# The contribution of vegetarian diets to health and disease: a paradigm shift?[1–3]

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**ABSTRACT** Advances in nutrition research during the past few decades have changed scientists' understanding of the contribution of vegetarian diets to human health and disease. Diets largely based on plant foods, such as well-balanced vegetarian diets, could best prevent nutrient deficiencies as well as diet-related chronic diseases. However, restrictive or unbalanced vegetarian diets may lead to nutritional deficiencies, particularly in situations of high metabolic demand. If some vegetarian diets are healthier than diets largely based on animal products, this constitutes an important departure from previous views on dietary recommendations to prevent disease conditions. Based on different paradigms, 3 models are presented depicting the population health risks and benefits of vegetarian and meat-based diets. This series of models encapsulates the evolution of scientific understanding on the overall effects of these dietary patterns on human health. Recent scientific advances seem to have resulted in a paradigm shift: diets largely based on plant foods, such as well-balanced vegetarian diets, are viewed more as improving health than as causing disease, in contrast with meat-based diets. *Am J Clin Nutr* 2003;78(suppl):502S–7S.

**KEY WORDS** Vegetarian diet, plant-based diet, meat-based diet, health risks, health benefits, deficiencies, paradigm shift

Scientific knowledge is far from complete regarding the relationship between vegetarian diets and human nutrition. However, scientific advances during the past few decades have been noticeably changing the understanding of the role of vegetarian diets in human health and disease. In the past century, populations living in industrialized countries have experienced a sharp increase in life expectancy because of successful public health interventions. As disease patterns shifted away from nutrient deficiencies and infectious diseases toward chronic and degenerative diseases, nutrition policy and research also changed emphasis.

An adequate diet, by definition, prevents nutrient deficiencies by providing sufficient nutrients and energy for human growth and reproduction. An optimal diet, in addition, promotes health and longevity, reducing the risk of diet-related chronic diseases. Although the composition of an adequate diet is basically known, the composition of an optimal diet is not. However, recent scientific findings are suggesting that diets largely based on plant foods, such as some vegetarian, Mediterranean, or Asian diets, could best prevent nutrient deficiencies as well as diet-related chronic diseases (1, 2). These diets contain no or very little meat. If plant-based diets are generally healthier than meat-based diets, this constitutes an important departure from previous views on dietary recommendations to prevent disease conditions (2).

## ARE WE IN THE MIDST OF A PARADIGM SHIFT?

The word *paradigm* has been used in science to refer to a theoretical framework and the generally accepted perspective of a particular discipline at a given time. Thus, *paradigm* refers to the assumptions, concepts, values, and practices that constitute a way of viewing reality. In his book *The Structure of Scientific Revolutions*, Thomas Kuhn (3) coined the term *paradigm shift* to define sudden changes or advancements in scientific thinking. A paradigm shift occurs when "one conceptual world view is replaced by another" (3).

This concept paper presents 3 models I recently developed for a book on vegetarian nutrition (4). The models depict the expected health risks and benefits of a population following either a vegetarian diet largely based on plant foods or a diet largely based on animal foods (meat-based diet). Each model is based on a different paradigm. This series of models—paradigms—attempts to sum up the historic progression of the scientific understanding of the overall effects of these dietary patterns on human health.

## EARLY MODEL OF THE ADEQUACY OF VEGETARIAN DIETS

**Figure 1** shows a model prevailing through the 1960s comparing the adequacy of vegetarian diets with meat-based diets. For this figure and subsequent ones, vegetarian diets are defined as diets that exclude meats and emphasize minimally refined plant foods. Meat-based diets are defined as diets that emphasize a generous intake of meats and other animal products. In this figure, the area under each curve represents the proportion of the population for which a given diet pattern may be adequate or deficient. The basic tenet of this model is that a population following a vegetarian diet is at higher risk for developing nutrient deficiency diseases than a population following a meat-based diet. This was and still is the case in poor countries, where the relation between diet and health, and particularly meat consumption and health, is confounded by protein-energy malnutrition and other poverty-related factors. Also, very restrictive or unbalanced vegetarian diets such

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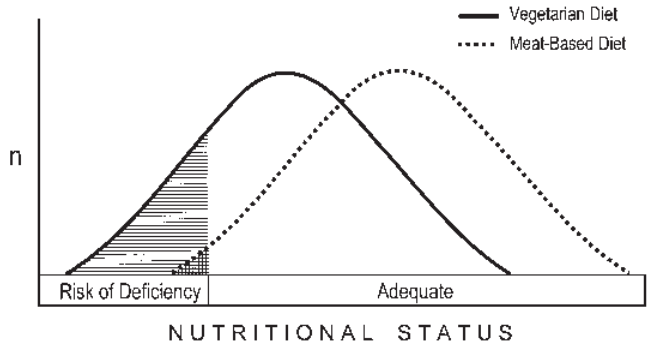


**FIGURE 1.** Early model prevailing through the 1960s on the adequacy of vegetarian diets. The area under each curve represents the proportion of individuals in a population for which a given diet may be adequate or deficient. Reprinted with permission from reference 4.

as fruitarian diets or some macrobiotic diets may lead to nutritional deficiencies, particularly in growing children and women during the reproductive years (5–7). Parenthetically, to decrease the risk of nutrient deficiencies, those following meatless diets were advised to add generous amounts of other animal products such as eggs, milk, and dairy products to their diet (8). This de facto makes it a mixed diet and displaces the curve to the right.

Compared with animal foods, plant foods generally have lower energy content as well as lower concentration and bioavailability of some essential nutrients. In situations of high metabolic demands such as during pregnancy, lactation, and the growing years, those following vegetarian diets, especially restrictive or unbalanced ones, may be at higher risk for marginal intakes or even biochemical or clinical nutrient deficiencies than those following meat-based diets. However, vegetarian diets may represent an advantage for adult sedentary populations and the prevention of chronic diseases. This early model used a unilateral approach to the relationship between vegetarian diets and health, because it pays attention to only the health risks and not the potential benefits.

## WERE HEALTH RISKS OF VEGETARIAN DIETS OVERESTIMATED?

A review of the early nutrition literature on vegetarian diets portrays a cornucopia of nutrient deficiencies and single case or case series reports on children with compromised physical growth (5, 9, 10). A systematic assessment of vegetarian nutrition articles published in the biomedical literature from 1966 to 1995 documented that, 30 y ago, half of the articles dealt with nutrition adequacy issues such as deficiency diseases, nutritional status, and growth or anthropometric indexes (**Table 1**). The overall frequency of articles on these issues decreased during the following 2 decades to one quarter, with a significant linear trend. In contrast, articles on the preventive and therapeutic aspects of vegetarian diets such as modification of risk factors, incidence of chronic diseases, and management of certain medical conditions followed opposite temporal trends (11).

Several historical, methodological, and sociological factors explain this emphasis in the earlier biomedical literature on the health risks related to the consumption of vegetarian diets. From a historical perspective, it is not surprising that some decades ago

**TABLE 1**
Main themes of articles on vegetarian nutrition published in biomedical literature between 1966 and 1995[1]

| | Time period | | | |
|---|---|---|---|---|
| | 1966–1975 | 1976–1985 | 1986–1995 | $P^2$ |
| | % | | | |
| Nutrition adequacy issues | 48 | 37 | 24 | 0.001 |
| Preventive and therapeutic applications | 24 | 38 | 40 | 0.196 |
| Other themes | 28 | 25 | 36 | — |

[1] Adapted from Sabaté et al (11).
[2] Chi-square test for linear trends.

the main focus of research into vegetarian diets was on nutrient adequacy rather than on optimal nutrient intake because in industrialized countries, nutrient deficiency diseases were much more prevalent than they are today. Consequently, nutritional science concentrated on identifying and proposing adequate nutrient intake values to meet nutritional needs. Dietary prevention of chronic and degenerative diseases was not an issue.

From the methodological point of view, nutritional science research and endeavors followed, until recently, the clinical model approach. It was easier to prepare case reports of vegetarians with medical problems coming to the clinic than to go to the community, identify vegetarians, follow them over time, and report on their health and disease status, as is required by the public health approach. Moreover, most of the earlier nutrition research was on the short-term health effects of diet. Studies of the relationship between diet and chronic diseases require a long-term approach. The classic methods of nutritionists, such as laboratory tests, animal experiments, or human metabolic studies, might be well suited for examining different aspects of the adequacy of vegetarian diets. However, nutritional epidemiology, a relatively young discipline, was needed to directly address the effect of vegetarian diets on chronic diseases and longevity.

Last, a cultural bias against meatless diets contributed to publications about and increased awareness of the potential health risks of vegetarian diets. Until the 1970s, those following vegetarian diets were assumed to be part of the antiestablishment, underground culture or a religious sect and the avoidance of meat to be practiced for reasons other than health (12, 13). Mainstream society in industrialized nations, those paying for research, was mainly composed of nonvegetarians. Therefore, most scientists performing research probably did not perceive or, consequently, resist this cultural bias.

All types of diets, including vegetarian diets, are associated with potential health risks as well as benefits, at both the individual and the collective level. Nutritionists and other health professionals should be aware of the potential nutritional risks associated with vegetarian diets, especially restrictive and/or unbalanced ones, and suggest ways to minimize them. However, it is also important to take notice of the potential benefits associated with a well-balanced vegetarian diet pattern.

## HEALTH BENEFITS OF VEGETARIAN DIETS

During the past 20 y, scores of nutritional epidemiologic studies have documented important and quantifiable benefits of vegetarian and other plant-based diets, namely a reduction of risk for many chronic degenerative diseases and total mortality (14, 15).

**TABLE 2**
Associations between consumption of specific foods and risk of different cancers and ischemic heart disease: Adventist Health Study summary results

| | Protective (reduces risk) | Hazardous (increases risk) | Reference |
|---|---|---|---|
| Cancer site | | | |
| Colon | Legumes | Meat | 40 |
| Lung | Fruit | —[1] | 41 |
| Pancreas | Legumes | — | 42 |
| | Plant protein products | | |
| | Dried fruit | | |
| Bladder | — | Meat | 43 |
| Prostate | Legumes | Meat | 44, 45 |
| | Tomatoes | | |
| | Soy milk | | 46 |
| Breast | — | — | 47 |
| Ischemic heart disease | | | |
| Myocardial infarction | Nuts | — | 33 |
| | Whole-grain bread | | |
| Fatal ischemic heart disease | Nuts | Meat | 33 |

[1] No relation was found.

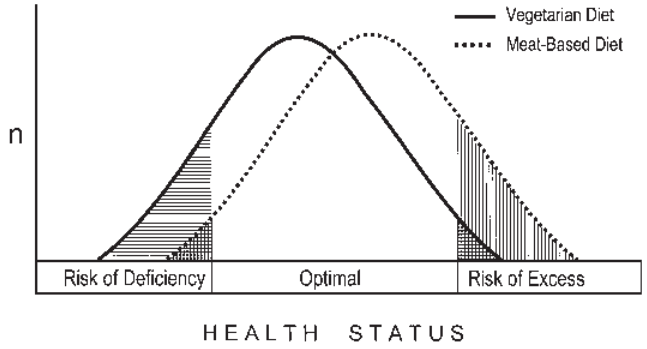


**FIGURE 2.** Current model prevailing from the 1970s to the present on the population health risks and benefits of vegetarian and meat-based diets. The area under each curve represents the proportion of individuals in a population for which a given diet pattern may be a health risk or benefit (optimal). At both extremes of the health continuum, there is risk of disease for deficiency or excess of nutrients. The area in the center represents the proportion of individuals for which the diet is optimal or most beneficial. Reprinted with permission from reference 4.

Vegetarians living in affluent countries enjoy remarkably good health, exemplified by low rates of obesity (16–18), coronary diseases (19–21), diabetes (22), and many cancers (21, 23, 24), and increased longevity (25–27). Those benefits are possibly due to the absence of meat in the diet as well as to a greater amount and variety of plant foods (28). While meat intake has been related to increased risk for a variety of chronic diseases such as ischemic heart disease (19) and some cancers (25, 29), abundant consumption of essential food components of the vegetarian diet such as fruit and vegetables (30–32), legumes and unrefined cereals (33–36), and nuts (33, 37, 38) has consistently been associated with a lower risk for many chronic degenerative diseases, and in some cases increased longevity. In the Adventist Health Study (39), a large prospective cohort study on diet and health of vegetarians and nonvegetarians, many more associations have been observed between plant foods and chronic diseases than with animal foods such as meat and dairy products (**Table 2**) (33, 40–47). All the protective effects were observed for foods of plant origin, while all the hazardous effects were correlated with meat intake (25). In conclusion, the positive effects of foods of plant origin on chronic disease prevention are possibly more definite than the detrimental effects of meats (28).

## RISK-TO-BENEFIT RATIO OF VEGETARIAN AND MEAT-BASED DIETS

It is currently well accepted that the relationship between a nutrient, food item, or diet pattern and health is not linear. There is an optimal range of intake, but at both extremes, there are marginal or detrimental intake ranges and further apart are deficient or toxic intake ranges (48). On the level of nutrients, this is being taken care of by recommending a minimal intake for essential nutrients (eg, vitamins C and E) (49) and by establishing upper limits for the intake of food constituents related to chronic diseases (eg, total, saturated, and polyunsaturated fats; cholesterol; protein; salt; and energy) (50, 51).

On the level of diet pattern, **Figure 2** depicts a model prevailing from the 1970s to the present for the health risks and benefits of vegetarian and meat-based diets. The area under each curve represents the proportion of the individuals in a population following a given diet pattern. To the left are those who may be at risk for disease due to deficiency of nutrients. To the right are those who may be at risk due to excess. The area in the center represents the proportion of individuals for which the diet is optimal or most beneficial. To calculate the proportion of the population at risk will require the addition of both the risk of deficiency and the risk of excess. Adding up both areas with horizontal lines (Figure 2) gives the proportion of the population at risk (deficiency or excess) by following a plant-based vegetarian diet pattern. Accordingly, both areas with vertical lines represent the proportion of the population at risk by following a diet pattern largely based on animal foods.

The risk-to-benefit ratio of a diet can easily be defined as the proportion of subjects at risk divided by the proportion of subjects benefiting. On this rendition of the model, there is no overall difference on the risk-to-benefit ratio of one compared with the other diet pattern. This model is likely to encourage the conclusion that no overall improvements can be accomplished if the population distribution curve is displaced to the right or left by changing the mix of plant and animal foods in the diet. If the curves moved, the same amount gained in one end would be lost at the other end.

This apparent public health dilemma, the seemingly inevitable trade-off of malnutrition with overnutrition diseases, was described in 1979 by Olson (52). He proposed a similar version of this model when contrasting the Asian diet, also largely based on plant foods, with the typical meat-based American diet at that time. Olson stated that if one were to change the American diet to greatly reduce animal protein and increase carbohydrate from processed grains, the nutritional status curve would move to the left, and he argued that "for every case of coronary disease

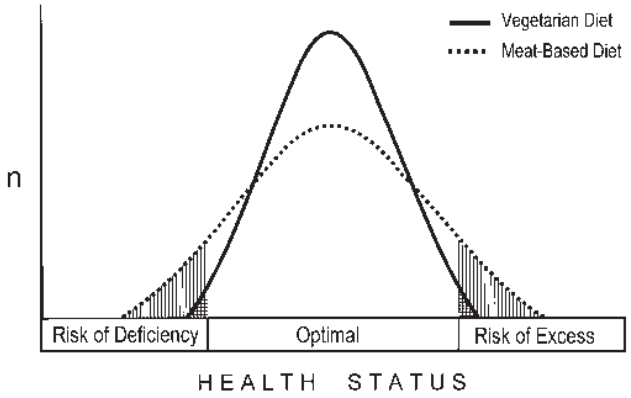


**FIGURE 3.** Proposed model on the population health risks and benefits of vegetarian and meat-based diets. The area under each curve represents the proportion of individuals in a population for which a given diet pattern may be a health risk or benefit (optimal). At both extremes of the health continuum, there is risk of disease for deficiency or excess of nutrients or other food compounds. The area in the center represents the proportion of individuals for which the diet is optimal or most beneficial. Reprinted with permission from reference 4.

avoided, there would be a case of infant malnutrition" (52). However, Olson failed to recognize that a trade-off in disease morbidity because of changes in the diet was not so predictable. Actually, this model shows that small displacements of the population distribution curve in one direction or another may result in substantial differences in the risk-to-benefit ratio of contrasting diet patterns.

For instance, moving the vegetarian diet curve slightly to the right will lead to a lower risk-to-benefit ratio for the vegetarian diet than for the meat-based diet. In practical terms, if one were to exchange small amounts of vegetables for small amounts of dairy products or eggs on a plant-only vegetarian diet, the substantial reduction in risk of vitamin B-12 deficiency in the population would not be offset by the small increase in risk for coronary diseases. Hence, a small displacement of the vegetarian diet curve to the right results in an overall more favorable risk-to-benefit ratio. However, on a diet largely based on animal foods, exchanging small amounts of meat for vegetables will not noticeably move the curve to the left. Major exchanges in the meat-based diet would be required to slightly displace the curve to the left and improve the risk-to-benefit ratio for this diet pattern. In industrialized societies, where food is abundant, for most individuals a meat-based diet can more easily exceed the optimal intake range of energy and many nutrients than a vegetarian diet can fall below the requirements for other nutrients.

## PROPOSED NEW MODEL

A new paradigm is emerging. For the past 10–20 y, epidemiologic, clinical, and basic science research on the health effects of several plant foods is greatly expanding scientists' understanding of the role these foods have on human health and nutrition. Antioxidants, abundantly present in plant foods, have been postulated to prevent cardiovascular disease and certain cancers (53–55). Anticarcinogenic properties have been described for a myriad of substances present mainly in fruits, vegetables, and other plant foods (56, 57).

Plant foods, such as fruits, vegetables, legumes, nuts, and whole grains, provide active substances on which human metabolism is dependent. However, only a few of those to date have been labeled as "essential nutrients." Fruits and vegetables are rich sources of not only vitamins, such as carotenoids, ascorbic acid, tocopherols, and folic acid, but also fiber, indoles, thiocyanates, cumarins, phenols, flavonoids, terpenes, protease inhibitors, plant sterols, and a host of other yet unknown and unnamed phytochemicals and nonnutrient compounds that may protect humans from many cancers and other diseases (57, 58).

Consequently, the increased risk of cancer and cardiovascular disease experienced by populations following diets largely based on animal foods, as opposed to vegetarians, may be due to not only an excess of energy, total and saturated fat, and other nutrients, but also a deficiency or very marginal intake of phytochemicals and other compounds abundant in plant foods but not yet labeled as nutrients. Accordingly, even though deviating from the classic definition of deficiency, chronic-degenerative diseases may also be considered as deficiency diseases, in addition to diseases of excess. Therefore, the overall contribution of diets largely based on animal foods to the causation of human diseases from excess, unbalance, and deficiency of nutrients or other food compounds appears to be noticeably different from earlier estimates.

**Figure 3** presents the proposed model that tries to capture the new understanding of the role of vegetarian and meat-based diets in human health and disease in affluent societies. In this new model, the relative contribution to the causation and prevention of diseases for excess or deficiency is clearly unequal for the 2 contrasted diets, with a more favorable risk-to-benefit ratio for the vegetarian diet. Corresponding to previous models, the total area under each diet pattern curve is the same, but the shape of the 2 curves varies considerably. The expanded area of risk of deficiency under the meat-based diet curve reflects the risk of diseases largely attributed to "phytochemical deficiency" because of the marginal intake of plant foods on this diet pattern. In affluent societies, this model considers the risk of "phytochemical deficiency" diseases—namely, an unknown proportion of cancers, cardiovascular diseases, and other degenerative diseases—among those following a meat-based diet to be greater than the risk of the classic acute nutrient deficiency diseases for vegetarians. In conclusion, recent scientific advances seem to have resulted in a paradigm shift: diets largely based on plant foods, such as well-balanced vegetarian diets, are viewed more as improving health than as causing disease, in contrast with meat-based diets.

Most of the concepts in this article were developed for a course on vegetarian diets that I taught over the past few years at the School of Public Health, Loma Linda University. I am most grateful for the ideas and constructive comments from my colleagues and former graduate students.

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