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The nutritional status of vegans and vegetarians

By F. R. Ellis, *Kingston Group Hospitals, Kingston-upon-Thames, Surrey,* and Pamela Mumford, *Department of Nutrition, Queen Elizabeth College, London, W8*

'There is no disease, bodily or mental, which adoption of vegetable diet and pure water has not infallibly mitigated, wherever the experiment has been fairly tried. Debility is gradually converted into strength, disease into healthfulness . . . the unaccountable irrationalities of illtemper, that make hell of domestic life, into a calm and considerable evenness of temper . . .'. So wrote the poet Shelley in his pamphlet, *A Vindication of Natural Diet*, first published in 1813, from his own experience of 8 months on a vegetable diet. Nutrition would indeed have much to offer mankind if a relatively simple change of dietary regime could be of such benefit to the individual and to society. We wish to examine the present stage of knowledge at least with regard to the adequacy of the diet.

For the purpose of this paper, we shall be considering three groups of people: (1) vegans, whose diet contains no animal foods whatsoever, and who may also refuse to eat vegetable foods in which animal products have been employed for processing—for example, white sugar clarified with bone charcoal, or margarine fortified with vitamin A from animal sources; (2) vegetarians, who eat no meat or fish, but who include milk or eggs, or both, in their diet; and (3) omnivores, who eat an ordinary mixed diet. Since various aspects of the nutrition of vegans and vegetarians were last discussed by the society in the 1950's in symposia on *The comparative merits of animal and vegetable foods in nutrition* (1951), *All flesh is grass* (1952) and *Vitamin B_{12}* (1952), *Diet and anaemia* (1956) (Nutrition Society, 1951, 1952, 1956) there have been a number of dietary surveys of these groups carried out in various parts of the world and some have been reviewed by Hardinge & Crooks (1963*a*,*b*; 1964). These authors concluded that a vegetarian diet meets the nutritional requirements of all age groups, and that vegan diets comprising unrefined cereal products, legumes, nuts, vegetables and fruits produce no detectable deficiency signs. However, they indicated that vegan and vegetarian diets are inadequate if

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they (a) are low in calories, or (b) contain a high proportion of refined cereals or of starchy foods. These limitations are unlikely to occur in the developed countries where people adopt such regimens from choice rather than economic necessity, but a deficiency of vitamin B_{12} may develop after a variable period on an unsupplemented vegan diet (Smith, 1965).

There are about 100 000 vegetarians and vegans in the United Kingdom, and a recent study (Jacoby, McKenzie, Miller & Mumford, 1966) indicated that at least 120 people had succeeded in giving up all foods of animal origin, but of these 41% had eaten a vegan diet for less than 5 years. We have carried out a weighed food intake survey of some vegans living in the London area, and the nutrient content of the diet was calculated by computer using the standard food tables of McCance & Widdowson (1960) supplemented with tables calculated from recipes provided by the manufacturers of special vegetarian foods (Miller & Mumford, 1967, to be published). These results together with those for some other groups of vegans and vegetarians are set out in Table 1.

The proximate analysis of the vegan diets is remarkably normal, and the average nutrient intakes meet recommended daily allowances (British Medical Association, 1950; WHO, 1962). However, the pattern of nutrient intake is different from that of people eating a mixed diet. Hardinge & Stare (1954*a*,*b*), Hitchcock & English (1963), and the present authors each examined a series of omnivores. It was found that the intake of total calories, protein, fat, and the percentage of calories from fat were all less in vegetarians than in omnivores, whilst intakes of calcium, thiamine and ascorbic acid were greater. Vegans had a lower intake of calories, protein, fat, calcium and riboflavine than the omnivores, but intakes of iron and thiamine were greater.

Three groups of workers have presented values from which it is possible to calculate the protein 'score' of the diets by comparing their essential amino acid pattern with that of an 'ideal' or completely utilizable reference protein proposed by FAO (1957). Since the quality of egg and milk proteins is as good as that of meat and fish proteins, it is hardly surprising that vegetarian diets do not differ markedly from mixed diets with regard to protein value and their adequacy for all physiological groups, provided the intake of calories is sufficient. The protein value of vegan diets is most likely to be limited by lysine, tryptophan, or (as in mixed diets) the sulphur amino acids. Hardinge, Crooks & Stare (1966) and Guggenheim, Weiss & Fostick (1962) have presented values showing the proportion of lysine in the dietary protein to compare favourably with the FAO pattern, and this is attributed to the use of legumes in vegan diets. Both Guggenheim *et al.* (1962) and Hughes (1959) suggest that tryptophan may be limiting, but this is unlikely since not only does the FAO reference pattern probably contain too high a proportion of tryptophan (Swendseid, Watts, Harris & Tuttle, 1961), but also analytical methods for estimation of this amino acid tend to be unreliable. Thus, as in most human diets, the sulphur amino acids are most limiting; the protein 'scores' are shown in Table 2. They are somewhat lower than those for mixed diets which are generally about 80. It has been claimed that vitamin B_{12} has a methionine-sparing action, but this is only in the presence of dietary homocysteine, which is methylated; it is difficult to see how the

Table 1. *Average daily intake of nutrients of vegetarians and vegans*

Reference	No. of subjects	Calories: Total (kcal)	Calories: From fat (as % of total)	Calories: From carbohydrate (as % of total)	Calories: From protein (as % of total)	Nitrogen (g)	Iron (mg)	Calcium (g)	Vitamin A* (i.u.)	Thiamine (μg)	Riboflavine (mg)	Nicotinic acid (mg)	Ascorbic acid (mg)
Vegetarians													
Oldham & Sheft (1951)†	7	2100	—	—	12	10·4	13	1·3	8,046	1·4	2·3	11	70
Hardinge & Stare (1954*a*,*b*)‡													
Adults	30	2735	33	54	12	14·4	19	1·6	14,590	2·0	2·7	16	235
Adolescents	30	3740	34	53	13	19·2	21	2·1	17,150	2·9	3·6	17	200
Pregnant women	26	2650	33	52	15	15·6	17	1·8	15,110	1·9	3·0	14	205
Mirone (1954)§	6	2470	8	81	11	10·2	15	1·0	7,364	2·0	1·7	16	100
Hitchcock & English (1963)‖	26	1980	32	57	11	8·5	10	0·8	6,800	1·0	1·3	11	107
Vegans													
Hardinge & Stare (1954*a*,*b*)‡, adults	25	2830	35	55	10	11·5	27	1·0	22,540	2·4	1·7	21	320
Guggenheim, Weiss & Fostick (1962)‖	119	2410	—	—	11	10·5	21	0·8	7,290	2·1	1·4	16	200
Lee, Kim, Han & Goodale (1962)	129	2600	7	82	11	11·2	—	—	—	—	—	—	—
Miller & Mumford (1967, to be published)†	20	2210	35	54	11	9·7	19	0·5	—	—	—	—	—

*Includes carotene.
†7-day weighed food intake.
‡Diet history method of Burke.
§3-day weighed food intake.
‖ 7-day survey using household measures.

presence of vitamin B_{12} could contribute to the synthesis of the sulphur-containing moiety of methionine, which is an essential amino acid.

Knowing the percentage of calories from protein in the diets, together with the score, the percentage of net dietary protein (NDpCal%) has been read from the nomogram of Miller & Payne (1961) and compared with requirements (Miller, 1967). An adequate percentage of useful protein is consumed by the vegans, and also, not unexpectedly, by the vegetarians. A restricted food intake may have reduced the protein value of the diets in some of our vegans (mean daily calorie intake ranged from 1130 to 4150 kcal), but since the subjects were in positive nitrogen balances the diets were considered adequate.

Table 2. *Protein score and percentage of net dietary protein* (ND*pCal*%) *of some vegetarian and vegan diets*

Reference	Type of subjects	Protein score (SAA)*	NDpCal % Found	NDpCal % Required (Miller, 1967)
		Vegetarians		
Hardinge *et al.* (1966)	Adults: ♂	75	8·4	4·4
	♀	75	8·4	5·2
	Adolescents: ♂	74	7·8	8·0
	♀	73	9·0	8·0
	Pregnant women	75	9·0	6·4
		Vegans		
Hardinge *et al.* (1966)	Adults: ♂	72	6·8	4·4
	♀	80	7·5	5·2
Guggenheim *et al.* (1962)	Household groups	62	6·4	—
Miller & Mumford (1967)	Adults: ♂ and ♀	58	6·3	—

*Sulphur amino acids.

Hardinge & Stare (1954*a*) could not demonstrate any significant differences between the vegetarians and omnivores in the physical, haematological and biochemical tests reported, although subsequently they reported lower levels of serum cholesterol in the vegetarians. Neither did they (Hardinge & Crooks, 1964) find specific vitamin B_{12}-deficiency symptoms in the vegans, but it is not clear whether or not these people were taking vitamin B_{12} supplements.

We also have carried out a clinical examination of our vegans and age-matched controls; this comprised a physical and neurological examination, chest X-ray, electrocardiogram (ECG), and relevant haematological and biochemical tests on blood and serum. There were slight neurological abnormalities in three male vegans, one of whom had pernicious anaemia, but the other cases were presumably due to low vitamin B_{12} levels since corrected by vitamin B_{12} supplements. Otherwise there were no detectable differences attributable to the diet between the clinical state of the vegans and control subjects, neither was there any difference in the chest X-ray and ECG findings. Haematological and biochemical results were mostly normal. Two haemoglobin levels fell outside the normal range; a male vegan had a slight iron-deficiency anaemia, and a female vegan had a mild normochromic anaemia. The average serum folate content in both male and female control subjects was low

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(4·0 and 5·9 ng/ml respectively). The serum vitamin B_{12} content of the vegans ranged from 50 to 650 pg/ml (mean 253) in the males and from 30 to 450 pg/ml (mean 221) in the females, and the lactic dehydrogenase values are of interest (97 and 93 i.u./l. respectively), being about the same as those of the controls (see Emerson & Wilkinson, 1966).

The only danger of eating a vegan diet over a prolonged period appears to be due to vitamin B_{12} deficiency (Badenoch, 1954; Hines, 1966), but the remarkable absence of signs and symptoms of deficiency in many vegans may be attributable to various factors. In the first place, length of time on the diet is important. The normal body store of the vitamin in omnivores is estimated at 3–5 mg, sufficient to maintain adequate serum levels for up to 5 years. The obligatory daily rate of loss is about 0·1% of the body pool, and a minimal daily dietary intake of only 0·6–1·2 μg is probably adequate to maintain health and normal haemopoiesis (Heyssel, Bozian, Darby & Bell, 1966), although a daily intake of 3–4 μg is generally thought desirable. It is, incidentally, notable than an injection of 1 μg vitamin B_{12} suffices to bring about a remission in pernicious anaemia. Secondly, the range of serum vitamin B_{12} levels associated with deficiency symptoms is wide, and the length of time individuals can maintain normal haemopoiesis and neurological function at low serum vitamin B_{12} levels is also variable. The serum vitamin B_{12} level of normal healthy persons lies between 140 and 900 pg/ml, an average value for omnivores being about 350 and for vegetarians about 250 pg/ml; values below 80 indicate vitamin B_{12} deficiency, but between 80 and 140 pg/ml there may or may not be deficiency signs and symptoms. In view of this it is not surprising that Smith (1962) could not find neurological signs and symptoms in his series of twelve vegans, eleven of whom had a serum vitamin B_{12} value above 80, and his hypothesis for the action of hydroxycobalamin on the nervous system thus seems unnecessary. In our own series of vegans, three who were not taking a vitamin B_{12} supplement had values below 80 pg/ml although at the time of the clinical examination they showed no signs of deficiency. The value of food preparations fortified with vitamin B_{12} in vegan dietaries has been discussed by Ellis & Wokes (1967); in eleven of our vegans using such foods the average serum vitamin B_{12} level was 260 pg/ml, and in another series of forty such vegans that we have examined the average level was 330 pg/ml. Both Smith (1962) and West & Ellis (1966) have reported abnormalities of the electro-encephalogram (EEG) in vegans. It appears unlikely that these abnormalities are related to chronically low levels of serum vitamin B_{12}, since large doses of the vitamin failed to correct them, whereas the marked abnormalities of the EEG in pernicious anaemia and folate deficiency were corrected by such therapy.

Whilst it is generally thought that vegetarians who include dairy products in their diet are unlikely to be lacking in vitamin B_{12}, unusually low serum levels have recently been reported. Mehta, Rege & Satoskar (1964) have found a mean value of 121 pg/ml in vegetarian Indian university students who accept milk but not eggs, although there were no associated neurological signs or symptoms of vitamin B_{12} deficiency, and their weight, height, blood picture and serum protein levels were not significantly different from the non-vegetarian controls. In this country, Ellis & Wokes (1967) have found six vegetarians with levels below 140 pg/ml out of the twenty-four they examined.

It is interesting in our series of vegans that their level of serum folate is high relative to the controls (average 14·6 and 4·9 ng/ml respectively), and in fact three of the control males had levels of only 2·0 ng/ml, which generally indicates folate deficiency (Patwardhan, 1966). The higher consumption of fresh fruits and vegetables by vegans could account for these differences, but the control levels indicate some cause for concern.

A number of studies of vegan and vegetarian groups have been stimulated by the search for the etiology of coronary heart disease and the relationship of atherosclerosis and serum cholesterol levels to this condition. Trappist monks, who are vegetarian, have lower serum cholesterol levels than Benedictine monks eating a mixed diet (Groen, Tijong, Koster, Willebrands, Verdonck & Pierloot, 1962), and vegan Buddhist monks and nuns studied by Lee, Kim, Han & Goodale (1962), who were eating only 7% of their calories as fat, had even lower cholesterol levels. Hardinge & Stare (1954*b*) found significantly lower serum cholesterol levels in their vegan subjects than in the vegetarians or omnivores. The serum cholesterol levels of our vegan and control subjects all fell within the normal range.

As McKenzie (1967) has demonstrated earlier in this Symposium, veganism embraces far more than the adoption of a particular dietary regime, and the same is to some extent true of vegetarianism, and such people living within an affluent society eating a mixed diet are particularly diet-conscious. A totally different situation prevails in many developing countries where a vegetarian diet is imposed on the population because as little as 6 g per head per day of animal protein is available (FAO, 1964), and where both total calorie intake and variety of vegetable proteins may be limited. From our study of vegans it is clear that their diet is of satisfactory nutritional value for adult man, provided it is supplemented with vitamin B_{12},

Table 3. *Annual yield of nutrients per acre (a) and per 100 man-hours of labour (b) (Christensen, 1943)*

	Calories (kcal × 10^{-6})		Protein (kg)		Calcium (kg)		Iron (kg)		Vitamin A (i.u. × 10^{-6})		Vitamin C (kg)	
	a	b	a	b	a	b	a	b	a	b	a	b
Dairy products	0·2	0·7	10	27	0·3	0·8	0	0	1	2	0	0
Chicken and eggs	0·1	0·3	12	27	0·1	0·1	0	0	1	1	0	0
Pigs	0·5	1·6	8	27	0	0	0	0	0	0	0	0
Beef	0·1	0·3	4	18	0	0	0	0	0	0	0	0
Lamb	0·1	0·5	6	27	0	0	0	0	0	0	0	0
Flour, white	0·8	9·3	27	280	0	0·4	2	26	0	0	0	0
Oats	1·0	11·0	36	395	0·2	2·2	13	144	0	0	0	0
Potatoes	2·3	3·4	54	77	0·4	0·5	20	29	1	2	0·3	0·4
Beans, dry	1·1	4·2	68	263	0·5	1·8	32	122	0	0	0	0
Cabbage	0·9	0·8	45	40	1·5	1·3	16	15	5	5	1·7	1·6
Carrots	2·7	0·8	77	23	2·4	0·7	48	15	431	133	0·4	0·1
Tomatoes	0·4	0·2	19	10	0·2	0·1	11	6	24	14	0·5	0·3
Apples	1·1	0·9	6	5	0·1	0·1	5	4	1	1	0·1	0·1

0, indicates that the yield of nutrient expressed in this way is insignificant, though not necessarily entirely absent.

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although it would be interesting to make a further study of children and adolescents raised on a vegan diet. However, Miller (1963) has shown that it is possible to construct an infant food entirely from vegetable ingredients with NDpCal 8%, thus meeting requirements.

Consideration of these facts is pertinent to the world food problem, since much greater yields per acre of most nutrients are obtained from vegetable crops than by animal husbandry (Table 3), and yields per man-hour follow a similar pattern. Miller & Mumford (1966) found that the cheapest foods to provide the daily requirement of three or more 'key' nutrients (calories, protein, calcium, iron, vitamin A and vitamin C) were flour, bread, oatmeal, potatoes, haricot beans, carrots, cabbage, spinach and watercress. It is possible to construct cheap, nutritionally sound, but appallingly monotonous diets from these ingredients; the vegan housewife has obviously mastered the art of providing such vegetable dishes in a palatable form. Brillat-Savarin, the eighteenth century French political economist, continued his oft-quoted aphorism 'Tell me what you eat and I will tell you what you are' with the sentence, 'The destiny of a people depends on the nature of its diet'. Perhaps today we may substitute 'world' for 'people'.

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Nutritional status of Asian infants

By M. A. Hussain and G. R. Wadsworth, *Department of Human Nutrition, London School of Hygiene and Tropical Medicine, London, WC* 1

Although the present discussion is the result of observations on Pakistanis living in Bradford, the Asian immigrants in this country come from both India and Pakistan. However, there is no reason to believe that Indian immigrants differ appreciably from Pakistani immigrants in their food habits and nutritional status, or that the Bradford residents are different in these respects from those living in other parts of this country.

In 1953 there were in Bradford about 350 coloured immigrants, but in the census of 1961 the count was over 5000 and nearly as many again arrived between May and August 1962. At first nearly all the Asians were men between about 20 and 45 years of age, but during 1963 an increasing number of wives and families began to arrive. In 1963 about 300 Pakistani and 300 Indian children were attending school in Bradford and about 150 coloured children were being born each year in the city. The size of the Asian population is still increasing owing mainly to births in this country. The proportion of births occurring in Asian families increased from less than 4% of the total births in Bradford in 1963 to over 8% in 1965, in which year over 500 babies were born into Asian families.

The history of the growth of the immigrant population suggests that the nature of nutritional problems may have changed over the past few years. The state of health in the past would have been influenced by dietary habits and environmental factors which had operated in Pakistan; recently those most liable to nutritional defects, namely mothers during pregnancy and lactation and children during the 1st year or so of life have been subjected exclusively to conditions in an urban location in this country. The results of earlier observations may not therefore be similar to those of inquiries being made now. Of particular importance is the fact that during pregnancy Pakistani mothers in this country benefit from the obstetric services which they are using conscientiously. At the same time they are, perhaps, being influenced by commercial advertising and other ways in their choice of foods for themselves