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NUTRITIONAL CONSEQUENCES OF VEGETARIANISM

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INTRODUCTION AND SCOPE

Scope

This review briefly discusses vegetarianism, which often is not only a way of eating but a reflection of a philosophy of life. Health aspects of vegetarianism are considered. Vegetarian, semi-vegetarian, and omnivorous eating styles that foster healthful food consumption practices are summarized. Of particular concern is how life-style, in addition to adequacy and type of diet, influences health. Particular attention is paid to the importance of dietary planning, especially for iron, calcium, zinc, vitamins B_{12}, D, and folic acid, to avoid low intakes of these nutrients. The role of vegetarian diets in disease treatment is considered. The association of vegetarianism with reduced risk factors for chronic degenerative diseases is discussed and recent studies are reviewed. The particular nutritional consequences of vegetarian diets at each stage in the life cycle are considered, with special emphasis on the risks and benefits. The article concludes with dietary advice and practical principles for diet and health counseling.

Definitions

A semi-vegetarian or partial vegetarian diet includes some but not all animal foods and usually excludes red meat. A lacto-ovo-vegetarian diet excludes meat, poultry, fish, and a lacto-vegetarian diet also excludes eggs. Other patterns range from partial to total avoidance of one or more of these animal foods and also of other foods in the diet that are mentioned later. A strict vegetarian, or vegan, diet specifically excludes all foods of and, in some cases, even products of animal origin: meat, poultry, fish, eggs, milk, and milk products. From the standpoint of nutrient profiles, dietary patterns such as the Zen macrobiotic diet, which do not totally exclude but very strictly limit animal foods, have virtually the same problems in achieving sufficiency as those found in completely vegan patterns.

HISTORY OF VEGETARIANISM: MYTHS AND REALITIES

The idea of a diet composed only of plant foods dates back to ancient times, although the word vegetarian was coined only a few centuries ago. All of the major world religions have sects within them that advocate vegetarian diets for spiritual reasons. Today, many Americans eat vegetarian diets because of a complex set of philosophical, ecological, and health concerns rather than because of religious beliefs alone (35, 44, 118, 119).

HEALTH ASPECTS OF VEGETARIANISM

Many types of diets, including but not limited to, vegetarian patterns, can be healthful (101). But the notion that by returning to plant-based diets the human race will attain spiritual innocence and perfect health persists and seems to attract many adherents. In fact, the nutritional and health consequences of vegetarian diets are neither necessarily all good nor all bad. The ultimate balance that vegetarian diets strike with respect to health depends on the extent to which they are integrated with current knowledge of nutritional science in dietary planning.

The Range of Eating Styles Compatible with Health

Current health guidelines recommend eating patterns that maintain appropriate body weight, reduce intakes of total fat, saturated fat, cholesterol, sodium, and fermentable carbohydrate, and increase consumption of calcium, dietary fiber, and iron (in certain subgroups) (17, 125, 126, 128). The *Year 2000 Goals* for promoting health and preventing disease in the nation, recently issued by the US Department of Health and Human Services, also emphasize the same general objectives (126). None of these dietary recommendations suggest that vegetarian diets are either necessary or especially desirable for health. To achieve health objectives they stress moderation and informed choice rather than elimination of all animal foods. New patterns of eating can be accomplished without abandonment of any particular food group.

These documents stress reductions in the type and amount of fat intake. They recommend that 30% or less of energy intake come from fat, that 10% or less of calories come from saturated fat, and not more than 10% from polyunsaturated fat, with the rest of fat calories coming from monounsaturates. They recommend that cholesterol intake be limited to not more than 300 mg per day. At present, individuals consuming vegetarian and, especially, vegan diets usually come closer to achieving the recommended dietary patterns in these respects than do omnivores (33, 82). American (omnivorous) adults currently eat diets in which 13% of kilocalories are derived from saturated fatty acids, 36–37% of kilocalories from fat, 7% from polyunsaturated fatty acids, and 14% from monounsaturated fatty acids. Dietary cholesterol intake per day ranges from an average of 204 mg for women to 435 mg for men. These differences between recommended and actual intakes have led some to assume that everyone should follow vegetarian diets because they more closely approximate the health objectives.

What is often not appreciated, however, is that these dietary goals can be met without eliminating specific foods or food groups. In fact, it is possible to reduce the fat content of menus, similar to typical US diets, from 40% of total kilocalories to approximately 25% of kilocalories without affecting usual intakes of meats, milk and milk products, fish, and eggs (30). Studies have shown that as the amount of fat decreased, carbohydrates in the form of grains, fruits, and vegetables increased, thus improving both the vitamin and mineral content of the diet. Intake of vitamin C, thiamin, riboflavin, niacin, vitamins B_6 and B_{12}, and folates increased in the 25% fat diet. Potassium, calcium, magnesium, phosphorus, iron, zinc, and copper intakes also increased when the dietary fat decreased. However, these changes were accomplished under metabolic ward conditions. The challenge facing nutrition scientists, health workers, nutrition educators, and the food industry today is to find strategies for implementing these dietary guidelines and achieving these goals in everyday situations in which individuals make their own free choices of foods.

DIETARY INADEQUACIES THAT MAY ARISE ON VEGETARIAN DIETS

Iron Deficiency Anemia

The two forms of dietary iron are the highly bioavailable heme iron, from cellular animal tissue, which is absorbed with iron still locked within the porphyrin molecule; and nonheme iron. Nonheme iron is usually less well absorbed than heme iron and is more dependent upon factors within the intestinal lumen and factors in the meal that enhance or inhibit absorption. Chelates of nonheme iron such as amino acids, ascorbic acid, citric acid, and hydrochloric acid enhance nonheme iron absorption. The so-called meat factor increases absorption of nonheme iron when meat, fish, or poultry are eaten in the same meal with it (94). Among vegetarians, who often have a limited intake of heme iron, the effect of vitamin C–containing foods on improving the absorption of nonheme iron may be particularly important (55). Intakes of vitamin C of 25–75 mg or more enhance the intestinal absorption of dietary nonheme iron by two- to fourfold (18, 108). According to Monsen (94) a gram of meat, fish, or poultry is roughly equal to 1 mg of ascorbic acid in its ability to enhance absorption of nonheme iron, and the effects of meat and ascorbic acid are both individually very effective. The Recommended Dietary Allowances (19) base iron recommendations on a reference adult who consumes one to three ounces of meat, fish, or poultry and 75 mg ascorbic acid daily; those who do not do so may need more iron in their diets.

Nonheme iron chelates that are insoluble or tightly bound include phytates, tannins, and phosphates, all commonly present in plant food diets. These can play an inhibitory role in iron absorption (94). Phytates are commonly found in whole grains, bran, and soy products, and have strong inhibitory effects (62). Oxalates, which are organic acids present in spinach, rhubarb, chocolate, and the food additive EDTA (ethylenediamine-tetracetic acid, which is used to chelate heavy metals in foods) also form insoluble complexes with iron and inhibit absorption (94). It is also possible, but not yet entirely clear, that calcium and phosphorus have small negative effects on iron absorption, particularly if they are present together (27). The effects of milk and milk products together with iron absorption enhancers are not so clear. Some forms of dietary fiber may also inhibit iron absorption among vegetarians. Other compounds, including tannins in tea and polyphenols in coffee, red wine, sorghum, and spinach, inhibit nonheme iron absorption by complexing with it (57, 95).

Vegetarians are currently advised to consume plant foods that are rich in nonheme iron sources and low in inhibiting substances that decrease the absorption of nonheme iron. They should include in their diets foods rich in ascorbic acid and other enhancers of iron absorption, small amounts of muscle foods (if acceptable), and foods rich in amino acids such as cysteine (including milk and eggs).

Megaloblastic Anemias Due to Vitamin B_{12} and Folic Acid Deficiencies

Deficiencies of vitamin B_{12} and folic acid are usually considered together because they both give rise to a megaloblastic anemia, although only deficiency of vitamin B_{12} produces inadequate synthesis of the lipoprotein myelin, which in turn results in neurologic damage. Unfortunately, the degree of neurological damage does not correlate well with the degree of anemia that is apparent clinically, and this relationship is further complicated by the level of folic acid in the diet. High folic acid intakes temporarily mask the development of anemia. Among those who eat high amounts of folic acid in their diets, as is the case with many vegetarians and others on unusual diets who eat large amounts of fresh leafy vegetables, the development of hematologic damage may be retarded while the neurologic damage that is due to B_{12} deficiency progresses unabated and undiscovered (67). For this reason, anticipatory guidance of vegetarians is most important; by the time anemia due to B_{12} deficiency is present, serious and irreversible damage to the central nervous system may have already occurred.

Vitamin B_{12} is present in substantial amounts only in animal foods. Its deficiency is a matter of concern in diets that are partially or totally devoid of animal foods. The development of the deficiency is a four-stage process. It is not until the third stage that metabolic derangement is sufficient to cause altered erythropoiesis, and it is unknown when neurological pathology begins to occur. In stage four the clinical damage and vitamin B_{12} deficiency anemia are clearly apparent, along with myelin damage in peripheral nerves, the spinal cord, and finally in the brain itself (66). The rarest but most serious form of the deficiency is patchy, diffuse, progressive demylelination with an insidious and progressive neuropathy that results from vitamin B_{12} deficiency. This disorder is variously referred to as subacute combined degeneration of the cord, or combined system disease of the spinal cord, or, if it progresses to the brain, megaloblastic madness.

Vitamin B_{12} is synthesized by bacteria, fungi, and algae but not by yeasts, higher plants, or animals. Occasional contamination of soil or water with microbes that produce vitamin B_{12} occurs, but plant foods are usually devoid of the active form of the vitamin and cannot be relied upon as a dietary source. Microbiologically active noncobalamin corrinoids do not have vitamin B_{12} activity in humans, and yet the microbiological assay used to determine the content of vitamin B_{12} in foods is now known to include them. When differential radioassays separate out the substances with biological activity in humans, large amounts of these substances are found, with the result that food sources of vitamin B_{12} are often seriously overestimated when only the microbiological assay using *Lactobacillus leichmannii* is used. Because such a microbiological assay is still utilized by the USP (United States Pharmacopeia) method, a good deal of confusion exists in the minds of many vegetarians and others about how much vitamin B_{12} is supplied by plant sources. Label claims are actually for corrinoids, not for the form of vitamin B_{12} that is active in humans (65). Previously it was thought that yeasts grown on vitamin B_{12}–enriched media provided the vitamin. Recently it was discovered that biologically active vitamin B_{12} is present only when the vitamin B_{12} enriching medium and the yeast are both eaten; the yeast itself produces only corrinoids that have no biological activity in humans (65). Also, fermented soy products such as tempeh contain many corrinoids but do not contain substantial amounts of vitamin B_{12} (68). Spirulina, another plant product sold in health food stores that proprietors often claim is high in vitamin B_{12}, is also composed of corrinoids with virtually no vitamin B_{12} activity. Some types of seaweed that are contaminated with adhering plankton contain small amounts of the vitamin, but this source of the vitamin is variable and unreliable. Similarly, while small amounts of vitamin B_{12} are on the nodules of certain pulses grown in India and on the roots of the rhizobium species, most of the corrinoids present are not biologically active in humans.

The major forms of the vitamin in humans are animal products in which the vitamin has accumulated from bacterial synthesis. In meats, the major forms present are the adenosyl- and hyroxy-cobalamins. In milks, the methyl and hydroxocobalamin forms predominate (46). Vitamin B_{12} in milk and milk products is adequate to meet the needs of lacto-ovo-vegetarians who have normal gastrointestinal function. However, if they develop diseases that diminish the gastric pancreatic and intestinal secretions necessary for releasing the peptide-bound form of the vitamin required for enterohepatic reabsorption, a deficiency may develop, since large amounts of the vitamin (from one to ten times the RDA) are secreted in the bile every day. Thus, although it takes 20 or more years for many adult vegans to develop a clinically evident deficiency of the vitamin, the deficiency can develop in three years or less if they have an absorption problem (63, 64, 68). Since some people suffer from pernicious anemia and other gastrointestinal disorders and about one in 100 individuals over 60 years of age has gastric atrophy, it is particularly important to be concerned about B_{12} status in older vegans and vegetarians. Boiling milk destroys much of the vitamin B_{12} it provides, and such practices have been found to destroy much of the vitamin among some groups of very strict vegetarians who consumed small amounts of milk. A small amount of vitamin B_{12} is synthesized by bacteria in the human gut, but this is insufficient to meet requirements for the vitamin, and, in any event, bacterial vitamin B_{12} is not absorbed through the human colon (2, 68). However, this bacterial B_{12} is active for humans, as was demonstrated by cures of the vitamin deficiency that were achieved by feeding vegan volunteers suffering from megaloblastic anemia water extracts of their own stools (16). It is thus possible that fecal contamination of vegetables grown on night soil (human manure) and poor hygienic practices may have added enough vitamin B_{12} to the diets of some vegans living in developing countries to slow the development of the deficiency (58).

The practical significance of these realities of food composition is that in order to achieve normal intakes of the vitamin from a diet devoid of animal foods either vitamin B_{12} supplements of approximately 1 mg per day or foods supplemented with the vitamin to that level must be provided. Pregnant and lactating women require even higher levels, and in the absence of supplementation, fetal stores and breast milk levels of the vitamin fall to dangerously low levels (110).

Folic acid deficiency and megaloblastic anemia due to it are relatively rare in this country and do not appear to be any higher among vegetarians than they are among omnivores. However, vegetarians in other countries who boil or heat their green leafy vegetables to very high temperatures may in fact be folate deficient (31, 32).

Calcium-Deficient Diets

Milk and milk products contribute more than half of all the calcium eaten in this country (12). Animal foods that contain edible bones such as sardines, salmon, and the tips of poultry leg bones are also lesser animal sources of the mineral. The reasons for concern about calcium intakes are several. There is a growing recognition that calcium nutritional status affects risk factors, particularly peak bone mass, for osteoporosis and alveolar bone loss later in life (19), and speculation that inadequate intakes may also contribute to hypertension and colorectal cancer incidence (100). Failure to meet the RDA for calcium is common among the population at large. Vegans often have low intakes of both vitamin D and calcium and have very high intakes of dietary fiber and its components, including oxalic acid (in spinach and in chocolate) and phytic acid (in wheat bran). All of these factors may inhibit calcium absorption and are thought to place vegans at particular risk of deficiency. However, protective factors also exist in vegan life-styles. Among them are physical activity, which apparently improves the efficiency of calcium utilization and bone strength (particularly if it involves weight-bearing activity). Vegans avoid prescribed medications that waste calcium, rarely use large amounts of caffeine, do not smoke, and seldom have very high protein intakes. These characteristics may mitigate the former risks to some extent (33).

Among lacto-ovo-vegetarians, calcium intakes tend to be quite high; it is only among vegans that dietary deficiencies in calcium are likely. Thus, recent studies suggest that calcium utilization is satisfactory among lacto-ovo-vegetarians (76, 78, 135).

Vitamin D, Rickets, and Osteomalacia

Vitamin D is essential in increasing the efficiency of calcium metabolism, especially when calcium intakes are low (69, 111). Exposure to sunlight, especially during certain seasons in the northern parts of the country, among those who use sunscreens, and among shut-ins, especially if they are elderly, is low enough so that sun-induced synthesis of vitamin D cannot be relied upon, and a dietary supply is needed (40, 117, 131). In the United States, milk and certain other foods are fortified with vitamin D, but vegans, who avoid all animal foods and often reject fortified foods and vitamin supplements, do not obtain vitamin D from these foods. In the absence of a dietary source of vitamin D for the infant, human milk from vegan mothers may not provide enough vitamin D to prevent rickets (51, 122), although the deficiency may take many months to develop and is unlikely among infants who are fed only a few months at the breast (107). When dietary sources of vitamin D are not available, as was the case among a group of American vegan-vegetarian weanlings and young children, some developed vitamin D deficiency rickets (131), and among strict vegetarians and other older British women on diets that were very low in fat, nutritional osteomalacia developed (29). Even among normal postmenopausal women living in the northern US during the winter months on usual dietary intakes and with usual sun exposures, vitamin D nutritional status is sometimes marginal (79).

Zinc Deficiency

Because over two thirds of the zinc most Americans consume in their diets comes from animal products such as red meat, liver, eggs, oysters, and other seafoods, zinc status is also of concern in vegetarian diets. The diets of some vegetarians may be deficient in zinc, especially if they consume large amounts of phytate-containing foods and fiber and abundant amounts of nonheme iron, both of which have detrimental effects on zinc absorption (5, 43). Cereal products are the richest plant source of zinc, but the zinc is in a less bioavailable form than it is in animal foods. Although phytates and dietary fiber inhibit zinc absorption (88), zinc nutriture is usually satisfactory in this country, even among vegetarians.

Vitamin B_6

The richest sources of pyridoxine are animal foods such as poultry, eggs, seafood, pork, and certain organ meats such as kidney and liver. Milk and milk products and most red meats are relatively poor sources. Although deficiencies of the nutrient are rarely reported, menu planning on vegetarian diets should include attention to rich sources of the nutrient, such as brown rice, oats, soybeans, whole wheat products, peanuts, and walnuts.

Other Nutrients Possibly Low in Vegetarian Diets

Several other nutrients that are found in high amounts in animal foods also need to be considered.

In the latest Recommended Dietary Allowances, evidence was judged sufficient to provide quantitative recommendations for vitamin K and selenium. Although the content of these nutrients in commonly consumed foods is still not known with certainty and food composition tables rarely include values for vitamin K, it is known that green leafy vegetables are the best dietary sources, providing 50–800 micrograms of the vitamin per 100 g of food (104). Small but significant sources of the vitamin (e.g. 1 to 50 micrograms per 100 g) are provided by milk and dairy products, meats, eggs, cereals, fruits, and vegetables (106). Only if dietary fat levels and green leafy vegetables were extremely restricted would intakes of this fat-soluble vitamin be in jeopardy.

Selenium is found in animal foods such as seafoods, kidney, liver, and other meats. Grains and seeds are variable sources of the mineral, and in part their nutrient content depends on the selenium content of the soils on which they are grown. Fruits and vegetables are poor sources of selenium, and water is also usually devoid of the nutrient (133). Thus there is at least theoretical concern about the selenium status of vegans. But as yet no reports of selenium deficiency in vegetarians exist; in this country the deficiency has been observed only occasionally among patients who were given intravenous feedings devoid of selenium for long periods of time (80, 81).

Retinol is found preformed only in animal foods, but it can be synthesized from several of the carotenoids, which are present and abundant in foods of plant origin. Therefore, deficiency of vitamin A is rarely a problem among American vegetarians. However, if an individual suffers from protein-calorie malnutrition, a lack of retinol-binding protein, the vitamin A transport protein, may cause the deficiency to develop even in the face of adequate stores.

Biotin is a nutrient that is especially plentiful in liver, egg yolk, soy flour, cereals, and yeast. Fruit and meats are poor sources. Nutrient information about biotin in food tables is incomplete, but one recent study of vegans, lacto-ovo-vegetarians, and omnivores found that levels were similar and satisfactory in all groups (84).

Carnitine is an essential nutrient for some higher animals but has not yet been proven to be a requirement for normal human beings. However, it is thought that preformed carnitine may be necessary in the diets of very young infants. Carnitine is synthesized in the liver from lysine and methionine. It is required for transport of the long-chain fatty acids within the cell to the mitochondria, where beta oxidation occurs, and thus is vital in energy metabolism. Animal products are richest in carnitine. As a general rule, the redder the meat, the more the carnitine. Dairy products, particularly the whey, also provide carnitine (13). Human milk is a good source of carnitine, and normal infants appear to be in good status with respect to this nutrient. However, there is some concern that among premature infants who are not fed human milk or who are maintained on total parenteral nutrition that values for the nutrient might be low. Although to date such problems have not been reported in vegetarians, the fact that breast milk is rich in carnitine provides another reason for encouraging vegan mothers to breast feed their infants (13, 85, 103).

Taurine, another amino acid (beta-aminoethanesulfonic acid), may also be necessary preformed in the diets of extremely premature infants although it can be synthesized in humans from dietary cysteine and methionine. However, taurine supplementation of premature infants does not seem to improve growth, and at present there is no RDA for the substance. It too is found in relatively large quantities in breast milk, as compared to formula—further encouragement for breast feeding by vegan mothers.

The long-chain polyunsaturated acids present in plant foods in greatest abundance are linoleic acid, an n-6 fatty acid with 18 carbons and 2 double bonds, and linolenic acid, an n-3 fatty acid with 18 carbons and three double bonds. Linoleic acid cannot be produced by human beings and therefore is considered an essential fatty acid. Once it is available, it can be used to form the polyunsaturated fatty acid, arachidonic acid (20:4 n-6), which is also regarded as essential in the presence of linoleic acid deficiency. Alpha linolenic acid, the n-3 polyunsaturated fatty acid, is also considered to be essential. The major polyunsaturated fatty acids in fish, eicosapentaenoic acid (EPA) (20:5 n-3) and docosahexaenoic acid (DHA) (22:6 n-3), are found in marine animals and in the phytoplankton and algae they eat. Vegans and some other vegetarians do not eat fish and seafood and are unlikely to have high intakes of DHA and EPA from these sources. However, both DHA and EPA can be synthesized from linolenic acid in the body if they are not obtained directly from seafood in the diet. DHA and EPA are also synthesized by phytoplankton and algae, and if these foods are eaten directly by human beings small amounts of these fatty acids will be obtained. The reason for concern is that some of these long-chain polyunsaturated fatty acids may be required in the diets of very young premature infants. The production of eicosanoids, which are important in platelet function and inflammatory responses, appears to be modified when the nutritional status of polyunsaturated fatty acids is altered. At present, there is no evidence that vegans or vegetarians are at high risk of essential fatty acid deficiencies at any age.

The other nutrient of at least theoretical concern in vegan diets is zinc, since the best food sources of zinc are meats, poultry, and seafood, and the type of fiber-rich, phytate- and oxalate-rich diet many vegans eat further reduces the bioavailability of zinc. Indeed, serum zinc levels do tend to be lower among vegans and vegetarians than they are among omnivores. A recent study showed that with dietary counseling lacto-vegetarian Trappist monks maintained satisfactory although low-normal zinc status even in the face of high intakes of phytates and other inhibitors of zinc absorption (59). Phytate intakes can be modified by use of more leavened bread products, since the phytates are altered during the leavening process. Oxalate-rich foods such as dark green leafy vegetables and cocoa can be eaten but should not be major sources of the diet.

Manganese intakes of vegetarians tend to be higher, not lower, than those of omnivores. It is possible that plasma uptake of iron in humans may be inhibited by very high doses of manganese.

DECREASED RISKS OF CHRONIC DEGENERATIVE DISEASES ON VEGETARIAN DIETS

There is a good evidence that vegetarian diets and life-styles have positive effects on weight, blood pressure, coronary artery disease, and laxation (33, 92). Whether a vegetarian diet per se is conducive to good health or whether the effects are due to differences in specific nutrients or combinations of nutrients consumed by vegetarians is not so clear. Vegetarian living habits and health-related behaviors have positive health advantages that are not easily separated from the effects of the vegetarian diet per se.

Studies completed in the past few years support the observation that risk factors for various diseases and conditions mentioned above are lower and, in some cases, incidence of disease or death is lower among vegetarians than among omnivores. But recent work also suggests that similar advantages can accrue to nonvegetarian diets that are more in synchrony with current dietary recommendations than are usual eating patterns (17). A few selected reports are cited below. The evidence has recently been reviewed more extensively (33, 34).

Vegetarians, and especially vegans, are usually leaner than omnivores. These differences are not explained by differences in metabolic rate at rest or by variations in postprandial thermogenesis, but are probably due to the lesser energy intakes and greater levels of physical activity of vegans (91). It is possible but not proven that relative leanness is favored by low fat, high carbohydrate diets. Vegetarian diets do not seem to provide any particular advantage in achieving weight reduction, however (54).

Blood pressures and hypertensive disorders are reported to be lower among vegetarians, especially vegans, than among the general population. However, it is unclear whether these findings are due to differences in weight, physical activity, smoking habits, and medication use, or to an independent effect of diet. Several recent Australian studies suggest that vegetarian diets lower blood pressure (9). However, American researchers have been unable to demonstrate diet-related effects of animal products, carbohydrate, or different types of fats, nor do white American lacto-ovo-vegetarians differ from white nonvegetarians in their blood pressures, although they have higher blood pressures than do black vegetarians (89, 109). It is possible that differences in alcohol intake or some other dietary factors play a role in the lower pressures that are common among vegetarians, but the main factors seem to be weight and physical activity.

Several recent studies confirm that vegetarians, and especially vegans, have decreased serum cholesterol when compared with omnivores (15, 41, 42, 77, 93). However, prudent semivegetarian and omnivorous diets that are altered in the type and amount of fat they contain also have positive lipid-lowering effects without sacrificing micronutrient adequacy or other positive health effects (11, 30, 77, 98).

Excellent evidence indicates that vegetarian diets, which are high in dietary fiber, improve laxation when they are compared to low fiber nonvegetarian diets (33). But high fiber omnivore diets provide similar benefits (17). The vegetarian diet has been claimed to be uniquely beneficial for many other diseases and conditions, including colon cancer, diverticular disease of the colon, diabetes mellitus, gallstones, kidney stones and renal failure, lung cancer, osteoporosis, arthritis, and dental caries, among others. Whether vegetarian diets decrease risks of these diseases remains a topic of active debate and is beyond the scope of this review. However, these claims are not as well supported by experimental or observational studies as are the effects already discussed above. Also, differences in disease rates between vegetarians and nonvegetarians are less dramatic, suggesting a lesser influence of diet.

For example, consider the question of the association between diet and a single form of cancer. The consumption of vegetarian diets may reduce certain risk factors that are of potential significance in colon carcinogenesis, but this effect may not be unique to vegetarian diets per se (1, 4, 10, 72, 97). The high plant food, high fiber, low fat diets currently advocated for decreasing cardiovascular disease risk are also thought to be appropriate for reducing colon cancer risk (17, 91) A large-scale randomized clinical trial of the utility of such high fiber, high plant food diets in decreasing the incidence of adenomatous polyps is now in progress under the sponsorship of the National Cancer Institute.

RISK FACTORS FOR OTHER DISEASES

The major risks involved in vegetarian diets are deficiency diseases and malnutrition secondary to the presence of some other associated cause that is neglected or untreated. Life-styles and habits often dictate beliefs and behavior that are at variance with conventional medical advice and practice. For example, some vegetarians refuse to accept vaccination or other forms of therapy. Malnutrition due to poor dietary planning or secondary to disease is largely avoidable or preventable, and is not a necessary concomitant of vegetarian diets.

The risks that may arise on unplanned diets vary, but are especially common on vegan or vegan-like diets. For vegans, low energy intakes, underweight, and insufficiency of a number of nutrients are likely to be a problem. To a lesser extent, unplanned lacto-ovo or other vegetarian diets may also present difficulties. These problems are likely to arise when a morbid condition is also present that has an adverse impact on intakes, digestion, absorption, metabolism, or excretion of nutrients. Risks of deficiency also rise during certain times of life, including pregnancy and lactation, infancy, early childhood, and the rapid period of growth in adolescence when nutrient needs are particularly high.

VEGETARIAN DIETS AND THE LIFE CYCLE

The most frequent risks and benefits of differing kinds of vegetarian diets over the life cycle are summarized in Table 1. More complete discussion of these issues is available in several recent reviews (32, 71, 73, 96, 113).

Table 1 Special risks of vegetarian diets during different times in the life cycle

Time of life and vegetarian diet type	Commonly reported risks	Commonly reported benefits
Pregnancy		
Vegetarian	Iron, folic acid, vitamin D, zinc deficiency.	Excess weight gain, smoking, alcohol or drug abuse rarely problems.
Vegan	Deficiencies of kilocalories, iron, folic acid, vitamin D, calcium, zinc, vitamin B_{12}, protein quality or quantity.	Excess weight gain, smoking, alcohol or drug abuse rarely problems.
Lactation		
Vegetarian	Iron, folic acid, vitamin D, zinc deficiency.	Long lactation maximizes postpartum amenorrhea and return to prepregnancy weight; obesity rarely a problem for other vegetarians or vegans.
Vegans	Deficiencies of kilocalories, iron, vitamin D, calcium, zinc, vitamin B_{12}, folic acid, protein quality and quantity.	
Early infancy (0–6 months)		
Vegetarian	Deficiencies of iron, vitamin D (rickets) if supplements are eschewed.	Extended breast feeding is common among both vegetarians and vegans.
Vegans	Bulk of diet/kcal high; deficiencies of kilocalories, vitamin D, calcium, zinc, vitamin B_{12} (esp. if breast feeding is avoided).	
Later infancy		
Vegetarian	Iron, vitamin D deficiency (if supplements are eschewed).	Obesity rarely a problem in either vegetarians or vegans.
Vegans	Bulk of diet/kcal high; deficiencies of kilocalories, protein, iron, vitamin D (rickets), calcium, zinc, vitamin B_{12}.	
Childhood		
Vegetarian	Iron deficiency	Obesity rarely a problem in either vegetarians or vegans.
Vegans	Deficiencies of kilocalories, protein, iron, calcium, vitamin D, vitamin B_{12}.	
Adolescence		
Vegetarian	Iron deficiency	Obesity, alcohol abuse, smoking, rarely a problem.
Vegans	Deficiencies of kilocalories (esp. during the pubertal growth spurt), iron, vitamin D, calcium, vitamins B_2, B_{12}, and poor protein quality.	Obesity, alcohol abuse, and smoking rarely problems.

Table 1 (*Contiued*)

Time of life and vegetarian diet type	Commonly reported risks	Commonly reported benefits
Young and middle-aged adults		
Vegetarian	Rare	Calcium intake satisfactory; weight, alc hol abuse, hyperlipidemia, smoking, and high blood pressure are rarely p lems in vegetarians or vegans. Physi cal activity levels are often very higl
Vegans	Excessive leanness, low iron, vitamin D, calcium, zinc, and vitamin B_{12}.	
Older adults		
Vegetarian	Vitamin D intake may be low. Bulk may be excessive.	Laxation good; weight excess, alcohol abuse, hyperlipidemia, smoking, anc high blood pressure are rarely problems.
Vegans	Excessive leanness may be problem. Risks of iron deficiency anemia due to low iron intake; vitamin D, calcium, and zinc may be low.	

Reproductive and Menstrual Status

Several reports in the literature suggest that vegetarians are more likely than nonvegetarians to suffer from menstrual irregularity, because of specific substances in the diet that perhaps modulate the effectiveness of circulating sex steroid hormones. Pedersen et al (105) found that high fiber or high magnesium intakes were associated with increased menstrual irregularity and that high cholesterol or protein intakes were associated with increased likelihood of menstrual regularity. Among female athletes high fiber intakes are associated with oligomenorrhea in both vegetarians and nonvegetarians (83). Observations of alterations in dietary fat and fiber intake also suggest that the bioavailability of estrogens is affected (47, 48, 53, 131). Related substances such as phytoestrogens and lignans may be involved (1). Such diets may also alter growth hormone and prolactin levels (112). While the practical significance of these alterations is not yet clear, the findings are relevant not only to reproductive health but also to certain hormone-dependent cancers (49, 132).

Pregnancy

Vegetarian diets in pregnancy set the stage for the infant's later health. The most common problems of vegans in pregnancy are inadequate weight gain, low protein intake, inadequate iron intake with resulting anemias, low calcium, zinc, and vitamin B_{12} intakes, and, in some instances, low vitamin D, zinc, and iodide intakes (32, 34). Dietary counseling of vegans during pregnancy needs to emphasize weight gain, increased intakes of calcium, iron, zinc, and vitamins B_{12} and D. If iron and calcium supplements are acceptable, dietary planning is simplified. Similarly, a multivitamin in RDA amounts is helpful. Pregnant lacto-ovo-vegetarians differ little in their nutritional status from those on usual omnivorous diets, but they may need special assistance in selecting high iron food sources.

Lactation

Even the strictest vegans usually provide their young with one animal food, human milk, during their infancy, and they tend to breast-feed their infants longer than do omnivores. The amount of human milk produced is little affected by the mother's vegetarian diet, but the milk varies in nutrient content of vitamin D, vitamin B_{12}, and some other water-soluble vitamins, especially when the mother is on a vegan diet (116). Vitamin D and B_{12} supplementation of the infant, especially the vegan infant, is therefore recommended (50). Vegan mothers should also use supplements or calcium-rich foods to increase their calcium intakes during lactation and thus avoid depletion of reserves in their bones. A multivitamin at RDA levels should meet the RDA for vitamins D and B_{12}. Iron stores, which may have been depleted during pregnancy, also should be restored via food or supplementary sources (31, 32, 34).

Early Infancy

The healthy breast-fed infants of vegetarians generally thrive during the first six months of life. Some evidence suggests that vegan mothers' milks may be marginal in vitamins D and B_{12}, and supplementation, if possible, provides assurance that nutrient needs are met.

Vegetarian infants who are fed commercial milk or soy-based formulas or home-made milk-based formulas are rarely reported to have health problems in early infancy.

Two groups of young vegetarian infants develop health problems. First are those infants of vegans who are weaned to home-made plant-based formulas and weaning foods early in the first year of life—especially under six months of age. They may fail to thrive because their diets are too low in energy and too high in bulk. Diets may also lack several vitamins and minerals, including vitamins D and B_{12}, iron, calcium, and zinc (31, 71). The second group of infants are those who are ill or of very low birth weight and whose parents eschew medical supervision. These infants may require special diets that are particularly high in nutrients and virtually impossible to formulate without special nutritional support.

Weanlings and Toddlers

Weaning from the breast, particularly if it occurs very early (e.g. under six months of age) or very late (after 12 months), is a time of particular peril to the nutritional status of vegetarian infants. The problems are most pronounced among vegans, because vegan weaning diets based on cereals are often very low in caloric density per unit volume. These diets may also be deficient in minerals and vitamins, giving rise to vitamin D deficiency rickets, iron deficiency anemia, low vitamin B_{12} levels, and shortfalls in intakes of other nutrients such as calcium (28, 31, 61, 71).

The recent cohort study by Dagnelie et al of Dutch macrobiotic infants born in 1985 (22–26) provides an illustrative example of the many unnecessary health problems that develop when infants are fed inadequate vegan-like diets in the weanling period. These macrobiotic infants, who ate a vegan-like diet, failed to thrive, and exhibited slowed gross motor and language development compared to control infants, increased incidence of rickets (22, 24, 26), and increased risk of iron and vitamin B_{12} deficiency (23, 25).

All of these risks can be avoided by adding energy sources to weaning foods to increase calorie intakes and by dietary planning to meet the RDA from food or food and supplementary sources (130). For example, the macrobiotic diet would be much improved by supplementation with fatty fish, milk and milk products, and fat, as well as by inclusion of reliable sources of vitamin B_{12} (115).

Lacto-ovo-vegetarians are less likely to experience problems, but their parents also need to take steps to ensure that the nutrient needs of these infants are met (102).

Preschoolers

That vegetarian diets have adverse effects on physical or intellectual growth has sometimes been claimed, but there is little evidence to support this contention. Difficulties appear to be confined to a few special groups (102, 120). Malnutrition, when it exists, is found among preschool children on very restricted vegan or vegan-like diets, among whom rickets, iron deficiency anemia, low serum vitamin B_{12} levels, low calcium intakes, and low weight, low fatness, and slightly lower height and muscle mass are occasionally reported. Deficiencies among children on other types of vegetarian diets are usually confined to mild iron deficiency anemia (71). On the basis of existing studies, neither the claims of vegetarians that their children are brighter than average nor of their opponents that they are duller are justified. Although gross motor development may lag in later infancy, the intellectual development of vegetarian preschool children as a group appears to be similar to that of other children (22, 38).

School-Age Children

By school age, lacto-ovo-vegetarian children appear to differ little in their nutritional status from omnivorous children. Vegan children also appear to have fewer diet-related health difficulties than they do earlier in life.

Adolescents

The pubertal growth spurt is a period of physiological stress accompanied by a rapid increase in nutrient needs. Few recent reports of the growth and nutritional status of vegan or vegetarian adolescents exist. However, because nutrient needs rise during the second decade of life, attention to dietary intakes, especially for energy, protein, calcium, phosphorus, iron, zinc, vitamins A, D, and B_{12} to accommodate enlarged body size, is warranted. At the same time, some positive benefits from vegetarian diets, including low saturated fat intakes, need to be preserved, since recent reports show that vegetarian adolescents often have lower serum lipids than do omnivores (71).

Young and Middle-Aged Adults

Vegetarian adults are a heterogeneous group with respect to dietary practices, use of nutrient supplements, and other habits that have an impact upon health. Recent studies of a group consisting predominantly of semi- and lacto-ovo-vegetarians living in France who eschewed nutrient supplements found that their dietary fat and cholesterol intakes and weight were lower, and the nutrient density of their diets higher, than a control population of nonvegetarians (93). Risks for deficiency of vitamins B_{12} and D as assessed from serum measures were also higher among the most restrictive vegetarians and vegans in the group (93). Intakes of other nutrients, including sources of thiamin, riboflavin, and vitamins A and E, were higher among the vegetarians.

Middle-Aged and Older Adults

Very few studies exist of older adults who are vegetarian. Their avoidance of meat, poultry, and fish, which are rich in protein, iron, zinc, thiamin, pyridoxine, and vitamin B_{12}, and the declines in energy intakes often associated with aging might be thought to place them at special risk. They are leaner than nonvegetarians of the same age (90). Recent studies do not provide evidence of widespread malnutrition among older vegetarians. Brants et al (14) studied 44 apparently healthy lacto-ovo-vegetarians aged 65–97 years of age. Their intakes (13% protein, 37% fat, and 50% carbohydrate, with a P/S ratio of 0.63) were closer to recommendations than were those of omnivores who were studied simultaneously. The nutrient density of the vegetarian diet was higher than that of omnivores. Zinc, iron, vitamin B_{12}, and water supplies were lower than recommendations and also lower than omnivores' intakes, however. Other studies suggest problems with trace element status (45). Also, in a recent study of omnivores, Krall et al (79) found that when vitamin D intakes among postmenopausal women were below approximately 220 IU per day, seasonal increases in parathyroid hormone secretion, which might jeopardize bone health, rose. Moreover, although vitamin B_{12} deficiency takes many years to develop from dietary causes, it can develop in months when pernicious anemia or other diseases that compromise the absorption of the vitamin are present, and consequent mental changes may be wrongly attributed to advanced age (65). Thus special attention should be given to monitoring the vitamin D and B_{12} status of older vegan vegetarians. Other vegetarians do not appear to be at increased risk in these or other respects.

The question of osteoporosis risk is also important. Cortical bone mineral content was reported in an early study to be low among vegetarians, but two recent studies of lacto-ovo-vegetarians ranging in age from the fifth to the ninth decades of life found no differences between them and omnivores (70, 75, 123). Indeed, in one other large study of lifelong American lacto-ovo-vegetarians, bone mineral content by the ninth decade of life was considerably higher than it was in omnivores (86, 87).

Large studies of the bone health of elderly vegans have not been carried out in the past few years, and they need to be done, since vegans usually have lower calcium and vitamin D intakes and they are more likely to refuse postmenopausal estrogen replacement therapy. Special attention is also needed for elderly people who are ill, since their diseases may have nutritional implications that must be addressed.

Vegetarian Diets and Disease Treatment

Chronic diseases of all types are more common as people age, and acute illnesses are frequent throughout life. The proponents of some vegetarian diets make special claims about their efficacy in treating and curing disease. For example, the macrobiotics, a group that advocates a vegan-like diet, often believe that their regimen is helpful in the treatment of serious diseases. When faced with serious disease some vegetarians may adopt more restrictive diets and some nonvegetarians may do so as well, in the hope that cancer or some other illness they suffer can be cured. Some evidence indicates that serious harm may result from such measures (36, 106). There is no evidence that vegetarian diets are efficacious. When therapeutic modifications are called for, if they incorporate the needed modifications and are more acceptable to the eater, they should be used. Individuals at any age, and particularly older adults, who suddenly adopt vegetarian diets require careful monitoring; some may be avoiding treatment for an undisclosed health problem and may inadvertently do themselves harm.

DIETARY ADVICE AND PRACTICAL PRINCIPLES FOR COUNSELING

Healthful Omnivorous Patterns

All Americans, both vegetarian and nonvegetarian, should consume diets that are in accord with the Recommended Dietary Allowances (19) and the *Year 2000 Goals* (126).

Although disagreement about the strength of the evidence on some points continues both among those who advocate lesser degrees of change (60) and those who contend that more radical dietary changes are required (39), these recommendations have elicited widespread support within the nutrition and health community. The dietary guidance plan now available can be adapted to many different dietary targets such as levels of fat. Regardless of specific details, sound dietary practices need to be placed in the context of overall health promotion, disease prevention practices, and disease treatment. Basic goals include control of blood pressure and blood cholesterol, nonsmoking, maintenance of desirable body weight, regular physical activity and exercise, and appropriate treatment of medical conditions when they develop. The recently published *Report of the US Preventive Health Services Task Force* (129) and *Healthy People Year 2000* goals (126) provide detailed dietary guidelines for each stage of the life cycle.

Adoption of a moderate omnivorous dietary pattern that follows the guidelines of the Committee on Diet and Health (17) and the National Cholesterol Education Program (98) should reduce chronic degenerative disease risks to the same level as similar nutrient intakes would in a vegetarian diet. Indeed, the latest report of the Expert Panel on Population Strategies of the National Cholesterol Education Program concluded that it was important to recognize that no single food or supplement was the answer to achieving a desirable blood cholesterol level: ". . . focusing solely on the elimination of a single food such as egg yolk, however, is not necessary and will not, by itself, achieve sufficient blood cholesterol lowering." The report continued, "As indicated earlier, skim or lowfat dairy products and small portions of trimmed, lean red meat are desirable and nutritionally valuable. These foods and eggs in moderation can all be a part of a blood cholesterol lowering eating pattern" (see Ref. 98, p. 23).

Reductions in type and amount of fat and cholesterol can be achieved by substituting moderate amounts (about 6 oz per day, cooked) of fish, poultry without the skin, trimmed lean red meats, and other fatty animal foods. Eggs are another protein-rich food; egg whites can be eaten in any amount; egg yolks, which are high in cholesterol, should not be eaten more than three times a week unless other sources of dietary cholesterol and saturated fat are restricted a great deal. The use of low fat milk and milk products in two or more servings a day is suggested instead of whole milk dairy products. Tropical oils such as palm kernel and coconut oil are relatively high in saturated fatty acids and should be used only sparingly; "soft margarines" and highly unsaturated oils such as sesame and sunflower seed oil are preferable. Baked goods made with unsaturated vegetable oils and fast or convenience foods low in saturated and total fat as well as in cholesterol are the best choices. Adding more vegetables, fruits, cereals, and legumes, and limiting oils, fats, egg yolks, and fried or other fat-rich methods of preparation for these kilocalories will add back energy while lowering the fat and cholesterol content of diets.

Semi-Vegetarian Diets

For those who wish to avoid meat while continuing to consume omnivorous diets in other respects, the recently updated food guide of the US Department of Agriculture can be adapted to meet all of the dietary recommendations of the National Academy of Sciences (20, 124). However, nutrients such as highly bioavailable iron and zinc and high biological value protein found in red meat should be replaced with nutrients from some other source (21). And if milk is omitted, some other rich sources of calcium, vitamin D, and riboflavin must be found.

Lacto-Ovo-Vegetarian Diets

For those who wish to eat vegetarian diets, the vegetarian approach to eating can be healthful (35). In fact, today it is likely that most vegetarian diets are higher in dietary fiber and lower in saturated fat and cholesterol than are most omnivorous diets (5). The major nutrients that need special attention in planning lacto-ovo-vegetarian diets are iron and zinc. In order to keep dietary intakes of all nutrients high, wise food selection is necessary (3). Excellent materials are provided by the American Dietetic Association (6, 114) and by another group of knowledgeable vegetarian dietitians and nutritionists (7).

In planning lacto-ovo-vegetarian diets, the following principles must be kept in mind:

- Reduction of all empty calorie foods high in fat, sugar, and other sources of calories. These foods provide few vitamins, minerals, and protein nutrients for the calories they provide. In their place are suggested unrefined foods, which are more balanced in their contributions of vitamins and minerals vis-à-vis their calorie contributions.

- Replacement of red meat with plant and other animal sources of high quality protein. Milk and milk products, particularly the low fat variety, some eggs (since other sources of dietary cholesterol are low, somewhat more eggs can be consumed than in typical omnivorous diets that have other animal food sources of cholesterol), and a variety of legumes, nuts, and meat analogues are called for (134). Although commercially prepared meat analogue protein products are popular among many vegetarians and supply high quality protein from plant sources, these are not essential to a well-balanced vegetarian diet. However, they do permit replacement of traditional animal food entrees with other foods and minimize menu changes for those who wish to eat vegetarian. Also they are convenient to prepare.

- Intakes of lowfat or nonfat milk and milk products should be maintained or increased, since in vegetarian diets milk is a major source of calcium, phosphorus, vitamin B_{12}, riboflavin, and vitamin D, as well as an excellent source of high quality protein and a source of the animal food factor that enhances iron absorption (even though milk products by themselves are low in iron).

Increased intakes of whole grain and/or iron fortified breads and cereals are needed not only to provide energy but to furnish protein, plant iron, and other vitamins and minerals.

A variety of fruits and vegetables is also needed. Citrus fruits should be included because they are good sources of ascorbic acid, which is an enhancer of iron absorption. Intakes of vitamin A–rich vegetables and fruits, such as the dark green and yellow vegetables, are also recommended because pre-formed vitamin A sources from animal foods may be eliminated by strictures against eating certain animal foods.

Protein quality is rarely a problem in lacto-ovo-vegetarian diets. Eggs have no limiting amino acids and provide high levels of essential amino acids, such as cystine, lysine, methionine, and tryptophan; therefore they should be included in moderation. Milk and milk products are also complete proteins, with especially high levels of lysine, isoleucine, and methionine. When these two groups are combined with grains, legumes, nuts and seeds, or other vegetables, high quality amino acid mixtures result.

Vegan Diets

For those who wish to progress to a vegan diet that includes no animal foods whatsoever, additional care in dietary planning is needed. In addition to iron and zinc, unplanned vegan diets are often low in kilocalories, calcium, and are always low in vitamin B_{12} and vitamin D unless supplementary sources of these vitamins are provided, since plant foods contain no known sources of these vitamins. The assistance of a registered dietitian is helpful, since a good deal of skill in planning and familiarity with unconventional food sources is needed by omnivores who wish to alter their dietary intakes in this way. Certainly, if the individual in question is an infant, child, pregnant or lactating woman, over 65 years of age, recovering from an illness, or a chronic sufferer of a disease, dietetic consultation is highly advisable in order to incorporate these additional considerations into dietary planning and to avoid or circumvent adverse nutritional consequences. Several good articles are available to guide counseling efforts for vulnerable groups (7, 121).

The following additional considerations must also be incorporated into vegan dietary planning.

Special attention must be given to meeting and maintaining energy needs. Many plant foods are low in fat and energy and high in bulk. The quantity of food needed to meet energy needs can be a problem, particularly among small children, light eaters, and those who limit the number of meals they eat per day to only a few. Also if diets are very high in fiber, as are most vegan diets, absorption may be slightly affected, perhaps by 1 or 2%. In addition, some vegans fast periodically for religious, quasi-religious, or philosophical reasons. And most vegans lead physically active lives. For all of these reasons, planning to include sufficient calories in the diet is essential.

Sources of nutrients such as calcium and riboflavin must be increased, since milk and milk products are no longer available as sources of these nutrients. Calcium absorption may also be hindered by the high amounts of fiber and phytates in many plant foods, which bind calcium. Some of the leafy green vegetables such as broccoli, kale, and collard greens, lime-processed tortillas, tofu precipitated with calcium, calcium-fortified breakfast cereals, and other products such as orange juice are alternative plant sources of the mineral. Calcium-fortified soy milk products also contain substantial portions of the mineral. Calcium is present in water and in medications consisting of calcium salts such as some of the antacids. Fortified soybean milk drinks, increased use of green, leafy vegetables, increased use of legumes, nuts, dried fruits, and food yeasts can all be helpful. If acceptable, calcium supplements such as calcium carbonate can also be used, and a multivitamin-mineral supplement at RDA levels may also be helpful.

Calcium equivalents from plant foods are available. A cup of milk provides about 300 mg calcium. These foods provide roughly the equivalent amounts of calcium: 1 cup calcium-fortified soy milk, 1 cup broccoli or collard greens, 1 cup almonds, 1¼ cups turnip greens, 1½ cups kale or mustard greens, 1⅔ cups sunflower seeds, 2 cups beet greens, 2 cups quick-cooking enriched farina, 3 cups cooked dried beans, or 3 pieces enriched cornbread (99).

Examples of some riboflavin equivalents are as follows for the amount of riboflavin in a cup of milk (0.4 mg.): 1 oz fortified cereal, 1 avocado, 1¼ cups of fresh mushrooms or cooked turnip greens, ½ cup winter squash, 1¾ cups asparagus or cooked spinach, 2 cups brussels sprouts, and 2¼ cups okra (99).

Protein in vegan diets also needs attention, especially if only one plant source of protein is relied upon. With careful planning, the adequacy of protein intakes from diets that are largely or entirely based on plant foods is relatively easy to achieve. Animal foods have an advantage over plant sources of protein because they are generally of high quality, providing most of the essential and nonessential amino acids, and are highly digestible. However, the disadvantage of single plant protein sources can be overcome by combinations of plant proteins. Thus, although single plant proteins are lower in quality because they are limited to one or more essential amino acids, combining various plant proteins over the course of a day is sufficient to overcome these deficiencies (113). For example, in one recent experiment rice and mungbeans complemented each other when given in alternate meals to experimental animals in patterns and time intervals similar to those preferred by human beings (74). However, in very small, rapidly growing infants, it is probably prudent to try to assure that complete proteins are fed in single meals and, if soy-based formulas are used, to include methionine in them. Protein quality is usually not a problem if care is taken to include a variety of legumes, whole grains, seeds, and nuts so that the various plant proteins supplement each other. The limiting essential amino acids in grains are lysine and isoleucine, and they can be complemented by addition of legumes, which are high in lysine and threonine. Legumes are limited in methionine, cystine, and tryptophan (except for soybean, which is high in this amino acid). By combining legumes with grains or nuts and seeds these disadvantages can be overcome. Nuts and seeds are limited in lysine and isoleucine (except for cashews and pumpkin seeds which are somewhat higher in these amino acids). By combining them with legumes their deficiencies can be overcome. Other vegetables generally tend to be low in cystine and methionine. Combining them with grains, nuts, and seeds or with small amounts of eggs, milk and milk products, or other animal foods helps to increase the quality of these proteins (5).

The main danger of most American vegan diets is not protein quality but energy: If energy needs are not met, protein will be catabolized for energy. Therefore energy deserves first attention. After this is done, protein quantity and quality can be considered. A half cup of soybeans provides about 10 g protein. About the same amount of protein is provided by the following amounts of cooked dried legumes: ½ cup soybeans, 2½ tablespoons of peanut butter, ⅓ cup peanuts, ⅔ cup split peans or beans of most common varieties, or ¾ cup blackeye or cowpeas. The half cup of soybeans' 10 g of protein equivalent is also provided by these roasted nuts: ½ cup almonds or cashews, ⅔ cup walnuts or filberts, and 1 cup pecans. And 10 g protein is also provided by ⅓ cup sesame seeds or ½ cup sunflower seeds. In contrast, 10 g protein of a higher quality is supplied by 2 small eggs, 1½ oz cheddar cheese, ½ cup cottage cheese, or 1⅓ cups of milk (99). The amount of fat and calories supplied by these various foods is quite low for the legumes, with the exception of the peanuts, and quite high for the nuts and seeds. For those who are ill, commercial soy protein concentrates and formulas, which are especially formulated to meet all protein needs and to maintain good health, may also be acceptable (8).

In planning vegan diets, average intakes over time should meet or exceed the RDA. The issues of protein and energy have been discussed to show that rigid planning of every meal is not necessary. In planning any dietary pattern, including vegetarian patterns, the goal is to meet or exceed the Recommended Dietary Allowances for nutrients daily, with daily being interpreted on the average over a timespan of several days (52). If the dietary pattern includes periodic fasts or drastic changes in food intakes on a regular basis, these also need to be taken into account in estimates of average intakes. The basic point to remember is that some nutrients, such as ascorbic acid or thiamine, turn over very rapidly and stores are low, so that in the face of total dietary inadequacy deficiencies develop very quickly. In contrast, stores in the body pool, slow turnover, and other factors mean that deficiencies of nutrients like vitamin D or vitamin B_{12} take longer to develop, and, at least among those with previously adequate intakes, body stores can temporarily compensate for dietary inadequacies.

Some reliable method must be devised for individuals of all ages to obtain sufficient amounts of vitamin D and vitamin B_{12} in their diets. No practical source of either vitamin D or vitamin B_{12} exists in plant foods, and these vitamins must therefore be provided from other sources.

Vitamin D can be obtained by exposure to sunlight, but climate, the increasing use of sunscreen, and in some cases, altered metabolism of the vitamin make this an unreliable source of the vitamin in some parts of this country (37, 79, 115). Vitamin D–fortified soy milk, cod liver oil, and water-miscible vitamin D provide alternative sources of the vitamin. Tanning parlors are another possibility, but concerns about skin cancer must also be taken into account. Caution is indicated and moderation is critical if they are to be used to provide a source of ultraviolet radiation to stimulate vitamin D synthesis from the provitamin in the skin.

Assuring that vitamin B_{12} intakes are satisfactory is also critical among vegan vegetarians of all ages. Seaweed, which sometimes but not always contains vitamin B_{12} activity because of the plankton that contaminate it in certain waters, is an unreliable source. Yeast also provides some vitamin B_{12} activity when microbiological assays are used, but most of the vitamin is a form that is not available for use by human beings, although it can be used by bacteria for growth. The only reliable source of vitamin B_{12} from yeast is from nutritional yeast grown on vitamin B_{12}–enriched media. Tempeh and other fermented foods have forms of the vitamin that are largely unavailable to human beings. However, animal food analogues such as soy milk or meat analogues provide a bioavailable source of vitamin B_{12} that can be relied upon. Also, some of the fortified cereals provide vitamin B_{12} in a bioavailable form. Finally, vitamin B_{12} is available in RDA levels in some vitamin pills if these are acceptable to the individual.

CONCLUSION

Vegetarianism is an option that some individuals freely choose for a variety of reasons. With appropriate attention to nutritional needs, the health consequences of vegetarianism itself are neutral and in some respects may even be positive. However, there is no magical, health-giving property that automatically adheres to vegetarian diets and, regardless of their composition, protects health. The substances, nutrients and other, that vegetarian diets provide are directly responsible for some of their purported health effects. Other health benefits, and health risks, are associated with other habits and behaviors practiced by vegetarians. Nutrition scientists and professionals have an obligation to take vegetarians seriously and to help them plan their diets and related health behaviors so that they conform to current knowledge about maintenance of good health.

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