The potato

The potato (*Solanum tuberosum*) is an herbaceous annual that grows up to 100 cm (40 inches) tall and produces a tuber - also called potato - so rich in starch that it ranks as the world's fourth most important food crop, after maize, wheat and rice. The potato belongs to the Solanaceae - or "nightshade"-family of flowering plants, and shares the genus *Solanum* with at least 1,000 other species, including tomato and eggplant. *S. tuberosum* is divided into two, only slightly different, subspecies: *andigena*, which is adapted to short day conditions and is mainly grown in the Andes, and *tuberosum*, the potato now cultivated around the world, which is believed to be descended from a small introduction to Europe of *andigena* potatoes that later adapted to longer day lengths.
The potato: Tuber - International Year of the Potato 2008

As the potato plant grows, its compound leaves manufacture starch that is transferred to the ends of its underground stems (or stolons). The stems thicken to form a few or as many as 20 tubers close to the soil surface. The number of tubers that actually reach maturity depends on available moisture and soil nutrients. Tubers may vary in shape and size, and normally weigh up to 300 g (10.5 oz) each.

At the end of the growing season, the plant's leaves and stems die down to the soil level and its new tubers detach from their stolons. The tubers then serve as a nutrient store that allows the plant to survive the cold and later regrow and reproduce. Each tuber has from two to as many as 10 buds (or "eyes"), arranged in a spiral pattern around its surface. The buds generate shoots that grow into new plants when conditions are again favourable.

**Chemical composition**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>72-75%</td>
</tr>
<tr>
<td>Starch</td>
<td>16-20%</td>
</tr>
<tr>
<td>Protein</td>
<td>2-2.5%</td>
</tr>
<tr>
<td>Fibre</td>
<td>1-1.8%</td>
</tr>
<tr>
<td>Fatty acids</td>
<td>0.15%</td>
</tr>
</tbody>
</table>
Origins

The potato's story

The potato's story begins about 8,000 years ago near Lake Titicaca, which sits at 3,800 m (12,500 ft) above sea level in the Andes mountain range of South America, on the border between Bolivia and Peru. There, research indicates, communities of hunters and gatherers who had first entered the South American continent at least 7,000 years before began domesticating wild potato plants that grew around the lake in abundance.

Some 200 species of wild potatoes are found in the Americas. But it was in the Central Andes that farmers succeeded in selecting and improving the first of what was to become, over the following millennia, a staggering range of tuber crops. In fact, what we know as "the potato" (Solanum species tuberosum) contains just a fragment of the genetic diversity found in the seven recognized potato species and 5,000 potato varieties still grown in the Andes.

Although Andean farmers cultivated many food crops - including tomatoes, beans and maize - their potato varieties proved particularly suited to the quechua or "valley" zone, which extends at altitudes of from 3,100 to 3,500 m (10,200 - 11,500 ft) along the slopes of the Central Andes (among Andean peoples, the quechua was known as the zone of "civilization"). But farmers also developed a frost-resistant potato species that survives on the alpine tundra of the puna zone at 4,300 m (14,100 ft).

The food security provided by maize and potato - consolidated by the development of irrigation and terracing - allowed the emergence around 500 AD of the Huari civilization in the highland Ayacucho basin. Around the same time, the city state of Tiahuanacu rose near Lake Titicaca, thanks largely to its sophisticated "raised field" technology - elevated soil beds lined with water canals - which produced potato yields estimated at 10 tonnes per hectare (4.4 tons per acre). At its height, around 800 AD, Tiahuanacu and neighbouring valleys are believed to have sustained a population of 500,000 or more.

Meteoric rise.

The collapse of Huari and Tiahuanacu between 1000 and 1200 led to a period of turmoil that ended with the meteoric rise of the Incas in the Cuzco valley around 1400. In less than 100 years, they created the largest state in pre-Columbian America, extending from present-day Argentina to Colombia.

The Incas adopted and improved the agricultural advances of previous highland cultures, and gave special importance to maize production. But the potato was fundamental to their empire's food security: in the Incas' vast network of state storehouses, potato - especially a freeze-dried potato product called chuño - was one of the main food items, used to feed officials, soldiers and corvéé labourers and as an emergency stock after crop failures.

The Spanish invasion, in 1532, spelt the end of the Incas - but not of the potato. For, throughout Andean history, the potato - in all its forms - was profoundly a "people's food", playing a central role the Andean vision of the world (time, for example, was measured by how long it took to cook a pot of potatoes).

Farmers in some parts of the high Andes still measure land in topo, the area a family needs to grow their potato supply - a topo is larger at higher altitudes, where plots need to lie fallow for longer. They classify potatoes not only by species and variety, but by the ecological niche where the tubers grow best, and it is not unusual to find four or five species cultivated on a single, small plot of land.
Diffusion

The diffusion of the potato from the Andes to the rest of the globe reads like an adventure story, but it began with a tragedy. The Spanish conquest of Peru between 1532 and 1572 destroyed the Inca civilization and caused the deaths - from war, disease and despair - of at least half the population.

The conquistadores came in search of gold, but the real treasure they took back to Europe was Solanum tuberosum. The first evidence of potato growing in Europe dates from 1565, on Spain's Canary Islands. By 1573, potato was cultivated on the Spanish mainland. Soon, tubers were being sent around Europe as exotic gifts - from the Spanish court to the Pope in Rome, from Rome to the papal ambassador in Mons, and from there to a botanist in Vienna. Potatoes were grown in London in 1597 and reached France and the Netherlands soon after.

But once the plant had been added to botanical gardens and herbalists' encyclopaedias, interest waned. European aristocracy admired its flowers, but the tubers were considered fit only for pigs and the destitute. Superstitious peasants believed the potato was poisonous. At the same time, however, Europe's "Age of Discovery" had begun, and among the first to appreciate potatoes as food were sailors who took tubers to consume on ocean voyages. That is how the potato reached India, China and Japan early in the 17th century.

The potato also received an unusually warm welcome in Ireland, where it proved suited to the cool air and moist soils. Irish immigrants took the tuber - and the name, "Irish potato" - to North America in the early 1700s.

Long summer days. The widespread adoption of the potato as a food crop in the northern hemisphere was delayed not only by entrenched eating habits, but by the challenge of adapting a plant grown for millennia in the Andes to the north's temperate climate. Only a drop of the rich potato gene pool had left South America, and it took 150 years before varieties suited to long summer days began to appear.

Those varieties arrived at a crucial time. In the 1770s, much of continental Europe was devastated by famines, and the potato's value as a food security crop was suddenly recognized. Prussia's Frederick the Great ordered his subjects to grow potatoes as insurance against cereal crop failure, while the French scientist Parmentier succeeded in having the potato declared "edible" (around the same time, on the other side of the Atlantic, US President Thomas Jefferson served french fries to White House guests).

After initial hesitation, European farmers - even those in Russia, where the potato was called the "devil's apple" - began growing potatoes on a large scale. Potato became Europe's food reserve during the Napoleonic wars, and by 1815 it had become a staple crop across northern Europe. By then, the Industrial Revolution was transforming agrarian society in the United Kingdom, displacing millions of rural people into crowded cities. In the new urban environment, the potato became the first modern "convenience food" - energy-rich, nutritious, easy to grow on small plots, cheap to purchase, and ready to cook without expensive processing.

Increased potato consumption during the 19th century is credited with helping to reduce the scourge of diseases such as scurvy and measles, contributing to higher birth rates and the population explosion in Europe, the US and the British Empire.
Cultivation

Potato is grown for food in about 100 countries, under temperate, subtropical and tropical conditions. In temperate zones, potatoes are planted in spring and harvested in late summer. In tropical areas, the best yields are obtained at altitudes of 1 800 to 2 500 m (5 900 to 8 200 ft) or, at low altitude, when the crop is grown during the coolest months.

The main limiting factor on potato production is temperature. Optimum yields are obtained when mean daily temperatures are 18 to 20°C (64 to 68°F), while a night temperature of below 15°C (59°F) is required for tuber initiation. Tuber growth is sharply inhibited in temperatures below 10°C (50°F) and above 30°C (86°F).

Potato cultivars are grouped into three basic types: early (which produce tubers for harvesting within 90 to 120 days of planting), medium (120 to 150 days) and late (150 to 180 days). Early varieties bred for temperate climates require a day length of 15 to 17 hours, while late varieties produce good yields under long and short day conditions. In tropical climates, varieties must be adapted to tolerate short days.

Growing potatoes involves extensive ground preparation. The crop is usually grown not from seed but from "seed potatoes" - small tubers or pieces of tuber sown to a depth of 5 to 10 cm. The planting density of a row of potatoes depends on the size of the tubers chosen, while the inter-row spacing must allow for ridging of the crop. Usually, about two tonnes of seed potatoes are sown per hectare.

For rainfed production in dry areas, planting on flat soil gives higher yields (thanks to better soil water conservation), while irrigated crops are mainly grown on ridges. To protect soil, control weeds and reduce losses from pests and diseases, potato is usually grown in rotations of three or more years with crops such as maize, beans and alfalfa. Crops susceptible to the same pathogens as potato (e.g., tomato) are avoided in order to break potato pests' development cycle.

Land and water. Potatoes require well-drained and well-aerated soil. The use of chemical fertilizer depends on the level of available soil nutrients - volcanic soils, for example, are typically deficient in phosphorus - and in irrigated commercial production, fertilizer requirements are relatively high. However, potato can benefit from application of organic manure at the start of a new rotation.

The soil moisture content must be maintained at a relatively high level. For best yields, a 120 to 150 day crop requires from 500 to 700 mm (20 to 27.5 inches) of water. In general, water deficits in the middle to late part of the growing period tend to reduce yield more than those in the early part. Where supply is limited, water is directed towards maximizing yield per hectare rather than being applied over a larger area.

Because the potato has a shallow root system, yield response to frequent irrigation is considerable, and very high yields are obtained with mechanized sprinkler systems that replenish evapotranspiration losses every one or two days. Under irrigation in temperate and subtropical climates, a crop of about 120 days can produce yields of 25 to 35 tonnes/ha (11 to 15.6 tons per acre), falling to 15 to 25 tonnes/ha (6.6 to 15.6 tons per acre) in tropical areas.
# Potato varieties

Although all cultivated potatoes belong to just one botanical species, *Solanum tuberosum*, they come in thousands of varieties with great differences in size, shape, colour, texture, cooking characteristics and taste. Here's a small sample of potato diversity...

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Atahualpa</td>
<td>Bred in Peru, a high yielding variety good for both baking and frying</td>
<td>2. Nicola</td>
</tr>
<tr>
<td>13. Spunta</td>
<td>Another popular commercial tuber, good for boiling and roasting</td>
<td>14. Mondial</td>
</tr>
</tbody>
</table>
Andes

Sources: CIP [1,6]; NIVAP, the Netherlands [2,13]; Canadian Food Inspection Agency [3,5,11,12,14]; Lapin Keittiömestarit [4]; FNPPPT/Gernod - France [7]; Wikipedia [8,10,15] Haalo [9]
Uses of potato

Once harvested, potatoes are used for a variety of purposes, and not only as a vegetable for cooking at home. In fact, it is likely that less than 50 percent of potatoes grown worldwide are consumed fresh. The rest are processed into potato food products and food ingredients, fed to cattle, pigs and chickens, processed into starch for industry, and re-used as seed tubers for growing the next season’s potato crop.

Food uses: fresh, "frozen", dehydrated

FAO estimates that just over two-thirds of the 320 million tonnes of potatoes produced in 2005 were consumed by people as food, in one form or another. Home-grown or purchased in markets, fresh potatoes are baked, boiled or fried and used in a staggering range of recipes: mashed potatoes, potato pancakes, potato dumplings, twice-baked potatoes, potato soup, potato salad and potatoes au gratin, to name a few.

But global consumption of potato as food is shifting from fresh potatoes to added-value, processed food products. One of the main items in that category goes by the unappetizing name of frozen potatoes, but includes most of the french fries ("chips" in the UK) served in restaurants and fast food chains worldwide. The production process is fairly simple: peeled potatoes are shot through cutting blades, parboiled, air dried, par fried, frozen and packaged. The world’s appetite for factory-made french fries has been put at more than 11 million tonnes a year.

Another processed product, the potato crisp ("chips" in the US), is the long-standing king of snack foods in many developed countries. Made from thin slices of deep-fried or baked potato, they come in a variety of flavours - from simple salted to "gourmet" varieties tasting of roast beef and Thai chili. Some crisps are produced using a dough made from dehydrated potato flakes.

Dehydrated potato flakes and granules are made by drying a mash of cooked potatoes to a moisture level of 5 to 8 percent. Flakes are used in retail mashed potato products, as ingredients in snacks, and even as food aid: potato flakes have been distributed as part of US international food assistance to more than 600,000 people. Another dehydrated product, potato flour, is ground from cooked, whole potatoes and retains a distinct potato taste. Gluten-free and rich in starch, potato flour is used by the food industry to bind meat mixtures and thicken gravies and soups.

Modern starch processing can retrieve as much as 96 per cent of the starch found in raw potatoes. A fine, tasteless powder with "excellent mouth-feel", potato starch provides higher viscosity than wheat and maize starches, and delivers a more tasty product. It is used as a thickener for sauces and stews, and as a binding agent in cake mixes, dough, biscuits and ice-cream.

Finally, in eastern Europe and Scandinavia, crushed potatoes are heated to convert their starch to fermentable sugars that are used in the distillation of alcoholic beverages such as vodka and akvavit.

Non-food uses: Glue, animal feed and fuel-grade ethanol

Potato starch is also widely used by the pharmaceutical, textile, wood and paper industries as an adhesive, binder,
The world potato sector is undergoing major changes. Until the early 1990s, most potatoes were grown and consumed in Europe, North America and countries of the former Soviet Union. Since then, there has been a dramatic increase in potato production and demand in Asia, Africa and Latin America, where output rose from less than 30 million tonnes in the early 1960s to almost 120 million tonnes by the mid-1990s. FAO data shows that in 2005, for the first time, the developing world's potato production - some 162 million tonnes - exceeded that of the developed world (156 million tonnes). China is now the biggest potato producer, and almost a third of all potatoes is harvested in China and India.
Potato production, by region, 2006

Asia and Europe are the world's major potato producing regions, accounting for more than 80 percent of world production in 2006. While harvests in Africa and Latin America were far smaller, production was at record levels. North America was the clear leader in yields, at more than 40 tonnes per hectare.

<table>
<thead>
<tr>
<th>Region</th>
<th>Harvested area (hectares)</th>
<th>Quantity (tonnes)</th>
<th>Yield (tonnes/hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>1,409,687</td>
<td>16,420,729</td>
<td>10.95</td>
</tr>
<tr>
<td>Asia/Oceania</td>
<td>9,143,495</td>
<td>131,286,181</td>
<td>14.36</td>
</tr>
<tr>
<td>Europe</td>
<td>7,348,420</td>
<td>126,332,492</td>
<td>17.19</td>
</tr>
<tr>
<td>Latin America</td>
<td>951,974</td>
<td>15,627,530</td>
<td>16.42</td>
</tr>
<tr>
<td>North America</td>
<td>608,131</td>
<td>24,708,603</td>
<td>40.63</td>
</tr>
<tr>
<td>WORLD</td>
<td>19,551,707</td>
<td>314,375,535</td>
<td>16.08</td>
</tr>
</tbody>
</table>

Source: FAOSTAT

Potato consumption, by region, 2005

Asia consumes almost half of the world's potato supply, but its huge population means that consumption per person was a modest 25 kg in 2005. The heartiest potato eaters are Europeans. Per capita consumption is lowest, but increasing, in Africa and Latin America.

<table>
<thead>
<tr>
<th>Region</th>
<th>Population</th>
<th>Total food (t)</th>
<th>Consumption kg per capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>905,937,000</td>
<td>12,850,000</td>
<td>14.18</td>
</tr>
<tr>
<td>Asia/Oceania</td>
<td>3,938,469,000</td>
<td>101,756,000</td>
<td>25.83</td>
</tr>
<tr>
<td>Europe</td>
<td>739,276,000</td>
<td>71,087,000</td>
<td>96.15</td>
</tr>
<tr>
<td>Latin America</td>
<td>561,344,000</td>
<td>13,280,000</td>
<td>23.65</td>
</tr>
<tr>
<td>North America</td>
<td>330,608,000</td>
<td>19,156,000</td>
<td>57.94</td>
</tr>
<tr>
<td>WORLD</td>
<td>6,475,634,000</td>
<td>218,129,000</td>
<td>33.68</td>
</tr>
</tbody>
</table>

Source: FAOSTAT
Africa

Potato arrived late in Africa, around the turn of the 20th century. In recent decades, production has been in continual expansion, rising from 2 million tonnes in 1960 to a record 16.5 million tonnes in 2006. Potatoes are grown under a wide range of conditions - from irrigated commercial farms in Egypt and South Africa to intensively cultivated tropical highland zones of Eastern and Central Africa, where it is mainly a small farmer's crop.

1. Egypt

The potato was introduced to Egypt during the 1800s, and large scale cultivation began during the First World War, when British colonial officials encouraged its production to feed their troops. After the war, however, expansion of potato growing was hampered by the poor quality of imported seed and by farmers' inexperience with the crop.

That has changed. Since 1961, Egypt's irrigated potato production - concentrated in the Nile River delta in the north - has expanded at a rate of more than 5 percent a year. Between 1990 and 2006, annual output rose from 1.6 million tonnes to some 2.5 million tonnes, making Egypt Africa's No. 1 potato producer.

Egypt also ranks among the world's top potato exporters - in 2004, exports totalled more than 380 000 tonnes of fresh potatoes and 18 000 tonnes of frozen potato products, destined mainly for markets in Europe.

2. Algeria

After Solanum tuberosum's introduction to Algeria, in the mid-1800s, potatoes were grown mainly for export to French markets. By national independence from France, in 1962, farmers were harvesting on average 250 000 tonnes a year, with about one third marked for export.

Since then, the potato has become an increasingly important crop for domestic consumption, with production in 2006 reaching a record 2.18 million tonnes. Potato is grown over an area of 100 000 ha, and can be planted and harvested somewhere in Algeria in virtually any month of the year.

The main fresh potato growing areas are along the Mediterranean coast, where a mild climate permits year-round production. Potatoes are also grown at elevations of 500 m in hills and valleys between the coast and the Atlas Mountains, and in high plateau areas. Annual potato consumption in Algeria has increased from 35 kg in 1990 to around 57 kg in 2005.
3. South Africa

Dutch seafarers heading for East Asia probably brought the potato to South Africa in the 1600s (it is thought sailors encouraged potato growing at ports of call so they could re-supply with fresh tubers during ocean voyages).

Today, South Africa produces more potatoes than any other country in the sub-Saharan region. Potato output has grown strongly over the past 15 years, from 1.2 million tonnes in 1990 to a record 1.9 million tonnes in 2005. In the same period, the potato farming area actually declined, from 63 000 ha to 53 000 ha. Most potatoes are grown on relatively large farms, increasingly under irrigation, with yields averaging around 30 tonnes per hectare.

South Africa boasts a sophisticated seed potato industry and - thanks largely to the country's rapid rate of urbanization - a vibrant potato processing sector, which utilizes some 250 000 tonnes of potatoes per year, mainly for frozen french fries and crisps. Annual potato consumption is around 30 kg per person.

4. Malawi

Potatoes came to East Africa in the 19th century, brought by missionaries and European colonialists. But the crop did not become important to Malawians until the 1960s, when production reached around 60 000 tonnes a year.

Now Malawi is sub-Saharan Africa's second biggest potato producer, with a 2006 harvest of 1.8 million tonnes, only slightly less than that of South Africa. The potato is grown mainly in highland areas in the country's southern and central regions, the most suitable areas being at altitudes of between 1 000 and 2 000 m and with more than 750 mm of annual rainfall. In parts of the southern region, farmers can grow two crops each year. Potatoes are often planted with maize and beans during the main October-March season.

Only a tiny proportion of Malawi's potatoes is exported. Annual consumption has more than tripled over the past 15 years to a high 88 kg per capita.

5. Morocco

The potato was probably well established in Morocco before the country became a French protectorate in 1910. Over the following century - and particularly since independence in 1956 - production has expanded strongly, rising from about 150 000 tonnes in 1961 to a record 1.56 million tonnes in 2006. In the same period, yields grew from 10 tonnes per ha to more than 26 tonnes.

By sheer weight, the potato is now Morocco's third biggest crop, after sugar beets and wheat, and second only to tomatoes among exported vegetables, with more than 40 000 tonnes shipped to Europe in 2005.

Except for a brief period during the May-July winter months, potatoes are grown year round. Production of fresh potatoes is concentrated along the Atlantic Coast north and south of Casablanca, where a modified Mediterranean climate provides very favourable growing conditions. Potatoes are also grown in high, rugged parts of the Atlas mountains, at elevations of more than 3 000 m. The average Moroccan consumes about 42 kg of potatoes a year.
6. Rwanda

The potato came with German soldiers and Belgian missionaries to Rwanda in the early 20th century. Today, *ibirayi* - derived from *uburayi* ("that which comes from Europe") - are the country's second most important crop after plantains and, in the sub-Saharan region, Rwanda is the third largest potato producer.

Since 1961, Rwanda's potato output has risen from less than 100 000 tonnes to a record 1.3 million tonnes in 2005. The harvest in 2006 was only slightly smaller. Potatoes grow well in several parts of country - mainly above elevations of 1 800 m - and some areas grow two crops a year. Most of potato sector consists of small family farms that intercrop potato with beans and maize, and yields average almost 10 tonnes per hectare.

The potato underpins Rwanda's food security. Annual consumption is a very high 124 kg per person, making potato the country's second most important source of calorie intake after cassava.

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7. Nigeria

In the potato world, Africa's most populous country, Nigeria, stands out: it is the fourth biggest producer of potato in sub-Saharan Africa, has almost as much land under potato as Germany, and potato output has grown sevenfold over the past decade, reaching 840 000 tonnes in 2006.

The main potato growing area is the Jos plateau, where altitudes ranging from 1 200 to 1 400 m and summer temperatures that rarely exceed 35 °C make for a temperate climate well suited to potato production. However, productivity is constrained by a lack of suitable varieties, and high land and labour costs. In fact, Nigeria records one of the world's lowest average potato yields, little more than 3.1 tonnes per hectare.

Potato consumption is also very low, at around 3.2 kg per capita per year. However, Nigeria's taste for potatoes, especially in rapidly growing urban areas, is increasing - since 2000, imports of raw and processed potatoes have risen from less than 9 000 tonnes to 40 000 tonnes a year.

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8. Kenya

Introduced to East Africa by British farmers in the 1880s, the potato has grown in importance - both as a staple food and as a source of farmer incomes - over the past 30 years. Measured by quantity harvested, it now ranks as the country's No. 2 food crop, after maize, with production in 2006 totalling around 780 000 tonnes.

The potato in Kenya is grown mainly by small scale farmers, many of them women, although some larger-scale growers specialize in commercial production. Cultivation is concentrated in highland areas of from 1 200 to 3 000 m above sea level.

Nearly all of Kenya's potatoes are consumed locally, at an average rate of almost 25 kg per capita a year. *Kiazi* is relished not only by the rural people who grow them, but by higher-income urban dwellers as well - while in some African countries potato is considered a "poor person's food", in Kenya it is considered a high quality and prestigious food item.

Sources: CIP World Potato Atlas; FAOSTAT; World Potato Congress; Potatoes South Africa
Asia and Oceania includes the world's potato giant, China, which accounts for more than 20 percent of both the global potato-growing area and the world potato harvest. Several other Asian countries - Bangladesh, India, the Islamic Republic of Iran, Japan and Turkey - also figure in the world's top 20 potato producing countries. The world's best yields are recorded in New Zealand - on average, more than 45 tonnes per hectare.

1. China

China is the world's biggest potato producer, with output in 2006 of 70.3 million tonnes (or more than 20 percent of the global harvest). It is also an increasingly important global supplier, with potato exports totalling some 440,000 tonnes (raw equivalent) in 2005.

The tuber probably reached coastal China aboard ships from Europe during the 17th century and was introduced to central China by Russian traders around the same time. Production has increased nearly fivefold since 1961. Although Chinese potato output ranks behind that of maize and sweet potato, more than 80 percent of the maize and 40 percent of the sweet potato are used as animal feed. Most of the potatoes go directly to human consumption - each year, the Chinese consume 30 kg per head.

The potato is important to China not only as a staple food, but also as a source of income, especially for farmers in mountainous areas with poor soils. In northern China's Inner Mongolia and Shanxi provinces, sales of potato account for more than half of rural household earnings.

2. India

The potato reached India in the late 16th and early 17th centuries, most likely aboard ships from Portugal. Today, India ranks as the world's third largest potato producing nation, with production in 2006 of around 24 million tonnes.

Between 1960 and 2000, potato production increased by almost 850 percent, partly in response to growing demand from higher-income urban populations. Since 1990, per capita consumption has risen from around 12 kg to 17 kg a year.

In India, the aloo is not primarily a rural staple but a cash crop that provides significant income for farmers: the value of the 2005 harvest is estimated at $3.6 billion and exports totalled about 80,000 tonnes that year. Potato varieties suited to the country's climate - hot summers and short winters - are grown on the Indo-Gangetic plain during the short winter days from October to March, while some year-round production takes place in...
3. Islamic Republic of Iran

A British ambassador, Sir John Malcolm, is said to have introduced the potato to the royal court of Persia during the early 1800s. For a time, the tuber was known as "Malcolm's plum", but it's called the "earth apple" by today's Iranians.

Iran is the world's No. 13 potato producer and the third biggest in Asia, after China and India. Since 1961, production has increased more than 15 times over. In 2006, the country's farmers achieved an all-time record harvest of 4.6 million tonnes, with per hectare yields averaging more than 24 tonnes. The potato is one of Iran's leading agricultural exports, with shipments in 2005 totalling around 166,000 tonnes.

Potatoes are grown mostly under irrigation around the southern shore of the Caspian Sea, in the Zagros Mountains, and on the southern lowlands, alternated with wheat, vegetables, sugar beets and fallow in three- or four year rotations. Traditional varieties prized for their culinary qualities continue to be grown in the mountainous north.

4. Turkey

In some areas of Anatolia, local potato varieties are still called *ruskartoe*, commemorating the tuber's introduction from the Russian Caucasus in the early 1800s. Potato cultivation has been officially encouraged in Turkey since 1872, and today the country is the Middle East's biggest producer after Iran, with output in 2006 of almost 4.4 million tonnes.

Second only to tomatoes as a horticultural crop, the *patates* is grown on an estimated 154,000 ha of land across the country. The Anatolian central plateau - with its hot, dry summers and cold winters - is the most important producing region, accounting for nearly half of the national potato area, while intensive cultivation is conducted on the Aegean and Mediterranean coasts. Yields in 2006 were a high 28.5 tonnes per hectare.

Turkey's current production hovers at 1990 levels, and is well below the 2000 record harvest of 5.4 million tonnes. Annual per capita potato consumption is contracting, from 63 kg in 1990 to a less than 50 kg in 2006.

5. Bangladesh

A British governor promoted potato cultivation in Bengal in the 1770s, and within a century it was a well established garden vegetable. However, large scale production was held back by the lack of suitable varieties: European cultivars were not adapted the hot Bengali plains.

Today, the potato has become a highly successful October-March winter crop in Bangladesh, with a production value - estimated at $560 million in 2005 - second only to that of paddy rice. In 2006, Bangladeshi farmers harvested more than 4.1 million tonnes of potatoes (12 times more than in 1961), which placed the country at No. 15 among the world's potato producers and No. 5 in Asia.

The potato is usually grown for cash sale, and much of national production is concentrated near the capital, Dhaka, the country's largest urban market. Annual consumption has been growing briskly, from around 7 kg per capita in 1990 to more than 24 kg in 2006.
6. Japan

The potato was probably brought to Japan by Dutch traders who established an enclave in Nagasaki early in the 17th century. But widespread cultivation of the tuber did not begin until late in the 19th century, when it proved well suited to the cool summers of the northern island of Hokkaido.

Today, Hokkaido's potato farmers produce yields of more than 41 tonnes per hectare and account for about two-thirds of the national harvest, which totalled some 2.6 million tonnes in 2006. While that placed the country at No. 6 among Asia's potato producers, it was also the smallest harvest recorded since the 1960s, when Japan was producing up to 4 million tonnes a year.

Along with the steady decline in production over recent decades, there has been a shift from home preparation to consumption of processed potato products such as chips and french fries. To meet domestic demand, Japan imports each year some 650 000 tonnes of potatoes, mainly from China.

7. Kazakhstan

At the break-up of the Soviet Union in 1991, Kazakhstan was producing annually around 2.5 million tonnes of potatoes from an area of 240 000 ha. In the turmoil of the following decade, there was a steady decline in the size of the potato growing area and in potato output, which dropped to 1.2 million tonnes in 1998.

Since then, production has rebounded, thanks largely to rapid gains in average per hectare yields, which rose from 7.6 tonnes in 1998 to more than 14 tonnes in 2006. In that year, Kazakh potato farmers harvested some 2.36 million tonnes of tubers from 160 000 ha of land.

Today, the potato is Kazakhstan's most important food crop after wheat, with average per capita consumption of a high 90 kg a year. While most potatoes are consumed fresh or used as fodder, recent years have seen strong growth in exports of processed potato products, which rose from 1 000 tonnes in 2000 to more than 15 000 tonnes in 2005.

8. Democratic People's Republic of Korea

The potato was introduced to the Korean peninsula - probably from China - during the early 1800s. It became a staple crop during the Japanese occupation from 1910 to 1945, replacing rice exported to Japan, and saved many farm families from starvation during the Second World War.

The potato remains an essential food security crop in the Democratic People's Republic of Korea. In 2006, it produced an estimated 2 million tonnes, placing the country among Asia's top 10 producers. The area under potato has grown from 36 000 ha to almost 200 000 ha since 1960, while potato output has increased fourfold over the past decade.

Farmers' average yields, however, have barely improved over 1960 levels, mainly owing to shortages of agricultural inputs and the lack of virus-free seed potato. To boost production, the government is promoting a "potato farming revolution" - innovations include a low-input potato-rice cropping system that produces, in a relatively short growing season, 11 tonnes of potatoes and rice.
9. Nepal

The first record of potatoes in Nepal dates back to 1793. Although it remained a relatively minor crop for the next 180 years, some researchers say that its early introduction to the high altitude Himalayas helped fuel the rise of Buddhist civilization in northern Nepal.

In the 1970s, a national potato development programme, focused on improving the quality of seed potato, stimulated a rapid expansion of both cultivated area and production, which increased from 300 000 tonnes in 1975 to a record 1.97 million tonnes in 2006. The potato is now Nepal's second staple food crop, after rice, and per capita consumption has almost doubled since 1990 to 51 kg a year.

Potatoes are widely grown in Nepal, at below 100 m altitude in the south to as high as 4 000 m in the northern mountains. The tuber is particularly favoured by farmers in high hills areas (roughly 1 800 to 3 000 m): it is more productive than rice and maize and the cool climate is well suited to production of seed tubers for sale at lower altitudes.

10. Pakistan

Although potato was grown on the Indian subcontinent from the late 16th or early 17th centuries, at Pakistan's foundation in 1947 cultivation was restricted to a few thousand hectares and total annual output was less than 30 000 tonnes.

In the decades since independence, the aalu has become the country's fastest growing staple food crop. Thanks to strong gains in cultivated area and average yields - both made possible mainly by irrigation - output rose between 1995 and 2006 from one million to more than 1.5 million tonnes. The lion's share of potato production comes from the Punjab, where spring and autumn crops account for 85 percent of the national harvest.

Apart from some subsistence growers in the north, most Pakistani farmers produce for urban markets rather than household consumption, and the potato has become a significant source of rural income (worth some $300 million in 2005). At present, annual intake is around 11 kg per capita.

11. Australia

Potatoes were aboard the ship of explorer James Cook when he claimed eastern Australia for Britain in 1770, and their cultivation began along with colonization eight years later. Today, "spuds" are grown across the continent, from the southern temperate state of Tasmania to tropical North Queensland.

Australian potato production exceeds one million tonnes a year. That makes potato tubers the country's most important horticultural crop, accounting for more than 40 percent of total vegetable production. More than 60 percent is processed into frozen potato products and crisps, while around 37 percent is fresh marketed.

Competition from foods such as pasta and rice has made recent inroads into the fresh potato market, and FAO estimates that between 1995 and 2005 annual per capita consumption of potatoes slipped from 55 kg to 53 kg.

25. New Zealand
Decades before British colonization began in the mid-1800s, explorers had introduced potato to New Zealand’s Maori people. The new crop, dubbed *taewa*, proved well adapted to the cool New Zealand climate, and today red- and blue-skinned “Māori potatoes” are recognized local varieties.

In 2006, New Zealand produced around half a million tonnes of potatoes from an area of just 11 000 ha, with average yields of a very high 45 tonnes. Commercial yields exceeding 70 tonnes are not uncommon. The potato is the country's most popular vegetable - fresh market potatoes are harvested all year round and per capita consumption is estimated at about 66 kg a year.

The past decade has seen strong growth in the processing sector (300 000 tonnes were processed into french fries and crisps in 2006) and in fresh and frozen potato exports, which totalled more than 90 000 tonnes. The retail and export value of New Zealand’s potatoes is put at some US$ 300 million a year.

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Sources: CIP World Potato Atlas; FAOSTAT; World Potato Congress; AusVeg; Horticulture New Zealand
**Potato and biodiversity**

The history of the potato provides a grim warning of the need to maintain genetic diversity in our staple food crops. In the 19th century, Ireland was heavily reliant on only a few varieties of potato, and those types contained no resistance to the devastating disease known as late blight. When late blight destroyed the 1845-1846 potato crop, widespread famine followed. An estimated one million people starved to death and more than a million were forced to migrate abroad.

To combat pests and diseases, increase yields, and sustain production on marginal lands, today’s potato-based agricultural systems need a continuous supply of new varieties. That requires access to the entire potato gene pool. But potato biodiversity is under threat: ancient varieties cultivated by Andean peoples for millennia have been lost to diseases, climate change and social upheaval.

Species and crop-associated diversity

While most varieties of potatoes belong to a single species, *Solanum tuberosum*, about 10 other *Solanum* species have been cultivated, and 200 wild species have been recorded. Climate change may threaten the survival of those wild relatives: it is forecast that as many as 12 percent will become extinct as their growing conditions deteriorate. If climate changes drastically, the area where wild potatoes grow naturally could be reduced by as much as 70 percent.

Since potatoes mostly propagate vegetatively, most commercial varieties of potato have a reduced ability to flower and breeders do not select for traits that make the flower attractive to pollinators. However, natural potato pollination remains important to sustaining the diversity of local, farmer-developed varieties. Fortunately, the diverse smallholder farming systems in the Andes encourage cross-pollination of potato flowers, vital to sustaining the diversity of local, farmer-developed varieties.

**International Treaty**

The potato is included in the multilateral system established under FAO’s International Treaty on Plant Genetic Resources for Food and Agriculture. The Treaty, which entered into force in 2004, aims at the conservation and sustainable use of crop plant diversity and the fair and equitable sharing of benefits derived from their use.
Conserving potato biodiversity in the Andes
Having lost many of their traditional potato varieties, Peruvian farmers in the Andes are now taking measures to conserve and sustainably use those that remain. A pact has been signed by six Quechua communities with the International Potato Center that recognizes the rights of the communities over potato strains they have developed.

Under the agreement, the Center’s genebank returns potato genetic resources – and knowledge associated with them – to the communities, which have established a “potato park” (Parque de la papa) in a conservation area where they grow and manage the plants. This repatriation of biological diversity effectively keeps control of genetic resources local. The 15,000 ha park is a “living library” of potato genetic diversity, holding some 1,200 varieties of potato cultivated in the highlands. A long-term goal is to re-establish all the world’s 4,000 known potato varieties in the valley, allowing the park to function as a second centre of origin for this vital staple crop.

Diversity conserved in trust
The International Potato Centre in Peru maintains the world’s largest bank of potato germplasm, including some 1,500 samples of about 100 wild species collected in eight Latin American countries, and 3,800 traditional Andean cultivated potatoes. The collection is maintained and managed under the terms of an agreement with the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture and, like all collections eligible for funding from the Global Crop Diversity Trust, is available to plant breeders worldwide upon request.

Credits:
Information provided by the Global Crop Diversity Trust and the Plant Production and Protection Division, FAO.

About IYP 2008
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www.potato2008.org

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Around the world, rural women are essential to conservation, seed selection, planting, harvesting, storing and marketing of potatoes

Key points

Women in developing countries play a central role in guaranteeing family food security and provide most of the labour for potato production.

Andean women possess a unique reservoir of knowledge and skills in domesticating wild potatoes and adapting new varieties.

New strategies are helping to empower small-scale farmers and ensure that gender issues are incorporated in potato development policies and programmes.

Since the beginning of Andean agriculture, seeds have been associated with reproduction and femininity. The Incas believed the moon conferred fertility on women and moved Pachamama (Mother Earth) to germinate and offer up her potatoes (known as Mama Acxo) at harvest time. Men deposited the seeds and women received them, to harbour and nurse. In the Andes today, and in many other parts of the developing world, potato growing is still highly labour-intensive. Rural women provide most of the labour in both small- and large-scale potato production – from conservation and seed selection to planting, harvesting, storing and marketing.

China: Increasing gender awareness

In China, most potatoes are grown in mountain areas of Inner Mongolia and Shaanxi provinces, both as a staple food and as a cash crop. Research in Wuchuan County, Inner Mongolia, shows how the labour-intensive nature of potato production, coupled with strong gender inequalities, can pose a threat to the sustainability of local livelihoods.

Says Zhang Ailian, a woman farmer: “Potato growing is very tiring, especially at harvest time, and the burden of household tasks is already very heavy. The Agriculture and Animal Husbandry Bureau provides technical training in potato production, but heads of the village usually tell men to attend. Women make up fewer than 10 percent of total participants.”

A project in Wuchuan is working to ease the burden of potato production on women by supplementing agricultural training with gender-sensitive materials. The project uses participatory approaches such as “farmer field schools”, and brings gender issues into potato development policies. It advocates a more equitable division of labour and financial decision making powers for women, and facilitates their access to extension services and training.

Peru: Women as conservationists

In the high-altitude Peruvian Andes, the genetic diversity found in hundreds of native potato varieties guarantees rural communities’ food security. Over centuries, Andean farmers and the descendants of ayllu family groups, primarily women, have selected countless varieties of potato to preserve and enhance plant diversity, allowing them to cultivate in different agro-ecological zones and cope with pests, diseases and climatic changes. The “bitter potato”, for example, is the result of crossing with frost-resistant varieties adapted to the freezing temperatures of the Puna agro-ecological zone.

Male migration to urban centres has left women farmers responsible for almost 70 percent of family farm work. In the Chetilla community in Cajamarca, the
tasks of seed selection and storage are exclusively women’s. Their participation in seed fairs is invaluable in preserving Andean potato biodiversity. Surveys have found that women attending fairs are able to identify up to 56 different varieties. However, the heavy burden placed on women in potato production highlights the need for a more equitable division of labour to ensure the conservation of agro-biodiversity.

Uganda: Enabling rural innovation
Potatoes have become an important staple and cash crop in sub-Saharan Africa’s highland zones, and Uganda is a major potato producer in the region. Virtually all households in southwestern Uganda grow potatoes, harvesting over 60 percent of the national crop. Most tubers are grown in highland areas of Kabale and Kisoro as a staple food and as the main source of income.

“Enabling rural innovation” is a gender-sensitive strategy being used in various development programmes. The idea is to empower both men and women farmers and rural communities to develop market opportunities. In Kabale, for example, farmer field school training covered integrated potato pest and disease management. It also helped the Nyabyumba United Farmers group to establish an enterprise that now supplies potatoes for french fries at fast-food restaurants in Kampala.

Gender roles in agriculture
FAO’s Gender Plan of Action underscores the need for rural and agricultural development policies that acknowledge the roles of both men and women in achieving food security. The Plan aims at promoting gender equality in access to food, in the control over and management of natural resources and agricultural support services, in policy- and decision-making processes at all levels in the agricultural and rural sector, and in opportunities for on- and off-farm rural employment.

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Credits:
Information provided by the Gender, Equity and Rural Employment Division, FAO.

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The global potato economy

Potato production in developed countries, especially in Europe and the Commonwealth of Independent States, has declined on average by one percent per annum over the past 20 years. However, output in developing countries has expanded at an average rate of five percent per year. Asian countries, particularly China and India, fuelled this growth.

In 2005, the developing countries’ share of global potato output stood at 52 percent, surpassing that of the developed world. This is a remarkable achievement, considering that just 20 years ago the developing countries’ share in global production was little more than 20 percent. Even so, world potato production and consumption are currently expanding more slowly than the global population.

Fresh potato consumption, once the mainstay of world potato utilization, is decreasing in many countries, especially in developed regions. Currently, more potatoes are processed to meet rising demand from the fast food, snack and convenience food industries. The major drivers behind this development include growing urban populations, rising incomes, the diversification of diets and lifestyles that leave less time for preparing the fresh product for consumption.

Potatoes are commonly regarded as a bulky, perishable commodity with high transport costs and limited export potential, confined mostly to cross-border transactions. These constraints have not hampered the international potato trade, which has doubled in volume and risen almost fourfold in value since the mid-1980s. This growth is due to unprecedented international demand for processed products, particularly frozen and dehydrated potato products. To date, developing countries have not been beneficiaries of this trade expansion. As a group, they have emerged as leading net importers of the commodity.

International trade in potatoes and potato products still remains thin relative to production, as only around 6 percent of output is traded. High transport costs, including the cost of refrigeration, are major obstacles to a wider international marketplace.

Trade policies
Ad valorem import tariffs are used to protect domestic potato markets. Other

Key points

In 2005, for the first time, the developing world’s potato production exceeded that of the developed world.

Subsistence potato growing in developing countries is declining as producers reorient toward domestic and international markets.

Global consumption is shifting from fresh potatoes to added-value processed products.

In international trade, both the value and volume of traded processed products far outweigh trade in fresh tubers.

Developing countries are net importers in international potato trade, which in 2005 was estimated to be worth US$6 billion.

Despite its importance as a staple food and in combating hunger and poverty, potato has been neglected in agricultural development policies for food crops.

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China and India now account for 30 percent of world potato output
policies that restrict access to markets include sanitary and phytosanitary measures and technical barriers to trade.

Import tariffs on potatoes and potato products are applied by most countries. The binding rates agreed under the aegis of the World Trade Organization vary considerably. Potato provides a classic example of “tariff escalation”, where importing countries protect processing industries by levying higher duties on processed products than on raw material. By preventing countries from diversifying their export base into higher-value processed products, tariff escalation can therefore keep them “trapped” as providers of raw material.

Countries wishing to supply potato commodities to the international market – especially to the more lucrative developed country markets – also face considerable hurdles in the form of food health standards and technical regulations. The Doha Development Round of trade negotiations recognizes the negative impacts of tariff escalation and contains important provisions aimed at ensuring that standards and regulations do not become de facto barriers to trade or hidden protectionist policies, while at the same time putting public health concerns foremost. Unfortunately, negotiations pertaining to the Doha agenda have suffered a series of setbacks, and agreement on a final solution has yet to materialize.

<table>
<thead>
<tr>
<th>Product</th>
<th>WTO Bound Tariff (%)</th>
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<tbody>
<tr>
<td>Fresh potatoes (inc. seed)</td>
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<tr>
<td>Frozen potatoes</td>
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<tr>
<td>Potato flour</td>
<td>38</td>
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<tr>
<td>Potato starch</td>
<td>109</td>
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* includes flour, meal, flakes, granules and pellets

Potato potential

Potato’s positive attributes, particularly its high nutritional value and potential to boost incomes, have not received the attention they deserve from governments. The lack of established marketing channels, inadequate institutional support and infrastructure, and restrictive trade policies are impediments to commercialization of the sector. National and international stakeholders need to place potato higher on the development agenda.

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Credits:
Information provided by the Trade and Markets Division, FAO.
Potato and biotechnology

In vitro conservation, molecular markers and recombinant DNA technologies are creating new opportunities in potato production and transformation

Key points

The potato industry has benefited from major recent discoveries about the plant’s genetics, physiology and pathology.

Micropropagation is helping developing countries produce low-cost, disease-free tuber “seed” and increase potato yields.

Use of molecular markers helps identify desirable traits in potato collections, thus simplifying the development of improved varieties.

Sequencing of the complete potato genome, now under way, will significantly increase knowledge and understanding of genetic interactions and functional traits.

Genetically modified varieties have the potential to produce more stable yields, improve nutritional quality and facilitate non-food industrial uses, but must be carefully assessed before release.

New molecular biology and plant cell culture tools have enabled scientists to understand better how potato plants reproduce, grow and yield their tubers, how they interact with pests and diseases, and how they cope with environmental stresses. Those advances have unlocked new opportunities for the potato industry by boosting potato yields, improving the tuber’s nutritional value, and opening the way to a variety of non-food uses of potato starch, such as the production of plastic polymers.

Producing high-quality propagation material

Unlike other major field crops, potatoes are vegetatively reproduced as clones, ensuring stable, “true-to-type” propagation. However, tubers taken from diseased plants also transmit the disease to their progenies. To avoid that, potato tuber “seed” needs to be produced under strict disease control conditions, which adds to the cost of propagation material and therefore limits its availability to farmers in developing countries.

Micropropagation or propagation in vitro offers a low-cost solution to the problem of pathogens in seed potato. Plantlets can be multiplied an unlimited number of times, by cutting them into single-node pieces and cultivating the cuttings. The plantlets can either be induced to produce small tubers directly within containers or transplanted to the field, where they grow and yield low-cost, disease-free tuber “seed”. This technique is very popular and routinely used commercially in a number of developing and transition countries.* For example, in Viet Nam micropropagation directly managed by farmers contributed to the doubling of potato yields in a few years.

Protecting and exploring potato diversity

The potato has the richest genetic diversity of any cultivated plant. Potato genetic resources in the South American Andes include wild relatives, native cultivated species, local farmer-developed varieties, and hybrids of cultivated and wild plants. They contain a wealth of valuable traits, such as resistance to pests and diseases, nutrition value, taste and adaptation to extreme climatic conditions. Continuous efforts are being made to collect, characterize and conserve them in gene banks, and some of their traits have been transferred to commercial potato lines through cross-breeding.

To protect collections of potato varieties and wild and cultivated relatives from possible diseases and pest outbreaks, scientists use a variation of micropropagation techniques to maintain potato samples in vitro, under sterile conditions. Accessions are intensively studied using molecular markers, the identifiable DNA sequences found at specific chromosomal locations on the genome and transmitted by the standard laws of inheritance.

Obtaining improved varieties

Potato genetics and inheritance are complex, and developing improved

varieties through conventional cross breeding is difficult and time consuming. Molecular-marker based screening and other molecular techniques are now widely used to enhance and expand the traditional approaches to potato in food production. Molecular markers for characteristics of interest help identify desired traits and simplify the selection of improved varieties. Such techniques are currently applied in a number of developing and transition countries, and commercial varieties are expected to be released within the next few years.

Through the Potato Genome Sequencing Consortium, significant progress is being made in mapping the complete DNA sequence of the potato genome, which will enhance our knowledge of the plant’s genes and proteins, and of their functional traits. Technical advances in the fields of structural and functional potato genomics – and the ability to integrate genes of interest into the potato genome – have expanded the possibility of genetic transformation of the potato using recombinant DNA technologies. Transgenic varieties with resistance to Colorado Potato Beetle and viral diseases were released for commercial production in the early 1990s in Canada and the USA, and more commercial releases can be expected in the future.

Transgenic potato varieties offer the possibility of increasing potato productivity and production, as well as creating new opportunities for non-food industrial use. However, all biosafety and food safety aspects must be carefully assessed and addressed before their release.

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Credits:

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The use of chemical pesticides on potato is increasing in developing countries, as farmers intensify production and expand cultivation into areas and planting seasons beyond the crop’s traditional range. The chemicals used are frequently highly toxic and applied with little or no protective equipment.

The result is alarming levels of pesticide poisoning in farming communities. Insecticide absorbed by soil often penetrates subsequent crops and runs off to contaminate water supplies. Overuse of pesticides even compounds pest and disease problems: in Colombia, outbreaks of a viral disease have been linked to insecticides that wiped out natural predators of the disease’s vector.

Increasing potato production while protecting producers, consumers and the environment requires a holistic crop protection approach encompassing a range of strategies – encouraging natural pest predators, breeding varieties with pest/disease resistance, planting certified seed potatoes, growing tubers in rotation with other crops, and organic composting to improve soil quality.

There is no effective chemical control, for example, against bacterial wilt. But planting healthy seed in clean soil, using

### Ecuador: training reduces pesticide poisoning

In Ecuador’s Carchi province, a programme supported by CIP and FAO used Farmer Field Schools to drastically reduce high rates of pesticide poisoning. Continuous cropping of potato had produced not only high yields, but highly favourable conditions for insects and fungal diseases, leading to massive applications of insecticides and fungicides. As a result of pesticide exposure, CIP scientists say, 60 percent of people in the area showed reduced neuro-behavioural functions. IPM training enabled farmers to reduce agrochemical application costs – including fertilizer, pesticide and labour costs - by an average of 75 percent with no effect on productivity. Follow-up studies show that the reduced exposure to pesticides was associated with recovery of previously suppressed nervous system functions.

### Key points

- Intensive potato cultivation tends to increase pest and disease pressure, which often leads to intensive use of harmful pesticides.
- Resistant potato varieties and improved cultural practices can reduce or eliminate many common pests and diseases.
- Integrated pest management has helped farmers drastically reduce the need for chemical controls while increasing production.

### Some of potato’s main enemies

#### Diseases

- **Late blight**: the most serious potato disease worldwide, is caused by a water mould, *Phytophthora infestans*, that destroys leaves, stems and tubers.
- **Bacterial wilt**: caused by the bacterial pathogen, leads to severe losses in tropical, subtropical and temperate regions.
- **Potato blackleg**: a bacterial infection, causes tubers to rot in the ground and in storage.
- **Viruses**: disseminated in tubers, can cut yields by 50 percent.

#### Pests

- **Colorado potato beetle** (*Leptinotarsa decemlineata*): a serious pest with strong resistance to insecticides.
- **Potato tuber moth**: most commonly *Phthorimaea operculella*, is the most damaging pest of planted and stored potatoes in warm, dry areas.
- **Leafminer fly** (*Liriomyza huidobrensis*): A South American native common in areas where insecticides are used intensively.
- **Cyst nematodes** (*Globodera pallida* and *G. rostochiensis*): serious soil pests in temperate regions, the Andes and other highland areas.
tolerant varieties in rotation with non-susceptible crops, and other sanitation and cultivation practices can lead to significant reduction of the disease. Incidence of potato tuber moth can also be reduced by preventing soil cracking that allows moths to reach the tubers.

Both the International Potato Center (CIP) and FAO advocate Integrated Pest Management (IPM) as the preferred pest control strategy during production. IPM aims at maintaining pest populations at acceptable levels and keeping pesticides and other interventions to levels that are economically justified and safe for human health and the environment.

FAO has promoted IPM in many developing countries using Farmer Field Schools, which centre around a “living laboratory” where farmers are trained to identify insects and diseases and compare results on two subplots – one using conventional chemical pest control and the other using IPM. On the improved management plot, participants strive to improve ecosystem health by cutting pesticide use while increasing productivity through management intensification. Farmers experiment with a variety of techniques, such as weevil traps, different strains of potatoes and targeted applications of lower toxicity pesticides.

In Peru’s Cañete River valley, CIP entomologists designed an IPM package to help growers protect their crops against the leafminer fly, which had become a major problem after massive use of insecticides exterminated its natural enemies. The IPM programme included traps to lure and kill adult flies and reintroduction to the valley of parasitic wasps. Participating growers were able to reduce spraying from 12 times per season to only one or two carefully timed applications of insect growth regulators.

## Virus control

Because virus-infected potato plants cannot be cured, CIP is working to incorporate into new varieties resistance to the three most common potato viruses. Some virus resistance is now available in about a quarter of CIP-bred genotypes.

## Beating late blight

The mould responsible for late blight has consistently overcome resistant cultivars and mutated into strains that survive spraying with powerful fungicides. The Global Initiative on Late Blight, a network of scientists, technologists and agricultural knowledge agents in 72 countries, is exploring new control strategies, including “organic management” using improved sanitation in storage, risk forecasting and genetic resistance.

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Credits: Information provided by the International Potato Center and FAO
The potato (Solanum tuberosum) is an herbaceous annual that grows up to 100 cm (40 inches) tall and produces a tuber - also called potato - so rich in starch that it ranks as the world's fourth most important food crop, after maize, wheat and rice. The potato belongs to the Solanaceae - or "nightshade"-family of flowering plants, and shares the genus Solanum with at least 1,000 other species, including tomato and eggplant. S. tuberosum is divided into two, only slightly different, subspecies: andigena, which is adapted to short day conditions and is mainly grown in the Andes, and tuberosum, the potato now cultivated around the world, which is believed to be descended from a small introduction to Europe of andigena potatoes that later adapted to longer day lengths.
The potato: Tuber - International Year of the Potato 2008

The tuber

As the potato plant grows, its compound leaves manufacture starch that is transferred to the ends of its underground stems (or stolons). The stems thicken to form a few or as many as 20 tubers close to the soil surface. The number of tubers that actually reach maturity depends on available moisture and soil nutrients. Tubers may vary in shape and size, and normally weigh up to 300 g (10.5 oz) each.

At the end of the growing season, the plant's leaves and stems die down to the soil level and its new tubers detach from their stolons. The tubers then serve as a nutrient store that allows the plant to survive the cold and later regrow and reproduce. Each tuber has from two to as many as 10 buds (or "eyes"), arranged in a spiral pattern around its surface. The buds generate shoots that grow into new plants when conditions are again favourable.
Origins

The potato's story begins about 8,000 years ago near Lake Titicaca, which sits at 3,800 m (12,500 ft) above sea level in the Andes mountain range of South America, on the border between Bolivia and Peru. There, research indicates, communities of hunters and gatherers who had first entered the South American continent at least 7,000 years before began domesticating wild potato plants that grew around the lake in abundance.

Some 200 species of wild potatoes are found in the Americas. But it was in the Central Andes that farmers succeeded in selecting and improving the first of what was to become, over the following millennia, a staggering range of tuber crops. In fact, what we know as "the potato" (Solanum species tuberosum) contains just a fragment of the genetic diversity found in the seven recognized potato species and 5,000 potato varieties still grown in the Andes.

Although Andean farmers cultivated many food crops - including tomatoes, beans and maize - their potato varieties proved particularly suited to the quechua or "valley" zone, which extends at altitudes of from 3,100 to 3,500 m (10,200 - 11,500 ft) along the slopes of the Central Andes (among Andean peoples, the quechua was known as the zone of "civilization"). But farmers also developed a frost-resistant potato species that survives on the alpine tundra of the puna zone at 4,300 m (14,100 ft).

The food security provided by maize and potato - consolidated by the development of irrigation and terracing - allowed the emergence around 500 AD of the Huari civilization in the highland Ayacucho basin. Around the same time, the city state of Tiahuanacu rose near Lake Titicaca, thanks largely to its sophisticated "raised field" technology - elevated soil beds lined with water canals - which produced potato yields estimated at 10 tonnes per hectare (4.4 tons per acre). At its height, around 800 AD, Tiahuanacu and neighbouring valleys are believed to have sustained a population of 500,000 or more.

Meteoric rise. The collapse of Huari and Tiahuanacu between 1000 and 1200 led to a period of turmoil that ended with the meteoric rise of the Incas in the Cuzco valley around 1400. In less than 100 years, they created the largest state in pre-Columbian America, extending from present-day Argentina to Colombia.

The Incas adopted and improved the agricultural advances of previous highland cultures, and gave special importance to maize production. But the potato was fundamental to their empire's food security: in the Incas' vast network of state storehouses, potato - especially a freeze-dried potato product called chuño - was one of the main food items, used to feed officials, soldiers and corvéé labourers and as an emergency stock after crop failures.

The Spanish invasion, in 1532, spelt the end of the Incas - but not of the potato. For, throughout Andean history, the potato - in all its forms - was profoundly a "people's food", playing a central role the Andean vision of the world (time, for example, was measured by how long it took to cook a pot of potatoes).

Farmers in some parts of the high Andes still measure land in topo, the area a family needs to grow their potato supply - a topo is larger at higher altitudes, where plots need to lie fallow for longer. They classify potatoes not only by species and variety, but by the ecological niche where the tubers grow best, and it is not unusual to find four or five species cultivated on a single, small plot of land.
**Diffusion**

The diffusion of the potato from the Andes to the rest of the globe reads like an adventure story, but it began with a tragedy. The Spanish conquest of Peru between 1532 and 1572 destroyed the Inca civilization and caused the deaths - from war, disease and despair - of at least half the population.

The conquistadores came in search of gold, but the real treasure they took back to Europe was *Solanum tuberosum*. The first evidence of potato growing in Europe dates from 1565, on Spain's Canary Islands. By 1573, potato was cultivated on the Spanish mainland. Soon, tubers were being sent around Europe as exotic gifts - from the Spanish court to the Pope in Rome, from Rome to the papal ambassador in Mons, and from there to a botanist in Vienna. Potatoes were grown in London in 1597 and reached France and the Netherlands soon after.

But once the plant had been added to botanical gardens and herbalists' encyclopaedias, interest waned. European aristocracy admired its flowers, but the tubers were considered fit only for pigs and the destitute. Superstitious peasants believed the potato was poisonous. At the same time, however, Europe's "Age of Discovery" had begun, and among the first to appreciate potatoes as food were sailors who took tubers to consume on ocean voyages. That is how the potato reached India, China and Japan early in the 17th century.

The potato also received an unusually warm welcome in Ireland, where it proved suited to the cool air and moist soils. Irish immigrants took the tuber - and the name, "Irish potato" - to North America in the early 1700s.

**Long summer days.** The widespread adoption of the potato as a food crop in the northern hemisphere was delayed not only by entrenched eating habits, but by the challenge of adapting a plant grown for millennia in the Andes to the north's temperate climate. Only a drop of the rich potato gene pool had left South America, and it took 150 years before varieties suited to long summer days began to appear.

Those varieties arrived at a crucial time. In the 1770s, much of continental Europe was devastated by famines, and the potato's value as a food security crop was suddenly recognized. Prussia's Frederick the Great ordered his subjects to grow potatoes as insurance against cereal crop failure, while the French scientist Parmentier succeeded in having the potato declared "edible" (around the same time, on the other side of the Atlantic, US President Thomas Jefferson served french fries to White House guests).

After initial hesitation, European farmers - even those in Russia, where the potato was called the "devil's apple" - began growing potatoes on a large scale. Potato became Europe's food reserve during the Napoleonic wars, and by 1815 it had become a staple crop across northern Europe. By then, the Industrial Revolution was transforming agrarian society in the United Kingdom, displacing millions of rural people into crowded cities. In the new urban environment, the potato became the first modern "convenience food" - energy-rich, nutritious, easy to grow on small plots, cheap to purchase, and ready to cook without expensive processing.

Increased potato consumption during the 19th century is credited with helping to reduce the scourge of diseases such as scurvy and measles, contributing to higher birth rates and the population explosion in Europe, the US and the British Empire.
Cultivation

Potato is grown for food in about 100 countries, under temperate, subtropical and tropical conditions. In temperate zones, potatoes are planted in spring and harvested in late summer. In tropical areas, the best yields are obtained at altitudes of 1,800 to 2,500 m (5,900 to 8,200 ft) or, at low altitude, when the crop is grown during the coolest months.

The main limiting factor on potato production is temperature. Optimum yields are obtained when mean daily temperatures are 18 to 20°C (64 to 68°F), while a night temperature of below 15°C (59°F) is required for tuber initiation. Tuber growth is sharply inhibited in temperatures below 10°C (50°F) and above 30°C (86°F).

Potato cultivars are grouped into three basic types: early (which produce tubers for harvesting within 90 to 120 days of planting), medium (120 to 150 days) and late (150 to 180 days). Early varieties bred for temperate climates require a day length of 15 to 17 hours, while late varieties produce good yields under long and short day conditions. In tropical climates, varieties must be adapted to tolerate short days.

Growing potatoes involves extensive ground preparation. The crop is usually grown not from seed but from "seed potatoes" - small tubers or pieces of tuber sown to a depth of 5 to 10 cm. The planting density of a row of potatoes depends on the size of the tubers chosen, while the inter-row spacing must allow for ridging of the crop. Usually, about two tonnes of seed potatoes are sown per hectare.

For rainfed production in dry areas, planting on flat soil gives higher yields (thanks to better soil water conservation), while irrigated crops are mainly grown on ridges. To protect soil, control weeds and reduce losses from pests and diseases, potato is usually grown in rotations of three or more years with crops such as maize, beans and alfalfa. Crops susceptible to the same pathogens as potato (e.g., tomato) are avoided in order to break potato pests' development cycle.

Land and water. Potatoes require well-drained and well-aerated soil. The use of chemical fertilizer depends on the level of available soil nutrients - volcanic soils, for example, are typically deficient in phosphorus - and in irrigated commercial production, fertilizer requirements are relatively high. However, potato can benefit from application of organic manure at the start of a new rotation.

The soil moisture content must be maintained at a relatively high level. For best yields, a 120 to 150 day crop requires from 500 to 700 mm (20 to 27.5 inches) of water. In general, water deficits in the middle to late part of the growing period tend to reduce yield more than those in the early part. Where supply is limited, water is directed towards maximizing yield per hectare rather than being applied over a larger area.

Because the potato has a shallow root system, yield response to frequent irrigation is considerable, and very high yields are obtained with mechanized sprinkler systems that replenish evapotranspiration losses every one or two days. Under irrigation in temperate and subtropical climates, a crop of about 120 days can produce yields of 25 to 35 tonnes/ha (11 to 15.6 tons per acre), falling to 15 to 25 tonnes/ha (6.6 to 15.6 tons per acre) in tropical areas.
# Potato varieties

Although all cultivated potatoes belong to just one botanical species, *Solanum tuberosum*, they come in thousands of varieties with great differences in size, shape, colour, texture, cooking characteristics and taste. Here's a small sample of potato diversity...

<table>
<thead>
<tr>
<th>No.</th>
<th>Variety</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Atahualpa</td>
<td>Bred in Peru, a high yielding variety good for both baking and frying</td>
</tr>
<tr>
<td>2.</td>
<td>Nicola</td>
<td>Widely grown Dutch variety, one of the best for boiling, also good in salads</td>
</tr>
<tr>
<td>3.</td>
<td>Russet Burbank</td>
<td>The classic American potato, excellent for baking and french fries</td>
</tr>
<tr>
<td>4.</td>
<td>Lapin puikula</td>
<td>Grown in Finland for centuries, in fields bathed in the light of the midnight sun</td>
</tr>
<tr>
<td>5.</td>
<td>Yukon Gold</td>
<td>A Canadian potato with buttery yellow flesh suitable for frying, boiling, mashing</td>
</tr>
<tr>
<td>6.</td>
<td>Tubira</td>
<td>CIP-bred variety grown in West Africa. White flesh, pink skin, and good yielding</td>
</tr>
<tr>
<td>7.</td>
<td>Vitelotte</td>
<td>A gourmet French variety prized for its deep blue skin and violet flesh</td>
</tr>
<tr>
<td>8.</td>
<td>Royal Jersey</td>
<td>From the Isle of Jersey: the only UK vegetable with an EU designation-of-origin</td>
</tr>
<tr>
<td>9.</td>
<td>Kipfler</td>
<td>Hails from Germany. Elongated with cream flesh, popular in salads</td>
</tr>
<tr>
<td>10.</td>
<td>Papa colorada</td>
<td>Brought to the Canary Islands by passing Spanish ships in 1567</td>
</tr>
<tr>
<td>11.</td>
<td>Maris Bard</td>
<td>Bred in the UK, a white variety with a soft waxy texture good for boiling</td>
</tr>
<tr>
<td>12.</td>
<td>DéSirée</td>
<td>Red-skinned, with yellow flesh and a distinctive flavour.</td>
</tr>
<tr>
<td>13.</td>
<td>Spunta</td>
<td>Another popular commercial tuber, good for boiling and roasting</td>
</tr>
<tr>
<td>14.</td>
<td>Mondial</td>
<td>A Dutch potato with smooth good looks. Boils and mashes well</td>
</tr>
<tr>
<td>15.</td>
<td>Unknown</td>
<td>From Chile, one of more than 5 000 native varieties still grown in the</td>
</tr>
</tbody>
</table>
Andes

Sources: CIP [1,6]; NIVAP, the Netherlands [2,13]; Canadian Food Inspection Agency [3,5,11,12,14]; Lapin Keittiömestarit [4]; FNPPPT/Gernod - France [7]; Wikipedia [8,10,15] Haalo [9]
Uses of potato

Once harvested, potatoes are used for a variety of purposes, and not only as a vegetable for cooking at home. In fact, it is likely that less than 50 percent of potatoes grown worldwide are consumed fresh. The rest are processed into potato food products and food ingredients, fed to cattle, pigs and chickens, processed into starch for industry, and re-used as seed tubers for growing the next season's potato crop.

Food uses: fresh, "frozen", dehydrated

FAO estimates that just over two-thirds of the 320 million tonnes of potatoes produced in 2005 were consumed by people as food, in one form or another. Home-grown or purchased in markets, fresh potatoes are baked, boiled or fried and used in a staggering range of recipes: mashed potatoes, potato pancakes, potato dumplings, twice-baked potatoes, potato soup, potato salad and potatoes au gratin, to name a few.

But global consumption of potato as food is shifting from fresh potatoes to added-value, processed food products. One of the main items in that category goes by the unappetizing name of frozen potatoes, but includes most of the french fries ("chips" in the UK) served in restaurants and fast food chains worldwide. The production process is fairly simple: peeled potatoes are shot through cutting blades, parboiled, air dried, par fried, frozen and packaged. The world's appetite for factory-made french fries has been put at more than 11 million tonnes a year.

Another processed product, the potato crisp ("chips" in the US), is the long-standing king of snack foods in many developed countries. Made from thin slices of deep-fried or baked potato, they come in a variety of flavours - from simple salted to "gourmet" varieties tasting of roast beef and Thai chili. Some crisps are produced using a dough made from dehydrated potato flakes.

Dehydrated potato flakes and granules are made by drying a mash of cooked potatoes to a moisture level of 5 to 8 percent. Flakes are used in retail mashed potato products, as ingredients in snacks, and even as food aid: potato flakes have been distributed as part of US international food assistance to more than 600,000 people. Another dehydrated product, potato flour, is ground from cooked, whole potatoes and retains a distinct potato taste. Gluten-free and rich in starch, potato flour is used by the food industry to bind meat mixtures and thicken gravies and soups.

Modern starch processing can retrieve as much as 96 per cent of the starch found in raw potatoes. A fine, tasteless powder with "excellent mouth-feel", potato starch provides higher viscosity than wheat and maize starches, and delivers a more tasty product. It is used as a thickener for sauces and stews, and as a binding agent in cake mixes, dough, biscuits and ice-cream.

Finally, in eastern Europe and Scandinavia, crushed potatoes are heated to convert their starch to fermentable sugars that are used in the distillation of alcoholic beverages such as vodka and akvavit.

Non-food uses: Glue, animal feed and fuel-grade ethanol

Potato starch is also widely used by the pharmaceutical, textile, wood and paper industries as an adhesive, binder,
The world potato sector is undergoing major changes. Until the early 1990s, most potatoes were grown and consumed in Europe, North America and countries of the former Soviet Union. Since then, there has been a dramatic increase in potato production and demand in Asia, Africa and Latin America, where output rose from less than 30 million tonnes in the early 1960s to almost 120 million tonnes by the mid-1990s. FAO data shows that in 2005, for the first time, the developing world's potato production - some 162 million tonnes - exceeded that of the developed world (156 million tonnes). China is now the biggest potato producer, and almost a third of all potatoes is harvested in China and India.

### Top potato producers, 2006

<table>
<thead>
<tr>
<th>Country</th>
<th>Quantity (t)</th>
<th>Kg per capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>70 338 000</td>
<td>835.6</td>
</tr>
<tr>
<td>Russian Fed.</td>
<td>38 572 640</td>
<td>415.1</td>
</tr>
<tr>
<td>India</td>
<td>23 910 000</td>
<td>414.8</td>
</tr>
<tr>
<td>USA</td>
<td>19 712 630</td>
<td>291.1</td>
</tr>
<tr>
<td>Ukraine</td>
<td>19 467 000</td>
<td>286.0</td>
</tr>
<tr>
<td>Germany</td>
<td>10 030 600</td>
<td>271.5</td>
</tr>
<tr>
<td>Poland</td>
<td>8 981 976</td>
<td>267.4</td>
</tr>
<tr>
<td>Belarus</td>
<td>8 329 412</td>
<td>261.2</td>
</tr>
<tr>
<td>Netherlands</td>
<td>6 500 000</td>
<td>259.0</td>
</tr>
<tr>
<td>Kyrgyzstan</td>
<td>6 354 333</td>
<td>219.4</td>
</tr>
</tbody>
</table>

Source: FAOSTAT
Asia and Europe are the world's major potato producing regions, accounting for more than 80 percent of world production in 2006. While harvests in Africa and Latin America were far smaller, production was at record levels. North America was the clear leader in yields, at more than 40 tonnes per hectare.

Asia consumes almost half of the world's potato supply, but its huge population means that consumption per person was a modest 25 kg in 2005. The heartiest potato eaters are Europeans. Per capita consumption is lowest, but increasing, in Africa and Latin America.
Potato arrived late in Africa, around the turn of the 20th century. In recent decades, production has been in continual expansion, rising from 2 million tonnes in 1960 to a record 16.5 million tonnes in 2006. Potatoes are grown under a wide range of conditions - from irrigated commercial farms in Egypt and South Africa to intensively cultivated tropical highland zones of Eastern and Central Africa, where it is mainly a small farmer's crop.

1. Egypt

The potato was introduced to Egypt during the 1800s, and large scale cultivation began during the First World War, when British colonial officials encouraged its production to feed their troops. After the war, however, expansion of potato growing was hampered by the poor quality of imported seed and by farmers' inexperience with the crop.

That has changed. Since 1961, Egypt's irrigated potato production - concentrated in the Nile River delta in the north - has expanded at a rate of more than 5 percent a year. Between 1990 and 2006, annual output rose from 1.6 million tonnes to some 2.5 million tonnes, making Egypt Africa's No. 1 potato producer.

Egypt also ranks among the world's top potato exporters - in 2004, exports totalled more than 380 000 tonnes of fresh potatoes and 18 000 tonnes of frozen potato products, destined mainly for markets in Europe.

2. Algeria

After Solanum tuberosum's introduction to Algeria, in the mid-1800s, potatoes were grown mainly for export to French markets. By national independence from France, in 1962, farmers were harvesting on average 250 000 tonnes a year, with about one third marked for export.

Since then, the potato has become an increasingly important crop for domestic consumption, with production in 2006 reaching a record 2.18 million tonnes. Potato is grown over an area of 100 000 ha, and can be planted and harvested somewhere in Algeria in virtually any month of the year.

The main fresh potato growing areas are along the Mediterranean coast, where a mild climate permits year-round production. Potatoes are also grown at elevations of 500 m in hills and valleys between the coast and the Atlas Mountains, and in high plateau areas. Annual potato consumption in Algeria has increased from 35 kg in 1990 to around 57 kg in 2005.
3. South Africa

Dutch seafarers heading for East Asia probably brought the potato to South Africa in the 1600s (it is thought sailors encouraged potato growing at ports of call so they could re-supply with fresh tubers during ocean voyages).

Today, South Africa produces more potatoes than any other country in the sub-Saharan region. Potato output has grown strongly over the past 15 years, from 1.2 million tonnes in 1990 to a record 1.9 million tonnes in 2005. In the same period, the potato farming area actually declined, from 63 000 ha to 53 000 ha. Most potatoes are grown on relatively large farms, increasingly under irrigation, with yields averaging around 30 tonnes per hectare.

South Africa boasts a sophisticated seed potato industry and - thanks largely to the country's rapid rate of urbanization - a vibrant potato processing sector, which utilizes some 250 000 tonnes of potatoes per year, mainly for frozen french fries and crisps. Annual potato consumption is around 30 kg per person.

4. Malawi

Potatoes came to East Africa in the 19th century, brought by missionaries and European colonialists. But the crop did not become important to Malawians until the 1960s, when production reached around 60 000 tonnes a year.

Now Malawi is sub-Saharan Africa's second biggest potato producer, with a 2006 harvest of 1.8 million tonnes, only slightly less than that of South Africa. The potato is grown mainly in highland areas in the country's southern and central regions, the most suitable areas being at altitudes of between 1 000 and 2 000 m and with more than 750 mm of annual rainfall. In parts of the southern region, farmers can grow two crops each year. Potatoes are often planted with maize and beans during the main October-March season.

Only a tiny proportion of Malawi's potatoes is exported. Annual consumption has more than tripled over the past 15 years to a high 88 kg per capita.

5. Morocco

The potato was probably well established in Morocco before the country became a French protectorate in 1910. Over the following century - and particularly since independence in 1956 - production has expanded strongly, rising from about 150 000 tonnes in 1961 to a record 1.56 million tonnes in 2006. In the same period, yields grew from 10 tonnes per ha to more than 26 tonnes.

By sheer weight, the potato is now Morocco's third biggest crop, after sugar beets and wheat, and second only to tomatoes among exported vegetables, with more than 40 000 tonnes shipped to Europe in 2005.

Except for a brief period during the May-July winter months, potatoes are grown year round. Production of fresh potatoes is concentrated along the Atlantic Coast north and south of Casablanca, where a modified Mediterranean climate provides very favourable growing conditions. Potatoes are also grown in high, rugged parts of the Atlas mountains, at elevations of more than 3 000 m. The average Moroccan consumes about 42 kg of potatoes a year.
6. Rwanda

The potato came with German soldiers and Belgian missionaries to Rwanda in the early 20th century. Today, ibirayi - derived from uburayi ("that which comes from Europe") - are the country's second most important crop after plantains and, in the sub-Saharan region, Rwanda is the third largest potato producer.

Since 1961, Rwanda's potato output has risen from less than 100 000 tonnes to a record 1.3 million tonnes in 2005. The harvest in 2006 was only slightly smaller. Potatoes grow well in several parts of country - mainly above elevations of 1 800 m - and some areas grow two crops a year. Most of potato sector consists of small family farms that intercrop potato with beans and maize, and yields average almost 10 tonnes per hectare.

The potato underpins Rwanda's food security. Annual consumption is a very high 124 kg per person, making potato the country's second most important source of calorie intake after cassava.

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7. Nigeria

In the potato world, Africa's most populous country, Nigeria, stands out: it is the fourth biggest producer of potato in sub-Saharan Africa, has almost as much land under potato as Germany, and potato output has grown sevenfold over the past decade, reaching 840 000 tonnes in 2006.

The main potato growing area is the Jos plateau, where altitudes ranging from 1 200 to 1 400 m and summer temperatures that rarely exceed 35 °C make for a temperate climate well suited to potato production. However, productivity is constrained by a lack of suitable varieties, and high land and labour costs. In fact, Nigeria records one of the world's lowest average potato yields, little more than 3.1 tonnes per hectare.

Potato consumption is also very low, at around 3.2 kg per capita per year. However, Nigeria's taste for potatoes, especially in rapidly growing urban areas, is increasing - since 2000, imports of raw and processed potatoes have risen from less than 9 000 tonnes to 40 000 tonnes a year.

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8. Kenya

Introduced to East Africa by British farmers in the 1880s, the potato has grown in importance - both as a staple food and as a source of farmer incomes - over the past 30 years. Measured by quantity harvested, it now ranks as the country's No. 2 food crop, after maize, with production in 2006 totalling around 780 000 tonnes.

The potato in Kenya is grown mainly by small scale farmers, many of them women, although some larger-scale growers specialize in commercial production. Cultivation is concentrated in highland areas of from 1 200 to 3 000 m above sea level.

Nearly all of Kenya's potatoes are consumed locally, at an average rate of almost 25 kg per capita a year. Kiazi is relished not only by the rural people who grow them, but by higher-income urban dwellers as well - while in some African countries potato is considered a "poor person's food", in Kenya it is considered a high quality and prestigious food item.

Sources: CIP World Potato Atlas; FAOSTAT; World Potato Congress; Potatoes South Africa
Asia and Oceania includes the world's potato giant, China, which accounts for more than 20 percent of both the global potato-growing area and the world potato harvest. Several other Asian countries - Bangladesh, India, the Islamic Republic of Iran, Japan and Turkey - also figure in the world's top 20 potato producing countries. The world's best yields are recorded in New Zealand - on average, more than 45 tonnes per hectare.

1. China

China is the world's biggest potato producer, with output in 2006 of 70.3 million tonnes (or more than 20 percent of the global harvest). It is also an increasingly important global supplier, with potato exports totalling some 440 000 tonnes (raw equivalent) in 2005.

The tuber probably reached coastal China aboard ships from Europe during the 17th century and was introduced to central China by Russian traders around the same time. Production has increased nearly fivefold since 1961. Although Chinese potato output ranks behind that of maize and sweet potato, more than 80 percent of the maize and 40 percent of the sweet potato are used as animal feed. Most of the potatoes go directly to human consumption - each year, the Chinese consume 30 kg per head.

The potato is important to China not only as a staple food, but also as a source of income, especially for farmers in mountainous areas with poor soils. In northern China's Inner Mongolia and Shanxi provinces, sales of potato account for more than half of rural household earnings.

2. India

The potato reached India in the late 16th and early 17th centuries, most likely aboard ships from Portugal. Today, India ranks as the world's third largest potato producing nation, with production in 2006 of around 24 million tonnes.

Between 1960 and 2000, potato production increased by almost 850 percent, partly in response to growing demand from higher-income urban populations. Since 1990, per capita consumption has risen from around 12 kg to 17 kg a year.

In India, the _aloo_ is not primarily a rural staple but a cash crop that provides significant income for farmers: the value of the 2005 harvest is estimated at $3.6 billion and exports totalled about 80 000 tonnes that year. Potato varieties suited to the country's climate - hot summers and short winters - are grown on the Indo-Gangetic plain during the short winter days from October to March, while some year-round production takes place in...
3. Islamic Republic of Iran

A British ambassador, Sir John Malcolm, is said to have introduced the potato to the royal court of Persia during the early 1800s. For a time, the tuber was known as "Malcolm's plum", but it's called the "earth apple" by today's Iranians.

Iran is the world's No. 13 potato producer and the third biggest in Asia, after China and India. Since 1961, production has increased more than 15 times over. In 2006, the country's farmers achieved an all-time record harvest of 4.6 million tonnes, with per hectare yields averaging more than 24 tonnes. The potato is one of Iran's leading agricultural exports, with shipments in 2005 totalling around 166 000 tonnes.

Potatoes are grown mostly under irrigation around the southern shore of the Caspian Sea, in the Zagros Mountains, and on the southern lowlands, alternated with wheat, vegetables, sugar beets and fallow in three- or four year rotations. Traditional varieties prized for their culinary qualities continue to be grown in the mountainous north.

4. Turkey

In some areas of Anatolia, local potato varieties are still called ruskartoe, commemorating the tuber's introduction from the Russian Caucasus in the early 1800s. Potato cultivation has been officially encouraged in Turkey since 1872, and today the country is the Middle East's biggest producer after Iran, with output in 2006 of almost 4.4 million tonnes.

Second only to tomatoes as a horticultural crop, the patates is grown on an estimated 154 000 ha of land across the country. The Anatolian central plateau - with its hot, dry summers and cold winters - is the most important producing region, accounting for nearly half of the national potato area, while intensive cultivation is conducted on the Aegean and Mediterranean coasts. Yields in 2006 were a high 28.5 tonnes per hectare.

Turkey's current production hovers at 1990 levels, and is well below the 2000 record harvest of 5.4 million tonnes. Annual per capita potato consumption is contracting, from 63 kg in 1990 to a less than 50kg in 2006.

5. Bangladesh

A British governor promoted potato cultivation in Bengal in the 1770s, and within a century it was a well established garden vegetable. However, large scale production was held back by the lack of suitable varieties: European cultivars were not adapted the hot Bengali plains.

Today, the potato has become a highly successful October-March winter crop in Bangladesh, with a production value - estimated at $560 million in 2005 - second only to that of paddy rice. In 2006, Bangladeshi farmers harvested more than 4.1 million tonnes of potatoes (12 times more than in 1961), which placed the country at No. 15 among the world's potato producers and No. 5 in Asia.

The potato is usually grown for cash sale, and much of national production is concentrated near the capital, Dhaka, the country's largest urban market. Annual consumption has been growing briskly, from around 7 kg per capita in 1990 to more than 24 kg in 2006.
6. Japan

The potato was probably brought to Japan by Dutch traders who established an enclave in Nagasaki early in the 17th century. But widespread cultivation of the tuber did not begin until late in the 19th century, when it proved well suited to the cool summers of the northern island of Hokkaido.

Today, Hokkaido's potato farmers produce yields of more than 41 tonnes per hectare and account for about two-thirds of the national harvest, which totalled some 2.6 million tonnes in 2006. While that placed the country at No. 6 among Asia's potato producers, it was also the smallest harvest recorded since the 1960s, when Japan was producing up to 4 million tonnes a year.

Along with the steady decline in production over recent decades, there has been a shift from home preparation to consumption of processed potato products such as chips and french fries. To meet domestic demand, Japan imports each year some 650 000 tonnes of potatoes, mainly from China.

7. Kazakhstan

At the break-up of the Soviet Union in 1991, Kazakhstan was producing annually around 2.5 million tonnes of potatoes from an area of 240 000 ha. In the turmoil of the following decade, there was a steady decline in the size of the potato growing area and in potato output, which dropped to 1.2 million tonnes in 1998.

Since then, production has rebounded, thanks largely to rapid gains in average per hectare yields, which rose from 7.6 tonnes in 1998 to more than 14 tonnes in 2006. In that year, Kazakh potato farmers harvested some 2.36 million tonnes of tubers from 160 000 ha of land.

Today, the potato is Kazakhstan's most important food crop after wheat, with average per capita consumption of a high 90 kg a year. While most potatoes are consumed fresh or used as fodder, recent years have seen strong growth in exports of processed potato products, which rose from 1 000 tonnes in 2000 to more than 15 000 tonnes in 2005.

8. Democratic People's Republic of Korea

The potato was introduced to the Korean peninsula - probably from China - during the early 1800s. It became a staple crop during the Japanese occupation from 1910 to 1945, replacing rice exported to Japan, and saved many farm families from starvation during the Second World War.

The potato remains an essential food security crop in the Democratic People's Republic of Korea. In 2006, it produced an estimated 2 million tonnes, placing the country among Asia's top 10 producers. The area under potato has grown from 36 000 ha to almost 200 000 ha since 1960, while potato output has increased fourfold over the past decade.

Farmers' average yields, however, have barely improved over 1960 levels, mainly owing to shortages of agricultural inputs and the lack of virus-free seed potato. To boost production, the government is promoting a "potato farming revolution" - innovations include a low-input potato-rice cropping system that produces, in a relatively short growing season, 11 tonnes of potatoes and rice.
9. Nepal

The first record of potatoes in Nepal dates back to 1793. Although it remained a relatively minor crop for the next 180 years, some researchers say that its early introduction to the high altitude Himalayas helped fuel the rise of Buddhist civilization in northern Nepal.

In the 1970s, a national potato development programme, focused on improving the quality of seed potato, stimulated a rapid expansion of both cultivated area and production, which increased from 300 000 tonnes in 1975 to a record 1.97 million tonnes in 2006. The potato is now Nepal’s second staple food crop, after rice, and per capita consumption has almost doubled since 1990 to 51 kg a year.

Potatoes are widely grown in Nepal, at below 100 m altitude in the south to as high as 4 000 m in the northern mountains. The tuber is particularly favoured by farmers in high hills areas (roughly 1 800 to 3 000 m): it is more productive than rice and maize and the cool climate is well suited to production of seed tubers for sale at lower altitudes.

10. Pakistan

Although potato was grown on the Indian subcontinent from the late 16th or early 17th centuries, at Pakistan’s foundation in 1947 cultivation was restricted to a few thousand hectares and total annual output was less than 30 000 tonnes.

In the decades since independence, the aalu has become the country’s fastest growing staple food crop. Thanks to strong gains in cultivated area and average yields - both made possible mainly by irrigation - output rose between 1995 and 2006 from one million to more than 1.5 million tonnes. The lion’s share of potato production comes from the Punjab, where spring and autumn crops account for 85 percent of the national harvest.

Apart from some subsistence growers in the north, most Pakistani farmers produce for urban markets rather than household consumption, and the potato has become a significant source of rural income (worth some $300 million in 2005). At present, annual intake is around 11 kg per capita.

11. Australia

Potatoes were aboard the ship of explorer James Cook when he claimed eastern Australia for Britain in 1770, and their cultivation began along with colonization eight years later. Today, "spuds" are grown across the continent, from the southern temperate state of Tasmania to tropical North Queensland.

Australian potato production exceeds one million tonnes a year. That makes potato tubers the country’s most important horticultural crop, accounting for more than 40 percent of total vegetable production. More than 60 percent is processed into frozen potato products and crisps, while around 37 percent is fresh marketed.

Competition from foods such as pasta and rice has made recent inroads into the fresh potato market, and FAO estimates that between 1995 and 2005 annual per capita consumption of potatoes slipped from 55 kg to 53 kg.

25. New Zealand

Decades before British colonization began in about 1800, the first potato tubers
Decades before British colonization began in the mid-1800s, explorers had introduced potato to New Zealand's Maori people. The new crop, dubbed *taewa*, proved well adapted to the cool New Zealand climate, and today red- and blue-skinned "Māori potatoes" are recognized local varieties.

In 2006, New Zealand produced around half a million tonnes of potatoes from an area of just 11 000 ha, with average yields of a very high 45 tonnes. Commercial yields exceeding 70 tonnes are not uncommon. The potato is the country's most popular vegetable - fresh market potatoes are harvested all year round and per capita consumption is estimated at about 66 kg a year.

The past decade has seen strong growth in the processing sector (300 000 tonnes were processed into french fries and crisps in 2006) and in fresh and frozen potato exports, which totalled more than 90 000 tonnes. The retail and export value of New Zealand's potatoes is put at some US$ 300 million a year.

Sources: CIP World Potato Atlas; FAOSTAT; World Potato Congress; AusVeg; Horticulture New Zealand
Potato and biodiversity

The history of the potato provides a grim warning of the need to maintain genetic diversity in our staple food crops. In the 19th century, Ireland was heavily reliant on only a few varieties of potato, and those types contained no resistance to the devastating disease known as late blight. When late blight destroyed the 1845-1846 potato crop, widespread famine followed. An estimated one million people starved to death and more than a million were forced to migrate abroad.

To combat pests and diseases, increase yields, and sustain production on marginal lands, today's potato-based agricultural systems need a continuous supply of new varieties. That requires access to the entire potato gene pool. But potato biodiversity is under threat: ancient varieties cultivated by Andean peoples for millennia have been lost to diseases, climate change and social upheaval.

Species and crop-associated diversity

While most varieties of potatoes belong to a single species, *Solanum tuberosum*, about 10 other *Solanum* species have been cultivated, and 200 wild species have been recorded. Climate change may threaten the survival of those wild relatives: it is forecast that as many as 12 percent will become extinct as their growing conditions deteriorate. If climate changes drastically, the area where wild potatoes grow naturally could be reduced by as much as 70 percent.

Since potatoes mostly propagate vegetatively, most commercial varieties of potato have a reduced ability to flower and breeders do not select for traits that make the flower attractive to pollinators. However, natural potato pollination remains important to sustaining the diversity of local, farmer-developed varieties.

With CIP support, Andean communities have created a "potato park" holding some 1,200 traditional varieties of potato.

Key points

- Potato farming systems need a continuous supply of new varieties drawn from the entire potato gene pool.
- Potato biodiversity is under threat – ancient varieties cultivated for millennia have been lost and wild species are threatened by climate changes.
- Smallholder farming systems in the Andes encourage cross-pollination of potato flowers, vital to sustaining the diversity of local, farmer-developed varieties.

Centre of origin

In the Andean region, generations of farmers have domesticated thousands of potato varieties. Even today, farmers cultivate up to 50 varieties on their farms. In the biodiversity reserve of the Chiloé archipelago in Chile, local people cultivate about 200 varieties of native potato. They use farming practices transmitted orally by generations of mainly women farmers.

International Treaty

The potato is included in the multilateral system established under FAO's International Treaty on Plant Genetic Resources for Food and Agriculture. The Treaty, which entered into force in 2004, aims at the conservation and sustainable use of crop plant diversity and the fair and equitable sharing of benefits derived from their use.
Conserving potato biodiversity in the Andes

Having lost many of their traditional potato varieties, Peruvian farmers in the Andes are now taking measures to conserve and sustainably use those that remain. A pact has been signed by six Quechua communities with the International Potato Center that recognizes the rights of the communities over potato strains they have developed.

Under the agreement, the Center’s genebank returns potato genetic resources – and knowledge associated with them – to the communities, which have established a “potato park” (Parque de la papa) in a conservation area where they grow and manage the plants. This repatriation of biological diversity effectively keeps control of genetic resources local. The 15 000 ha park is a “living library” of potato genetic diversity, holding some 1 200 varieties of potato cultivated in the highlands. A long-term goal is to re-establish all the world’s 4 000 known potato varieties in the valley, allowing the park to function as a second centre of origin for this vital staple crop.

Diversity conserved in trust

The International Potato Centre in Peru maintains the world’s largest bank of potato germplasm, including some 1 500 samples of about 100 wild species collected in eight Latin American countries, and 3 800 traditional Andean cultivated potatoes. The collection is maintained and managed under the terms of an agreement with the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture and, like all collections eligible for funding from the Global Crop Diversity Trust, is available to plant breeders worldwide upon request.

Credits:
Information provided by the Global Crop Diversity Trust and the Plant Production and Protection Division, FAO.

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www.potato2008.org

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Since the beginning of Andean agriculture, seeds have been associated with reproduction and femininity. The Incas believed the moon conferred fertility on women and moved Pachamama (Mother Earth) to germinate and offer up her potatoes (known as Mama Acxo) at harvest time. Men deposited the seeds and women received them, to harbour and nurse.

In the Andes today, and in many other parts of the developing world, potato growing is still highly labour-intensive. Rural women provide most of the labour in both small- and large-scale potato production – from conservation and seed selection to planting, harvesting, storing and marketing.

China: Increasing gender awareness
In China, most potatoes are grown in mountain areas of Inner Mongolia and Shaanxi provinces, both as a staple food and as a cash crop. Research in Wuchuan County, Inner Mongolia, shows how the labour-intensive nature of potato production, coupled with strong gender inequalities, can pose a threat to the sustainability of local livelihoods.

Says Zhang Ailian, a woman farmer: “Potato growing is very tiring, especially at harvest time, and the burden of household tasks is already very heavy. The Agriculture and Animal Husbandry Bureau provides technical training in potato production, but heads of the village usually tell men to attend. Women make up fewer than 10 percent of total participants.”

A project in Wuchuan is working to ease the burden of potato production on women by supplementing agricultural training with gender-sensitive materials. The project uses participatory approaches such as “farmer field schools”, and brings gender issues into potato development policies. It advocates a more equitable division of labour and financial decision making powers for women, and facilitates their access to extension services and training.

Peru: Women as conservationists
In the high-altitude Peruvian Andes, the genetic diversity found in hundreds of native potato varieties guarantees rural communities’ food security. Over centuries, Andean farmers and the descendants of ayllu family groups, primarily women, have selected countless varieties of potato to preserve and enhance plant diversity, allowing them to cultivate in different agro-ecological zones and cope with pests, diseases and climatic changes. The “bitter potato”, for example, is the result of crossing with frost-resistant varieties adapted to the freezing temperatures of the Puna agro-ecological zone.

Male migration to urban centres has left women farmers responsible for almost 70 percent of family farm work. In the Chetilla community in Cajamarca, the...
tasks of seed selection and storage are exclusively women’s. Their participation in seed fairs is invaluable in preserving Andean potato biodiversity. Surveys have found that women attending fairs are able to identify up to 56 different varieties. However, the heavy burden placed on women in potato production highlights the need for a more equitable division of labour to ensure the conservation of agro-biodiversity.

Uganda: Enabling rural innovation

Potatoes have become an important staple and cash crop in sub-Saharan Africa’s highland zones, and Uganda is a major potato producer in the region. Virtually all households in southwestern Uganda grow potatoes, harvesting over 60 percent of the national crop. Most tubers are grown in highland areas of Kabale and Kisoro as a staple food and as the main source of income.

“Enabling rural innovation” is a gender-sensitive strategy being used in various development programmes. The idea is to empower both men and women farmers and rural communities to develop market opportunities. In Kabale, for example, farmer field school training covered integrated potato pest and disease management. It also helped the Nyabyumba United Farmers group to establish an enterprise that now supplies potatoes for french fries at fast-food restaurants in Kampala.

Gender roles in agriculture

FAO’s Gender Plan of Action underscores the need for rural and agricultural development policies that acknowledge the roles of both men and women in achieving food security. The Plan aims at promoting gender equality in access to food, in the control over and management of natural resources and agricultural support services, in policy- and decision-making processes at all levels in the agricultural and rural sector, and in opportunities for on- and off-farm rural employment.
Potato production in developed countries, especially in Europe and the Commonwealth of Independent States, has declined on average by one percent per annum over the past 20 years. However, output in developing countries has expanded at an average rate of five percent per year. Asian countries, particularly China and India, fuelled this growth.

In 2005, the developing countries’ share of global potato output stood at 52 percent, surpassing that of the developed world. This is a remarkable achievement, considering that just 20 years ago the developing countries’ share in global production was little more than 20 percent. Even so, world potato production and consumption are currently expanding more slowly than the global population.

Fresh potato consumption, once the mainstay of world potato utilization, is decreasing in many countries, especially in developed regions. Currently, more potatoes are processed to meet rising demand from the fast food, snack and convenience food industries. The major drivers behind this development include growing urban populations, rising incomes, the diversification of diets and lifestyles that leave less time for preparing the fresh product for consumption.

Potatoes are commonly regarded as a bulky, perishable commodity with high transport costs and limited export potential, confined mostly to cross-border transactions. These constraints have not hampered the international potato trade, which has doubled in volume and risen almost fourfold in value since the mid-1980s. This growth is due to unprecedented international demand for processed products, particularly frozen and dehydrated potato products. To date, developing countries have not been beneficiaries of this trade expansion. As a group, they have emerged as leading net importers of the commodity.

International trade in potatoes and potato products still remains thin relative to production, as only around 6 percent of output is traded. High transport costs, including the cost of refrigeration, are major obstacles to a wider international marketplace.

Trade policies
Ad valorem import tariffs are used to protect domestic potato markets. Other

China and India now account for 30 percent of world potato output

World potato production 1990-2006

Developed countries
Developing countries

In 2006, the world produced some 315 million tonnes of potatoes. Photo: © FAO
policies that restrict access to markets include sanitary and phytosanitary measures and technical barriers to trade. Import tariffs on potatoes and potato products are applied by most countries. The binding rates agreed under the aegis of the World Trade Organization vary considerably. Potato provides a classic example of “tariff escalation”, where importing countries protect processing industries by levying higher duties on processed products than on raw material. By preventing countries from diversifying their export base into higher-value processed products, tariff escalation can therefore keep them “trapped” as providers of raw material.

Countries wishing to supply potato commodities to the international market – especially to the more lucrative developed country markets – also face considerable hurdles in the form of food health standards and technical regulations. The Doha Development Round of trade negotiations recognizes the negative impacts of tariff escalation and contains important provisions aimed at ensuring that standards and regulations do not become de facto barriers to trade or hidden protectionist policies, while at the same time putting public health concerns foremost. Unfortunately, negotiations pertaining to the Doha agenda have suffered a series of setbacks, and agreement on a final solution has yet to materialize.

### Summary of WTO Bound Tariffs

<table>
<thead>
<tr>
<th>Product</th>
<th>Trade Weighted Average</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh potatoes (inc. seed)</td>
<td>29</td>
<td>378</td>
</tr>
<tr>
<td>Frozen potatoes</td>
<td>16</td>
<td>414</td>
</tr>
<tr>
<td>Potato flour*</td>
<td>38</td>
<td>446</td>
</tr>
<tr>
<td>Potato starch</td>
<td>109</td>
<td>550</td>
</tr>
</tbody>
</table>

* includes flour, meal, flakes, granules and pellets

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**Credits:**

Information provided by the Trade and Markets Division, FAO.
New molecular biology and plant cell culture tools have enabled scientists to understand better how potato plants reproduce, grow and yield their tubers, how they interact with pests and diseases, and how they cope with environmental stresses. Those advances have unlocked new opportunities for the potato industry by boosting potato yields, improving the tuber’s nutritional value, and opening the way to a variety of non-food uses of potato starch, such as the production of plastic polymers.

**Key points**

The potato industry has benefited from major recent discoveries about the plant’s genetics, physiology and pathology.

Micropropagation is helping developing countries produce low-cost, disease-free tuber “seed” and increase potato yields.

Use of molecular markers helps identify desirable traits in potato collections, thus simplifying the development of improved varieties.

Sequencing of the complete potato genome, now under way, will significantly increase knowledge and understanding of genetic interactions and functional traits.

Genetically modified varieties have the potential to produce more stable yields, improve nutritional quality and facilitate non-food industrial uses, but must be carefully assessed before release.

Producing high-quality propagation material

Unlike other major field crops, potatoes are vegetatively reproduced as clones, ensuring stable, “true-to-type” propagation. However, tubers taken from diseased plants also transmit the disease to their progenies. To avoid that, potato tuber “seed” needs to be produced under strict disease control conditions, which adds to the cost of propagation material and therefore limits its availability to farmers in developing countries.

Micropropagation or propagation in vitro offers a low-cost solution to the problem of pathogens in seed potato. Plantlets can be multiplied an unlimited number of times, by cutting them into single-node pieces and cultivating the cuttings. The plantlets can either be induced to produce small tubers directly within containers or transplanted to the field, where they grow and yield low-cost, disease-free tuber “seed”. This technique is very popular and routinely used commercially in a number of developing and transition countries. For example, in Viet Nam micropropagation directly managed by farmers contributed to the doubling of potato yields in a few years.

Protecting and exploring potato diversity

The potato has the richest genetic diversity of any cultivated plant. Potato genetic resources in the South American Andes include wild relatives, native cultivated species, local farmer-developed varieties, and hybrids of cultivated and wild plants. They contain a wealth of valuable traits, such as resistance to pests and diseases, nutrition value, taste and adaptation to extreme climatic conditions. Continuous efforts are being made to collect, characterize and conserve them in gene banks, and some of their traits have been transferred to commercial potato lines through cross-breeding.

To protect collections of potato varieties and wild and cultivated relatives from possible diseases and pest outbreaks, scientists use a variation of micropropagation techniques to maintain potato samples in vitro, under sterile conditions. Accessions are intensively studied using molecular markers, the identifiable DNA sequences found at specific chromosomal locations on the genome and transmitted by the standard laws of inheritance.

Obtaining improved varieties

Potato genetics and inheritance are complex, and developing improved

* Source: FAO-BiDeC database on biotechnologies in developing countries www.fao.org/biotech/inventory_admin/dep/default.asp
varieties through conventional cross breeding is difficult and time consuming. Molecular-marker based screening and other molecular techniques are now widely used to enhance and expand the traditional approaches to potato in food production. Molecular markers for characteristics of interest help identify desired traits and simplify the selection of improved varieties. Such techniques are currently applied in a number of developing and transition countries, and commercial varieties are expected to be released within the next few years.

Through the Potato Genome Sequencing Consortium, significant progress is being made in mapping the complete DNA sequence of the potato genome, which will enhance our knowledge of the plant’s genes and proteins, and of their functional traits. Technical advances in the fields of structural and functional potato genomics – and the ability to integrate genes of interest into the potato genome – have expanded the possibility of genetic transformation of the potato using recombinant DNA technologies. Transgenic varieties with resistance to Colorado Potato Beetle and viral diseases were released for commercial production in the early 1990s in Canada and the USA, and more commercial releases can be expected in the future.

Transgenic potato varieties offer the possibility of increasing potato productivity and production, as well as creating new opportunities for non-food industrial use. However, all biosafety and food safety aspects must be carefully assessed and addressed before their release.

**Glossary**

- **cell culture** – *in vitro* growth of cells isolated from multi-cellular organisms;
- **functional genomics** – research aimed at determining patterns of gene expression and interaction in the genome;
- **genome** – the entire complement of genetic material present in each cell of an organism;
- **genome sequencing** – process of determining the exact order of chemical building blocks that make up the DNA of an organism;
- **genetically modified** – transformed by the insertion of one or more transgenes;
- **in vitro** – in an artificial environment (e.g. cells, tissues or organs cultured in glass or plastic containers);
- **micropropagation** – miniaturized *in vitro* multiplication or regeneration of plant material under aseptic and controlled environmental conditions;
- **molecular biology** – study of living processes at molecular level;
- **molecular marker** – a genetic marker that is assayed at the DNA level;
- **trait** – one of the many characteristics that define an organism;
- **transgene** – an isolated gene sequence – often derived from a different species – used to transform an organism.

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**Credits:**

Information provided by the Research and Extension Division and the Plant Production and Protection Division, FAO.
The use of chemical pesticides on potato is increasing in developing countries, as farmers intensify production and expand cultivation into areas and planting seasons beyond the crop’s traditional range. The chemicals used are frequently highly toxic and applied with little or no protective equipment.

The result is alarming levels of pesticide poisoning in farming communities. Insecticide absorbed by soil often penetrates subsequent crops and runs off to contaminate water supplies. Overuse of pesticides even compounds pest and disease problems: in Colombia, outbreaks of a viral disease have been linked to insecticides that wiped out natural predators of the disease’s vector.

Increasing potato production while protecting producers, consumers and the environment requires a holistic crop protection approach encompassing a range of strategies – encouraging natural pest predators, breeding varieties with pest/disease resistance, planting certified seed potatoes, growing tubers in rotation with other crops, and organic composting to improve soil quality.

There is no effective chemical control, for example, against bacterial wilt. But planting healthy seed in clean soil, using

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**Key points**

Intensive potato cultivation tends to increase pest and disease pressure, which often leads to intensive use of harmful pesticides.

Resistant potato varieties and improved cultural practices can reduce or eliminate many common pests and diseases.

Integrated pest management has helped farmers drastically reduce the need for chemical controls while increasing production.

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**Some of potato’s main enemies**

**Diseases**

- **Late blight:** the most serious potato disease worldwide, is caused by a water mould, *Phytophthora infestans*, that destroys leaves, stems and tubers.
- **Bacterial wilt:** caused by the bacterial pathogen, leads to severe losses in tropical, subtropical and temperate regions.
- **Potato blackleg:** a bacterial infection, causes tubers to rot in the ground and in storage.
- **Viruses:** disseminated in tubers, can cut yields by 50 percent.

**Pests**

- **Colorado potato beetle** (*Leptinotarsa decemlineata)*: a serious pest with strong resistance to insecticides.
- **Potato tuber moth**: most commonly *Phthorimaea operculella*, is the most damaging pest of planted and stored potatoes in warm, dry areas.
- **Leafminer fly** (*Liriomyza huidobrensis)*: A South American native common in areas where insecticides are used intensively.
- **Cyst nematodes** (*Globodera pallida* and *G. rostochiensis*): serious soil pests in temperate regions, the Andes and other highland areas.
tolerant varieties in rotation with non-susceptible crops, and other sanitation and cultivation practices can lead to significant reduction of the disease. Incidence of potato tuber moth can also be reduced by preventing soil cracking that allows moths to reach the tubers.

Both the International Potato Center (CIP) and FAO advocate Integrated Pest Management (IPM) as the preferred pest control strategy during production. IPM aims at maintaining pest populations at acceptable levels and keeping pesticides and other interventions to levels that are economically justified and safe for human health and the environment.

FAO has promoted IPM in many developing countries using Farmer Field Schools, which centre around a “living laboratory” where farmers are trained to identify insects and diseases and compare results on two subplots – one using conventional chemical pest control and the other using IPM. On the improved management plot, participants strive to improve ecosystem health by cutting pesticide use while increasing productivity through management intensification. Farmers experiment with a variety of techniques, such as weevil traps, different strains of potatoes and targeted applications of lower toxicity pesticides.

In Peru’s Cañete River valley, CIP entomologists designed an IPM package to help growers protect their crops against the leafminer fly, which had become a major problem after massive use of insecticides exterminated its natural enemies. The IPM programme included traps to lure and kill adult flies and reintroduction to the valley of parasitic wasps. Participating growers were able to reduce spraying from 12 times per season to only one or two carefully timed applications of insect growth regulators.

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Credits:
Information provided by the International Potato Center and FAO
Potatoes, nutrition and diet

Potatoes can be important staple foods, but balanced diets need to include other vegetables and whole grain foods

Key Points

The potato is a good source of dietary energy and some micronutrients, and its protein content is very high in comparison with other roots and tubers.

Potato is low in fat – but preparing and serving potatoes with high fat ingredients raises the caloric value of the dish.

Boiling potatoes in their skins prevents loss of nutrients.

Potatoes are important in many diets, but need to be balanced with other vegetables and whole grain foods.

Further research is needed to determine the link between potato consumption and Type 2 diabetes.

Nutrient content of potatoes

Water 77 grams

Energy 87 kcal

Thiamin 0.106 milligrams

Riboflavin 0.02 milligrams

Vitamin C 13.0 milligrams

Niacin 1.44 milligrams

Potassium 379 milligrams

Iron 0.31 milligrams

Calcium 5 milligrams

Phosphorus 44 milligrams

Protein 1.87 grams

Carbohydrate 20.13 grams

Fat 0.1 grams

Fibre 1.8 grams

(Per 100 g, after boiling in skin and peeling before consumption)

Source: United States Department of Agriculture, National Nutrient Database

Potatoes is a versatile, carbohydrate-rich food highly popular worldwide and prepared and served in a variety of ways. Freshly harvested, it contains about 80 percent water and 20 percent dry matter. About 60 to 80 percent of the dry matter is starch. On a dry weight basis, the protein content of potato is similar to that of cereals and is very high in comparison with other roots and tubers. In addition, the potato is low in fat.

Potatoes are rich in several micronutrients, especially vitamin C – eaten with its skin, a single medium-sized potato of 150 g provides nearly half the daily adult requirement (100 mg). The potato is a moderate source of iron, and its high vitamin C content promotes iron absorption. It is a good source of vitamins B1, B3 and B6 and minerals such as potassium, phosphorus and magnesium, and contains folate, pantothenic acid and riboflavin. Potatoes also contain dietary antioxidants, which may play a part in preventing diseases related to ageing, and dietary fibre, which benefits health.

Effects of potato preparation methods

The nutritive value of a meal containing potato depends on other components served with them and on the method of preparation. By itself, potato is not fattening (and the feeling of satiety that comes from eating potato can actually help people to control their weight). However, preparing and serving potatoes with high-fat ingredients raises the caloric value of the dish.

Since the starch in raw potato cannot be digested by humans, they are prepared for consumption by boiling (with or without the skin), baking or frying. Each preparation method affects potato composition in a different way, but all reduce fibre and protein content, due to leaching into cooking water and oil, destruction by heat treatment or chemical changes such as oxidation.

Boiling – the most common method of potato preparation worldwide – causes a significant loss of vitamin C, especially in peeled potatoes. For french fries and chips, frying for a short time in hot oil (140 ºC to 180 ºC) results in high absorption of fat and significantly reduces mineral and ascorbic acid content. In general, baking causes slightly higher losses of vitamin C than boiling, due to the higher oven temperatures, but losses of other vitamins and minerals during baking are lower.

Potato’s role in the developing world’s “nutrition transition”

In many developing countries, and especially in urban areas, rising levels of income are driving a “nutrition transition” toward more energy-dense foods and prepared food products. As part of that transition, demand for potato is increasing. In South Africa, potato consumption has been growing in urban areas, while in rural areas maize is still the staple. In China, higher income and increased urbanization have led
to increased demand for processed potatoes. Thus, the potato already plays a role in diet diversification in many countries. However, where other staple crops are available to meet energy requirements, potato should not replace them but rather supplement the diet with its vitamins and mineral content and high quality protein. Potatoes can be important staple foods, but balanced diets need to include other vegetables and whole grain foods.

As part of the trend toward greater consumption of “convenience foods”, demand for fried potatoes is increasing. Over-consumption of these high-energy products, along with reduced physical activity, can lead to overweight. Therefore the role of fried potato products in the diet must be taken into consideration in efforts to prevent overweight and diet related non-communicable diseases, including heart disease and diabetes. Type 2 diabetes is caused by many factors, and further research is needed to determine whether potato consumption and Type 2 diabetes may be linked.

Toxic components of potato

As part of the potato plant’s natural defences against fungi and insects, its leaves, stems and sprouts contain high levels of toxic compounds called glycoalkaloids (usually solanine and chaconine). Glycoalkaloids are normally found at low levels in the tuber, and occur in the greatest concentrations just beneath the skin.

Potatoes should be stored in a dark, cool place in order to keep glycoalkaloid content low. Under exposure to light, potatoes turn green in colour due to increased levels of chlorophyll, which can also indicate higher levels of solanine and chaconine. Since glycoalkaloids are not destroyed by cooking, cutting away green areas and peeling potatoes before cooking ensures healthy eating.

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