# Chapter 1

# Definitions and classifications for fruit and vegetables

## Botanical and culinary definitions

### Botanical definitions

Broadly, the botanical term *fruit* refers to the mature ovary of a plant, including its seeds, covering and any closely connected tissue, without any consideration of whether these are edible. As related to food, the botanical term *fruit* refers to the edible part of a plant that consists of the seeds and surrounding tissues. This includes fleshy fruits (such as blueberries, cantaloupe, peach, pumpkin, tomato) and dry fruits, where the ripened ovary wall becomes papery, leathery, or woody as with cereal grains, pulses (mature beans and peas) and nuts.

In the broadest sense, the botanical term *vegetable* refers to any plant, edible or not, including trees, bushes, vines and vascular plants, and distinguishes plant material from animal material and from inorganic matter. There are two slightly different botanical definitions for the term *vegetable* as it relates to food. According to one, a vegetable is a *plant* cultivated for its edible part(s); according to the other, a vegetable is the *edible part(s) of a plant,* such as the stems and stalk (celery), root (carrot), tuber (potato), bulb (onion), leaves (spinach, lettuce), flower (globe artichoke), fruit (apple, cucumber, pumpkin, strawberries, tomato) or seeds (beans, peas). The latter definition includes fruits as a subset of vegetables.

**Definition of fruit and vegetables applicable in epidemiological studies**

**Fruit and vegetables**

Edible plant foods excluding cereal grains, nuts, seeds, tea leaves, coffee beans, cacao beans, herbs and spices

**Fruit**

Edible parts of plants that contain the seeds and pulpy surrounding tissue; have a sweet or tart taste; generally consumed as breakfast beverages, breakfast and lunch side-dishes, snacks or desserts

**Vegetables**

Edible plant parts including stems and stalks, roots, tubers, bulbs, leaves, flowers and fruits; usually includes seaweed and sweet corn; may or may not include pulses or mushrooms; generally consumed raw or cooked with a main dish, in a mixed dish, as an appetizer or in a salad

Whether mushrooms and seaweed (foods commonly used as vegetables) are regarded as part of the plant kingdom depends on the choice of one out of four schemes used to classify living organisms into kingdoms. The traditional scheme of two kingdoms (plant and animal) places fungi and algae (sources of food mushrooms and seaweed, respectively) in the plant kingdom. In the other three schemes, the fungi and algae are placed either together in the Protista kingdom or separately in the Protista and fungi kingdoms (Stern, 1988).

## Culinary definitions

The main culinary groupings for edible plant materials are fruit, vegetables, cereal grains, nuts, and seeds. (Minor groupings include herbs or spices and plant parts used to make coffee, tea and chocolate). Populations are accustomed to these culinary groupings and use them to communicate about plant foods and to distinguish the types of plant food used in meals. These culinary groupings are used in households for meal planning and preparation, in educational settings where nutrition professionals communicate cooking skills and dietary advice to consumers, in the market place, where people purchase plant foods for home use, and in restaurants, where people order and consume prepared foods.

The culinary term *fruit and vegetables* may be defined as edible plant foods excluding cereal grains, nuts, seeds, coffee, tea, cacao and herbs and spices. Domel *et al.* (1993b) provided a similar but more detailed definition for fruit and vegetables, noting the exclusion of nuts, seeds, peanuts, peanut butter, grains and vegetables when used as grains and the inclusion of olives, avocados, pickles, coconut and products and mixed dishes that contain any amount of fruit and vegetable. They also provided a narrow definition of fruit and vegetables that has specific conditions relating to macronutrient content, processing and serving sizes, but this definition is not practical for use in relation to epidemiological studies.

The culinary term *fruit* refers to the edible part of a plant, tree, bush or vine that contains the seeds and pulpy surrounding tissue and has a sweet or tart taste. In essence, culinary fruits are the subset of botanical fruits that remains after excluding cereal grains (wheat, rye, oats, barley), nuts, seeds and fruits used as vegetables. Fruits are used as a breakfast beverage or side-dish (for example, orange juice, berries, grapefruit, melon), lunch side-dish or dessert, snack food between meals or dinner dessert. Raw and canned fruits are also used as appetizers, salad ingredients and side-dishes.

The culinary term *vegetable* refers to edible part(s) of a plant consumed raw or cooked, generally with a main dish, in a mixed dish, as an appetizer or in a salad. Vegetables include edible stems and stalks, roots, tubers, bulbs, leaves, flowers, some fruits, pulses (mature beans and peas), fungi (mushrooms, truffles), algae (seaweed) and sweet corn and hominy (cereal grains used as vegetables). The culinary term *vegetable* excludes other cereal grains, nuts, peanuts (a type of pulse) and culinary fruits. The distinction as to which botanical fruits are considered to be culinary vegetables depends on cultural use in meal patterns and the flavours they impart. Botanical fruits used as vegetables (e.g., eggplant, okra, zucchini) tend to be savory in taste, while those used as fruits are generally sweet (due to a higher sugar concentration) or tart as in cranberries, lemons and limes (due to a higher acid content).

## Cultural differences in culinary definitions

Culinary distinctions as to which plant parts are used as fruits and vegetables (and which are designated as fruits and which as vegetables) are based on traditional use and tend to be imprecise, varying within and between cultures. Information about which foods serve as fruits and vegetables is generally presented in books on cookery and in food guides that are developed for consumers by government public health agencies or by professional nutrition associations. Food guides are used by nutrition educators to communicate the types and quantities of foods that should be consumed on a daily basis to meet nutrient needs, prevent deficiency diseases and lower the risk for diet-related chronic diseases.

A recent comparison of food guides used in Australia, China, Canada, Germany, Korea (Republic of), Mexico, the Philippines, Portugal, Puerto Rico, Sweden, the United Kingdom and the United States (USA) revealed that despite the cultural differences in dietary patterns, food groupings (cereal grains, vegetables, fruit, meat and meat substitutes, dairy products, fats and sweets) are generally similar (Painter *et al.*, 2002). Fruit and vegetables appear as a single group in six food guides (Canada, China, Korea, Portugal, Mexico and the United Kingdom), but are separate groups in the other guides. All the guides separate nuts, seeds and cereal grain products from fruit and vegetables.

There are differences in the placement of starchy root and tuber vegetables and pulses between the guides. Six of the guides (Australia, Canada, China, the Philippines, Puerto Rico and the USA) group potatoes in the vegetable group. Germany, Korea, Mexico, Portugal and the United Kingdom group potatoes in the grain group, but place other root and tuber vegetables such as turnips and parsnips in the vegetable group. Potatoes might be grouped with grains because, like grain products, they are starchy, inexpensive, readily available and commonly consumed. The Swedish food guide has a separate food group for potatoes and other root vegetables and recommends that root vegetables be the foundation for a daily inexpensive diet supplemented with other vegetables that vary from day to day and between seasons.

Seven of the guides place pulses in the meat group because of their protein content; Australia, Germany and Sweden put pulses in the vegetable group because of their vitamin, mineral and dietary fibre content. The US food guide places immature pulses in the vegetable group and mature pulses in the meat, poultry and fish group. The Chinese guide places pulses (primarily soybeans and soymilk) in the milk and dairy products group. A food guide for vegetarians and vegans (Venti & Johnston, 2002), places beans in a protein group and provides separate groups for dark green leafy vegetables and dried fruit to encourage use of sources of iron and other minerals that are usually obtained from meat.

Foods derived from fruit and vegetables such as preserves, jams and jellies, sugared fruit pieces used as candies, and sweet cucumber pickles fit into the sweets or sugars group of food guides. Food guides do not have groupings for mixed dishes or desserts that contain fruit or vegetables, for condiments or snack foods that are derived from fruit or vegetables, or for herbs and spices.

## Summary of definition issues

Botanical definitions for fruit and vegetables are more precise than culinary definitions. However, culinary definitions are based on cultural uses of foods and are more commonly under-

stood by nutrition researchers and by participants in epidemiological studies. The following botanical and culinary issues may affect the grouping of fruits, vegetables, mixed dishes and desserts containing fruits and vegetables, and foods derived from fruits and vegetables:

- Mushrooms (fungi) and seaweed (algae) are commonly considered to be vegetables because of their culinary use. However, botanically, they may or may not be considered to be derived from plants, depending on the scheme used to classify organisms into kingdoms.
- In some cultures, potatoes and other starchy root and tuber vegetables (e.g., taro) are separated from other vegetables and considered to be a separate group or part of the grain group.
- Pulses (mature beans and peas) may be considered as meat alternatives (substitutes) rather than vegetables (or in addition to being vegetables) in some cultures. Products derived from soybeans such as tofu and soy-based meat substitutes are often grouped with high-protein foods (meat, fish, poultry, eggs, nuts and seeds), rather than with vegetables. Soymilk is usually classified in the milk group, with the assumption that it is fortified with calcium.
- Peanuts (groundnuts) are a type of pulse with various cultural uses (e.g., snack food, part of a main dish, boiled side-dish, peanut butter, or peanut sauce). Peanuts are usually considered to be nuts and grouped with the high-protein foods.
- Fresh or sweet corn and hominy are cereal grains, but are generally used as vegetables (i.e., side-dishes with a dinner meal). Mature corn (also known as field corn or maize) is generally used as a cereal grain in the form of corn grits, corn meal or corn flour. Corn meal and flour are used to make cornbread, tortillas and tortilla chips.
- Although most fruits and vegetables are low in fat, several (avocados, coconut, olives) have higher fat content and varied uses in cuisines. Food guides do not provide sufficient detail to indicate where these foods are grouped. Avocados and olives may be grouped with fruit, vegetables or fats. Coconut may be grouped with nuts, fruit (e.g., cut or shredded in a fruit salad) or vegetables (e.g., used in stews mixed with meats and other vegetables).
- Herbs (e.g., coriander, parsley) include the stems and leaves of plants, and some vegetables (e.g., garlic and chili peppers) are used as spices or garnishes. Herbs and spices are not included in food guides, mainly due to the small amounts used, but they may contribute important food components and should not be ignored in terms of dietary assessment.
- Fruits and vegetables that are part of mixed dishes (i.e., main dishes or desserts) may be overlooked when assessing total fruit and vegetable intake. Food guides do not have groupings for mixed dishes (meat and vegetable casseroles, stews, stir-fries) or desserts that may contain fruits or vegetables (chocolate-covered raisins, fig bars, fruit pies, pumpkin pie, carrot cake).
- Some food products derived from fruit and vegetables may not retain the nutritive value of the original fruit and vegetable and may contain added fat or sugar. Food guides usually group jams, jellies, and fruit drinks (lemonade, fruit punches) with the sweets or sugars food group, but it is not clear where potato crisps, fried potatoes or pickled fruits or vegetables are grouped.

## Subgroup classifications for plants, fruit and vegetables

Subgroup classifications for plants, fruits and vegetables according to their content of food components can be

useful for epidemiological studies. Because most fruit and vegetables have low calorie, fat, saturated fat and sodium content and are devoid of cholesterol, the classifications may focus more on vitamins, minerals and other bioactive components. Such classification is complicated by the large number of food components in fruit and vegetables, and by the facts that not all the components have yet been identified and that not all fruits and vegetables have been analysed to determine the level of the components that have been identified. Some components (dietary fibre, potassium, plant sterols) are present in most fruit and vegetables, while others (vitamin C, carotenoids, folacin (folic acid), iron, zinc, magnesium, calcium, flavonoids) occur mainly in specific fruits and vegetables. For many of the food components, the published data have not yet been aggregated and summarized and therefore have not been incorporated into food composition databases.

Table 1 lists selected vitamins and other bioactive components and their fruit and vegetable sources. Current food composition databases provide information about fruit and vegetable sources of β-carotene (dark green leafy vegetables, deep yellow and orange fruits and vegetables), vitamin C (citrus fruits, dark green leafy vegetables, cantaloupe) and folacin (dark green leafy vegetables, oranges, pulses). Food composition data and databases are beginning to be developed for other bioactive components such as glucosinolates, indoles and isothiocyanates in cruciferous vegetables (Fahey *et al.*, 2001); flavonols, flavones and other flavonoids (Hertog *et al.*, 1992, 1993b; Häkkinen *et al.*, 1999; Peterson & Dwyer, 2000; Sampson *et al.*, 2002); flavonoids and phenolic acids in fruit juices (Spanos & Wrolstad, 1992); flavonoids and carotenoids in citrus fruits (Ranganna *et al.*, 1983); carotenoids (Mangels *et al.*, 1993); isoflavones (Coward *et al.*, 1993; Wang & Murphy, 1994; USDA, 1999a); isoflavones, coumesterol and lignans (Boker *et al.*, 2002); phytoestrogens (Reinli & Block, 1996; Pillow *et al.*, 1999); and lemonoid glucosides in citrus juices (Fong *et al.*, 1989).

Several subgroup classifications for plants, fruits, and vegetables are considered below, to assess how they relate to the presence of nutrients and bioactive food components. The subgroups include botanical families and growing conditions for classifying plants and botanical fruit development terms for classifying fruit. Fruit and vegetable subgroups used for reporting food supply and consumption data are presented, as are subgroups based on edible parts, colour and processing and preparation.

## Botanical families

Botanical classification of plants is based on the physiological characteristics of plant development, organization and structure. The 11 levels of botanical classification are kingdom, division, class, subclass, order, family, genus, species, variety, cultivar and strain. As an example, the 11 classification terms for the Gray zucchini summer squash are, respectively, Plant, Spermatophyta, Angiospermae, Dicotyledonae, Cucurbitales, Cucurbitaceae, Cucurbita, Pepo L., Melopepo Alef., Zucchini, and Gray (Yamaguchi, 1983). Botanical classification is useful for biologists to establish plant origins and relationships and to help identify plants across different cultures and languages; it is also useful for horticulturists because plants within a family may have similar climatic requirements, economic uses, and disease and insect controls. The usefulness of botanical classification in dietary assessment is less clear, because foods derived from the same botanical family may or may not contain similar levels of bioactive food components.

The plant kingdom (using the traditional two-kingdom scheme) has four divisions, of which three (Thallophyta, Pteridophyta and Spermatophyta) contain foods consumed by humans *(Encyclopedia Britannica,* 1974). Most human foods are within the Spermatophyta (seed

## Table 1. Selected vitamins and other bioactive components in fruit and vegetables[a]

### Vitamins

**Folacin:**
Avocado, orange; asparagus, black bean, black-eyed pea, Brussels sprout, chickpea, chives, endive, green pea, kidney bean, lentil, mustard greens, navy bean, okra, pinto bean, soybean, spinach, turnip greens

**Vitamin C:**
Blackberry, blueberry, cantaloupe, cranberry, elderberry, grapefruit, kiwi fruit, lemon, lime, mango, orange, papaya, peach, raspberry, strawberry, tangerine; broccoli, Brussels sprout, cabbage, cauliflower, kale, kohlrabi, spinach, sweet red/green pepper, tomato

### Other bioactive components

**Allyl sulfides:**

**Allicin:**
Chives, garlic, leek, onion, shallot

**Capsaicin:**
Chili pepper

**Carotenoids:**

**α-carotene:**
Carrot, pumpkin, sweet potato

**β-carotene:**
Apricot, cantaloupe, guava, mango, peach, persimmon, red/pink, grapefruit; Arugula, asparagus, beetgreens, broccoli, Brussells sprouts, cabbage, carrot, cassava leaves, chicory, chili pepper, collards, cress, dandelion greens, fiddlehead greens, kale, mustard greens, pak-choy, pumpkin, sweet redpepper, romaine, spinach, sweet potato, Swiss chard, tomato, turnip greens, winter squash

**β-cryptoxanthin:**
Apple, apricot, avocado,cantaloupe,carambola, grape fruit, jackfruit, kiwifruit, kumquat, mango, olive, orange, papaya, passion fruit, peach, persimmon, plum, tangerine, watermelon; broccoli, corn, pumpkin, red pepper, tomato, winter squash

**Lycopene:**
Guava, red/pink grapefruit, watermelon; tomato

**Lutein:**
Kiwifruit, orange, tangerine, watermelon; asparagus, broccoli, Brussels sprouts, cabbage, carrot, collards, corn, kale, lettuce, potato, pumpkin, spinach, sweet red pepper, tomato, turnip greens

**Zeaxanthin:**
Orange, persimmon; collards, corn, kale, lettuce, pumpkin, red pepper, spinach, tangerine, turnip greens

**Flavonoids[b]:**

**Anthocyanins:**
Apple, blackberry, blackcurrant, blueberry, cherry, chokecherry, cranberry, elderberry, nectarine, peach, plum, raspberry, pomegranate, red grape, red/green pear, strawberry; asparagus, carrot, red cabbage, red onion, redbean; red wine

**Flavanols:**
Apple, apricot, nectarine, peach, pear, red grape, strawberry; green bean

**Catechins**: Apple, blackberry, cranberry, elderberry, red-purple grape

**Epicatechin**: Apple, red-purple grape

**Proanthocyanidins**: Apple, blueberry, cranberry, red-purple grape, strawberry

**Flavanones:**
Grapefruit, lemon, orange; tomato

**Hesperidin:** Grapefruit, lemon, lime, orange, tangerine

**Naringenin:** Grapefruit

**Neohesperidin**: Grapefruit, orange

**Flavones:**
Grapefruit, lemon, orange; carrot, celery, parsley sweet red/green pepper

**Apigenin:**
Carrot, celery

**Luteolin:**
Sweet red/green pepper

**Flavonols:**
Orange, red-purple grape; broccoli, Brussels sprouts, cauliflower, onion, turnip greens

**Quercetin:** Apple, apricot, bilberry, blackberry, blackcurrant, blueberry, cherry, cranberry, elderberry, grapefruit, lemon, mango, peach, pear, plum, raspberry, red bilberry, redcurrant, red-purple grape, strawberry, whitecurrant; broccoli, cabbage, chives, corn, endive, kale, lettuce, pepper, red cabbage, red onion, string bean, sweet potato, tomato

**Myricetin:** Apple, bilberry, blackcurrant, blueberry, cranberry, red-purple grape, red bilberry, redcurrant, whitecurrant; carrot

**Kaempferol:** Apple, apricot, bilberry, blackberry, blackcurrant, cherry, cranberry, mango, peach, pear, plum, raspberry, red bilberry, redcurrant, red/pink grapefruit, red-purple grape, whitecurrant; broccoli, Brussels sprouts, cabbage, chives, endive, green bean, horse radish, kale, lettuce, leek, red onion, tomato

**Isorhamnetin:** Apple, blackberry, cherry, pear

**Rutin:** Apple, blackcurrants, cantaloupe; asparagus

## Table 1 (contd)

**Isoflavones:** Green bean, legumes, soybean
- **Genistein:** Currants; alfalfa sprouts, legumes, soybean

**Daidzein:** Currants; legumes, soybean
**Daidzin**: Soybean
**Genistin:** Soybean
**Glycitin/Glycitein**: Soybean
**Biochanin A**: Legume
**Coumestrol:** Legumes, soybean
**Formononetin:** Legumes

**Glucosinolates, indoles and isothiocyanates:**
Bok choy, broccoli, Brussels sprouts, cabbage, cauliflower, collard greens, kale, napa cabbage, turnip

**Glutathione:**
Cantaloupe, grapefruit, orange, strawberry; asparagus, spinach

**Lignans**:
Banana, cantaloupe, cranberry, orange, pear, peach, pomegranate, strawberry; asparagus, bok choy, broccoli, cabbage, carrot, cauliflower, iceberg lettuce, lentil, napa cabbage, onion, potato, pumpkin, rutabaga, soybean, summer squash, sweet red/green pepper, tomato, turnip, winter squash

**Phenolic acids:**
Apple, citrus fruit; olive

**Cinnamic acids**
- **Caffeic acid:** Apple, gooseberry, grape, olive, raspberry, strawberry; broccoli, Brussels sprout, carrot, endive, red onion, savoy cabbage, sweet potato, tomato
- **Chlorogenic acid**: Apple, apricot, blackberry, blueberry, cherry, cranberry, grape, plum, pomegranate, strawberry; cabbage, carrot, sweet red/green pepper, tomato
- **Ferulic acid:** Apple, blackberry, blueberry, cantaloupe, grapefruit, plum, raspberry, strawberry; Brussels sprout, corn, endive, red onion
- ***para*-Coumaric acid:** Apple, blueberry, cherry, goose berry, plum, red-purple grape, strawberry; Brussels sprout, cabbage, carrot, savoy cabbage, sweet red pepper, tomato

**Ellagic acid:**
Blackberry, blueberry, boysenberry, cranberry, elderberry, marionberry, pomegranate, red/black raspberry, red grape, strawberry

**Gallic acid:** Blackberry, cherry, mango, pomegranate, red-purple grapes

**Citric acid:**
Grapefruit, lemon, lime, orange, tangerine

**Plant sterols**
- **β-sitosterol:** Apple, apricot, avocado, banana, cantaloupe, cherry, fig, grapefruit, lemon, orange, peach, pear, pineapple, plum, pomegranate, red grape, strawberry, watermelon; asparagus, Brussels sprout, carrot, cauliflower, cucumber, eggplant, lettuce, okra, onion, pea, potato, pumpkin, radish, soybean, tomato
- **Campesterol:**
  Apple, apricot, banana, fig, grapefruit, lemon, pineapple, orange, peach; asparagus, Brussels sprout, carrot, cauliflower, lettuce, okra, onion, pea, radish, soybean, tomato
- **Phytosterol:**
  Pulses
- **Saponins:**
  Asparagus, beet, garlic, spinach
- **Stigmasterol:**
  Banana, fig, grapefruit, lemon, orange, peach; asparagus, carrot, cauliflower, eggplant, lettuce, okra, pea, potato, soy bean, tomato

**Pectin:**
Apple, cherry, pear

**Resveratrol:**
Blueberry, red-purple grape

**Rutin:**
Cantaloupe; asparagus

**Salicylates:**
Apricot, cantaloupe, cherry, date, grape, guava, orange, pineapple, raisin, raspberry, strawberry; Chili pepper, endive, radish, sweet green pepper, zucchini

**Terpenes/terpenoids:**
Lemon, lime, orange, pink grapefruit
- **Limonene:**
  Grapefruit, lemon, orange, tangerine; carrot, celery

[a] Fruits are listed first, followed by a semicolon and the listing of vegetables.
[b] There are over 4000 flavonoid compounds, but far fewer have been identified in commonly consumed foods; most of them are within the six classes listed here.
Sources: Smith *et al.*, 1995; Perry *et al.*, 1996; USDA, 1998, 1999a, 2002; Holden *et al.*, 1999; Barratt-Fornell & Drewnowski, 2002; Mayo Clinic *et al.*, 2002; McCann *et al.*, 2002; Pennington, 2002; World Health Organization & Tufts University School of Nutrition and Policy, 2002

plants) division. Of the two classes within the Spermatophyta (Gymnosperm and Angiosperm), almost all human foods are in the Angiosperm (flowering) class. Within the two Angiosperm subclasses (Monocotyledonae and Dicotyledonae), there are approximately 93 orders and 432 families (20 orders and 67 families for the Monocotyledonae and 73 orders and 365 families for the Dicotyledonae). Even though only a small percentage of available plants are used as human foods, hundreds of different types of fruit and vegetable are consumed across the world and consideration of the various cultivars and strains for each fruit and vegetable increases the number of available fruit and vegetables into the thousands.

Table 2, which lists the subclasses, orders, and families of Spermatophyta that are used as human foods and provides examples of food plants within each family, illustrates the complexity of the botanical classification. Various food components in fruit and vegetables are concentrated in some families, but are also widely and variously distributed among the families. Peterson and Dwyer (1998) reported that botanical classifications may be helpful in ascertaining the likely presence of flavonoids in foods when food composition data are not available; however, they noted that quantitative estimates are likely to be imprecise.

Table 3 lists 16 botanical families that are sources of food components (as identified from Table 2) and lists some of the fruits and vegetables within these families. The asparagus (Asparagaceae), olive (Oleaceae), grape (Vitaceae) and morning glory (Convolvulaceae) families contain only one type (or main type) of food, and each has a unique food component profile. Individual families that contain fruits and vegetables with somewhat similar food component profiles include rue (Rutaceae), rose (Rosaceae), cabbage (Cruciferae), amaryllis (Amaryllidaceae), goosefoot (Chenopodiaceae), heath (Ericaceae), legume (Leguminosae) and sunflower (Asteraceae). Foods within the gourd (Cucurbitaceae), nightshade (Solanaceae), carrot and laurel families do not contain similar food component profiles. The gourd family includes cantaloupe (vitamin C and β-carotene), watermelon (lycopene) and pumpkin and deep yellow winter squash (β-carotene). Other members of the gourd family (honeydew melon, summer squash, and non-yellow winter squash) do not serve as major sources of these or other food components. The nightshade family includes chili peppers (β-carotene, capsaicin); sweet peppers (vitamin C, lycopene if red); tomatoes (vitamin C, β-carotene, lycopene); and eggplant and white potatoes (not major sources of food components). The laurel family includes avocado (folacin, vitamin B6) and plants that are sources of herbs or spices (cinnamon, sassafrass, sweet bay). The carrot family includes carrot (α- and β-carotenes); the stalk vegetable celery; the root vegetables celeriac and parsnip; and plants used as herbs (anise, caraway, coriander, dill, fennel, parsley).

Thus, although, some botanical families have some fruits and vegetables with similar food components, not all foods within a family may be reliable sources of a given food component. Another issue that makes the use of botanical families somewhat difficult for classifying fruits and vegetables as foods is that different parts of some plants may be eaten separately and have different food components (e.g., beet roots and greens, turnip roots and greens, broccoli stems and flowers, chive bulbs and green tops). Botanical classification applies to the entire plant and is not

specific for the different parts of a plant that are consumed.

## Growing conditions

Plants may be classified according to habitat, i.e., whether they grow in water or in soil, and the soil-growing plants may be further classified according to whether they grow in areas that are desert (low humidity, high temperature), tropical (high humidity, high temperature) or temperate (moderate humidity and temperature) (Yamaguchi, 1983). Aquatic plants include lotus, taro, water chestnut, water convolvulus and watercress. Desert plants include cactus and some desert cucurbits (buffalo gourd). Tropical plants include avocado, banana, breadfruit, carambola, cassava, date, durian, guava, mango, papaya, passion fruit, pineapple and winged beans (goa beans). Plants grown in temperate areas may be divided according to their growing season. Cool-season crops, which are adapted to mean monthly temperatures of 16–18°C (60–65°F), include artichoke, asparagus, Brussels sprout, broccoli, cabbage, carrot, cauliflower, celery, chard, endive, garlic, kale, lettuce, mustard, onion, parsnip, pea, radish, spinach, turnip and white potato. Warm-season crops, which are adapted to mean monthly temperatures of 18–30°C (65–86 °F) and are intolerant of frost, include cantaloupe, cucumber, eggplant, lima bean, okra, pepper, snap bean, squash and pumpkin, sweet corn, sweet potato, tomato and watermelon.

Several foods within the tropical plants (avocado, mango, papaya), the cool-season plants (Brussels sprout, broccoli, cabbage, carrot, cauliflower, chard, endive, garlic, kale) and the warm-season plants (pumpkin, sweet potato, tomato, watermelon) contain a range of vitamin and bioactive components. However, it appears that classification by growing season, habitat, or climate is not directly related to food component composition and not very useful for nutritional epidemiology. Classification by growing conditions might have some use for population studies where fruits and vegetables are locally grown and are of limited variety. Such a classification is less useful for populations with access to national and international food commerce and commercial methods of food preservation (freezing, canning), processing and preparation.

## Fruit development from flowers

In addition to the botanical classification of whole plants (Table 2), there is a botanical classification of fruits according to how they develop from their flowers. Fruits typically have three regions, the exocarp, which is the skin (peel) or outermost layer of the fruit wall; the mesocarp or middle region; and the endocarp, which is the innermost area around the seeds (Stern, 1988). Fruits with a mesocarp that is dry at maturity are classified as *dry fruits* (cereal grains, beans, peas, and nuts), and fruits with a mesocarp that is at least partly fleshy at maturity are classified as *fleshy fruits* (all others). Fleshy fruits may be *simple, aggregate or multiple.*

*Simple fleshy fruits* develop from a flower with a single pistil; the ovary alone may develop into the fruit, or other parts of the flower may develop with it. Simple fleshy fruits include *drupes, pomes* and *berries.* Drupes have a single seed enclosed by a hard, stony pit, as in the apricot, cherry, coconut, date, nectarine, olive, peach and plum. In pomes, the flesh comes from the enlarged receptacle that grows up around the ovary, and the endocarp around the seeds is papery or leathery, as with the apple, pear and quince. Berries develop from a compound ovary and usually contain more than one seed. The three types of berry are *true berries, pepos* and *hesperidiums.* True berries are fruits with a thin skin that is soft at maturity, as in avocado, blueberry, cranberry, date, eggplant, gooseberry, grape, persimmon, red/green pepper and tomato. Pepo berries have a relatively thick rind and include cantaloupe, cucumber, pumpkin, squash and watermelon. Hesperidium berries have a leathery oil-containing skin, and outgrowths from the inner lining of the ovary wall become sac-like and swollen with juice as the fruit develops. All members of the rue family (grapefruit, kumquat, lemon, lime, orange and tangerine) produce this type of fruit.

*Aggregate fruits* develop from a single flower with several to many pistils. The pistils develop into tiny drupes and mature as a clustered unit on a single receptacle. Examples are blackberries, loganberries, raspberries and strawberries.

*Multiple fruits* are formed when a cluster of flowers grouped closely

## Table 2. Botanical classification of edible angiosperms

**Class: Monocotyledons/liliopsida**
**Subclass: Alismidae**
*Order: Alisamales*
Alismataceae (*Water plantain family*)
California soaproot, old world arrowhead, sarsaparilla
**Subclass: Arecidae**
*Order: Arales*
Araceae (*Arum family*)
Alocasia, ape, belembe, calalu, cocoyam, dasheen, giant swamp taro, giant taro, tannia, taro, yautia
*Order: Arecales*
Palmae/Arecaceae (*Palm family*)
Coconut, date, palm cabbage, palm heart, palmito
**Subclass: Commelinidae**
*Order: Bromeliales*
Bromeliaceae (*Pineapple family*)
Pineapple
*Order: Cyperales*
Cyperaceae (*Sedge family*)
Water chestnut (matai)
*Order: Poales*
Gramineae/Poaceae (*Grass family*)
Bamboo shoots, barley, corn/maize, oats, rice, rye sorghum, sugarcane, wheat
**Subclass: Liliidae**
*Order: Liliales*
Amaryllidaceae (*Amaryllis family*)
Chinese chive, chive, garlic, Japanese bunching onion, leek, onion, rakkyo, scallion, Welsh onion
Asparagaceae (*Asparagus family*)
Asparagus
Dioscoreaceae (*Yam family*)
Chinese yam, nagaimo, winged/water yam, white/Guinea yam, yam
Liliaceae (*Lily family*)
Tiger lily
*Order: Zingiberales*
Cannaceae (*Canna family*)
Queensland arrowroot
Marantaceae (*Arrowroot family*)
Arrowroot
Musaceae (*Banana family*)
Banana, plantain
Zingiberaceae (Ginger family)
Ginger, Japanese ginger (mioga)

**Class: Dicotyledons/magnoliopsida**
**Subclass: Asteridae**
*Order: Asterales*
Asteraceae/Compositae (*Sunflower family*)
Butterhead lettuce, cardoon (edible burdock, gobo), dandelion, endive (Belgian endive, chicory, radicchio), fuki, garland chrysanthemum, globe artichoke, iceberg lettuce, Jerusalem artichoke (sunchoke), loose leaf lettuce, romaine, salsify (vegetable oyster, oyster plant)
*Order: Dipsacales*
Caprifoliaceae
Elderberry
*Order: Lamiales*
Lamiaceae/Laminariaceae (*Mint family*)
Basil, marjoram, oregano, peppermint, rosemary, sage, spearmint, thyme
*Order: Polemoniales*
Boraginaceae (*Borage family*)
Borage
Convolvulaceae (*Morning Glory family*)
Sweet potato, water convolvulus (*water spinach*)
*Order: Scrophulariales*
Solanaceae (*Nightshade family*)
African eggplant, chili/hot pepper (red, green), eggplant (aubergine), garden huckleberry (wonderberry), jilo, naranjillo (lulo), pepino, pimento pepper, sweet/bell pepper (red, green, orange, yellow), tobasco pepper, tomatillo, tomato (red, green, yellow), white/Irish potato
**Subclass: Caryophyllidae**
*Order: Caryophyllales/Chenopodiales*
Aizoaceae (*Carpetweed family*)
New Zealand spinach
Amaranthaceae (*Amaranth family*)
Amaranth, tampapa (*Chinese spinach, edible amaranth*)
Basellaceae (*Basella family*)
Malabar nightshade (*malabar spinach*)
Cataceae (*Cactus family*)
Prickly pear (Indian fig, nopal, nopalitos, Sharon's fruit)
Chenopodiaceae (*Goosefoot family*)
Beet (greens and root), orach (mountain spinach), spinach, Swiss chard
Portulacacea (*Purslane family*)
Purslane
*Order: Polygonales*
Polygonaceae (Buckwheat family)
French sorrel, garden sorrel, rhubarb (pieplant)
**Subclass: Dilleniidae**
*Order: Capparales*
Cruciferae/Brassicaceae (*Cabbage family*)
Arugula (Italian cress, garden rocket), bok choy (Chinese cabbage), broccoli, broccoli raab (rapa, Italian turnip), brown mustard (Chinese spinach), Brussels sprouts, cabbage, cauliflower, collards, garden cress, horseradish, Indian mustard, Japanese horseradish, kale, kohlrabi, maca, mustard greens, mustard spinach, napa cabbage (Chinese cabbage), pak choi (Chinese mustard), radish, rocket salad (sea rocket), rutabaga (Siberian kale, hanover salad), turnip (turnip greens), upland cress (winter cress), watercress cress, garden cress)
*Order: Cucurbitales*
Cucurbitaceae (*Gourd family*)
Bitter melon (balsam pear, bitter cucumber, bitter gourd), calabash gourd (zucca melon, white flowering gourd), cantaloupe (musk-melon), chayote, Chinese okra (vegetable

## Table 2 (contd)

gourd), cucumber, dishcloth gourd (sponge gourd, loofa), honeydew melon, snake gourd (serpent gourd), summer squash (e.g., zucchini), watermelon, wax gourd (Chinese winter melon, preserving melon), West India gherkin, winter squash (e.g., pumpkin)

*Order: Ebenales*

Ebenaceae (Ebony family)

Persimmon

Sapotaceae

Sapotes

*Order: Ericales*

Actinidiaceae (*Actinidia family*)

Kiwi (kiwi fruit, Chinese gooseberry)

Ericaceae (*Heath family*)

Blueberry, cranberry, lingonberry

*Order: Euphorbiales*

Euphorbiaceae (*Spurge/Castor Bean family*)

Cassava (manioc, tapioca, yucca), Chinese artichoke, shiso

*Order: Malvales*

Bombacaceae (*Bombax family*)

Durian

Malvaceae (*Mallow/Cotton family*)

Egyptian mallow, okra (lady's finger, gumbo), roselle (Jamaican sorrel)

Tiliaceae (*Basswood/Lindin family*)

Jew's mallow

*Order: Passiflorales*

Caricaceae (*Carica family*)

Papaya (tree melon)

Passifloraceae (*Passionflower family*)

Passion fruit (granadilla)

*Order: Theales*

Theaceae (*Tea family*)

Mangosteen

**Subclass: Hamamelididae**

*Order: Urticales*

Moraceae (*Mulberry family*)

Breadfruit, fig, jackfruit, mulberry

**Subclass: Magnolidae**

*Order: Laurales*

Lauraceae (*Laurel family*)

Avocado, cinnamon, sassafrass, sweet bay

*Order: Magnoliales*

Annonaceae (*Custard apple family*)

Cherimoya (custard apple)

*Order: Nymphaeales*

Nymphaeceae (Water Lily family)

Lotus root (East Indian lotus)

**Subclass: Rosidae**

*Order: Cornales/Umbellales*

Araliaceae (*Aralia/Ginseng family*)

Udo

Umbelliferae/Apiaceae (*Carrot/Parsley family*)

Anise, arracacha, caraway, carrot, celeriac, celery, coriander, dill, fennel (sweet anise), Florence fennel, mitsuba, parsley, parsnip

*Order: Fabales*

Leguminosae/Fabaceae (*Legume family*)

Adzuki beans, alfalfa, asparagus beans, bambara ground nuts, black beans, broad beans (horse beans, field beans, fava beans), carob, chickpeas (garbanzo beans), cluster beans (guar), cowpeas, edible-podded peas (e.g., sugar peas, China peas), Egyptian lupines, fenugreek, green/garden peas, hyacinth beans (chickling peas), jack beans, jicama (yam bean), kidney beans, lentils, lima beans, mat beans, mung beans, peanuts (ground nuts), potato beans, ricebeans, scarlet runner beans, snapbeans (includes green beans, string beans, wax beans, yellow snap beans, romano beans, haricots), soy beans, sword beans, tamarind (Indian date), winged beans (goa beans)

*Order: Geraniales*

Malpighiaceae

Acerola (Barbados cherry, West Indian cherry)

Oxalidaceae

Carambola

*Order: Myrtales*

Myrtaceae (*Myrtle family*)

Feijoa (pineapple guava), guava

Punicaceae (*Pomegranate family*)

Pomegranate

*Order: Oleales*

Oleaceae (*Olive family*)

Olives

*Order: Rhamnales*

Rhamnaceae (*Buckthorn family*)

Jujube (Chinese date, red date)

Vitaceae (*Grape family*)

Grapes

*Order: Rosales*

Rosaceae (*Rose family*)

Apple, apricot, blackberry (brambleberry, dewberry), cherry (sweet cherry), loganberry, loquat (may apple, Japanese medlar, Japanese plum), nectarine, peach, pear, plum, quince, raspberry, strawberry

*Order: Rutales*

Anacardiaceae (*Cashew family*)

Mango

Rutaceae (*Rue family*)

Calamondin, grapefruit, kumquat, lemon, lime, orange, pummelo (pomelo, pommelo, Chinese grapefruit, shaddock), tangerine

*Order: Sapindales*

Sapindaceae (*Soapberry family*)

Longan, lychee (litchi), rambutan

*Order: Saxifragales*

Saxifragaceae (*Saxifrage family*)

Currants (red, pink, white, black, Asian), gooseberry

Sources: Masefield *et al.*, 1969; *Encyclopedia Britannica*, 1974

## Table 3. Foods and food components listed by botanical families

| Family | Foods in family | Food components |
|---|---|---|
| Amaryllis | Chive, garlic, leek, onion, scallion | Allyl sulfides |
| Asparagus | Asparagus | Folacin, lignans, β-sitosterol, campesterol, vitamin B6 |
| Cabbage | Arugula, bok choy, broccoli, Brussels sprout, cabbage, cauliflower, collards, garden cress, kale, kohlrabi, mustard greens, mustard spinach, napa cabbage, pak choi, radish, rutabaga, turnip, watercress | β-Carotene, lutein, folacin (collards, kale), magnesium, calcium, quercetin, kaempferol, glucosinolates, indoles, isothiocyanates, lignans, caffeic acid, *para*-coumaric acid, chlorogenic acid, vitamin C |
| Carrot | Anise, caraway, carrot, celeriac, celery, coriander, dill, fennel, parsley, parsnip | α- and β-Carotene, lutein, apigenin, lignans, β-sitosterol, campesterol (all in carrot) |
| Goosefoot | Beet greens and root, spinach, Swiss chard | β-Carotene, lutein (spinach), zeaxanthin, folacin, magnesium, calcium, glutathione (spinach), vitamin C |
| Gourd | Bitter melon, calabash gourd, cantaloupe, chayote, cucumber, honeydew melon, summer squash, watermelon, winter squash | β-Carotene (cantaloupe, pumpkin, orange-yellow squash, lycopene (watermelon), vitamin C (cantaloupe) |
| Grape | Red-purple grapes, green grapes | Anthocyanins, catechins, proanthocyanidins, quercetin, myricetin, ellagic acid, gallic acid, resveratrol (all in red-purple grapes) |
| Heath | Blueberry, cranberry, lingonberry | Anthocyanins, proanthocyanidins, quercetin, ellagic acid, vitamin C |
| Laurel | Avocado, cinnamon, sassafrass, sweet bay | Folacin, β-sitosterol, *para*-coumaric acid, chlorogenic acid, ferulic acid, caffeic acid, gallic acid, glutathione, vitamin B6 (all in avocado) |
| Legume | Black beans, broad beans, carob, chickpeas, cowpeas, green peas, jicama, kidney beans, lentils, lima beans, mung beans, peanuts, snap beans, soybeans | Folacin, iron, isoflavones, protein, starch, vitamin B6 |
| Morning glory | Sweet potato, water convolvulus | α- and β-Carotene (sweet potato) |
| Nightshade | Chili pepper, eggplant, sweet red/green pepper, tomato, white potato | Capsaicin (chili pepper), β-carotene (chili pepper), lycopene (tomato), luteotin (sweet pepper), lignans, vitamin C (tomato, sweet pepper) |
| Olive | Olives | Monounsaturated fatty acids, β-cryptoxanthin, phenolic acids |
| Rue | Grapefruit, lemon, lime, orange, tangerine | Lycopene (red grapefruit), hesperidin, neohesperidin, citric acid, β-sitosterol, campesterol, salicylates (orange), limonene, vitamin C |
| Rose | Apple, apricot, blackberry, cherry, loganberry, loquat, nectarine, peach, pear, plum, quince, raspberry, strawberry | β-Carotene (apricot, nectarine, peach), anthocyanins, quercetin, kaempferol, isorhamnetin, caffeic acid, ellagic acid, β-sitosterol, campesterol, pectin, salicylates, vitamin C |
| Sunflower | Butterhead lettuce, endive, globe artichoke, | Kaempferol, stigmasterol, lignans iceberg lettuce, Jerusalem artichoke, loose leaf lettuce, romaine, salsify |

together consolidates into a mass during ripening. For example, each of the many sections that make up a pineapple is a developed flower, and each one is attached to the center core, which has a woody stem structure. Other multiple fruits are fig, mulberry and osage orange.

Classification of fruits based on development from flowers is not likely to be useful for epidemiological studies because the classes are not specific for food component content. One exception is the hesperidium berry class, which contains the rue family (citrus) fruits. Classification by fruit development would be confusing for nutritionists and survey participants because the botanical term *berries* is used for some fruits that are not commonly considered to be berries, such as avocado, banana, cantaloupe, cucumber, date, grapefruit, kumquat, lemon, lime, orange, squash, tangerine and watermelon. Fruits that are commonly referred to as *berries* are found in the true berry and aggregate fruit classes.

## Food supply and consumption data

Government agencies often use fruit and vegetable classifications for reporting national food supply (availability) and food consumption data. For example, the United States Department of Agriculture (USDA) Economic Research Service (ERS) reports national food supply data (i.e., *per capita* food availability) for fruit and vegetable classes (USDA, 1999b; United States General Accounting Office, 2002) and the USDA Agriculture Research Service (ARS) uses these same classes to report summarized results from national food consumption surveys (Krebs-Smith & Cantor, 2001). The classifications are based on fruit and vegetable type as well as on processing methods. For fruits, there are four type classes (citrus, melons, berries and other) and five processing classes (fresh, juices, canned/chilled, dried and frozen). For vegetables, there are five type classes (dark green leafy; deep yellow/orange; starchy; dry beans, peas, and lentils; and other) and four processing classes (fresh, canned, frozen and dehydrated). Although these classes are broad, they provide rank orders for individual fruits and vegetables, so that the most commonly consumed foods can be identified.

## Edible parts of plants

Classification by edible part attempts to group fruits and vegetables by the part of the plant, bush, vine or tree that is used as food (Table 4). This classification is useful because of the similar nutrient composition of some plant tissues (e.g., leaves, stalks and stems, roots and tubers, and pulses). This type of classification is found in some food composition databases. The similarity in nutrient content among some plant parts is due to the functions of these tissues. Stem and stalk vegetables (e.g., celery, rhubarb) are usually high in dietary fibre, which serves to support the structure of the plant. Leaves, especially the dark green ones, tend to be the most metabolically active and most nutritious part of plants and are usually good sources of dietary fibre, folacin, carotenoids, vitamin C, flavonoids, and minerals such as iron, zinc, calcium and magnesium. Pulses (mature beans and peas) are high in protein, starch, isoflavones, vitamin B6, folacin, iron and other minerals. Bulbs (chives, garlic, onion, shallots) are noted for allicin. Enlarged roots and tubers are storage organs for plants and usually have high starch content; they may serve as inexpensive sources of energy (potatoes, sweet potatoes, taro). Other roots and tubers are lower in energy content (e.g., Jerusalem

artichokes, parsnips, turnips) and may provide specific food components (e.g., α- and β-carotene in carrots). Fruits, which are grouped as vegetable fruits, citrus, berries, melons, and other, are more variable in nutrient content; some are especially high in vitamin C and/or β-carotene.

## Colour

The main pigments responsible for colour in fruit and vegetables are chlorophyll (green), various carotenoids (yellow, orange and red) and anthocyanins, a type of flavonoid (red, blue and purple). Variations in colour between different fruits and vegetables and between various cultivars of a fruit or vegetable result from the different concentrations of pigments. Carotenoids and anthocyanins function as antioxidants. Although chlorophyll does not appear to be useful in human physiology, foods that are high in chlorophyll are usually also high in β-carotene. (The yellow-orange colour of β-carotene is masked by the green chlorophyll). The carotenoids most extensively investigated in relation to human health are α-carotene, β-carotene, β-cryptoxanthin, lycopene, lutein and zeaxanthin (IARC, 1998). α- and β-carotene, β-cryptoxanthin, and lutein provide an orange-yellow colour; lycopene red and zeaxanthin yellow. There are over 300 different anthocyanins and about 70 have been identified in fruits and vegetables. Their colours range from crimson or magenta red to violet or indigo purple or blue.

Colour classifications for fruit and vegetables have been used to help consumers select a wider variety of these foods in their daily diets (Mangels *et al.*, 1993; Heber & Bowerman, 2001; Joseph *et al.*, 2002; National Cancer Institute, 2002).

Table 5 lists some common green, orange, red and blue fruits and vegetables by colour, the pigment(s) responsible for their colour, and other components that are present in these foods. In relation to food consumption, colour may be a useful indicator of the presence of some food components in fruit and vegetables, but may not be specific for a bioactive component. For example, red could be due to anthocyanins or lycopene. White is indicative of the allyl sulfides in garlic and onion, but other white vegetables such as potatoes, parsnips and turnips do not contain these protective components. As indicated in Table 5, fruits and vegetables that contain the pigments chlorophyll, anthocyanins or carotenoids may not have similar profiles with respect to other food components such as vitamin C, minerals and phenolic acids. Some green vegetables are sources of carotenoids; some are sources of glucosinolates, indoles and thiocyanates; and some (iceberg lettuce, green peas, green beans) do not contain these food components.

Some fruits and vegetables have a peel with a colour that is different to the underlying tissue. The peel constitutes only a small part by weight of the fruit or vegetable and the peel may not be consumed. Thus, reliance on peel color could be misleading with regard to food component content. Examples are summer squash with yellow or green peel; cucumber with green peel; eggplant with purple peel; potatoes with red peel; and apple with red, green, or yellow peel. Another issue is that there are many different cultivars for each fruit and vegetable, and the cultivars may vary by colour and hence by their concentration of pigments. For example, most cultivars of cherries are red, but some are white and others are yellow. Sweet potatoes show variation in β-carotene concentration among the orange, yellow-white and purple cultivars (Huang *et al.*, 1999).

## Processing and preparation

The usefulness of processing terms for classifying fruits and vegetables depends on their association with food component concentrations. The terms *fresh, juice, canned/chilled, dried* and *frozen* for fruits and *fresh, canned,*

## Table 4. Classification of fruits and vegetables by edible parts

**Flowers/flower buds with stems/stalks**
Asparagus; broccoli; broccoli raab; Chinese broccoli; cauliflower; globe/French artichoke; green cauliflower; pumpkin flower

**Stems and stalks**
Cardoon; celery; fennel bulb; green/spring onion (scallion); kohlrabi; leek; rhubarb

**Leaves**
Amaranth leaves; arugula; balsam pear leafy tips (bitter melon/bitter gourd); beet greens; borage; Brussels sprouts; butterbur (fuki) leaves; Chinese cabbage (pak-choi, pe-tsai); cabbage (green, red, savoy, swamp/skunk); chard (Swiss chard); chicory greens; chicory, witloof; chrysanthemum leaves; collards; coriander/cilantro; cornsalad; cowpeas, leafy tips; dandelion greens; dock/sorrel; endive; eppaw; fiddlehead ferns; garden cress; garland chrysanthemum; grape leaves; horseradish tree, leafy tips; jew's mallow; jute, potherb; kale; kale, scotch; lambsquarters; lettuce (butterhead, iceberg, looseleaf/leaf, romaine/cos); malbar spinach; mustard greens; mustard spinach/tendergreen; New Zealand spinach; pumpkin leaves; purslane; radicchio; salsify (oyster plant, vegetable oyster); spinach; sweet potato leaves; taro leaves; tree fern; turnip greens; vinespinach; watercress; winged bean leaves

**Pulses**
Adzuki beans; black beans; black turtle beans; broadbeans (fava beans); chickpeas (garbanzo beans, bengal gram); cowpeas (blackeye peas, crowder peas, southern peas); catjang; cranberry (roman) beans; French beans; great northern beans; hyacinth beans; kidney beans; lentils; lima beans; lima beans, baby; lupins; mothbeans; mung beans; mungo beans; navy beans; peas, green; peas, split; pigeon peas (red gram); pink beans; pinto beans; shellie (shell) beans; soybeans; white beans; winged beans; yardlong bean; yellow beans; winged beans

**Roots** (part of the plant below the ground that holds the plant in place, draws water and nourishment from the soil, and stores food)
Arracacha; arrowroot; beet (beetroot); burdock root; carrot; cassava; celeriac (celery root); chicory root; jicama (yambean); lotus root; parsnip; radish; radish, oriental; radish, white icicle; rutabaga (swede); salsify; sweet potato; turnip; wasabi root

**Tuber** (short, thickened, fleshy part of an underground stem)
Jerusalem artichoke (sunchoke); Hawaiian mountain yam; poi (taro root paste); potato (brown-, red-, white- skinned and russet); Tahitian taro; yautia (tannier); yam

**Shoots/sprouts**
Alfalfa sprouts; bamboo shoots; kidney bean sprouts; lentil sprouts; mung bean sprouts; navy bean sprouts; pea sprouts; pokeberry shoots (poke); radish seed sprouts; soybean sprouts; taro shoots

**Bulbs** (underground bud with roots and short stem covered with leafy layers)
Chives; garlic; leek; onion; onion, Welsh; shallot

**Fruits used as vegetables**
Avocado, balsam pear (bitter melon, bitter gourd); breadfruit; calabash/white-flowered gourd; cucumber; dishcloth gourd (towel gourd); eggplant (aubergine); snap beans, green, yellow; hominy, white/yellow; horseradish tree pods; okra (lady's finger, gumbo); pepino; chili/hot peppers (ancho, banana, Hungarian, jalapeno, pasilla, pimiento, serrano); sweet/bell peppers, green/red/yellow; plantain; sesbania flower; snow peas (edible podded peas); summer squash (chayote, crookneck, marrow, scallop, straightneck, zucchini); sweet corn; tomatillo; tomato (green, orange, red, cherry, Italian, plum, yellow); waxgourd (Chinese preserving melon); winter squash (acorn, butternut, hubbard, pumpkin, spaghetti); zucca melon

**Fruits – citrus**
Grapefruit (pink, red, white); lemon; lime; mandarin oranges; orange; tangerine

**Fruits – berries**
Blackberry; blueberry; boysenberry; cranberry; elderberry; gooseberry; loganberry; mulberry; oheloberry; raspberry; strawberry

**Fruits – melons**
Cantaloupe (muskmelon); casaba melon; honeydew melon; watermelon

**Fruits – other**
Abiyuch; acerola (West Indian cherry); apple; apricot; Asian pear, banana; carambola (star fruit); carissa (natal-plum); cherimoya; cherry (sour, sweet); crabapple; currants (black, red, white, zante); custard apple (bullock's heart); date; durian; feijoa; fig; grape, red/green; groundcherry; guava; guava, strawberry; jackfruit; java plum; jujube; kiwi fruit (Chinese gooseberry); kumquat; lychee (litchi); longan; loquat; mammy apple (mamey); mango; mangosteen; nectarine; papaya; passion fruit (grandilla), purple; peach; pear; persimmon, Japanese; persimmon; pineapple; pitanga (Surinam cherry); plum; pomegranate; prickly pear; prune; pummelo; quince; rambutan; rose apple; roselle; rowal; sapodilla; sapote; soursop; sugar apple; tamarind

## Table 5. Pigment in fruits and vegetables

| Colour | Food | Pigment(s) | Other food components |
|---|---|---|---|
| Dark green | Kale | Chlorophyll, β-carotene, lutein | Calcium, iron, magnesium, quercetin, kaempferol, glucosinolates, indoles, isothiocyanates, vitamin C |
| Dark green | Spinach | Chlorophyll, β-carotene, lutein | Folacin, calcium, iron, magnesium, glutathione, saponins, vitamin C |
| Green | Asparagus | Chlorophyll, β-carotene, lutein, anthocyanin | Folacin, glutathione, lignans, saponins, rutin |
| Green | Broccoli | Chlorophyll, β-carotene, lutein | Quercetin, glucosinolates, indoles, isothiocyanates, lignans, caffeic acid, vitamin C |
| Green | Brussels sprout | Chlorophyll, β-carotene, lutein | Glucosinolates, indoles, isothiocyanates, *para*-coumaric acid, caffeic acid, ferulic acid, vitamin C |
| Green | Cabbage | Chlorophyll, β-carotene, lutein | Quercetin, kaempferol, glucosinolates, indoles, isothiocyanates, chlorogenic acid, vitamin C |
| Green | Kiwi fruit | Chlorophyll, β-cryptoxanthin, lutein, zeaxanthin | Vitamin C |
| Deep orange-yellow | Apricot | β-Carotene | Quercetin, chlorogenic acid |
| Deep orange | Cantaloupe | α-Carotene, β-carotene | Glutathione, ferulic acid, rutin, vitamin C |
| Deep orange | Carrot | α-Carotene, β-carotene, β-cryptoxanthin, lutein | Apigenein, myricetin, caffeic acid, *para*-coumaric acid, chlorogenic acid, limonene |
| Deep orange | Mango | β-Carotene, β-cryptoxanthin, anthocyanins | Quercetin, kaempferol, gallic acid, vitamin C |
| Deep orange | Pumpkin | α-Carotene, β-carotene, lutein, zeaxanthin | Lignans, ferulic acid |
| Deep orange | Sweet potato | β-Carotene | Quercetin, caffeic acid, chlorogenic acid |
| Orange | Orange | β-Cryptoxanthin, lutein, zeaxanthin | Hesperidin, glutathione, β-sitosterol, limonene, vitamin C |
| Orange | Tangerine | β-Cryptoxanthin, lutein | Limonene, vitamin C |
| Yellow | Corn | Lutein, zeaxanthin | Quercetin, ferulic acid |
| Red | Cherry | Anthocyanins | Quercetin, kaempferol, chlorogenic acid, *para*-coumaric acid, gallic acid |

**Table 5 (contd)**

| Colour | Food | Pigment(s) | Other food components |
|---|---|---|---|
| Red | Cranberry | Anthocyanins | Catechins, epigallocatechin gallate, proanthocyanidins, quercetin, myricetin, kaempferol, lignans, ellagic acid, chlorogenic acid, vitamin C |
| Red | Pomegranate | Anthocyanins | Lignans, ellagic acid, chlorogenic acid, gallic acid |
| Red | Raspberry | Anthocyanins | Quercetin, kaempferol, caffeic acid, ellagic acid, ferulic acid, salicylates, vitamin C |
| Red | Red onion | Anthocyanins | Allicin, quercetin, kaempferol, caffeic acid, ferulic acid |
| Red skin | Red-skinned apple | Anthocyanins | Quercetin, myricetin, ferulic acid, pectin, rutin |
| Red | Strawberry | Anthocyanins | Glutathione, lignans, ellagic acid, caffeic acid, ferulic acid, vitamin C |
| Red | Tomato | Lycopene, β-carotene | Quercetin, kaempferol, *para*-coumaric acid, chlorogenic acid, vitamin C |
| Red-pink | Red-pink grapefruit | β-Carotene, lycopene | Hesperidin, naringenin, quercetin, kaempferol, glutathione, ferulic acid, limonene, β-sitosterol, vitamin C |
| Red | Sweet red pepper | β-Carotene, lutein | *para*-Coumaric acid, chlorogenic acid, vitamin C |
| Blue-black | Blackberry | Anthocyanins | Catechins, quercetin, kaempferol, chlorogenic acid, ellagic acid, ferulic acid, gallic acid, vitamin C |
| Blue | Blueberry | Anthocyanins | Proanthocyanidins, quercetin, myricetin, kaempferol, chlorogenic acid, *para*-coumaric acid, ferulic acid, resveratrol, vitamin C |
| Blue | Elderberry | Anthocyanins | Catechins, quercetin, ellagic acid, vitamin C |
| Red-purple | Red-purple grape | Anthocyanins | Catechins, epicatechin, proanthocyanidins, quercetin, myricetin, kaempferol, chlorogenic acid, caffeic acid, gallic acid, *para*-coumaric acid, resveratrol |
| Purple | Plum | Anthocyanins | Chlorogenic acid, *para*-coumaric acid, ferulic acid |

Source: Barratt-Fornell & Drewnowski, 2002; Joseph *et al.*, 2002; National Cancer Institute, 2002; Pennington, 2002.

*frozen* and *dehydrated* for vegetables were presented earlier in this chapter. Current methods of commercial processing, such as the freezing and canning of fruit and vegetables appear not to significantly alter the nutrient content of these foods, although there may be some loss of components such as vitamin C and folacin. Often the cultivars used for freezing and canning are different from those sold in markets as the raw product. Thus, differences in nutrient profiles between a raw and processed food may be due to differences in cultivar as well as the effects of processing. The drying of fruit and vegetables removes water and probably also some volatile nutrients, reducing the volume and weight of the product and concentrating the remaining food components. The juicing of fruit and vegetables usually removes the pulp, which contains dietary fibre, and may concentrate other nutrients on a weight basis. The cultivars used for commercial juicing may be different from those available in the market as raw fruit and vegetables, so again food component levels may be different. Some commercial orange and grapefruit juices are fortified with calcium, giving significantly higher levels than in unfortified juices.

Fruit and vegetable juices and dried fruit offer different levels of nutrients and bioactive components on a weight basis compared with their fresh, canned and cooked counterparts. For example a serving of orange juice might constitute the juice from two or more oranges; dried plums will weigh less than the fresh. For dark green leafy vegetables, the quantity (weight) consumed could vary considerably between the raw and the cooked. For example, a given volume of raw spinach yields only about half that volume of cooked spinach. Processing and preparation may remove peels from fruits and vegetables and may add other ingredients (fat and sugar) as in frying vegetables, preparing vegetables in a cream or butter sauce, adding mayonnaise or salad dressing to potatoes or salads, canning fruit in a sugar syrup or juice, or preparing pickled vegetables in a salt brine.

Classification of fruits and vegetables by processing and preparation methods could be especially important in cultures where there is reliance on a limited number of local crops and the processing techniques alter the composition so as to limit the intake of critical food components. For populations that have access to a wide variety of fruit and vegetables and a range of processing and preparation methods, these methods are not likely to be useful as classification terms.

## Considerations for epidemiological studies

### Fruit and vegetable groupings used in dietary assessment tools

The various instruments used to assess dietary intakes in epidemiological studies are discussed in Chapter 2, which covers the advantages and disadvantages of various methods as well as the estimation of associated measurement errors. Dietary assessment tools are mentioned in this chapter with respect to aspects of fruit and vegetable definitions and classifications. The definitions and classifications for fruit and vegetables vary between epidemiological studies because of differences in the purposes of the study and the dietary patterns of the population being evaluated. Table 6 provides examples of several fruit and vegetable groupings based on plant part, colour and/or botanical family that have been used to collect and/or report information from

epidemiological studies. The table provides information on botanical families, important food components and some considerations with respect to food processing. The list does not cover all fruits and vegetables, e.g., it does not include some commonly consumed fruits such as apples, pears and bananas. Open-ended dietary assessment tools (e.g., 24-hour recalls or food records) allow flexibility in terms of identifying and classifying fruit and vegetable consumption because the investigators may organize the results as desired after the survey has been completed. Food frequency questionnaires (FFQs) require *a priori* decisions as to which foods are to be listed on the questionnaire and how the foods are organized into groups.

There are many similarities between available FFQs with respect to questions asked about fruit and vegetable consumption. Differences include the number of fruits and vegetables that are listed; which foods are considered to be fruits and which vegetables; the placement of certain fruits and vegetables in other food groups; and the listing and placement of foods that contain fruit and vegetables or are derived from these foods. For example, fruit and vegetables that are used as dietary staples (i.e., as a main source of energy) for a population may not be considered to be fruits or vegetables. These foods include pulses (mature beans and peas), bananas, plantain, white potatoes, sweet (yellow) potatoes and taro. Soybeans are usually considered with pulses; however, soybean products (tofu, miso, temph, soy-based meat analogues, soymilk) are generally grouped elsewhere. FFQs usually ask questions about mixed dishes containing fruit or vegetables (casseroles, stews, stir-fries; pasta, rice and pizza with tomato sauce; soups with vegetables; and pies containing fruit, pumpkin or sweet potato) separately from questions about fruit and vegetables. For a number of fruit and vegetable foods, decisions about placement and grouping in FFQs may be made according to how they are usually used in dietary patterns. Examples of these foods are tomato ketchup, paste, puree, sauce and salsa; fried potatoes; soups containing tomatoes, pulses, or other vegetables; garlic and onion (used as garnish versus vegetable); coconut; sauerkraut; pickled fruits and vegetables; and olives. Potato crisps, jams, jellies, preserves and candied fruit are usually not counted as vegetables or fruits in FFQs.

## Fruit and vegetable groupings familiar to survey participants

Because food guides and related dietary guidance information are provided to children and teenagers in schools and to the general public from government health and/or agricultural agencies and from health professionals (dietitians, nurses, physicians), many survey participants are likely to be familiar with the food groups presented in these materials. Dietary guidance materials emphasize the weekly or biweekly consumption of dark green leafy vegetables and/or deep yellow-orange fruits and vegetables as a source of the vitamin A precursor, β-carotene; daily consumption of citrus fruit or juice for vitamin C; and daily consumption of protein sources such as meat and meat substitutes, which include beans, peas, and soy products. Thus, the public is usually exposed to and has some understanding of several fruit and vegetable groups depicted by colour, plant part and/or botanical family.

Dark green leafy vegetables represent both the plant part and colour; deep orange/yellow fruits and vegetables represent colour; and citrus fruits and pulses represent both botanical families and plant parts. Consumers are also generally familiar with the plant part groupings of berries, melons and starchy root/tuber vegetables and with processing terms such as fresh, frozen, canned and dried. Cabbage family vegetables are likely to be familiar to survey participants because of media attention over the past 10–15 years. Consumers who are especially interested in food and health may also have read or heard about bioactive components in garlic, onions, tomatoes, tomato products, watermelon, grapes, cherries and blueberries. Consumer knowledge of fruit and vegetable groupings might be used to advantage by researchers in designing epidemiological studies.

## Table 6. Some fruit and vegetable groupings used to collect or report information in epidemiological studies

| Suggested groupings | Botanical family and foods | Important components | Processing considerations; Notes |
|---|---|---|---|
| **Dark green leafy vegetables** | *Goosefoot:* beet greens, spinach, Swiss chard Cabbage: collards, kale, mustard greens, mustard spinach, turnip greens | β-Carotene, folacin, magnesium, calcium | Separate questions for raw and cooked because of changes in weight and volume |
| **Cabbage family** (some green leafy vegetables, stem and flower vegetables) | *Cabbage*: arugula, bok choy, broccoli, Brussels sprouts, cabbage, cauliflower, collards, kale, mustard greens, napa cabbage, pak choi | Glucosinolates, isothiocyanates, indoles | Separate questions for coleslaw and sauerkraut; some overlap with dark green leafy vegetables (collards, kale) |
| **Lettuce** | *Sunflower:* butterhead lettuce, endive, iceberg lettuce, loose leaf lettuce, romaine | | May be commonly consumed |
| **Deep orange-yellow fruits and roots** | *Gourd:* cantaloupe, pumpkin<br>*Carica:* papaya<br>*Rose:* apricot, nectarine, peach<br>*Carrot:* carrot<br>*Morning Glory:* Sweet potato<br>*Cashew:* mango | β-Carotene, α-carotene (carrot, pumpkin, sweet potato) | |
| **Citrus family fruits and juices** | *Rue:* clementine, lime, lemon, grapefruit, orange, tangerine, clementine | Hesperidin, naringenin (grapefruit), neohesperidin (grapefruit, orange), limonene, vitamin C | Separate questions for citrus fruit juices and juices fortified with calcium |
| **Tomatoes, tomato products, and several red fruits** | *Nightshade:* tomato<br>*Gourd:* watermelon<br>*Rue:* red-pink grapefruit<br>*Myrtle:* guava | β-Carotene, lycopene, vitamin C | Separate questions about tomato juice, tomato sauce, ketchup, salsa, pizza, tomato soup and pasta with tomato sauce |
| **Red cherries, berries, several vegetables** | *Rose:* cherry, raspberry, strawberry<br>*Health:* cranberry<br>*Nightshade:* red sweet pepper, red chili pepper<br>*Goosefoot:* beets<br>*Legume*: red beans<br>*Brassica:* red cabbage<br>*Allium*: red onion | Anthocyanins, quercetin, phenolic acids (berries) | |
| **Blue-black berries and red-purple grapes** | *Rose:* blackberry, loganberry<br>*Heath*: blueberry, lingonberry<br>*Saxifrage*: gooseberry<br>*Grape*: red-purple grape | Anthocyanins, quercetin, phenolic acids; red-purple grapes also have proanthocyanidins, catechins, myricetin, resveratrol, vitamin C | Separate question for juices; separate questions for grapes of other colours |

**Table 6 (contd)**

| Suggested groupings | Botanical family and foods | Important components | Processing considerations; Notes |
|---|---|---|---|
| **Allium family bulbs** | *Amaryllis:* chives, garlic, leeks, onion, shallots | Allyl sulfides | Clarify if garlic and onion are consumed as a vegetable, garnish, powder or salt |
| **Legume family** | *Legume:* black beans, broad beans, chickpeas, cowpeas, edible-podded peas, green peas, hyacinth beans, kidney beans, lentils, lima beans, soybeans | Iron, isoflavones, protein, starch, vitamin B6 | Include beans in mixed dishes (chili, burritos, soups), tofu, soy-based meat substitutes, and other soy products |
| **Starchy vegetables** | *Nightshade*: potato<br>*Grass*: corn, hominy<br>*Arum:* taro<br>*Yam:* yam | Calories, starch, phenolic acids | Separate questions for deep-fried potatoes or potatoes made with sauce or mayonnaise |