Meat or wheat for the next millennium? A Debate
Pro veg

The nutritional adequacy of plant-based diets

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The nutritional adequacy of plant-based diets is discussed. Energy and protein intakes are similar for plant-based diets compared with those containing meat. Fe and vitamin B_{12} are the nutrients most likely to be found lacking in such diets. Bioactive substances present in foods of plant origin significantly influence the bioavailability of minerals and requirements for vitamins. Well-balanced vegetarian diets are able to support normal growth and development. It is concluded that meat is an optional rather than an essential constituent of human diets.

Vegetarians: Vitamin B_{12}: Vitamin D: Nutritional requirements: Growth

The majority of the world population consumes a diet that is based on plant foods. It is only recently that meat has formed such a large proportion of the dietary intake of developed countries. Malnutrition in developing countries is classically associated with a limited dietary repertoire and overdependence on a nutritionally-inadequate staple food. People in developing countries have little choice over what they eat. However, in the developed countries, such as the UK, an increasing number of people are eschewing meat and opting for a vegetarian diet. The decision to eat meat is not just a moral and personal one, but one that has environmental, welfare and economic implications. Several health arguments have been advanced for reducing total meat consumption such as the associations between high intakes of meat and animal fat and the risks of cancer and heart disease. When considering the hazards posed by food to health, it is important to remember that meat can be a vector for food-borne disease. Most food-borne disease in developed countries is transmitted via meat, eggs, shellfish and milk. If global meat consumption was to rise to the level currently consumed in developed countries, this is only likely to be achieved through the use of intensive methods of animal production, which are intrinsically more hazardous. The intensive methods used in poultry production are probably responsible for the current Salmonella epidemic affecting the UK and the USA (Hogue *et al.* 1997). The use of antibiotics as growth promoters may partially explain the emergence of multi-drug-resistant strains of pathogenic bacteria (Glynn *et al.* 1998). The sewage sludge generated from intensive poultry and meat production may be an important source of the spread of antibiotic-resistance genes. The recent centralization of food processing and distribution increases the potential to spread zoonotic disease, as hopefully has been learnt from the bovine spongiform encephalopathy epidemic (Johnson & Gibbs, 1998). Animal welfare and the ethical issues surrounding the conditions under which food animals are reared also deserve consideration. However, the present paper will focus on the nutritional adequacy of plant-based diets, and will provide evidence to reject the hypothesis that meat is an essential constituent of human diets.

Types of meatless diets

Meat, for the purpose of the present paper, is defined as being the flesh of animals, including fish. Vegetarians will be referred to as those who exclude meat, and vegans as those who exclude all food of animal origin. These definitions are based on the exclusion of animal products, whereas the nutritional quality of a diet is a product of the quantity and quality of the foods included. Dietary inadequacy can occur because of a bulky diet that fails to provide an adequate energy intake, or because the diet consists of a limited variety of nutritious foods. This situation often occurs in

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developing countries where there is overdependence on a staple food of limited nutritional value, e.g. maize or cassava (*Manihot esculenta*). However, in developed countries the opposite is true, as vegetarians often consume a wider variety of foods than meat-eaters and are more likely to consume unrefined carbohydrate foods, salads, fruit, nuts and pulses on a regular basis. Consequently, the intakes of several nutrients, notably thiamin, folate, vitamin C, carotene, potassium and vitamin E, are higher among vegetarians than in the general population. Most studies of adult vegans and vegetarians living in the UK, Europe and North America show that they have similar energy intakes compared with omnivores (Reddy & Sanders, 1992; Sanders & Roshanai, 1992; Draper *et al*. 1993; Sanders, 1995; Nathan *et al*. 1996). The relative amount of energy derived from protein is generally slightly lower but adequate at about 12 % energy, and that from complex carbohydrates is greater. Sugar intakes are similar to those in omnivores. Fat intake, particularly that of saturated fatty acids, tends to be lower, but the intake of linoleic acid tends to be greater. Fibre intakes are usually considerably greater in vegetarians, and especially vegans, owing to their preference for unrefined cereals.

While strict vegetarian or vegan diets may offer certain advantages to the health of adults, in view of their low saturated fat and high fibre contents, their adequacy for children has been controversial. There have been several reports of severe protein–energy malnutrition in infants and toddlers fed on inappropriate vegetarian diets, as well as deficiencies of Fe, vitamins B_{12} and D (Roberts *et al*. 1979; Jacobs & Dwyer, 1988; Dagnelie *et al*. 1989; Kuhne *et al*. 1991; Lovblad *et al*. 1997). However, as shall be discussed, there is good evidence that children can be successfully reared on vegetarian and even vegan diets providing sufficient care is taken. However, among children under the age of 5 years, energy intakes may be restricted by the bulk of food on plant-based diets. This deficit in energy is easily rectified by increasing the intake of dietary fat and by selecting more-energy-dense foods.

It is generally accepted that in economically-developed countries diets devoid of meat are 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. Meat and fish are important sources of protein, vitamin A, I, Fe, Zn, vitamin B_{12}, Se, taurine, and long-chain polyunsaturated fatty acids. The nutritional issue is whether these nutrients can be supplied by foods acceptable to vegetarians.

Protein

Protein intakes are slightly lower in vegetarians than in meat-eaters. However, these intakes support N balance. Although plant proteins have a lower biological value than meat, the protein quality of vegetarian diets differs little from that of diets containing meat, as the constituent amino acids in the different plant proteins mutually complement each other. Many legumes contain protease inhibitors that can decrease the digestibility of protein. However, these inhibitors are inactivated by heat treatment. Meat is also 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 compared with meat-eaters, and markedly lower concentrations of taurine in breast-milk from vegans. However, the concentration of taurine was still considerably greater than that in unsupplemented breast-milk substitute.

Iron

Vegetarians are probably more prone to Fe-deficiency anaemia because of their low Fe stores (Dagnelie *et al*. 1989; Reddy & Sanders, 1990; Donovan & Gibson, 1995). 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 (Sanders, 1995). An increased prevalence of Fe deficiency was reported in macrobiotic vegetarians who consume brown rice, which is rich in phytates, as their staple food (Dagnelie *et al*. 1989). Haemoglobin concentrations are generally normal in both Seventh-Day Adventist vegetarians (Armstrong *et al*. 1974) and white UK vegans and vegetarians (Sanders *et al*. 1978; Reddy & Sanders, 1990) who consume wheat bread as their staple food (the leavening of bread with yeast breaks down phytates). Fe absorption can be enhanced by the coingestion of vitamin C with meals containing a plant source of Fe, and by avoiding the coingestion of inhibitors of absorption such as tannins in tea.

Vitamin A

Liver is a significant source of retinol in the British diet, but retinol is not required in the diet as it can be synthesized from β-carotene which is abundant in green and orange fruits and vegetables. However, the bioavailability of β-carotene from foods is variable and depends on the food matrix within which it is consumed (de Pee & West, 1996). An increased intake of dark-green vegetables did not improve vitamin A status in vitamin A-deficient women in Indonesia, but a biscuit containing β-carotene dissolved in oil was effective (de Pee *et al*. 1995). However, in developed countries plasma retinol concentrations are normal in vegans and vegetarians, but plasma carotene concentrations tend to be elevated compared with the general population (Sanders & Roshanai, 1992).

Vitamin D

Vitamin D has been found to be present in meat in the form 25-hydroxycholecalciferol. Meat probably provides about 1 µg/d in the average diet. However, there are richer alternative sources such as oily fish, margarine, fortified breakfast cereal and sunlight. 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' (Dunnigan & Henderson, 1997). A high prevalence of rickets was noted in children reared on macrobiotic vegetarian diets (Dwyer *et al*. 1979; Dagnelie *et al*.

1990). However, rickets does not appear to be a problem in Adventist vegetarians and white vegetarians in the UK. It seems likely that the high phytate content of the macrobiotic diet is the major causative factor in conjunction with a low Ca intake and vitamin D status, as with Asian rickets.

Vitamin B_{12}

Cases of dietary vitamin B_{12} deficiency in both white vegans and vegetarians have occasionally been reported (Herbert, 1994). White vegans and vegetarians tend to present with neurological signs of deficiency because of their high intakes of folic acid, which masks the megaloblastic anaemia of vitamin B_{12} deficiency. Although many foods are supplemented with vitamin B_{12}, these foods may not be consumed by vegetarians. Consequently, the true prevalence of vitamin B_{12} deficiency in the UK vegetarian population is uncertain. The incidence of megaloblastic anaemia resulting from combined vitamin B_{12} 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 B_{12} deficiency, particularly if breast-fed with milk of low vitamin B_{12} content, leading to persistent neurological deficits (Grattan-Smith et al. 1997). Non-meat-eaters have low intakes of vitamin B_{12} and are at greater risk of developing deficiency, and they may also present with pernicious anaemia at an earlier age. Vitamin B_{12} is derived mainly from meat, but is found in much higher amounts in fish. It is not necessary to eat large amounts of meat or fish to meet vitamin B_{12} requirements, as little as 30 g meat or 10 g fish meets the UK reference nutrient intake of 1·5 µg/d (Department of Health, 1991). Vitamin B_{12} is unique among the vitamins in that it is derived exclusively from microbial synthesis. In developing countries, faecal contamination of water supplies may contribute to dietary intake. In developed countries many foods are fortified with vitamin B_{12}, particularly meat-substitutes, yeast extracts such as Marmite (CPC (UK) Ltd, Esher, Surrey) and breakfast cereals. Providing these foods are consumed regularly, the hazard of vitamin B_{12} deficiency is easily avoided. There is clearly a need for both vegans and vegetarians to be vigilant in avoiding dietary vitamin B_{12} deficiency. Vitamin B_{12} deficiency may also be precipitated or exacerbated by exposure to cyanide through cyanogenic glycosides in plant foods. The recent epidemic of optic nerve neuropathy in Cuba has been attributed to poor vitamin B_{12} status, resulting from a fall in meat consumption, coupled with an increased intake of cyanide from improperly-processed cassava root (Sadun et al. 1994).

n-3 Fatty acids

Docosahexaenoic acid (22 : 6n-3; DHA) is believed to play an important role in the retina and in the central nervous system. Lower proportions of DHA have been found in both plasma and cord artery phospholipids of vegetarians compared with omnivores (Reddy et al. 1994). This finding is not unexpected, as lower proportions of these fatty acids are found in the plasma phospholipids of adult vegetarians. Lower levels of DHA were also found in the milk of vegan mothers compared with omnivore controls, and the erythrocyte lipids of the infants also contained a lower proportion of DHA than those of infants breast-fed by omnivorous mothers or those of infants bottle-fed on cow's milk formula (Sanders & Reddy, 1992). Recent studies have shown that both term and preterm infants deprived of DHA also show abnormalities in visual and cortical functions. It is uncertain whether the size of changes reported in vegans and vegetarians are sufficient to result in significant changes in physiological functioning.

Pregnancy

The duration of pregnancy is approximately 4–5 d shorter in Hindu vegetarians, and earlier onset of labour and Caesarian section are more common than in the white population in the UK even after correction for gestational age, sex of infant, parity, smoking habits, maternal age and height (McFadyen et al. 1984; Reddy et al. 1994). Lower birth weights have also been reported in white communities consuming macrobiotic diets and in white vegans (Sanders, 1995). It is possible that the lower birth weight in these women is related to poor nutritional status with regard to Fe or folate and/or vitamin B_{12}. However, birth weights are similar in vegetarians compared with omnivores in the UK (R Drake, personal communication).

Growth and development

At the end of the Second World War, Widdowson & McCance (1954) showed that children could grow normally on diets containing plenty of wheat with minimal amounts of meat. The growth and development of white lacto-vegetarian populations in developed countries appears virtually indistinguishable from that of white omnivores (Tayter & Stanek, 1989; Sabate et al. 1991; Nathan et al. 1996, 1997). Lower rates of growth, particularly in the first 5 years of life, have been reported in children reared on vegan (Sanders & Manning, 1992) and macrobiotic 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 (Van Dusseldorp et al. 1996). 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 in some of these children under the age of 5 years can be attributed to low energy intakes. A later age of menarche has indeed been noted in Seventh-Day Adventist vegetarian girls (Sabate et al. 1991).

Conclusion

Vegetarian diets as consumed in developed countries differ little in terms of nutrient composition from diets containing meat in developing countries. However, in developing countries where the choice of foods is more restricted, nutritional deficiencies are more likely, particularly those of

Fe and vitamin B_{12}. In isolated areas where soil levels of Se and I are low, Se deficiency and goitre are also more likely to occur on plant-based diets. Thus, plant-based diets are nutritionally adequate providing they are not restricted in variety or quality. Furthermore, care needs to be taken to ensure that plant foods are adequately processed to inactivate anti-nutritive substances such as phytates, trypsin inhibitors and cyanogenic glycosides. In conclusion, meat is an optional rather than an essential constituent of human diets.

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