



## Original Article

## Classification of fruits and vegetables

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## ABSTRACT

Classifications for fruits and vegetables are most helpful for dietary assessment and guidance if they are based on the composition of these foods. This work determined whether levels of food components in fruits and vegetables correlated with classification criteria based on botanic family, color, part of plant, and total antioxidant capacity (TAC). A database of 104 commonly consumed fruits and vegetables was created that contained food components known to be provided primarily by these foods. A mathematical clustering algorithm was used to group the foods into homogeneous clusters based on food component levels and the classification criteria. Most useful in categorizing were the botanic families rose, rue (citrus), amaryllis, goosefoot, and legume; color groupings blue/black, dark green/green, orange/peach, and red/purple; and plant parts fruit-berry, seeds or pods, and leaves. Groupings based on TAC levels did not match well with the identified clusters. Clusters were often best defined by a combination of classification variables such as color and part of plant. Results suggest that the groupings dark green leafy vegetables; cabbage family vegetables; lettuces; allium family bulbs; legumes; deep orange/yellow fruits, roots, and tubers; citrus family fruits; tomatoes and other red vegetables and fruits; and red/purple/blue berries are predictive for food components provided by fruits and vegetables.

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## 1. Introduction

Consumption of fruits and vegetables is important for human health because these foods are primary sources of some essential nutrients and contain phytochemicals that may lower risk of chronic disease (DGAC, 2005). Because the many fruits and vegetables available to the United States (US) population vary in composition for both nutrients and phytochemicals, classification of fruits and vegetables is important to researchers who attempt to assess relationships among diet, health, and disease. For example, researchers who develop food frequency questionnaires often need to gauge their fruit and vegetable questions to assess intakes of specific food components.

Classification of fruits and vegetables is also needed for dietary guidance materials to help people select appropriate types of these foods to meet their nutrient and health needs. Many countries have food guides with graphic depictions of the food groups and subgroups along with recommendations for consumption (Painter et al., 2002). The fruit and vegetable groups and subgroups vary from country to country because the focus of food guides is not only on the important components in fruits and vegetables but also on which fruits and vegetables are commonly available to and consumed by population groups.

Food guides created by the US Department of Agriculture (USDA) have included the Basic 7 Food Groups, the Basic 4 Food Groups, the Food Guide Pyramid, and, most recently, MyPyramid (CNPP, 2008). In the Basic 7 and Basic 4 food group guides there were recommendations to consume dark green leafy and deep-orange fruits and vegetables several times a week (for beta-carotene as precursor to vitamin A) and citrus fruits daily (for vitamin C). In the mid-1980s, a food guide from the National Cancer Institute (NCI) encouraged consumption of cruciferous vegetables (i.e. cabbage family vegetables) several times a week for their role in cancer prevention (NCI, 1986). Another NCI campaign called “5 A Day” encouraged classification of fruits and vegetables by color, but did not provide scientific background information that directly associated color to specific concentrations of food components. (The 5 A Day program was transferred to the Centers for Disease Control and Prevention and is now called “Fruits & Veggies—More Matters” (CDC, 2008). It no longer emphasizes the colors of fruits and vegetables, but is consistent with the MyPyramid (CNPP, 2008) recommendations.)

MyPyramid, which was issued in 2005, places all fruits together in one group and has five vegetable subgroups (Tables 1 and 2). The fruit group and vegetable subgroup consumption recommendations were based on the composition and national consumption patterns for food clusters consisting of 12 fruits and 36 different vegetables (Britten et al., 2006; Marcoe et al., 2006). The food components included in the development of the consumption recommendations included macronutrients, nine vitamins, and eight minerals.

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**Table 1**  
MyPyramid fruits and vegetables.

Group or subgroup	MyPyramid website examples (CNPP, 2008) <sup>a</sup>	MyPyramid composites (Marcoe et al., 2006)
Fruits	<u>Apple</u> , apricot, avocado, <u>banana</u> , berries ( <u>strawberries</u> , blueberries, raspberries, cherries), <u>grapefruit</u> , <u>grapes</u> , kiwifruit, lemon, lie, mango, melon ( <u>cantaloupe</u> , honeydew, <u>watermelon</u> ), nectarine, <u>orange</u> , <u>peach</u> , <u>pear</u> , papaya, pineapple, <u>plum</u> , prune, <u>raisins</u> , and tangerine	12 fruits: banana, apple, watermelon, strawberries, grapes, cantaloupe, orange, peach, raisins, pear, plum, and grapefruit
Dark green vegetables	Boy choy, <u>broccoli</u> , <u>collard greens</u> , dark green leafy lettuce, <u>kale</u> , mesclun, <u>mustard greens</u> , <u>romaine</u> , <u>spinach</u> , <u>turnip greens</u> , and <u>watercress</u>	7 vegetables: raw and cooked broccoli, romaine, raw and cooked spinach, cooked collard greens, cooked mustard greens, cooked kale, and cooked turnip greens
Orange vegetables	<u>Acorn squash</u> , <u>butternut squash</u> , carrots, <u>hubbard squash</u> , <u>pumpkin</u> , and <u>sweet potatoes</u>	4 vegetables: raw and cooked carrots, cooked sweet potato, cooked winter squash, and cooked pumpkin
Dry beans and peas	<u>Black beans</u> , <u>black-eyed peas</u> , <u>garbanzo beans (chickpeas)</u> , <u>kidney beans</u> , <u>lentils</u> , <u>lima beans (mature)</u> , navy beans, <u>pinto beans</u> , <u>soy beans</u> , <u>split peas</u> , <u>tofu (bean curd made from soybeans)</u> , and <u>white beans</u>	10 vegetables: pinto beans, white beans, soybeans, kidney beans, black beans, lentils, chickpeas, lima beans, cowpeas, and split peas
Starchy vegetables	<u>Corn</u> , <u>green peas</u> , lima beans (green), and <u>potatoes</u>	3 vegetables: boiled and baked potato, corn, and green peas
Other vegetables	Artichokes, asparagus, <u>bean sprouts</u> , beets, Brussels sprouts, <u>cabbage</u> , <u>cauliflower</u> , <u>celery</u> , <u>cucumber</u> , eggplant, <u>green beans</u> , <u>green or red peppers</u> , <u>iceberg lettuce</u> , <u>mushrooms</u> , okra, <u>onions</u> , parsnips, <u>tomato</u> , <u>tomato juice</u> , vegetable juice, turnip, wax beans, and <u>zucchini</u>	12 vegetables: raw and cooked tomato and tomato juice, lettuce, raw cucumber, raw pepper, raw and cooked onion, raw and cooked celery, raw and cooked cabbage, cooked green beans, mushroom, cooked bean sprouts, cooked summer squash, and cooked cauliflower

<sup>a</sup> Vegetables may be raw or cooked; fresh, frozen, canned, or dried/dehydrated; and may be whole, cut-up, or mashed. Fruit may be fresh, canned, frozen, or dried, and may be whole, cut-up, or pureed. MyPyramid provides recommendations for daily intakes for fruits and vegetables and weekly intakes from the five vegetable subgroups. Underlined foods are those included in the composites used to develop the food group recommendations.

Other systems for classifying fruits and vegetables that appear to be related to food composition include those based on botanic families, colors, and edible parts of plants (Pennington, 2003). Another potentially important classification might be total antioxidant capacity (TAC) because the protection that fruits and vegetables offer against cancer, cardiovascular diseases, and other diseases has been attributed to various antioxidants they contain (Wang et al., 1996; Wu et al., 2004). TAC is thought to reflect concentrations of ascorbic acid, alpha-tocopherol, beta-carotene, various flavonoids, glutathione, and other (mainly phenolic) compounds present in foods.

The goal of this work was to group fruits and vegetables into homogeneous clusters based on their food component profiles and investigate potential classification variables for these foods that relate specifically to food composition (irrespective of food consumption). Such classifications could help researchers develop the fruit and vegetable sections of their food frequency questionnaires, teach students about food composition, and assist

**Table 2**  
MyPyramid fruit and vegetable clusters (Marcoe et al., 2006).

Fruit or vegetable	Foods represented by fruit or vegetable
Banana	Plantain
Strawberries	Kiwifruit, blueberries, cranberries, raspberries, blackberries
Grapes	Cherries, rhubarb
Cantaloupe	Honeydew melon, casaba melon
Orange	Tangerine
Peach	Mango, papaya, apricot, guava, avocado
Raisins	Date, fig
Plum	Prune
Romaine	Endive, chicory, escarole, parsley
Kale	Chard, parsley, dandelion
Soybeans	Tofu, soy-based meal replacements, soy beverages
Boiled potato	Fried potatoes, chips
Cooked tomato	Tomato sauce
Lettuce	Iceberg and butterhead lettuce
Pepper	Green, red, and chili peppers; olives
Onion	Mature and green onions, leeks, chives, garlic
Cabbage	Red and green cabbage
Green beans	Snow peas, asparagus, okra, artichokes
Summer squash	Zucchini

dietitians in providing dietary guidance to patients and clients. Previous studies suggest that mathematical clustering algorithm methods can be used to overcome the challenge of dealing with multiple food components simultaneously to objectively classify foods (Akbat et al., 2000; Windham et al., 1985).

## 2. Methods and materials

### 2.1. Fruit and vegetable definitions

Although the botanic term “fruit” refers to the seeds and surrounding tissues of a plant, the foods that are commonly referred to as “fruits” for culinary purposes are pulpy seeded tissues that have a sweet (oranges, apples, pears, blueberries) or tart (lemons, limes, cranberries) taste. In the US diet, fruits are often consumed as snacks, desserts, or a sweet side dish to a meal.

By culinary definition, “vegetables” are edible plant parts including stems and stalks (celery), roots (carrots), tubers (potatoes), bulbs (onions), leaves (spinach, lettuce), flowers (artichokes), some fruits (cucumbers, pumpkin, tomatoes), and seeds (beans, peas). Vegetables are less sweet or tart than “fruits” and are usually consumed as salads, cooked side dishes, and savory appetizers. Using this definition, avocado was grouped with vegetables for this work. Mushrooms (fungi) and sweet corn (a cereal grain) are included as vegetables here because they are commonly used as vegetables in US diets. The term “legumes” is used here to mean beans and peas; however, peanuts (a type of legume used as nuts) are not included. Herbs (e.g. coriander, basil) and vegetables used primarily as spices (e.g. chives) are not included here because they are generally used in small amounts and were assumed not to contribute greatly to food component intake.

### 2.2. Identifying fruits and vegetables for the database

Table 3 provides alphabetical lists for the 37 fruits and 67 vegetables selected for the database. The goals for the database were to include only commonly consumed fruits and vegetables, to have only one version (i.e. one listing) of each fruit and vegetable, to have a complete food component profile for each food (i.e. no

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