

American Institute for Cancer Research 11th Annual Research Conference on Diet, Nutrition and Cancer

Applying Science to Changing Dietary Patterns¹

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ABSTRACT The intake of 400–600 g/d of fruits and vegetables is associated with reduced incidence of many common forms of cancer. These foods contain phytochemicals that can modulate gene expression to inhibit carcinogenesis via multiple pathways. Many phytochemicals are colorful, providing an easy way to communicate increased diversity of fruits and vegetables to the public. Red foods contain lycopene, the pigment in tomatoes, which is localized in the prostate gland and may be involved in maintaining prostate health. Yellow-green vegetables, such as corn and leafy greens, contain lutein and zeaxanthin, which are localized in the retina where age-related macular degeneration occurs. Red-purple foods contain anthocyanins, which are powerful antioxidants found in red apples, grapes, berries and wine. Orange foods, including carrots, mangos, apricots, pumpkin and winter squash, contain β -carotene. Orange-yellow foods, including oranges, tangerines and lemons contain citrus flavonoids. Green foods, including broccoli, Brussels sprouts and kale, contain glucosinolates. White-green foods in the onion family contain allyl sulfides. Consumers are advised to ingest one serving of each of the above groups daily, putting this recommendation within the National Cancer Institute and American Institute for Cancer Research guidelines of five to nine servings per day. The color code provides simplification, but it is also important as a way to help consumers to find common fruits and vegetables easily while traveling, eating in restaurants or working. At home, simple ways of preparing foods rapidly and easily are needed to influence dietary patterns. *J. Nutr.* 131: 3078S–3081S, 2001.

KEY WORDS: • *dietary guidelines* • *phytochemicals* • *nutritional science*

The evolution of human dietary patterns has been driven by necessity, economics and more recently, by the selection of foods carefully designed and promoted on the basis of taste, cost and convenience, often without regard to their nutritional and health value. International studies of the food habits of a number of different populations over the past 40 y have clearly documented the diversity of human dietary patterns and defined those associated with a lower risk of chronic diseases including common forms of cancer (1). In comparison with the diet of Americans, dietary patterns including a consistently higher intake of fruits, vegetables, whole grains and plant proteins such as soy are associated with a markedly reduced risk of cancer. In the nutritional science and epidemiological literature these dietary patterns have often been characterized as simply low-fat, high-fiber diets or the intake of vegetables was quantitated as a single phytochemical such as β -carotene (2). Such simplified terminologies led to the concept that fiber or phytochemical supplementation could repro-

duce the benefits of the healthy dietary patterns they represented.

The idea that a dietary pattern conferred its benefits through a single component led to trials that purported to test one component of the diet in an American population while all other variables were held constant. When research based on these flawed concepts was conducted, the expected benefits were not realized for fiber supplementation (3) or β -carotene supplementation (4). This led to a series of publications resulting from intervention trials, which have been interpreted as evidence that nutrition simply does not work in cancer prevention. On the other hand, international studies suggest that for some cancers of the aerodigestive tract, a 50% reduction in risk is associated with intakes of 400–600 g/d of fruits and vegetables (1). The challenge for nutrition scientists is to translate this scientific information into dietary guidelines that result in healthful changes in dietary patterns.

For the first time in the history of humans, globalization of world economies and agriculture threatens to homogenize diets based on manufactured foods that are most popular and profitable (5). In a process that began slowly with the development of agriculture some 10,000 y ago, humans have gradually shifted away from a diverse plant-based diet that provides not only essential vitamins and minerals but also over 25,000 phytochemicals to a diet based on refined grains, added oils, sugar and salt. Today most Americans eat between two and three servings of fruits and vegetables per day and a minority

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eat none at all (6). As a result, although vitamin deficiencies are not common because of food fortification and the use of vitamin supplements, there is an epidemic of obesity and associated common forms of cancer, including breast, prostate and colon cancer, that is sweeping the world. In many countries, poverty and malnutrition exist together with obesity and chronic diseases in different socioeconomic groups.

The history, obstacles to change and a new system based on choosing fruits and vegetables according to color (7) are described in this review.

Evolution of the modern food supply

Agriculture began in the Middle East, in what is now Iran and Iraq, and took advantage of spontaneous mutations in wheat at the end of the Ice Age that caused the wheat to hold on to its seed rather than scatter it to the wind (9). The early farmers were then able to harvest and store the wheat, ensuring some food security. However, this was achieved at a price. Farmers living adjacent to hunter-gatherer populations were shorter and less well-nourished because they shifted from a diverse nutrient-rich diet to more limited diets with nutritional deficiencies. Recent studies of existing hunter-gatherer populations have revealed that these individuals eat >800 different varieties of plant-based foods (9), but when they move into urban areas and begin eating so-called street foods, they begin to develop nutritional deficiencies (10).

Agriculture had a great deal to do with developing economics, mathematics, city governments, slavery and national identity. In China, rice was domesticated at about 6500 B.C. and in MesoAmerica corn and beans were domesticated at about 3500 B.C. (9). By the time the Pilgrims arrived at New England's shore, the Native Americans were subsisting on a diet of corn, beans and some wild turkey. Corn and other grains became important crops in the new nation and with the industrialization of agriculture beginning in the mid-1800s, America became a major agricultural power (11). In the 1800's, one man working one acre of land could feed one person for a year. Today with the development of hybrid corns that increase production, one person working 1 acre can feed 120 people for 1 y (11). After World War II, this led to a great surplus of wheat, corn and soy, and the USDA developed an elaborate system of price supports and subsidies to stabilize farm prices (12). Originally, this was justified because the small farmer was subject to wild price fluctuations. A bumper crop would send the price of his crop down drastically, making it impossible to pay the loans that enabled him to buy seed at the beginning of the season. Today, the small farmer in America is a dwindling and endangered species, and much of the grain is produced by large agribusiness corporations. Over 70% of all grain produced in the United States is fed to beef and dairy cattle, pigs and sheep (8). As a result of these economic forces, the American diet has become centered on three grain-based ingredients: refined flour, corn sweeteners and vegetable oils. The USDA pyramid has grains at its base and does not distinguish between refined flour products and whole grains (13). At the top of the pyramid, with the admonition "use sparingly," are the sweets, fats and oils, which are depicted as drops. These drops are found throughout the pyramid, demonstrating how fats and sugar permeate all the levels of the pyramid below.

This pyramid was conceived by scientists influenced in overt and subtle ways by the prevailing economic interests of agriculture and the food industry as a whole (8). Far from being a sinister plot or a mistake, the pyramid, nutritional guidelines, food labeling and recommended dietary allowances

represent the predictable outcome of political policy-making that characterizes all aspects of our governmental process in the United States. Therefore, it was possible for diet cola manufacturers to argue that half a can of soda, which contained <1 kcal, was a typical serving as was a quarter of a small bag of corn chips. The law defines a fat-free food as any food delivering <0.5 g fat per serving, and it represents the only place in mathematics that you can round down from 0.5 to zero. Individualized exchange plans select foods from lists of carbohydrate exchanges, protein exchanges and fat exchanges and assume that all foods within a category are nutritionally similar. Therefore, peanut butter and a skinless breast of chicken are both proteins, and a muffin, ice cream and a 70-kcal slice of high-fiber bread are all carbohydrates. Fat exchanges include margarine, butter and olive oil, each of which has very different effects in the human body.

Although Americans are used to accepting the promise of political compromise in many parts of their lives, many Americans are outraged when they learn of deception in food labeling. Nutrition is highly personal and the public has appreciated the connection between nutrition and health as illustrated by the fact that multivitamin and multimineral supplements are the most common nonprescription items bought by the American public. The outrage over misleading food labeling has been used to power such nongovernmental watchdog agencies as the Center for Science in the Public Interest. Unfortunately, this group has itself been caught up in the political controversies because its positions on major issues benefit one industry and hurt another.

Over the past 200 y, a series of uniquely American foods have been developed through adaptation from other cultures: pizza made with oil added to the crust and large amounts of melted cheese, potato chips, corn chips, peanut butter, hot dogs, hamburgers made with beef fat flavoring and profitable soft drinks made with corn sugar and artificial flavors (5). Westernized Chinese food is among the highest-fat foods in America because it was adapted from low-fat Chinese versions to meet American tastes. Moreover, refried beans or frijoles have added lard or vegetable oil in the Mexican-American adaptation of beans eaten in Mexico and South America without added fat. Special offers of larger portions delivering an extra 800 kcal for only an additional 39 cents have made fast food restaurants especially popular with teenagers, low income Americans and the elderly. These foods have displaced the fruits, vegetables and whole grains recommended in the U.S. Dietary Guidelines, and consumers have increasingly reduced their commitments to cooking healthy meals and eating as a family over the past few decades.

We are now separated from the system that enabled us to select foods according to color and taste. Humans and a few primate species have trichromatic color vision so that they are able to distinguish red from green (14). All other mammals have dichromatic vision and cannot distinguish between the two colors. One hypothesis for the evolution of this visual ability was that it conferred an advantage by enabling primates to distinguish red fruits from the green background of forest leaves. Today colors are still used to promote food choices, as most fast food restaurants package their beige french fries in a red cardboard package. Contrasting colors have been shown to be one of the key factors in food selection by Drewnowski (15). A new method for selecting fruits and vegetables based on colors keyed to the content of phytochemicals is described as a way of translating the science of phytochemical nutrition into dietary guidelines for the public.

The color code

Most Americans eat only two to three servings of fruits and vegetables per day without regard to the phytochemical contents of the foods being eaten. Certain phytochemicals give fruits and vegetables their colors and also indicate their unique physiological roles. All of the colored phytochemicals that absorb light in the visible spectrum have antioxidant properties. In artificial membrane systems, it is possible to show synergistic interactions of lutein and lycopene in antioxidant capacity and there are well-known antioxidant interactions of vitamin C and vitamin E based on their solubilities in hydrophilic and hydrophobic compartments of cells.

However, many phytochemicals have other functions beyond acting as antioxidants. For example, lycopene stabilizes the connexin 43 gene product that is essential for gap junction communication (16) while also interacting with vitamin D in the differentiation of HL-60 leukemia cells (17). In breast cancer cells, lycopene can interfere with insulin-like growth factor-1-stimulated tumor cell proliferation (18). Lycopene levels in the blood are associated with a reduced risk of prostate cancer (19), and lycopene administration may reduce proliferation and increase apoptosis in human prostate tissue where lycopene is the predominant carotenoid (20). Lutein is concentrated in the retina, where it may help prevent macular degeneration, the most common preventable form of age-related blindness (21). Other studies have found that lycopene, α -carotene and β -carotene are associated with a reduced risk of lung cancer (22). On the basis of a recent review of functional properties of foods (23) and research from our laboratories demonstrating that it is relatively simple to influence circulating levels of lycopene with administration of only 177 mL (6 fluid ounces) of mixed vegetable juice daily (24), we developed a color code for a book aimed at helping consumers to change dietary patterns to include more fruits and vegetables by including one serving from each of the seven color groups each day (Table 1).

Strengths and weaknesses

This method of selecting foods is easy for consumers to use in restaurants and while traveling. However, increased efforts must be made to make these foods available in restaurants, airports and hotels. Busy homemakers want to be able to cook their foods quickly and with minimal preparation and cleanup,

so the time efficiency of preparing a meal will compete with the local fast food restaurant that can deliver food to the home. Precut fruits, vegetables and salad ingredients and take-out-to-eat prepared foods with fruits and vegetables are available in large urban centers but not throughout the country. The National Cancer Institute has developed an enhancement of the 5-A-Day for Better Health program entitled, "Sample the Spectrum" introduced in March, 2001, which uses color to highlight the phytochemical contents of fruits and vegetables (25). Until colorful fruits and vegetables become a feature of restaurant and fast food eating throughout the country, the dietary pattern of Americans will remain unchanged.

Although the color method is superior to the current system of simply encouraging increased fruit and vegetable intakes, it does not account for actual phytochemical delivery to the consumer. Today, there is no labeling law that enables fruit and vegetable manufacturers to list the phytochemicals in their products. Fruits and vegetables are developed and grown less for their flavor and nutritional content and more to accommodate the need to transport these products over long distances and extend their shelf life once they get to market. Finally, research in this area needs to continue on the > 25,000 phytochemicals provided by fruits and vegetables including those that do not have color, such as isoprenoids (26). These important phytochemicals are widely distributed among different plant species, but the delivery of phytochemicals and their effects on biomarkers relevant to cancer prevention need to be documented.

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TABLE 1

Color code groups of fruits and vegetables

Color	Phytochemical	Fruits and vegetables
Red	Lycopene	Tomatoes and tomato products such as juice, soups, and pasta sauces
Red-purple	Anthocyanins and polyphenols	Grapes, blackberries, red wine, raspberries, blueberries
Orange	α - and β -Carotene	Carrots, mangos, pumpkin
Orange-yellow	β -Cryptoxanthin and flavonoids	Cantaloupe, peaches, tangerines, papaya, oranges
Yellow-green	Lutein and zeaxanthin	Spinach, avocado, honeydew melon
Green	Glucosinolates and indoles	Broccoli, bok choy, kale
White-green	Allyl sulfides	Leeks, garlic, onion, chives

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