presence of light, but Ethel M. Luce and Ida S. Maclean (*Biochemical Journ.*, 1925, vol. 19, p. 47) have concluded that it can be formed by yeast cells in the absence of sunlight: it can easily be extracted from the dried yeast by ether.

Vitamin-A is characterised by being associated with the fats of both plant and animal tissues, but it frequently happens in modern life that it is precisely these two types of foodstuffs which fail to reach the consumer in a fresh or natural condition. Appropriate sources of the vitamin for human consumption are green leaves, milk and butter, and cod liver oil: but the leaves are frequently cooked, the milk may contain little of the vitamin to start with, and still less after the treatment it may undergo before consumption, margarine may replace butter in the diet, whilst raw cod liver oil is unpalatable without further treatment. What factors may destroy the vitamin and how may this destruction be avoided? How may an adequate supply be ensured in the human diet?

It is known that the fat soluble factor is easily oxidised, especially at a high temperature: but in an atmosphere free from oxygen it will withstand a temperature of more than 100° C. without much loss of its activity. S. S. Zilva (*ibid.*, 1924, vol. 18, p. 881) has shown that the hardening of cod liver oil in the absence of oxygen does not result in the destruction of the vitamin: this fact may have an important bearing on the preservation of the factor in margarine, which is largely made from hardened oils. Most often, however, the vegetable oils used contain little or none of the vitamin before the hardening process takes place. Storage alone, for example of cod liver oil, does not result in complete destruction although the activity of the oil gradually becomes less: the presence of the vitamin in a sample thirty years old has been detected by E. Poulsson (*ibid.*, 1924, vol. 18, p. 919).

Since animals do not form vitamin-A, it is important to see that animal products used as food should come from animals which have had an abundant supply of the vitamin in their diet. The most important products in this connexion are undoubtedly milk and its derivatives. Ethel M. Luce (*ibid.*, 1924, vol. 18, p. 1279) has compared the effects of sunlight and a diet rich in vitamin-A in producing a milk rich in this factor. At this point we must digress for a moment to mention that the methods of testing for the presence of the vitamin by feeding animals on a diet deficient in the factor supplemented by the product under test have led to the conclusion that there is probably more than one fat soluble vitamin in existence: one is concerned with the *growth* of animals whilst the other keeps this growth in normal channels; the former may be called the *growth* factor (or vitamin-A) and the latter the antirachitic factor. Luce has found that cow's milk only contains the growth factor when it is present in the food of the cow, but that exposure of the animal to sunlight whilst on a diet deficient in vitamin-A increases somewhat the content of the antirachitic factor in the milk; the amount of this latter factor is, however, increased much more by the presence of fat soluble vitamins in the cow's diet. The quantity and fat content of the milk are not apparently increased by a diet rich in vitamin-A, from some experiments on goats by E. T. Sheehy (Proc. Roy. Dublin Soc., 1924, vol. 17, p. 333).

The study of experimental rickets has shown the importance of the fat soluble vitamins in the etiology of this disease, but it is probable that other factors are concerned as well. The question is complicated by the fact that rickets is a disease of growth and may not be developed if the animals are on a diet from which fat soluble vitamin-A has been excluded, the animals on this diet ceasing to grow. If the diet is simply deficient in the vitamin, so that growth does occur, then rickets will also appear. S. S. Zilva, J. Golding, and J. C. Drummond have recently shown this to be true also in the case of young pigs (*Biochem. Journ.*, 1924, vol. 18, p. 872). On the other hand, if young animals are fed on a diet which, besides being deficient in fat soluble vitamins, is badly balanced as regards the proportion of its mineral elements, or deficient in calcium or phosphorus, rickets can be produced fairly easily, although growth may be also retarded. This conclusion shows that it is essential to consider not only the vitamins but also the other elements of the diet, especially the minerals, in connexion with this disease.

Attention must be directed to a further factor which influences the development of rickets. The animal body seems able to store a supply of the fat soluble vitamins, so that until this store has been exhausted, exposure to a deficient diet will be without effect. The amount in this store will obviously depend on the diet given before the experimental period commenced, and it has been found that the diet of the mother during pregnancy and lactation has a marked influence in this respect, a conclusion which has an obvious practical bearing on human dietetics. Thus V. Korenchevsky and Marjorie Carr (*Biochem. Journ.*, 1924, vol. 18, pp. 1308, 1313, and 1925, vol. 19, p. 112) have shown that if the mother's diet is deficient in fat soluble vitamins during pregnancy and lactation, the young (rats) placed on a deficient diet at weaning develop rickets more easily than those whose mothers had been fed on a rich diet during corresponding periods. An excess of calcium in the mother's diet, provided that the fat soluble vitamins are in excess also, still further improves the resistance of the young to the development of rickets afterwards. If the parent rats of either sex are fed on a deficient diet before mating, the animals are less fertile, and the young born are weaker than normal, but there is no sign of any deficiency of calcium in their skeletons; thus the mother draws on her own reserves for the sake of her young.

Once rickets has developed on a deficient diet, it has been of interest to determine whether any other factors besides the replacement of the missing vitamins will have any influence on the course of the disease. The addition of more calcium or phosphorus to the diet has little effect, unless these elements are already deficient; but V. Korenchevsky and M. Carr (*ibid.*, 1925, vol. 19, p. 101) have found that the subcutaneous injection of calcium glycero-phosphate may improve the calcification of the animals on the deficient diet; the injection of sodium phosphate alone was almost without effect. Apparently only a certain maximum amount of calcium can be absorbed from the digestive tract; but that this is probably not due to the absence of the vitamins from the diet is shown by the results of some experiments by Katharine M. Soames (*ibid.*, 1924, vol. 18, p. 1349); the intraperitoneal injection of cod liver oil in rats afforded some protection against rickets; presumably these vitamins exert their influence on the tissues after absorption and do not facilitate the absorption of other elements of the diet. The same author in collaboration with R. Robison (*ibid.*, 1925, vol. 19, p. 153) has investigated further the cause of the deficient calcification of the bones in rickets. They find no deficiency in the blood of the phosphoric ester hydrolysable by the bone enzyme or of the enzyme itself in the bones. The administration of cod liver oil has no effect on this ester or on the enzyme, but increases the organic phosphorus present in the blood. It only influences the inorganic phosphorus of the blood when the diet is deficient in this element. The inference from their results is that the deficient calcification on a diet deficient in the fat soluble factor alone is due to a deficiency of calcium ions; deficiency of phosphorus only plays a part when the diet is deficient in this factor also.

A further factor in the cure or prevention of the effects produced by a diet deficient in fat soluble vitamins has been found within the last few years in the influence of ultra-violet rays. In the earlier observations children suffering from rickets were exposed directly to the source of light, with the result that the bone lesions were healed; the subject was taken up experimentally later and it was found that the growth of rats could also be stimulated by ultra-violet light when the animals were fed on a diet deficient in fat soluble vitamins. Later work has suggested that the ultra-violet rays may cause a synthesis of the antirachitic factor, but only a mobilisation of the body's store of vitamin-A without a true synthesis. This agrees with the results of Luce and Maclean mentioned above, who conclude that light plays no part in the formation of vitamin-A. Some of the other effects of irradiation have recently been referred to in these pages (December 20, 1924, p. 901, and May 2, 1925, p. 642).

A further step from this work was the examination of the effects of the ultra-violet rays upon the *food* given to the animal; and S. J. Cowell (*Brit. Med. Jour.*, 1925, vol. 1, p. 594) has tried the effect of feeding irradiated milk to rickety children; his paper also gives a brief account of some of the earlier work on irradiation. He has found that the irradiated milk has produced a great increase in the calcification of the bones of two children with rickets, whilst a third fed on the same milk without irradiation showed very much less improvement. It appears then that the antirachitic factor can be synthesised outside the body under the influence of ultra-violet light; this conclusion is of great importance, since it implies that a further method is available for the improvement of a ration which we may suspect to be deficient; it also opens up the way to a knowledge of the chemical constitution of the antirachitic factor and possibly its supply in some convenient and more palatable form than cod liver oil.

Further information as to the use and effects of light treatment in disease, together with accounts of the physiological actions of ultra-violet radiations, may be found in articles by J. H. Sequeira and W. J. O'Donovan (*Lancet*, 1925, vol. 1, p. 909) and F. H. Humphris (*ibid.* p. 912).

Power Alcohol from Root Crops.

THE third memorandum of the Fuel Research Board on fuel for motor transport[1] deals with the production of power alcohol from tuber and root crops in Great Britain. Potatoes, mangolds, and Jerusalem artichokes are the only practicable raw materials which could be grown for this purpose, but it seems unlikely that potatoes would prove of economic value in this respect. One ton of potatoes produces 20 gallons of 95 per cent. alcohol, so that every pound sterling it costs to grow a ton of potatoes is equivalent to 1*s.* on a gallon of alcohol for raw material alone. Co-operation between the potato grower and distiller has been suggested as a means of utilising the distillery residues for cattle-feeding, and so reducing the net cost of the power alcohol. In the southern counties the mangold is superior to the potato in that it is easier to grow, harvest, and store, and is less liable to disease and failure, while the manufacture of alcohol from it is simpler as the carbohydrates are in the form of sugar. The comparative cost per gallon for the raw material works out at 7*s.* for potatoes and 3*s.* 9*d.* for mangolds. The latter cannot, however, be grown in the north of England and Scotland owing to its susceptibility to frost. The distillation residues would appear to have considerable value as an ingredient in a feeding material rich in carbohydrates but poor in protein.

The Jerusalem artichoke will grow in almost any well-drained soil, and as it is difficult to clear the ground completely when harvesting, no replanting is needed for many years when once a plot is well established, the cultivation being thus reduced to a minimum. The crop yields are very variable, probably being about 10-12 tons per acre in England, and 15-25 gallons of 95 per cent. alcohol per ton of tubers have been produced. Experiments also indicate that by using an organism of the *Bacillus butylicus* group, about 12 gallons of mixed butyl alcohol and acetone can be obtained. The simultaneous fermentation of the tubers by yeast and the same organisms yielded a liquor consisting of 70 per cent. of ethyl alcohol, 10 per cent. of acetone, and 20 per cent. of butyl alcohol. The sun-dried artichoke stalks can be so treated as to give a pure resistant cellulose at the rate of about $\frac{1}{3}$ ton per acre, of a type that would be very suitable for certain purposes.

The memorandum concludes with a series of tables setting forth the results of cultivation experiments together with various analytical figures.

[1] Department of Scientific and Industrial Research: Fuel Research Board. Fuel for Motor Transport: Third Memorandum. Power Alcohol from Tuber and Root Crops in Great Britain. Pp. vi+37. (London: H.M. Stationery Office, 1925.) 9*d.* net.