

Nutritional implications of a meatless diet

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A study commissioned by the Vegetarian Society claimed that there were as many as 3.5 million vegetarians in the UK (The Realeat Survey Office, 1990). While this may well be an overestimate, as some people who call themselves vegetarians do eat meat and fish occasionally, it is apparent that many people are now claiming to avoid 'red meat' ostensibly because they believe it to be healthier (Cathro, 1991). The trend towards vegetarianism is strongest in the younger age-groups and particularly in women. The present paper considers the nutritional adequacy of diets devoid of meat and the health of vegetarians, and questions whether avoidance of meat offers advantages to health.

TYPES OF VEGETARIAN DIET

A vegetarian is usually defined as someone who does not eat animal flesh (meat, poultry, fish) but whose diet includes eggs and dairy products. Usually the first stage in becoming a vegetarian is to give up consuming red meat, this is followed by the exclusion of poultry and fish. Many vegetarians aspire to being pure vegetarians or vegans who exclude all food of animal origin. Veganism is a way of life that avoids the exploitation of animals. Besides avoiding food of animal origin, vegans will not use products that have been derived from animals, such as leather and wool. Fruitarians restrict their diet to raw fruits, nuts and berries because they believe that this was the natural diet of man. Macrobiotic diets which originate from the teachings of George Ohsawa (1971) consist of relatively large amounts of brown rice, accompanied by smaller amounts of fruits, vegetables and pulses; processed foods and Solanaceae species (tomatoes, aubergines and potatoes) are avoided; meat and fish are permitted if they are hunted or wild. In practice, however, most macrobiotic diets are vegetarian and contain only small amounts, if any, of milk products.

Pythagoras was one of the earlier advocates of a meatless diet in the West, and abstinence from meat (flesh) has been associated with asceticism throughout the world for thousands of years. Vegetarianism is advocated by the Hindu religion and the Seventh-Day Adventists' Church. The Rastafarian cult advocates a vegan–fruitarian diet. In the UK, many vegetarians and vegans follow their diets for ethical reasons. They claim that it is cruel to eat animals and that it is environmentally more economical to live on foods of plant origin than foods of animal origin. Vegetarianism in the UK has a long history of association with radical and often altruistic causes ranging from teetotalism and food reform in the 19th century, to feminism, nuclear disarmament, environmental issues and animal rights in the 20th century. Many radical figures such as George Bernard Shaw and Beatrice Webb have openly promoted vegetarianism. In more recent times, pop idols such as Madonna have espoused the vegetarian cause. It is, perhaps, not surprising that vegetarianism appeals to the younger age-groups.

In the Netherlands and the USA, many of the 'new vegetarians' are followers of the

teachings of George Ohsawa (1972). He advocated the consumption of 'organic' foods and attempted to apply Zen Buddhist philosophy to the selection of natural unprocessed foods which he called macrobiotics. Foods are designated Yin or Yang and the aim is to achieve a diet with a balance of Yin and Yang. In the late 1960s, there was disenchantment with science and technology, and growing awareness of the hazards of pesticides and other chemical residues in food. Macrobiotics offered a diet based on natural and unprocessed foods that rejected the conventional scientific wisdom and was based on fashionable oriental philosophy. Macrobiotics was embraced by the 'hippie' culture of San Francisco in the 1960s and spread to the UK and Europe from the USA in the 1970s. In the UK, in the early 1970s, the traditional health food shops sold dietary supplements and catered for the needs of the ethical vegetarians with processed foods. These were joined by a new type of health food shop that promoted the macrobiotic message; these shops typically sold a variety of grains and pulses and 'organic' foods, hitherto unavailable, such as adzuki beans (*Phaseolus angularis*), miso, tamari and brown rice. They promoted the view that vegetarian diets are more natural and wholesome than ordinary mixed diets. However, vegetarian diets had already been promoted by practitioners of 'alternative' medicine since at least the beginning of this century.

Other factors have contributed to the increased popularity of vegetarianism. Many people have been put off meat following the scares over bovine spongiform encephalopathy and salmonella in poultry. The media has also highlighted several distasteful practices used in intensive farming. As the population has become more isolated from the production of food animals and preparation of meat, it is perhaps not surprising that many people simply find the concept of eating meat repulsive. In practice there is probably a combination of reasons why people follow vegetarian diets.

DIET ADEQUACY

The quality of any diet depends on what foods are included, whereas vegetarian diets are defined on the basis of those foods that are excluded. It is generally accepted that vegetarian and vegan, but not fruitarian, diets can be nutritionally adequate if sensibly selected. Problems are more likely to arise if the variety of foods making up the diet is restricted, particularly when the consumption of dairy products is low. Food choice is also influenced by the reasons why individuals follow vegetarian diets. Many ethical vegetarians will refuse to use products that contain derivatives of animal products such as gelatine or that contain additives that have been tested on animals. However, many ethical and macrobiotic vegetarians favour the consumption of unrefined carbohydrate foods, such as wholemeal bread, salads, fruit, nuts and pulses and often consume a wider variety of foods than many individuals on mixed diets.

Most studies of vegans and vegetarians in the UK have been carried out on members of the Vegan and Vegetarian Societies, who follow their diets for ethical reasons. These groups are generally keen to volunteer for studies in order to demonstrate their health and the adequacy of their diets. Studies have also been carried out on Asian vegetarians, who generally are not zealous. Both adult vegans and vegetarians have similar, or slightly lower, intakes of dietary energy compared with non-vegetarians (Roshanai & Sanders, 1984; Sanders & Key, 1987; Reddy & Sanders, 1992; Draper *et al.* 1993). The percentage of energy derived from protein is generally slightly lower, about 12, and that from carbohydrates greater. However, sugar intakes are similar for vegans and vegetarians

compared with those of omnivores. The percentage of energy derived from fat is only slightly lower than that of omnivores and is typically in the region of 30–37. Saturated fatty acid intakes are slightly lower for vegetarians but markedly lower for vegans than in omnivores. Intakes of linoleic acid (18:2n-6) are considerably greater for vegans and vegetarians than for omnivores. Compared with omnivores, fibre intakes are usually higher for vegans and vegetarians as a result of their preference for unrefined cereals. However, fibre intakes are similar for Asian vegetarians compared with omnivores. Therefore, despite the absence of meat from the diet, vegan and vegetarian diets are unremarkable in their composition with regard to the macronutrients.

With regard to the dietary adequacy of meatless diets, two crucial issues need to be addressed. First, can the micronutrients supplied by meat and fish (retinol, I, Fe, Zn, vitamin B₁₂, taurine, and docosahexaenoic acid (22:6n-3; DHA)) be supplied by foods of plant origin? Second, in practice do vegetarian and vegan diets provide all the required micronutrients in a form that can be utilized by the body?

Iron-deficiency anaemia

Although Fe is ubiquitous, its availability from foods of plant origin is low compared with that from meat. Consequently, vegetarians are probably more prone to Fe deficiency than meat eaters. The Asian vegetarian population in the UK and North America has a higher incidence of Fe-deficiency anaemia, particularly among women and infants, compared with the general population. The incidence is highest in those who rely on rice rather than wheat. An increased prevalence of Fe-deficiency anaemia has also been reported in macrobiotic vegetarians (Dagnelie *et al.* 1989). However, Fe intakes appear to be relatively high in vegetarians and vegans whose staple food is wholemeal bread. Haemoglobin concentrations are generally normal for both Seventh-Day Adventist and ethical vegans and vegetarians (Armstrong *et al.* 1974; Sanders *et al.* 1978a; Gear *et al.* 1980). However, serum ferritin concentrations are low (below 12 µg/l) for both ethical white and Asian vegetarian women of child-bearing age (Reddy & Sanders, 1990) compared with women who eat meat, despite their high intakes of vitamin C. Serum ferritin levels were strongly correlated with the intake of haem-Fe. This implies that meat plays an important role in determining serum ferritin concentrations. This has a number of implications for pregnancy and its outcome. First, it means that infants born to vegetarian women will be born with lower stores of Fe and if they are breast-fed for a prolonged period, they will be more likely to develop anaemia. Second, low Fe status in the first trimester of pregnancy may increase the risk of premature birth and low birth weight (Kim *et al.* 1992; Scholl *et al.* 1992). Therefore, an additional intake of Fe before conception and during the pregnancy may be desirable for vegetarians.

Zinc

Zn is a nutrient that has attracted a lot of attention since the discovery that deficiency occurs among certain populations consuming large amounts of unleavened bread. Several studies have found lower levels of plasma Zn for vegetarians and vegans compared with non-vegetarians (Anderson *et al.* 1981; King *et al.* 1981), even though Zn intakes were similar to, or greater than, those of non-vegetarians. These lower plasma Zn concentrations have been attributed to their higher intakes of dietary fibre and other

modifiers of mineral absorption such as phytate and oxalate. Whether the slightly lower levels of plasma Zn are of clinical significance remains uncertain.

Vitamin B₁₂ deficiency

Cases of dietary vitamin B₁₂ deficiency, sometimes fatal, have been reported in both vegans and vegetarians (Misra & Fallowfield, 1971; Campbell *et al.* 1982; Dagnelie *et al.* 1989). White vegans and vegetarians tend to present with neurological signs of deficiency because of their high intake of folic acid which masks the megaloblastic anaemia of vitamin B₁₂ deficiency. The incidence of megaloblastic anaemia resulting from combined vitamin B₁₂ and folate deficiency in Asian vegetarians is three times the UK national average (Chanarin *et al.* 1985). Megaloblastic anaemia may be precipitated during pregnancy and babies may also be prone to develop severe vitamin B₁₂ deficiency, particularly if breast-fed with milk of low vitamin B₁₂ content (Specker *et al.* 1990). Many ethical vegans are aware of the need to supplement their diets with vitamin B₁₂ but intakes are often worryingly low (Sanders & Key, 1987; Sanders & Manning, 1992). Vegetarians may also need to consider supplementing their diet with the vitamin (Reddy & Sanders, 1990). Many processed foods are fortified with vitamin B₁₂ but these are not necessarily acceptable to ethical vegetarians. There is clearly a need for both vegans and vegetarians to be vigilant in avoiding dietary vitamin B₁₂ deficiency. There are also other ramifications of a low intake of vitamin B₁₂. Chanarin & Stephenson (1988) have reported a link between dietary and non-dietary vitamin B₁₂ deficiency and susceptibility to tuberculosis. There are also implications for the elderly population where intrinsic factor deficiency is more common. Lower stores of vitamin B₁₂ as would result from decreased meat intake, would mean more rapid development of pernicious anaemia.

Rickets and osteomalacia

Modifiers of Ca absorption such as phytic acid contributed by unrefined cereals, particularly in chapattis (unleavened breads), have been implicated in the causation of 'Asian rickets', possibly by stimulating parathyroid hormone production which increases the catabolism of vitamin D. A high prevalence of rickets has also been noted in children, predominantly vegetarians (Dagnelie *et al.* 1990), reared on macrobiotic diets and in Rastafarian vegans (Ward *et al.* 1982). However, rickets is not a problem in Adventist vegetarians and vegans. It seems likely that the high phytate content of the macrobiotic diet is a contributory factor, as it is with 'Asian rickets'.

Taurine

Meat is a rich source of taurine. Taurine is thought to be an essential nutrient in the newborn where the capacity to synthesize it from cysteine is limited. Rana & Sanders (1986) found lower rates of urinary excretion of taurine in vegan women than in meat-eaters and markedly lower concentrations of taurine in breast-milk from vegans. However, the concentration of taurine was still considerably greater than in bovine milk formula.

n-3 Fatty acids

DHA is believed to play an important role in the retina and in the central nervous system. Lower levels of DHA (about 30% less) have been found in both plasma and cord artery phospholipids from vegetarians compared with omnivores (Sanders & Reddy, 1992). This is not unexpected as lower proportions of these fatty acids are found in the plasma phospholipids of adult vegetarians. Even lower levels of DHA (about 66% less) were found in the milk of vegan mothers compared with omnivore controls. The erythrocyte lipids of infants born to vegan mothers and breast-fed contained one-third of the proportion of DHA compared with infants breast-fed by omnivore mothers and half the level compared with infants fed on cow's-milk formula (Sanders & Reddy, 1992). Recent studies have shown that formula-fed infants show abnormalities in visual and cortical functions that are related to the absence of DHA from the formula (Birch *et al.* 1993). It is possible that vegan and some vegetarian diets may have subtle effects on visual function. Animal studies suggest that the proportion of DHA in erythrocyte lipids is reflected in brain lipids. However, it is possible that the DHA in the breast-milk of vegans or vegetarians is preferentially taken up by the brain. More research in this area is required before any firm conclusions can be drawn.

PREGNANCY

The duration of pregnancy is approximately 4–5 d shorter for Hindu vegetarians and earlier onset of labour and Caesarian section are more common than for the white population in the UK. Babies born to Hindus are lighter than those born to Muslim or white women even when adjustments are made for gestational age and maternal frame size (McFadyen *et al.* 1984). We have recently confirmed the shorter duration of pregnancy and that birth weight, head circumference and length are all lower for the Hindu vegetarians even after correction for gestational age, sex of infant, parity, smoking habits, maternal age and height (Reddy *et al.* 1994). The mean adjusted birth weight was 240 g lower for the Hindu vegetarians than that for the non-vegetarian white population. Lower birth weights have also been reported for white communities consuming macrobiotic diets and for vegans (Sanders & Reddy, 1992). The lower birth weight does not appear to be related to differences in essential fatty acid status. It is possible that the lower birth weight for these vegetarian women is related to poor nutritional status with regard to Fe or folate and/or vitamin B₁₂. The pathophysiological significance of a slightly lower birth weight is uncertain. However, Barker *et al.* (1993) argue that a lower birth weight and head circumference increase the risks of developing cardiovascular disease in later life.

INFLUENCE OF A MEATLESS DIET ON GROWTH AND DEVELOPMENT

Widdowson & McCance (1954) in their classic experiment carried out at the end of World War II clearly demonstrated that children will grow and develop quite normally on a diet consisting of plenty of bread and vegetables with minimal amounts of milk and meat. The growth of the white Seventh-Day Adventist vegetarian population appears virtually indistinguishable from that of white omnivores (Sabate *et al.* 1991) except for a later age of menarche. Lower rates of growth particularly in the first 5 years of life have been reported for children reared on vegan (Sanders & Manning, 1992) and macrobiotic

(Dagnelie *et al.* 1988) diets. Despite these lower rates of growth in the first few years of life, catch-up growth occurs by the age of about 10 years. Height is normal but there is still a tendency for these children to be lighter in weight-for-height than children on mixed diets. The lower rates of growth observed for some of these children under the age of 5 years can be attributed to low energy intakes. Impaired psychomotor development has been reported in previously malnourished macrobiotic infants, but a follow-up study reported higher than average intelligence quotients in older macrobiotic children (Hevens *et al.* 1992) which confirmed an earlier observation made on a different macrobiotic community. However, this may reflect the relatively high educational status of the parents.

It needs to be more widely recognized that severe nutritional deficiencies, which are extremely rare in the general population, have occurred in children reared on inappropriate vegetarian and vegan diets (Jacobs & Dwyer, 1988). With the increasing popularity of vegetarian diets and the trend for a small majority to ignore conventional nutritional wisdom, it seems inevitable that more children will fall victims to parental folly.

HEALTH OF VEGETARIANS

The interpretation of studies on the health of vegetarians is fraught with many problems. Vegetarians often differ from the general population in other respects, besides diet. For example, many ethical vegetarians are non-smokers and teetotalers; a vegetarian diet may also be adopted for health reasons. Macrobiotic vegetarians and Rastafarians often smoke cannabis. Many clues about the health effects of vegetarianism have come from the studies of members of the Seventh-Day Adventist Church. Adventists do not smoke tobacco, drink alcohol, tea or coffee. They have lower death rates from cancer and heart disease compared with the rest of the population (Snowden, 1988; Fonnebo, 1992). Fraser *et al.* (1991) showed that the lower rates of lung cancer in Adventists could be attributed to their abstinence from tobacco. However, they also found an independent protective effect of fruit and vegetable consumption. Other religious groups such as Mormons, who also abstain from tobacco, alcohol, tea and coffee, but who are not vegetarians show similarly lower rates of death from cancer and heart disease (Lyon *et al.* 1976). This implies that much of the protection is associated with factors other than the avoidance of meat.

Clinical studies on the general health of white vegetarians and vegans have failed to show that they are less healthy than non-vegetarians. Vegetarians are less prone to gallstones (Pixley *et al.* 1985) and diverticular disease (Gear *et al.* 1979) than the general population. However, these differences have been attributed to their high intake of complex carbohydrates and fibre rather than the absence of meat from their diets. Vegetarians, and particularly vegans, tend to be lighter in weight than non-vegetarians and this is related to a lower proportion of body fat (Sanders *et al.* 1978*b*). However, this generalization is not true of Asian vegetarians in the UK, where there is a tendency for centripetal obesity (Reddy & Sanders, 1992).

Coronary heart disease

It is commonly held that a high intake of red meat is associated with an increased risk of coronary heart disease (CHD). Indeed, a study of Seventh-Day Adventists found that

the rate of CHD increased with increasing meat intake (Snowden, 1988). A recent study from Finland has also shown an association between plasma ferritin and CHD (Salonen *et al.* 1992). Mortality and morbidity from CHD are generally lower for white vegetarians than for non-vegetarians (Burr & Butland, 1988; Snowden, 1988; Chang-Claude & Frentzel-Beyme, 1993), especially among men. This has recently been confirmed by a large prospective study carried out by the Oxford group (M. Thorogood, personal communication). However, the extent to which lifestyle factors other than diet, such as smoking habits and exercise, contribute to their lower susceptibility is difficult to quantify. In contrast to the findings for white vegetarian groups, both morbidity and mortality from coronary disease appear to be above average in the Asian vegetarian population of the UK (Reddy & Sanders, 1992).

The absence of meat from the diet may lead to only a slight reduction in the intake of saturated fatty acids as many vegetarians consume slightly higher amounts of dairy products which contain a high proportion of saturated fatty acids. Vegans who avoid both meat and dairy products have very low intakes of saturated fatty acids and it is not surprising that their plasma cholesterol concentrations are much lower than those of either vegetarians or non-vegetarians (Sanders *et al.* 1978*b*; Roshanai & Sanders, 1984), while those of vegetarians are similar or intermediate between those of vegans and non-vegetarians (Burr *et al.* 1981; Thorogood *et al.* 1987). The differences in total plasma cholesterol concentrations are mainly a consequence of lower low-density lipoprotein (LDL)-cholesterol concentrations. However, lower concentrations of high-density lipoprotein (HDL)-cholesterol have been reported in Asian vegetarians (Reddy & Sanders, 1992). Plasma antioxidant concentrations such as tocopherol, β -carotene and ubiquinone are generally higher in vegans and vegetarians than in omnivores (Pronczuk *et al.* 1992; Reddy & Sanders, 1992; Sanders & Roshani, 1992; Prasad *et al.* 1993). These may help protect against oxidative modification of LDL, a process currently believed to be important in the atherogenesis.

Lower levels of certain clotting factors (II, V, VII and X) and higher levels of antithrombin III and fibrinolytic activity have been reported for vegans and vegetarians (Haines *et al.* 1980). The lower level of factor VIIc may be related to slightly lower fat intakes. Most, but not all, studies have found the systolic and diastolic blood pressure to be lower for Caucasian vegetarians than for the general population (Armstrong *et al.* 1979; Haines *et al.* 1980; Sanders & Key, 1987). The addition of meat to a vegetarian diet does not lead to an increase in blood pressure but the change from meat eating to a vegetarian diet resulted in a modest fall in both systolic and diastolic pressure (Margetts *et al.* 1986). The reduction in blood pressure has been attributed to an increased K:Na value in the vegetarian diet. However, many of the studies that show differences in blood pressure also show differences in body weight, which is well-known to be related to blood pressure.

Breast cancer

Meat consumption is strongly correlated with breast cancer in between-country and in some case-control studies (Lee *et al.* 1991). Elevated plasma oestradiol concentrations are believed to be associated with breast cancer risk. Some studies have found that vegetarian women have lower plasma oestradiol concentrations. In vegetarians menarche occurs later and menopause occurs at an earlier age. These are factors that would argue in favour of a decreased risk of breast cancer among vegetarians. Indeed,

Adventist women have lower rates of breast cancer than the general population (Mills *et al.* 1989). However, there are no differences in breast cancer mortality rates between vegetarian and non-vegetarian Adventists. Obesity is associated with high circulating oestrogen concentrations and is a known risk factor for postmenopausal breast cancer. The lower breast cancer rates in Adventists, which occurs predominantly among postmenopausal women, is associated with the lower prevalence of obesity compared with the general population rather than with avoidance of meat (Mills *et al.* 1989).

Colon cancer

International comparisons show a strong relationship between the consumption of meat and colorectal cancer. A large prospective study in American nurses also found the intake of meat to be associated with increased risk of colon cancer (Willet *et al.* 1990). It has been argued that high concentrations of faecal steroids are associated with increased risk of colon cancer (Thompson, 1985). Faecal steroid concentrations are influenced by a number of factors: the dietary intake of fat and cholesterol, the gut microflora and the intake of complex carbohydrates. Meat-eaters have higher faecal concentrations of coprostanol and secondary bile acids than vegetarians (Turjman *et al.* 1984; Reddy, 1991). Lower rates of colon cancer have been reported in Seventh-Day Adventist and other vegetarian groups (Jensen, 1983; Snowden, 1988). However, the association between meat intake and colon cancer is still unclear, as other religious groups such as Mormons, who consume meat, have a lower incidence of colon cancer compared with the general population (Enstrom, 1975).

CONCLUSION

It needs to be acknowledged that there are good and bad vegetarian diets and that it is probably easier to select a balanced diet containing meat than one without it. Problems of dietary inadequacy are most likely to occur in children and women of reproductive age rather than in men and postmenopausal women. Several hazards of vegetarian diets have been identified, these include: Fe-deficiency anaemia; vitamin B₁₂ deficiency; rickets and a bulky diet that can restrict energy intake in the first few years of life. However, these known pitfalls are easily avoided. While the general health and development appears to be normal in vegetarians there may be subtle differences compared with omnivores. In conclusion, a diet devoid of meat does not pose any specific hazards to health providing it is sensibly selected. The high intakes of fibre, complex carbohydrates and antioxidant nutrients provided by many vegetarian diets may offer some advantages to health. However, there is little evidence that the avoidance of meat has health benefits especially among young women who are those most likely to avoid 'red' meat.

REFERENCES

- Anderson, B. M., Gibson, R. S. & Sabry, J. H. (1981). The iron and zinc status of long term vegetarian women. *American Journal of Clinical Nutrition* **34**, 1042–1049.
- Armstrong, B. K., Clarke, H., Martin, C., Ward, W., Norman, N. & Masarei, J. (1979). Urinary sodium and blood pressure in vegetarians. *American Journal of Clinical Nutrition* **32**, 2472–2476.
- Armstrong, B. K., Davis, R. E., Nicol, D. J., van Merwick, A. J. & Larwood, C. J. (1974). Haematological, vitamin B₁₂ and folate studies on Seventh-Day Adventist vegetarians. *American Journal of Clinical Nutrition* **27**, 712–718.

- Barker, D. J., Osmond, C., Simmonds, S. J. & Wield, G. A. (1993). The relation of small head circumference and thinness at birth to death from cardiovascular disease in adult life. *British Medical Journal* **306**, 422–426.
- Birch, E., Birch, D., Hoffman, D., Hale, L., Everett, C. O. & Uauy, R. (1993). Breast-feeding and optimal visual development. *Journal of Pediatric Ophthalmology and Strabismus* **30**, 33–38.
- Burr, M. L., Bates, C. J., Fehily, A. M. & St Leger, A. S. (1981). Plasma cholesterol and blood pressure in vegetarians. *Journal of Human Nutrition* **35**, 437–441.
- Burr, M. L. & Butland, B. K. (1988). Heart disease in British vegetarians. *American Journal of Clinical Nutrition* **48**, 830–832.
- Campbell, M., Lofters, W. S. & Gibbs, W. N. (1982). Rastafarianism and the vegans syndrome. *British Medical Journal* **285**, 1617–1618.
- Cathro, J. (1991). Consumer attitudes and market developments in vegetarian products. *Vegetarian Foods – A Green Future, Conference/Workshop* no. T330. Leatherhead: Food Research Association.
- Chanarin, I., Malkowska, V., O'Hara, A. M., Rinsler, M. G. & Price, A. B. (1985). Megaloblastic anaemia in a vegetarian Hindu community. *Lancet* **ii**, 1168–1172.
- Chanarin, I. & Stephenson, E. (1988). Vegetarian diet and cobalamin deficiency: their association with tuberculosis. *Journal of Clinical Pathology* **41**, 759–762.
- Chang-Claude, J. & Frentzel-Beyme, R. (1993). Dietary and lifestyle determinants of mortality among German vegetarians. *International Journal of Epidemiology* **22**, 228–236.
- Dagnelie, P. C., van Staveren, W. A., van Klaveren, J. D. & Burema, J. (1988). Do children on macrobiotic diets show catch-up growth? *European Journal of Clinical Nutrition* **42**, 1007–1016.
- Dagnelie, P. C., van Staveren, W. A., Vergote, F. J. V. R. A., Dingjan, P. G., van den Berg, H. & Hautvast, J. G. A. J. (1989). Increased risk of vitamin B₁₂ and iron deficiency in infants on macrobiotic diets. *American Journal of Clinical Nutrition* **50**, 818–824.
- Dagnelie, P. C., Vergote, F. J. V. R. A., van Staveren, W. A., van den Berg, H., Dingjan, P. G. & Hautvast, J. G. A. J. (1990). High prevalence of rickets in infants on macrobiotic diets. *American Journal of Clinical Nutrition* **51**, 202–208.
- Draper, A., Lewis, J., Malhotra, N. & Wheeler, E. (1993). The energy and nutrient intake of different types of vegetarian: a case for supplements? *British Journal of Nutrition* **69**, 3–19.
- Enstrom, J. E. (1975). Colo-rectal cancer and consumption of beef and fat. *British Journal of Cancer* **32**, 432–439.
- Fonnebo, V. (1992). Mortality in Norwegian Seventh-day Adventists 1962–1986. *Journal of Clinical Epidemiology* **45**, 157–167.
- Fraser, G. E., Beeson, W. L. & Phillips, R. L. (1991). Diet and lung cancer in California Seventh-day Adventists. *American Journal of Epidemiology* **133**, 683–693.
- Gear, J. S. S., Mann, J. I., Thorogood, M., Carter, R. & Jeffs, R. (1980). Biochemical and haematological variables in vegetarians. *British Medical Journal* **280**, 1415.
- Gear, J. S. S., Ware, A. C., Nolan, D. J., Fursdon, P. A., Brodribb, A. J. M. & Mann, J. I. (1979). Symptomless diverticular disease and dietary fibre. *Lancet* **i**, 511–514.
- Haines, A. P., Chakrabarti, R., Fisher, D., Meade, T. W., North, W. R. S. & Stirling, Y. (1980). Haemostatic variables in vegetarians and non-vegetarians. *Thrombosis Research* **19**, 139–148.
- Hevens, M. C., Dagnelie, P. C., Kleber, R. J., Mol, M. C. J. & van Staveren, W. A. (1992). Nutrition and mental development of 4–5 year old children on macrobiotic diets. *Journal of Human Nutrition and Dietetics* **5**, 1–10.
- Jacobs, C. & Dwyer, J. T. (1988). Vegetarian children: appropriate and inappropriate diets. *American Journal of Clinical Nutrition* **43**, Suppl. 3, 811–818.
- Jensen, O. M. (1983). Cancer risk among Danish male Seventh-Day Adventists and other temperance society members. *Journal of the National Cancer Institute* **70**, 1011–1014.
- Kim, I., Hungerford, D. W., Yip, R., Kuester, S. A., Zyrkowski, C. & Trowbridge, F. L. (1992). Pregnancy nutrition surveillance system – United States, 1979–1990. *MMWR Center for Disease Control Surveillance Summaries* (United States) **41**, 25–41.
- King, J. C., Stein, T. & Doyle, M. (1981). Effect of vegetarianism on zinc status of pregnant women. *American Journal of Clinical Nutrition* **34**, 1049–1055.
- Lee, H. P., Gourley, L., Duffy, S. W., Estene, J., Lee, J. & Day, N. E. (1991). Dietary effects on breast-cancer risk in Singapore. *Lancet* **337**, 1197–1200.
- Lyon, J. L., Klaubner, M. R., Gardner, J. W. & Smart, C. R. (1976). Cancer incidence in mormons and non-mormons in Utah, 1966–1970. *New England Journal of Medicine* **294**, 129–133.

- McFadyen, I. R., Campbell-Brown, M., Abraham, R., North, W. R. S. & Haines, A. P. (1984). Factors affecting birthweight in Hindus, Moslems and Europeans. *British Journal of Obstetrics and Gynaecology* **91**, 968–972.
- Margetts, B. M., Beilin, L. J., Vandongen, R. & Armstrong, B. K. (1986). Vegetarian diet in mild hypertension: a randomised controlled trial. *British Medical Journal* **293**, 129–133.
- Mills, P. K., Beeson, W. L., Phillips, R. L. & Fraser, G. E. (1989). Dietary habits and breast cancer incidence among Seventh-day Adventists. *Cancer* **64**, 582–590.
- Misra, H. N. & Fallowfield, J. N. (1971). Sub-acute combined degeneration of the spinal cord in a vegan. *Postgraduate Medical Journal* **47**, 624–626.
- Ohsawa, G. (1971). *Macrobiotics: An Invitation to Health and Happiness*. San Francisco: George Ohsawa Macrobiotic Foundation.
- Pixley, S., Wilson, D., McPherson, K. & Mann, J. (1985). Effect of vegetarianism on the development of gallstones in women. *British Medical Journal* **291**, 11–12.
- Prasad, K., Reddy, S. & Sanders, T. A. B. (1993). Plasma ubiquinone (Q₁₀) concentrations in female vegetarians and omnivores. *Proceedings of the Nutrition Society* **52**, 332A.
- Pronczuk, A., Kipervarg, Y. & Hayes, K. C. (1992). Vegetarians have higher plasma alpha-tocopherol relative to cholesterol than do non-vegetarians. *Journal of the American College of Nutrition* **11**, 50–55.
- Rana, S. K. & Sanders, T. A. B. (1986). Taurine concentrations in the diet, plasma, urine and breastmilk of vegans compared with omnivores. *British Journal of Nutrition* **56**, 17–27.
- Reddy, S. (1991). A comparison of the diet and health of pre-menopausal Indian and caucasian vegetarian women. PhD Thesis. University of London.
- Reddy, S. & Sanders, T. A. B. (1990). Haematological studies on pre-menopausal Indian and Caucasian vegetarians compared with Caucasian omnivores. *British Journal of Nutrition* **64**, 331–338.
- Reddy, S. & Sanders, T. A. B. (1992). Lipoprotein risk factors in vegetarian women of Indian descent are unrelated to dietary intake. *Atherosclerosis* **95**, 223–229.
- Reddy, S., Sanders, T. A. B. & Obeid, O. (1994). The influence of maternal vegetarian diet on the essential fatty acid status of the newborn. *European Journal of Clinical Nutrition* **48** (In the Press).
- Roshani, F. & Sanders, T. A. B. (1984). Assessment of fatty acid intakes in vegans and omnivores. *Human Nutrition: Applied Nutrition* **38A**, 345–354.
- Sabate, J., Lindsted, K. D., Harris, R. D. & Sanchez, A. (1991). Attained height of lacto-ovo-vegetarian children and adolescents. *European Journal of Clinical Nutrition* **45**, 51–58.
- Salonen, J. T., Nyssonen, K., Korpela, H., Tuomilehto, J., Seppanen, R. & Salonen, R. (1992). High stored iron levels are associated with excess risk of myocardial infarction in eastern Finnish men. *Circulation* **86**, 803–811.
- Sanders, T. A. B., Ellis, F. R. & Dickerson, J. W. T. (1978a). Haematological studies on vegans. *British Journal of Nutrition* **40**, 9–15.
- Sanders, T. A. B., Ellis, F. R. & Dickerson, J. W. T. (1978b). Studies of vegans: the fatty acid composition of plasma choline phosphoglycerides, erythrocytes, adipose tissue, and breast milk, and some indicators of susceptibility to ischemic heart disease in vegans and omnivore controls. *American Journal of Clinical Nutrition* **31**, 805–813.
- Sanders, T. A. B. & Key, T. J. A. (1987). Blood pressure, plasma renin activity and aldosterone concentrations in vegans and omnivore controls. *Human Nutrition: Applied Nutrition* **41A**, 101–108.
- Sanders, T. A. B. & Manning, J. (1992). The growth and development of vegan children. *Journal of Human Nutrition and Dietetics* **5**, 11–21.
- Sanders, T. A. B. & Reddy, S. (1992). The influence of a vegetarian diet on the fatty acid composition of human milk and essential fatty acid status of the infant. *Journal of Pediatrics* **120**, S71–S77.
- Sanders, T. A. B. & Roshanai, F. (1992). Platelet phospholipid fatty acid composition and function in vegans compared with age- and sex-matched omnivore controls. *European Journal of Clinical Nutrition* **46**, 823–831.
- Scholl, T. O., Hediger, M. L., Fischer, R. L. & Shearer, J. W. (1992). Anemia vs iron deficiency: increased risk of preterm delivery in a prospective study. *American Journal of Clinical Nutrition* **55**, 985–988.
- Snowden, D. A. (1988). Animal product consumption and mortality because of all causes combined, coronary heart disease, stroke, diabetes, and cancer in Seventh Day Adventists. *American Journal of Clinical Nutrition* **48**, 739–748.
- Specker, B. L., Black, A., Allen, L. & Morrow, F. (1990). Vitamin B₁₂: low milk concentrations are related to low serum concentrations in vegetarian women and to methylmalonic aciduria in their infants. *American Journal of Clinical Nutrition* **52**, 1073–1076.

- The Realeat Survey Office (1990). *The Realeat Survey 1984–1990. Changing Attitudes to Meat Consumption*. Altrincham: The Realeat Company Ltd, The Vegetarian Society.
- Thompson, M. H. (1985). Fecal bile acids in health and disease. In *Liver, Nutrition, and Bile Acids*, pp. 113–130 [G. Galli and E. Bosisia, editors]. London: Plenum.
- Thorogood, M., Carter, R., Benfield, L., McPherson, K. & Mann, J. I. (1987). Plasma lipids and lipoprotein cholesterol concentrations in people with different diets in Britain. *British Medical Journal* **295**, 351–353.
- Turjman, N., Goodman, G. T., Jaeger, B. & Nair, P. P. (1984). Diet, nutrition intake, and metabolism in populations at high and low risk for colon cancer. *American Journal of Clinical Nutrition* **40**, 937–941.
- Ward, P. S., Drakeford, J. P., Milton, J. & James, A. (1982). Nutritional rickets in Rastafarian children. *British Medical Journal* **285**, 1242–1243.
- Widdowson, E. M. & McCance, R. A. (1954). *Studies on the Nutritive Value of Bread and the Effect of Flour on the Growth of Undernourished Children*. MRC Special Report Series no. 287. London: H.M. Stationery Office.
- Willet, W. C., Stampfer, M. J., Colditz, G. A., Rosner, B. A. & Speizer, F. E. (1990). Relation of meat, fat and fibre intake to the risk of colon cancer in a prospective study among women. *New England Journal of Medicine* **323**, 1664–1672.