malnutrition is high in the children will themselves have suffered the same stresses in their infancy. One could expect, therefore, that the liver lesion would progress in any individuals who had failed to recover completely from malignant malnutrition in infancy. In the children's departments of the hospitals in the West Indies and South Africa, one sees small patients, generally boys, with every grade of liver damage from an enlarged hard liver to the final stages of advanced cirrhosis. In those countries and in India routine post-mortem examinations and hospital records provide the evidence of a very high incidence of cirrhosis and carcinoma of the liver; the incidence is far higher than among Europeans and the lesions occur at a much earlier age. True malignant malnutrition also is found among adults, and Trowell & Muwazi (1945) quote a figure of 10% of all admissions to the Uganda Medical School Hospital at Kampala.

The clinical picture in populations weaned on to and existing on diets predominantly or almost entirely of vegetable origin includes underdevelopment, poor physique, anaemia, liver damage associated with cirrhosis and malignant disease, abnormal values for serum proteins with a tendency to develop oedema, and often all the signs and symptoms of vitamin B_2-complex deficiencies. Given a diet with an inadequate supply of calories derived mainly from one or more staple carbohydrates and with little or no animal protein, and malignant malnutrition will appear with all its sequelae. That adequate calories from mixed vegetable staples can prevent the syndrome and give maximum health has yet to be demonstrated.

REFERENCES

Altmann, A. (1948). *Clin. Proc., J. Cape Town Post-Grad. med. Assoc.* **7**, 32.
Gillman, T. & Gillman, J. (1945). *Nature, Lond.*, **155**, 634.
Gillman, T. & Gillman, J. (1946). *Lancet*, **251**, 446.
Hoch, H. & Marrack, J. (1945). *Brit. med. J.* ii, 151.
McNaught, J. B., Scott, V. C., Woods, F. M. & Whipple, G. H. (1936). *J. exp. Med.* **63**, 277.
Marriott, H. L. (1945). *Lancet*, **248**, 679.
Taylor, G. F. & Chhuttani, P. N. (1945). *Brit. med. J.* i, 800.
Trowell, H. C. & Muwazi, E. M. K. (1945). *Trans. R. Soc. trop. Med. Hyg.* **39**, 229.
Walt, F., Wills, L. & Nightingale, R. P. (1950). *S. Afr. med. J.* **24**, 920.
Walters, J. H., Rossiter, R. J. & Lehmann, H. (1947). *Lancet*, **252**, 205.
Waterlow, J. C. (1948). *Spec. Rep. Ser. med. Res. Coun., Lond.*, no. 263.

EXPLANATION OF PLATES

Pl. 1. Bantu child, aged about 18 months, with the oedematous form of kwashiorkor, showing severe generalized anasarca and moderate skin lesions.

Pl. 2. Head of same child as in Pl. 1. Note pale, scanty hair and severe oedema of face.

Both plates by the courtesy of the Senior Pathologist, Central Pathological Laboratory, Durban, South Africa.

The Nutritional Adequacy of a Vegetable Substitute for Milk

By R. F. A. DEAN, *Department of Experimental Medicine, University of Cambridge and Medical Research Council*

The problem of supplying a substitute for milk can be resolved into the separate problems of finding substitutes for the various components: minerals, carbohydrate, fat, protein and vitamins.

The supply of minerals seems to be the easiest to deal with. Sodium must always be added to a vegetable diet, calcium nearly always, and iron usually. Carbohydrate forms the greater part of most plant foods, soya being a notable exception, and here the problem is to alter the carbohydrate into a form that is easily digestible. There are many vegetable sources of easily absorbed and well-tolerated fats. The fat requirements of man are unknown. It may be necessary to supply small quantities of unsaturated fatty acids, but fats can be synthesized in the human body, even by children. The chief importance of dietary fats seems to lie in their high calorific value and, since most vegetable foods are bulky in proportion to the calories they provide, the inclusion of fats is usually an advantage. The vitamins of milk are seldom regarded as among its most important constituents, and I want to be excused from discussing most of them. Dr Chick (1951) and Dr Wills (1951) have emphasized the importance of protein, and I am going to discuss principally the possibilities of replacing the proteins of milk.

Fairly convincing evidence could be brought forward, from what we can deduce of the food habits of our prehistoric ancestors, from the pattern of our dentition, from the comparatively recent establishment of agriculture, to show that through the ages the proportion of animal protein in the diet of man has undergone considerable reduction. Now we have a disease, kwashiorkor, malignant malnutrition, which may be the result of the reduction of the animal protein to below the minimum compatible with life, at least, with life at a time of rapid growth.

There can be few races or even individuals who exist on diets that are exclusively vegetable in origin. There must surely be only a handful of vegetarians who deny themselves or their children milk or cheese or an unfertilized hen's egg. Some races, who are obliged by scarcity to live on a vegetarian diet, eat meat in an orgy on the rare occasions when they can get it. Others add insects, ants, caterpillars and locusts (dried locusts are 50% crude protein) to their diets when they can, especially when there is no meat or fish available. It is probable that if the whole, not merely the largest items, of the diet of any race of fine physique were analysed, it would be found to contain a set of amino-acids resembling more or less closely that in milk protein, or in the protein of meat or fish.

It seems then that we are being ambitious if we attempt to provide a good diet from none but plant sources. In spite of this, I intend to confine myself to the problem of feeding young children on such diets. My own experience has been mostly with children. They probably exaggerate the adult's need for amino-acids (just as the rat, which grows even more rapidly, exaggerates the child's needs), and we know how great is the necessity of providing a cheap and adequate transitional diet, to fill the gap between breast milk and the adult diet. In this country we use for this purpose large amounts of cow's milk and increasing amounts of cereals. Is it possible, in less fortunate countries, to do without the milk? Has anyone succeeded so far? Success must have been achieved, but there are very few reliable scientific records. Most of them, as Dr Chick (1951) has said, related to diets which included soya-bean products. Tso (1928, 1929) reared a few children in the 1st year of life on diets in which soya milk, and a small amount of egg, provided the protein. The children throve, but had to be given extra calcium if rickets was to be avoided. Lane (1931) weaned a pair of twins on to a truly vegetarian diet at the age of 5 months, using a milk made chiefly from soya, almonds, peanuts and wheat flour. These children also throve, and continued to do so for the whole period of observation, which lasted nearly 3 years. The experiments of Rittinger, Dembo & Torrey (1935) are well known. They fed infants on various soya milks with satisfactory results, and could not detect any improvements when they added a little dried skim milk. One of these experiments was an apparently unrecognized trial of protein supplementation; a malt syrup was used to supply carbohydrate, but may have supplied also 20–30% of the total protein. Cereals were added to the diets of most of the children at the age of 12 weeks. Soya milks have been given also to Indian infants, and have in some experiments been thought not far inferior to cow's milk, but the reports of the experiments have always been given in an incomplete form, so that the weight gains cannot be properly assessed. Soya preparations are used extensively in the United States for feeding children who cannot tolerate cow's milk, but when Stoesser (1944) tried one of the most widely advertised of these preparations, his results were very poor. The food caused gastro-intestinal upsets in most of the children, and it was obviously unsuitable for use as a permanent diet. We can only hope it has been improved by now.

Willemin-Clog (1930) investigated the use of sunflower-seed meal in infant feeding, and had a fair measure of success, although she noticed that sunflower as the only source of protein was not, apparently, adequate for more than a few weeks. One of her collaborators (Ribadeau-Dumas, 1946) has more recently expressed the opinion that the vegetable proteins are best considered as 'milk-sparers', although a mixture of rice, barley and sunflower was a valuable food for children.

Dr Chick (1951) referred to mixtures of malted cereals, barley and wheat, with soya which she found could produce good growth in rats. I have already given this Society a survey of the results of our use of similar mixtures in child feeding (Dean, 1949). Our first discovery was that there were unexpected and very important difficulties in the way of manufacture. One whole batch of mixture which we thought had been made in the same way as Dr Chick's most successful mixture had to be abandoned because it caused diarrhoea. To-day, I am going to give some additional details of our use of more successful mixtures. In these, 25% of the protein was derived from barley, 5% from wheat and 70% from soya. In Dr Chick's best mixture of these three ingredients, 34% of the protein was derived from barley, 10% from wheat and 56% from soya.

Our two mixtures were exactly the same except that one of them (mixture B) contained soya that had been steamed only long enough to remove the bitter material, whereas the other (mixture C) contained soya that had been steamed for 100 min. to remove also the trypsin inhibitor.

The children, who were between 1 and 2 years old, and were living in a rather overcrowded orphanage, were divided into two equal groups. One was given a simple diet, semolina, vegetables (mostly potato), butter, and some bread, supplemented by cow's milk; and the other group had the same basic diet supplemented by one of the cereal-soya mixtures. The milk and the mixtures were made into a pudding with the semolina. All the children were liberally provided with vitamins A, D and C, and we made sure there was no shortage of calcium.

In the milk group, about 33 % of the calories were obtained from fresh whole milk, but in the other group about 50 % of the calories came from the cereal-soya mixtures. Of the total calories in the milk diet 11 % were protein calories, and of these 60 % were derived from milk; in the cereal-soya diets, 13 % of the total calories were protein calories, and 70 % of these came from the mixtures. The results of the trials are given in Fig. 1. Trial 1 lasted 16 weeks, and trial 2, 8 weeks. The periods are short, but we

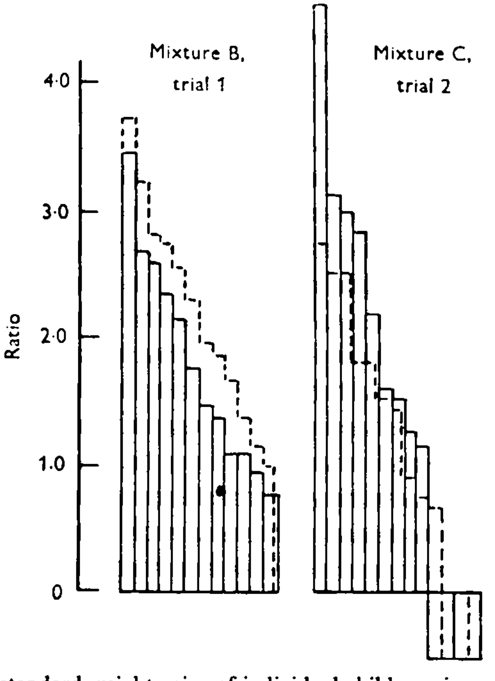

Fig. 1. Ratios of actual to standard weight gains of individual children given cereal-soya mixtures B (in trial 1) and C (in trial 2). The dotted lines indicate the ratios of the children in the contemporary control groups, who were given a diet containing fresh whole milk.

were quite sure that during these periods the children on the cereal-soya diets had no animal protein of any kind. Nearly all the children exceeded the standard gain in weight. There was an epidemic of infective diarrhoea in trial 2 which affected children in both groups. Some of the trouble, however, may have been due to mixture C. We were unable to find the exact cause, but it was probably over-heating during the spray-drying process used for large-scale manufacture. Trial 2 and some later trials made us decide that the removal of the trypsin inhibitor increased the nutritive value of the soya. The approximate amounts of the essential amino-acids in the mixtures, and in the complete diets were calculated from the data of Block & Mitchell (1946–7). When the amounts were compared with the amounts of the same amino-acids in human milk, on the basis of equal amounts of total nitrogen, the differences were small, but the essential amino-acids represented about 63 % of the total nitrogen in the human milk, and only 47 % of that in the cereal-soya mixtures. This was one reason why we found it necessary to give a higher proportion of protein in the cereal-soya diets than in the milk diets.

It seems justifiable to conclude that if the mixture of amino-acids is suitably adjusted, a diet entirely of plant origin can give excellent results, at least for short periods, in the feeding of children. Dr Chick's (1951) work on young rats is, in fact, applicable to young human beings.

We have sought to extend the scope of our work to other plant materials, and, following Willemin-Clog's example, we have studied sunflower-seed meal, which is a rich source of protein and seems a useful alternative to soya. The soya bean is not universally available, and it cannot, for instance, be grown well in this country, whereas sunflowers can. We have also, not entirely by chance, taken an interest in maize. Sunflower protein contains twice as much of both lysine and tryptophan as maize protein, and we have found that rats grow excellently on various combinations of sunflower and maize, especially if a little yeast is added to the diets.

The success of these experiments has made us speculate on the possible cause of kwashiorkor. We know the disease can be cured by milk. It appears also to have been cured by various other substances which contain animal protein, serum given intravenously, liver and hog's stomach. Does the disease occur because of amino-acid deficiencies in the diet, a single or multiple deficiency of one or more of the amino-acids I have mentioned or of some other, and is it cured by proteins which contain large amounts of those amino-acids? There is another, and quite different, possibility which also has occurred to us as a result of our experiments. We were anxious to find out if our cereal-soya mixtures were improved by the addition of vitamin B_{12}. It is not present in soya or in any of the cereals we have used in our child-feeding experiments. When we added it to the cereal-soya mixture B, we found that it had an effect on the growth of rats as beneficial as the addition of quite considerable amounts of milk protein, and we hope to have an opportunity in the near future of demonstrating a similar effect in children. There is a further point worth consideration. Vitamin B_{12} has not been demonstrated in maize, but it is, I believe, to be found in all those substances which can cure kwashiorkor. This may be merely a coincidence, but a trial of vitamin B_{12} seems to be indicated, not only on these empirical grounds, but because the vitamin is believed to be of importance in transmethylation and therefore in the utilization of lipotrophic substances such as choline and methionine.

We think we have evidence enough to show that it is possible to evolve diets containing protein exclusively from plant sources, which will successfully rival diets containing fair amounts of animal protein. This circumlocution is preferable to the use of the term 'milk substitutes', because so many diets do not contain milk. We are really only at the beginning, however, of knowing how best to apply our experience. There are many diverse factors that have to be taken into account. They include variations in the amounts of amino-acids in our raw materials, depending on the strain of wheat or yeast, for instance, or the method of cultivation of rice; alterations in biological value caused by heating and by the reactions between amino-acids and sugars, reactions which may escape detection by the ordinary methods of analysis; variations in the methods of preparation of foods which may impair digestibility and cause loose stools, as our mixture C did; differences introduced by the necessary jump from the laboratory or 'pilot' scale of production to the full factory process, and all the time we must remember that economic necessity forces us to prepare our new foods in the simplest and cheapest way, and as far as possible from materials locally available.

We cannot be experts in all the sciences simultaneously involved. We rely on the co-operation of the paediatricians, the biochemists, the agriculturalists, the cereal chemists, the educators, the administrators, even the politicians.

We know there are millions of undernourished children. We believe they could be better nourished if we used our plant resources more perfectly. We must find means of translating our belief into fact.

REFERENCES

Block, R. J. & Mitchell, H. H. (1946–7). *Nutr. Abstr. Rev.* **16**, 249.
Chick, H. (1951). *Brit. J. Nutrit.* **5**, 261.
Dean, R. F. A. (1949). *Brit. J. Nutrit.* **3**, xii.
Lane, D. E. (1931). *Amer. J. Dis. Child.* **42**, 1384.
Ribadeau-Dumas, L. (1946). *Bull. Soc. sci. Hyg. aliment., Paris*, **34**, 56.
Rittinger, F., Dembo, L. H. & Torrey, G. G. (1935). *J. Pediat.* **6**, 517.
Stoesser, A. V. (1944). *Ann. Allergy.* **2**, 404.
Tso, E. (1928). *Chin. J. Physiol.* **2**, 33.
Tso, E. (1929). *Amer. J. Physiol.* **90**, 542.
Willemin-Clog, L. (1930). *L'Emploi des Protéines Végétales en Diététique Infantile.* Paris: Arnette.
Wills, L. (1951). *Brit. J. Nutrit.* **5**, 265.