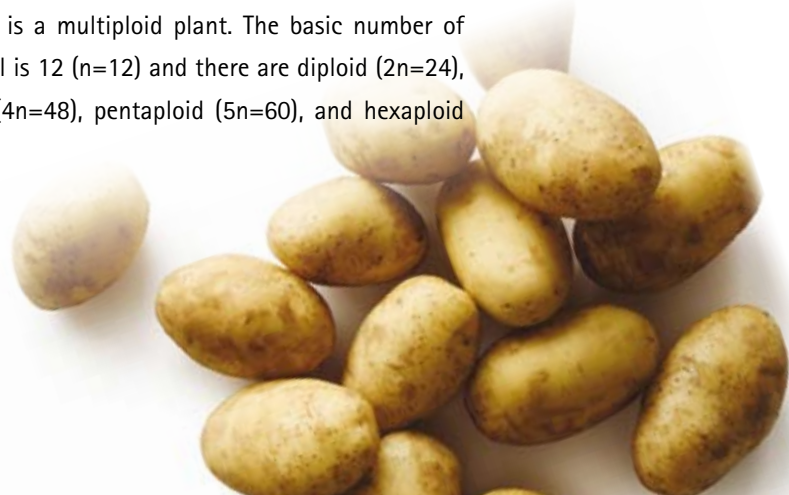


# The **Biology** of the **Potato**

The potato is a tuber crop that originated in the Andes of South America. It is known as papa in Spanish, pomme de terre in French, and *Solanum tuberosum* in Latin. In China, the potato has more than 20 different names. Among them, the following names are most common: tudou in northeast China, shanyao in northern China, and yangyu in both northwest and southwest China. In Chinese, the scientific name for potato is malingshu.

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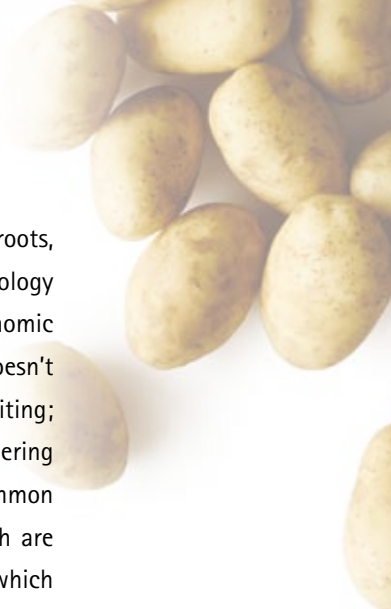
According to its botanical taxonomy, the potato is an annual herbaceous plant with both cultivated and wild species, and belongs to the *Tuberosa* series, *Petota* section, *Solanum* genus, *Solanaceae* family. Based on its set of chromosomes, potato is a multiploid plant. The basic number of chromosomes in a potato cell is 12 ( $n=12$ ) and there are diploid ( $2n=24$ ), triploid ( $3n=36$ ), tetraploid ( $4n=48$ ), pentaploid ( $5n=60$ ), and hexaploid ( $6n=72$ ).



## Potato morphology

As an annual herbaceous plant, the potato plant is comprised of roots, stems, leaves, flowers, fruits and seeds (see Figure 1). Its morphology includes the tuber—a transformed stem, and the most important economic organ—which is different from other plants. The potato's lifecycle doesn't always include the full cycle of planting, emergency, flowering and fruiting; an ideal harvest may be obtained without the two key stages of flowering and fruiting, which are common for most other crops. The most common seeds for potatoes are called seed tubers (or seed potatoes), which are the storage organs of potatoes. This is different from other crops, which usually use seeds as planting material. The real seeds (true potato seeds, or TPS) from the pollinated potato flowers can also be used for multiplication of progenies, but they are mostly used for potato breeding, and not for potato production.

**Roots:** Potato roots vary according to the planting materials used. A fiber root system will develop if seed tubers are used, and all the roots will be adventitious roots, without differentiation between main and lateral roots. A tap root system will develop if true seeds are used as the planting material, with tap roots and lateral branches. Adventitious roots are produced first from junctures between the seed tuber and the primary buds and more and more adventitious roots will be produced from the knots of underground stems with the growing of buds. Most of the



adventitious roots are white, but can be colorful for some varieties. The adventitious roots are distributed within 30 cm of the topsoil.

A tap root system will be formed when the true seeds are used as planting materials. The tap root will be produced from the radicle and extended to the soil. The first lateral roots will be produced when the tap root reaches a length of 3 cm, and additional lateral roots may be produced as the plant continues to grow. These lateral roots are distributed in a netlike structure in the soil.

28 > **Stem:** There are several types of stems for potato plants, including an upper stem, underground stem, creeping stem (stolon) and tuber (transformed stem). All of the stems originate from the same tissue and organ, but they are quite different in shape and function.

The upper stems are the upper branches developed from the eyes of seed tubers or from the young seedlings of true seeds. They are also called main stems and there may be several main stems in one plant. The knot of the upper stem is round and the stem cross section can have three, four or multiple

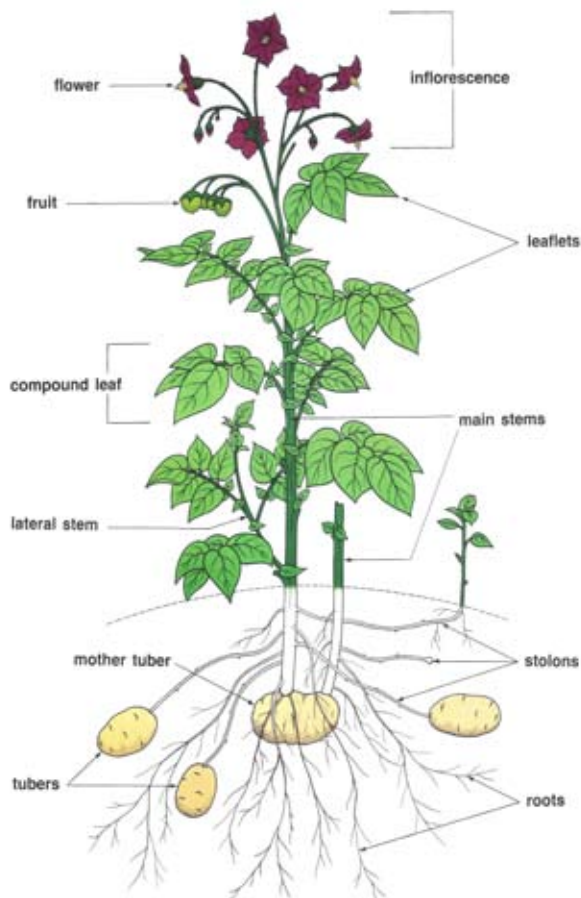
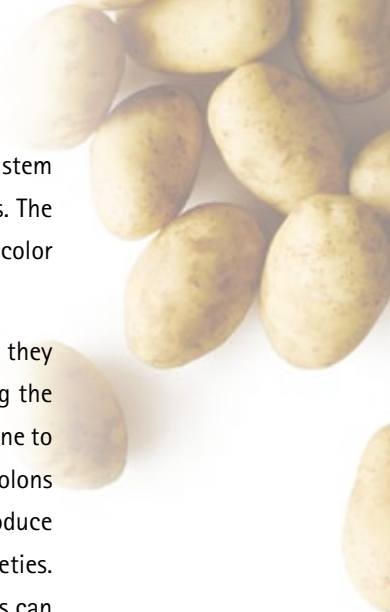


Figure 1: Potato plant (Source: CIP)

ridges. There may also be margin wings with different shapes. The stem color is generally green, but can vary according to different varieties. The stem shape in cross section, the wings' characteristics and the stem color are the key indicators for identifying different varieties.

The underground stems are the parts that produce the tubers, and they vary according to the planting depth and the hilling situation during the growth period. Generally, they are 10 cm long and have eight knots. One to three stolons will be produced from the axil in each knot and the stolons will develop tubers after swelling. The stolons are the organs that produce tubers and are generally white, but may be colorful for some varieties. Normally, one main stem can produce 4–8 stolons and 20–50 stolons can be formed in one plant. Generally, the more stolons there are the more tubers that will be produced. The stolons are geotropic and apheliotropic and most of them are distributed in the soil at a depth of 5 cm to 20 cm. The stolons can develop into new lateral stems, not tubers, if they are not covered well and exposed on the soil surface.

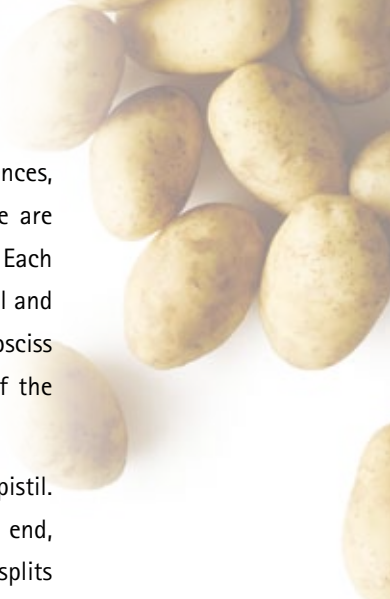
The potato tuber is an economic organ, a propagating organ and also a transformed stem. There are eyebrows, eyes and lenticels in the tubers. The end attached to the stolon is called the basal end, or heel, and the other end is called the apical end, or distal end. Potato tubers vary in shape, skin color and flesh color according to the different varieties. For a particular variety, the tuber shape, skin color and flesh color will not change under normal cultivation conditions and are important indicators



for identifying different varieties. Changes in cultivation conditions and planting locations can result in the tuber flesh color ranging from heavy to light for the varieties with colored tuber flesh.

Besides glucides, tubers also contain proteins, vitamins, dietary fibers and minerals. The nutritional value of tubers will be discussed in detail in the second part in this chapter.

**Leaf:** The well-developed potato leaf is an odd pinnate compound leaf with several leaflets. Most potato varieties will have compound leaves with 7, 9, 11, 13 or 15 leaflets each. The leaflet at the end of the compound leaf is called the terminal leaflet and the other opposite pairs of leaflets are called the lateral leaflets. There can be interjected leaflets or small split leaflets between two pairs of the lateral leaflets. There are some tiny leaflets, called as small leaflets, in the petiolules of the lateral leaflets or in the juncture of the leaflets and the petiole. In the upper area of the juncture of the petiole and the main stem, there is a pair of leaf-shaped structures, called as stipules or leaf ears. For a particular variety, the terminal leaflet, pairs of leaflets, the leaf margin, the surface flatness, occurrence of hairs, and the shape of the stipules are very stable and they are indicators for the identification of different varieties. However, the first leaf of the potato plant is a single leaf regardless of whether tubers or true seeds are used as the planting material.



**Flower:** Potato flowers are attached to one or several inflorescences, which are called ramificate cymose inflorescences. Normally, there are 2–5 branches in each inflorescence and 4–8 flowers in each branch. Each flower will be connected to the branch or sub-branch from the basal and connected to the basal of the calyx by the flower stalk. There is an absciss layer in the upper part of the flower stalk, also called the knot of the flower stalk, where the flower buds and flowers will fall off.

Each flower comprises four components: calyx, corolla, stamen and pistil. The basal of the calyx is cylindraceous, has five splits at the apical end, and is green in color. The basal of the corolla is funnel-form, has five splits at the apical end, and is pentacle-like. When there are additional petals inside or outside the corolla, they are called inside double petal or outside double petal corollas. The common colors for the corollas are white, light red, purple, amaranthine, and blue.

The stamen comprises five anthers, which are alternately arranged with petals and embrace the pistil in the middle. Different potato varieties can be identified from the calyx, corolla, shape of stamen and pistil, and the fertility of the anthers. The potato is a self-pollinated crop because there is nectar in the flower and the natural hybrid rate is very low.

**Fruit:** Potato fruits are the berries of the solanaceae family and are similar to the fruits of the berry tomato. Most of the pericarps are green,

although they may be brown or purple-green. The fruit is normally divided into two or three locules. Each fruit usually has 100–250 seeds, but can have up to 500 seeds or no seeds. Around 5–7 days of successful pollination, the ovary will start to swell and the fruit will be ripen 30–40 days later. In the meantime, the pericarp will become soft, yellow-white or white, and emit a special fragrance.

**Seed:** Potato seeds are very small and weigh 0.3–0.6 grams per 1,000 seeds. The seeds are shaped like flat eggs and the end attached to the fruit is a little bit smaller and yellow or dark gray. The dormancy for newly harvested seeds is about six months. A higher sprouting rate can be obtained after storing seeds for one year. Potato seeds can be stored for 20–30 years in low temperature and low moisture conditions. Seeds are used in important gene banks around the world to store the wild potato germplasm.

# The potato's nutritional value




The potato's nutritional value refers mainly to the nutritional value of tuber when it is used as food. The many differences in potato variety, cultivation conditions and other factors make it difficult to clearly define the nutritional value of a potato. However, the United States Potato Board has developed a Nutrition Facts table based on a 148 g potato (see Figure 2).. So in 2008, the International Year of the Potato, the Journal of Food Composition and Analysis, under the guidance of the United Nations' Food and Agriculture Organization (FAO), is advocating to collect information about the nutritional composition of potato varieties and potato products. It is going to publish a special issue to describe the potato's nutritional value. Before the publication of this special issue, we present here a table comparing the nutritional composition of the potato versus other foods (see Table 1), based on information from the website <http://www.swcfcx.cn/>.

Figure 2: Potato nutrition facts (Source: United States Potato Board)

From Table 1, we can see that the potato contains high level of vitamin C. This explains why Western people do not need to eat other vegetables after they eat potatoes, and it is the same reason that people in high and cold regions in China remain healthy—they are consuming potatoes as their main food in the long winter, when other vegetables and fruits are difficult to obtain.

Table 1: Comparison of the nutritional composition of potatoes and other foods (content in each 100 g)

Nutrition	Fresh tuber	Flake	Rice	Wheat flour	White corn flour	Millet flour
Edible part(g)	94	100	100	100	100	100
Water(g)	79.8	12	13.3	12.7	13.4	11.8
Energy(K cal)	76	337	346	344	340	356
Energy(K J)	318	1410	1448	1439	1423	1490
Protein(g)	2	7.2	7.4	11.2	8	7.2
Fat(g)	0.2	0.5	0.8	1.5	4.5	2.1
Carbohydrates(g)	17.2	77.4	77.9	73.6	73.1	77.7
Dietary fiber(g)	0.7	1.4	0.7	2.1	6.2	0.7
Ash(g)	0.8	2.9	0.6	1	1	1.2
Vitamin A(mg)	5	20	0	0	0	0
Carotene (mg)	30	120	0	0	0	0
Vitamin B1(μg)	0.08	0.08	0.11	0.28	0.34	0.13
Vitamin B2(mg)	0.04	0.06	0.05	0.08	0.06	0.08
Vitamin B5(mg)	1.1	5.1	1.9	2	3	2.5
Vitamin C(mg)	27	0	0	0	0	0
Vitamin E(T)(mg)	0.34	0.28	0.46	1.8	6.89	0
a-E	0.08	0.28	0	1.59	0.94	0
(β-γ)-E	0.1	0	0	0	5.76	0



Nutrition	Fresh tuber	Flake	Rice	Wheat flour	White corn flour	Millet flour
δ-E	0.16	0	0	0.21	0.19	0
Calcium (mg)	8	171	13	31	12	40
Phosphorus (mg)	40	123	110	188	187	159
Potassium (mg)	342	1075	103	190	276	129
Sodium (mg)	2.7	4.7	3.8	3.1	0.5	6.2
Magnesium (mg)	23	27	34	50	111	57
Iron (mg)	0.8	10.7	2.3	3.5	1.3	6.1
Zinc (mg)	0.37	1.22	1.7	1.64	1.22	1.18
Selenium (μg)	0.78	1.58	2.23	5.36	1.58	2.82
Copper (mg)	0.12	1.06	0.3	0.42	0.23	0.32
Manganese (mg)	0.14	0.37	1.29	1.56	0.4	0.55
Iodine (mg)	1.2	0	0	0	0	0

Source: <http://www.swcfcx.cn/>

**Glucides:** The glucides in potato tubers can be divided into single glucides (reducing sugars, including sucrose and fructose) and poly-glucides (starch, including amylose and amylopectin). The content of glucides ranges from 13.9% to 21.9%, and 85% of this is starch. The reducing sugars will produce a brown color when a potato is fried in the oil, and their content is one of the important indicators when determining varieties for chipping purposes. The ratio between amylose and amylopectin will affect the dietary quality of potato tubers, and it is one of the important indicators for starch content. A potato tuber contains about 0.6% to 0.8% of coarse fiber, which is also called as dietary fiber, and this content is 2–14 times that of millet, rice and wheat flour.

**Protein:** Generally, the protein content in potato tubers is 1.6% to 2.1%, but the highest can be over 3%. Potato protein is similar to the protein found in meat; the digestible composition is high and it can be easily absorbed by the human body. The amino acids of potato protein are very abundant, including all of the necessary amino acids.

**Minerals:** Potato tubers contain high levels of potassium, calcium, phosphorus and iron, and also contain many of the necessary nutrients for humans and animals, such as magnesium, sulfur, chloride, silicon, sodium, boron, manganese, zinc and copper. Because of the alkaline minerals in the potato tuber, it is considered an alkaline food, which means it can neutralize the acidity of acidic food (rice, wheat flour, fish, and animal products) and keep the balance between acidity and alkalinity.

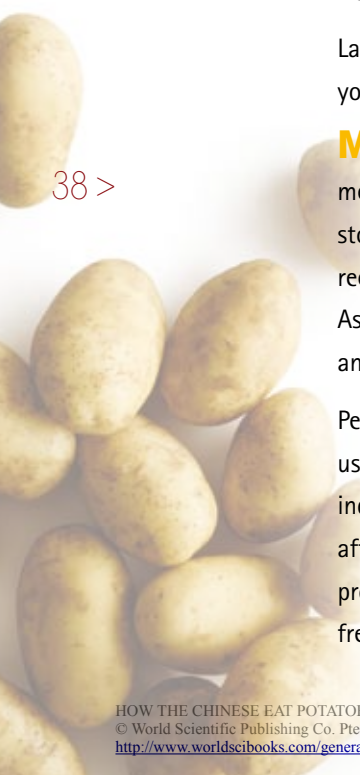
**Vitamins:** Potato tubers contain more kinds and higher levels of vitamins than most other crops, including vitamins A, B1, B2, B3, B5, B6, C, H, K and M. Of them, the content of vitamin C is the highest, and can reach 20 to 40 mg per 100 g of fresh tubers.

**Fat:** The fat content in potato tubers is very low, usually about 0.1%. So, the potato is considered to be a typical low-fat food.



# Special nutritional and medicinal functions of potatoes

**Baby food:** One of the best foods for babies is that made from mashed fresh potatoes or dehydrated potatoes. There are three main reasons for this. First, the potato contains a complete range of nutrients, including those necessary for growth and development of human beings, such as proteins, glucides, fat, vitamins and minerals. Some ingredients can't be found in other grain crops.

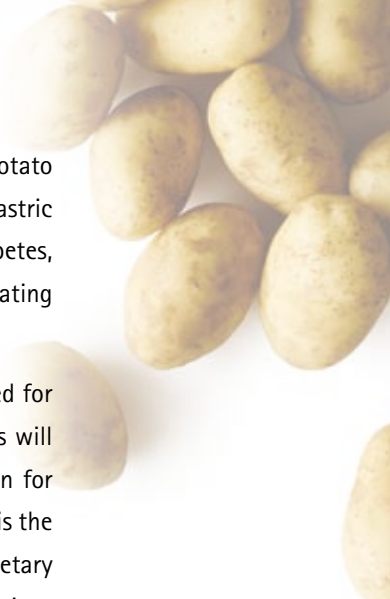


Second, potatoes contain high levels of vitamins A and C, both of which help in the development of the human body, especially for the infants and young children. The level of vitamin A intake recommended by the FAO and World Health Organization (WHO) is 300~725 µg per day for the children at 1 to 15 years. Vitamin C has about ten functions in the human body; one of the most important being the synthesis of collagen, which is the basic component in cartilages, bones, teeth and blood vessel endotheliums. However, other grain foods don't contain vitamin C.

Lastly, potato is very tender, which is suitable for the digestive organs of young infants.

**Medicinal food:** According to the theory of traditional Chinese medicine, the potato is sweet and smooth and is good for the intestines, stomach, spleen and detumescence. The potato is suitable for patients recovering from diseases of the stomach and spleen, as well as indigestion. As a medicinal food, the potato can be used in two main ways: externally and internally.

People in the Andes of South America, where the potato originated, have used potatoes externally to treat bone fractures, headaches, rheumatism, indigestion and others diseases. Fresh potato slices can be plastered on affected areas of the body to reduce bumps created when muscles cannot properly absorb the medicine from an intramuscular injection. Mashed fresh potatoes can also cure skin burnt by fires.




According to the practices of Mr. Wang Shanggong, fresh extracted potato liquid can control and cure many diseases, such as constipation, gastric ulcers, heavy acidity, duodenum ulcers, high blood pressure, diabetes, hepatitis, and the spread of cancer cells. It is also useful for treating nasosinusitis, the exclusion of toxins, and the banting.

Recovery food for cancer patients: Normally chemotherapy is applied for the recovery of early-stage cancer patients whose cancerous tissues will be cut by surgery. In this stage, the vomit reaction is very common for patients. Mashed potatoes from flakes or from boiled fresh potatoes is the best food for patients undergoing chemotherapy treatment. The dietary fibers in potatoes are very tender and do not stimulate the intestines or stomach. Potatoes also contain a high level of potassium, which can cure indigestion. Vitamin B6, which is found in potatoes, can also help to control vomiting, while the complete set of nutrients in potatoes is helpful for the overall recovery of patients.

The liquid from potato tubers is also good for the stomach. The high levels of vitamin A and carotene (which can be converted to vitamin A once ingested) can maintain the integrity of epithelia, control the development of tumors in epidermises, relieve the toxins of carcinogen, and facilitate the recovery of the cancerous cells.

**Anti-senescence food:** The potato's anti-senescence functions are a result of the high content of several vitamins (C, E and B5),



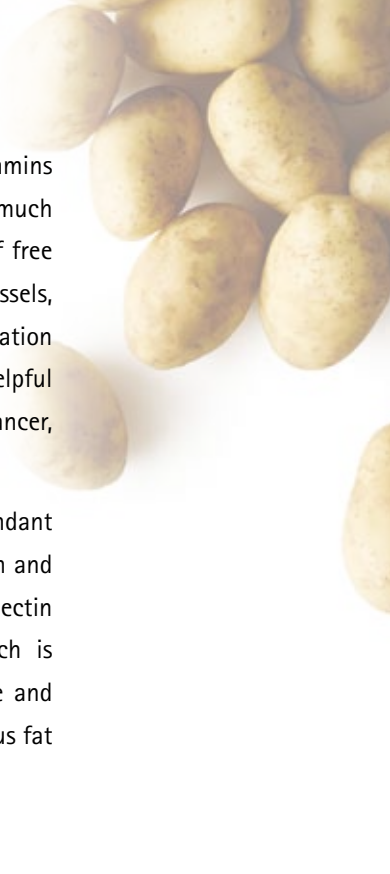
its excellent dietary fibers and its high potassium content. As mentioned before, vitamin C, while found in the potato tuber, is not present in other grain foods. Vitamin C is an effective antioxidant, which can protect the health of cells in the body. It is also good for tooth health, protects the body's immune system, and is the main component for synthesizing collagen, which is a kind of structural protein that exists largely in the skin, bones, muscles and gums.

Vitamin E has a wide range of functions in the body, including improving metabolism. It is also an excellent antioxidant and it can slow down senescence, maintain the integrity of red cells, facilitate the synthesis of cells, protect against pollution, and cure sterility.

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Vitamin PP is an important element in the oxidation function of the metabolism of proteins, fats, glucides, and over 40 other biochemical reactions. It also maintains the normal functioning of the nervous system, digestive system and skin. The dietary fibers in potato tubers can reduce the cholesterol content in the blood and the risk of heart disease, maintain peristalsis in the intestines, and reduce the risk of colon cancer. High potassium foods, such as the potato, can also reduce the rate of apoplexy. Consuming 5–6 potatoes every week can significantly decrease the risk of apoplexy.

The latest research shows that some purple flesh potato tubers have very high anthocyanin content. Anthocyanin is thought by some researchers to



be the seventh nutriment after water, protein, fat, carbohydrates, vitamins and minerals. Anthocyanin is a strong oxidant and its efficiency is much higher than vitamin C and vitamin E in terms of the elimination of free radicals. Anthocyanin can also increase the elasticity of the blood vessels, improve the cycle system and skin smoothness, control inflammation and hypersensitivity, and improve joint tenacity. Anthocyanin is helpful in controlling the many diseases related to free radicals, such as cancer, heart disease, premature senility and arthritis.

**Weight management food:** The potato's abundant dietary fibers can increase the feeling of satisfaction in the stomach and reduce the intake of superfluous food. Potato starch has high amylopectin content and can't be digested by normal amylase. Potato starch is sometimes also called a resistant starch. The potato's low- calorie and low-fat qualities are helpful to manage one's weight, and superfluous fat can be burnt if more potatoes have been eaten.