



Impact of the Potato on Society

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Abstract The first impact of the potato on society was the intimate relationship between the domestication of the potato and the evolution of Andean civilization which affected Andean culture and religion. In addition to food potatoes were used for several non-food purposes. In the Inca Empire the freeze-dried chuño was collected as taxes from the peasants and disbursed from imperial storehouses to labor gangs for building roads, waging war, and erecting monuments. After the Spanish conquest chuño was used to feed the slaves in the Andean silver and gold mines. This in turn set the stage for flooding the Spanish and eventually the global market with these precious metals and subsequent world-wide inflation of consumer goods. The potato became the major contributor to the European population explosion of 1750–1850 which in turn resulted in increased urbanization and contributed to the underpinning of the Industrial Revolution in England in the nineteenth century. By feeding rapidly growing populations the potato permitted a small number of nations in northern Europe to assert dominion over much of the world between 1750 and 1950. The failure of the potato crop in Ireland in the 1840s led Britain to repeal the protectionist Corn Laws and set the country on a path of free trade. At least one million Irish refugees emigrated, mostly to North America where they left a great legacy. The past 50 years have seen a major global shift in potato production towards many developing countries in Asia, including China and India. Throughout its history the

potato has provided bread for the poor. Today it contributes to food security on a global scale. The potato's depiction on postage stamps demonstrates the esteem in which it is held worldwide and the many references to the potato in art, literature and folklore worldwide are evidence how it has become interwoven in the cultures of many societies today.

Resumen El primer impacto de la papa en la sociedad fue la relación íntima entre su domesticación y la evolución de la civilización Andina, la cual afectó la cultura y la religión de los Andes. Además de como alimento, las papas se usaron para varios propósitos no alimentarios. En el Imperio Inca, el chuño deshidratado-congelado se colectaba como impuesto a los campesinos y se desembolsaba de los almacenes imperiales a grupos de trabajo para la construcción de caminos, tributos de guerra y para la erección de monumentos. Después de la conquista española, el chuño se usó para alimentar a los esclavos en las minas andinas de plata y oro. Esto a su vez estableció el escenario para inundar a los españoles y eventualmente al mercado global con estos metales preciosos y la inflación mundial subsecuente de bienes de consumo. La papa se volvió en la mayor contribuyente para la explosión demográfica europea de 1750–1850, que a su vez resultó en aumento en la urbanización y contribuyó a sustentar la revolución industrial en Inglaterra en el siglo 19. Mediante la alimentación de poblaciones en rápido crecimiento, la papa permitió a un pequeño número de naciones en el norte de Europa afirmarse el dominio sobre una gran parte del mundo entre 1750 y 1950. El fracaso del cultivo de la papa en Irlanda en los 1840's condujo a la Gran Bretaña a derogar las leyes proteccionistas del maíz y ubicó al país en una ruta del libre mercado. Por lo menos un millón de refugiados irlandeses emigró, principalmente a Norteamérica en donde dejaron un gran legado. Los últimos 50 años han visto un giro global

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mayúsculo en la producción de papa en muchos países en desarrollo en Asia, incluyendo China y la India. A través de su historia la papa ha suministrado pan para el pobre. Hoy contribuye a la seguridad alimentaria a escala global. La papa plasmada en estampillas postales demuestra la estimación en la que se encuentra a nivel mundial, y la multitud de referencias de la papa en el arte, literatura y folklor mundialmente son evidencias de como se ha asimilado en las culturas de muchas sociedades hoy.

Keywords Domestication · Chuño · History · Food security · Population explosion · Bread for the poor · Consumption pattern

Introduction

The potato has had a profound impact on society and vice versa. Today, as the world's third largest food crop (after wheat and rice) it has a major role to play in feeding the world (Smith 2011). One of the reasons for its worldwide popularity is that potatoes can be grown under a wide range of environments. Another reason is that it has a high nutritional value (Woolfe 1987) and produces more nutritious food more quickly, on less land, and in harsher climates than any other major crop (FAO 2008b).

The well-known quote from Jean-Henri Fabre (1823–1915) about the origin of wheat is equally applicable to potatoes: *History celebrates the battlefields whereon we meet our death, but scorns to speak of the plowed fields whereby we thrive; it knows the names of kings' bastards but cannot tell us the origin of wheat. This is the way of human folly.* Nevertheless, as result of the painstaking work of scientists and historians we are slowly able to get a better picture about the origin and history of the potato.

Towards the end of the last Ice Age plant gatherers, hunters and fishermen were already inhabiting the western coast of South America. In Monte Verde in Southcentral Chile people probably consumed (wild) potatoes as early as 13,000 years ago (Ugent et al. 1987). These species likely grew in the (then) humid coastal plains of South America. As the glaciers retreated from the Altiplano the prototypes of the cultivated potato may have been introduced to the highlands of what are now Peru and Bolivia (Ugent and Peterson 1988).

Domestication

Archeological and genetic evidence indicates that the domestication of the potato probably took place about 8000 years ago in the vicinity of Lake Titicaca, located on the border of present day Peru and Bolivia (Morales Garzón 2007). The raised fields (Fig 1) in the Lake Titicaca basin where potatoes

were cultivated in pre-Colombian times still exist today and have been proposed as a world heritage site (Erickson 2003). Today the Andean region is recognized as one of the most important centers of crop origins and diversity in the world. In addition to the potato at least 15 other species of root and tuber crops as well as several grains, legumes and fruits were also domesticated in the same general area (Flores et al. 2003; Wust 2001).

For many crop plants there is a debate whether there has been a single origin (after which it would have diffused over a wider area) or if there were several origins at different locations and times. This is also the case in potatoes (Jacobs and van den Berg 2008). Multiple origins of the cultivated potato have been proposed by several authors and others have hypothesized that primitive indigenous cultivated potatoes (landraces) have a single origin. There is general agreement that *S. stenotomum* was the first domesticated species. This is a diploid ($2n = 2 \times = 24$) species and in turn is considered to be the parent of several other cultivated potato species, including *S. tuberosum* subsp. *andigena*.

Selection for non-bitterness (low glycoalkaloid content) probably preceded the cultivation of *S. stenotomum*. When this happened is not known, but the general historical-archeological context suggests the period 5000–2000 BC, concurrently with the domestication of the llama (Simmonds 1995). Many wild potato species contain glycoalkaloids which confer resistance to insects and diseases. While useful to the plant, glycoalkaloids also have a serious drawback in that they impart a bitter taste and, at high enough levels, are toxic to humans. A major step in the domestication of wild potato species was discovering ways to circumvent glycoalkaloids. One of these methods was to eat bitter potatoes with a quantity of clay that was specifically collected for this purpose. This clay apparently contains elements that bind to the glycoalkaloids, thus neutralizing them. Some Aymará people around Lake Titicaca are still practicing this method (Reader 2008). The production of chuño (see below) also resulted in a reduction in glycoalkaloid content.



Fig. 1 Raised fields on shore of Lake Titicaca near Puno. Source: Francisco J. Morales, CIAT, Colombia

The Potato in Andean Societies

As is the case with domestication of other crops (and animals), the domestication of the potato involved unforeseen consequences in two ways (a) changes in the potato and (b) changes in human society (Diamond 2002). The domestication of the potato gradually resulted in greater food production which in turn stimulated population growth, development of cities, technology, crafts, arts, sciences, and political centralization. There were several relatively small societies in the Andean region, such as Nazca (100 BC - 800 AD), Moche (0–600 AD), Chimú (900 AD –1470 AD) and finally Inca who consolidated much of this area. Much of the evidence for the cultivation of the potato in several Andean societies is based on pottery of pre-Inca cultures (Hawkes 1990; Salaman 1985). Tiwanaku (near Lake Titicaca), which reached its peak between 500 AD – 1000 AD, was the first state to be based largely on the cultivation of potatoes (Reader 2008). The Inca Empire arose in the twelfth century in the highlands of current Peru. There are only broad-ranging estimates of the population, most of which are in the 6–14 million range (Dunnell 2012) for which the potato served as a major food. The empire eventually stretched for 4000 km from Ecuador in the north to just south of current Santiago (Chile) in the south. The Incas adopted and improved upon the agricultural advances of previous highland civilizations (FAO 2008a).

There was a very intimate relationship between the domestication of the potato and the evolution of Andean civilization; the potato played a central role in the myths and rituals that define the Andean vision of the world (Glave 2001; Millones 2001). Ceremonies sometimes involved pouring the blood of a llama over seed potatoes before planting. Potatoes with a blood-red flesh were used in fertility ceremonies. Tubers with pigmented flesh were a source of dye in the dyeing of textile fabrics (Antúnez de Mayolo 1989). Freeze-dried potatoes (*chuño*) as well as funeral vases in the form of potatoes were sometimes placed in tombs along with the bodies of the departed (Safford 1925b; Salaman 1985). Among the many deities of the Incas at least two were dedicated to the potato. One of these was adopted as the well-known logo of the International Potato Center. Fig 2 is *Axomama*, the “mother of the potato.” She is one of the daughters of *Pachamama*, “mother earth.” There is an old Andean custom where some recently harvested food is offered to *Pachamama*. Potatoes were reburied among hot stones so *Pachamama* could eat before the farm workers. This practice gave rise to the method of cooking food by roasting it underground in the *pachamanca*, the traditional festive way of cooking in the ground (Fig 3). The prominence of the *pachamanca* is another reflection of the important role that the potato has played in the development of the Andean worldview (Glave 2001).

The close relationship between potatoes and people in the Andean societies is also demonstrated in the many descriptive

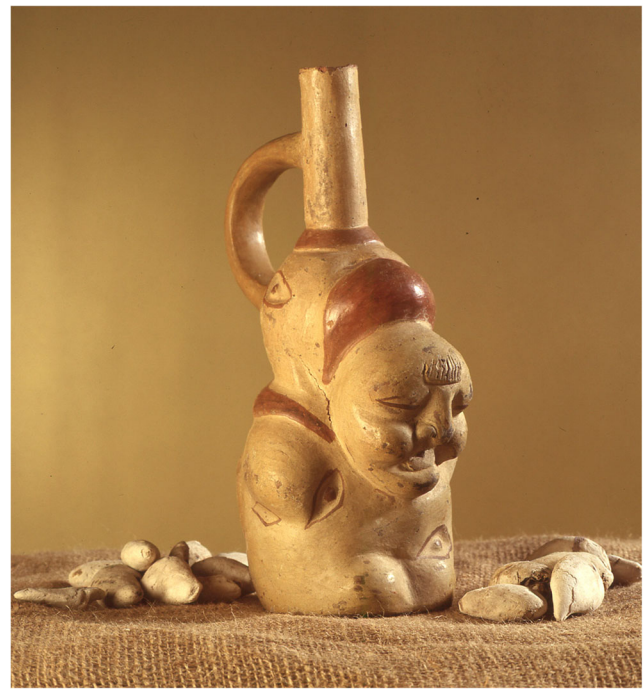


Fig. 2 Axomama, Inca potato goddess. 200 A.D. Source: Das Kartoffelmuseum, Munich, Germany

and colorful names. The most ancient names for potato come from the Aymará and Quechua languages. Aymará is spoken primarily around Lake Titicaca; Quechua was the official language of the Inca Empire. The first taxonomy of the potato was developed by the Aymará (La Barre 1947). The most



Fig. 3 Preparation for pachamanca. © International Potato Center

common word for potato in South America is the Quechua word *papa*. Originally used in the Inca Empire, this word was later adopted by the Spanish Conquerors who spread it further throughout South America and also took it to Europe. Cultivar names in both Aymará and Quechua usually consist of a noun and a qualifying adjective. In addition to color, shape and taste, these names may also invoke gender, animal and human body parts, tools, utilization and other concepts. Examples include the Quechua *Katari Papa* which means *Snake Potato*, the shape resembles a snake. A rather amusing name is the Quechua *Cachan huacachi* which means *Potato which makes the daughter-in-law cry*. It is apparently so named because it has very deep eyes that makes it difficult to peel (Hawkes 1947).

Chuño

A major form of food security in the Andean societies was the development of chuño, a freeze-dried product which is at least 2000 years old. It caught the attention of early Spanish writers (De Cieza De León 1553; De Acosta 1590). The procedure utilizes the occurrence of nighttime freezing temperatures in June and July in the Andean region. Tubers are exposed to freezing temperatures for three or four nights. They thaw out during the day and are then trampled by foot to remove the moisture and allowed to dry in the sun. There are two types of chuño: chuño blanco (white) and chuño negro (black), see Fig 4. In the preparation of chuño blanco the tuber skins are also removed and the tubers are washed in a stream. The chuño processing methods remove most of the glycoalkaloids. This is an important feature because it facilitates the consumption of bitter potatoes that, because of their frost resistance, can be grown at high altitudes.

Chuño can be stored for a year or longer (Woolfe 1987). It occupied a very important place in the Andean societies and made human life in the Andes above 3800 m possible. It was collected as taxes from the peasants and disbursed from imperial storehouses to labor gangs for building roads, waging

war, erecting monuments and sustain all the other aspects of imperial civilized society in the Altiplano. It was transported by llama convoys to lower valleys and coastal towns and used by populations from higher altitudes to barter for products from lower elevations. After the Spanish conquest chuño was used to feed the slaves in the infamous silver mines of Potosí (McNeill 1999; Salaman 1985). The large amounts of silver and gold which the Spanish took to Europe resulted in inflated prices for consumer goods, known as the *Price Revolution* first in Spain and then across Europe and elsewhere for about 150 years from 1501 to 1650 (Hamilton 1934; Weatherford 1988). McNeill (1999) summarized the direct impact of chuño on the Inca Empire and the indirect impact on the world at large: *In the high Andes, chuño, in effect, provided the principal fuel of empire, since human muscles did most of the work, and chuño was the indispensable food for labor gangs. Without it, nothing resembling Andean civilization could have arisen... And chuño was what allowed a freset of silver from the Spanish Empire in the Americas to upset prices and traditional human relationships and expectations among all the civilized peoples of the Old World. This then is how the cultivation of potatoes changed the world's history for the first time, initially on a merely American scale, then quite literally worldwide.*

Introduction and Early History in Europe

The first record of the potato being grown in Europe is from the Canary Islands where they were being grown in 1567 and exported to Antwerp (Hawkes and Francisco-Ortega 1993). There are two hypotheses about the origin of the European potato which have been reviewed by Ríos et al. (2007). One is that the first potatoes taken to Europe were *S. tuberosum* subsp. *andigena*. These potatoes would have originated in the Andes, and might have been shipped from present day Colombia. The second hypothesis is that the first potatoes taken to Europe came from southern Chile, where the day length during the growing season is comparable to southern Europe. There is evidence that there were multiple introductions of both Andean and Chilean germplasm to the Canary Islands and that the Chilean introductions (which were introduced into Europe before the late blight epidemics in the 1840's) were better adapted and quickly became the dominant germplasm sources for early European varieties (Ames and Spooner 2008; Ríos et al. 2007).

The first record on the continent is from 1573 when potatoes were recorded on a list of purchases by a Carmelite hospital in Seville, Spain (Hawkes and Francisco-Ortega 1992). In 1584 the Carmelite order founded a monastery in Genova, Italy and they brought the potato to Italy (Biadene 1996; Gentilcore 2012; Oliemans 1988). For a couple of centuries the potato was primarily grown in botanical gardens and



Fig. 4 Chuño negro and chuño blanco at La Paz market. Source: Fremen Tours, La Paz, Bolivia

described in several herbals. The name *Solanum tuberosum* (“swollen underground stem”) was first applied by the Swiss botanist Gaspard Bauhin (1596) in his eminent *Phytopinax*. Unfortunately the English herbalist Gerard (1597) made several errors in his *Herball or historie of plantes*. He stated that the potato had come from Virginia and called it *Battata virginiana* (which he referred to as *Potatoes of Virginia*) where he thought it was growing naturally. He apparently confused potatoes with openauks which were growing in Virginia. Gerard’s naming of sweet potatoes as *Batata hispanorum* (which he called *Potatus* or *Potatoes*) created further confusion. This in turn may have led to the legend that the potato was introduced into Europe by Sir Walter Raleigh who supposedly had obtained it from his colony that he called *Virginia* (now North Carolina). This is incorrect because Raleigh never visited there (Safford 1925a; Salaman 1985). A similar legend that the potato was introduced into England from Virginia by Sir Francis Drake has also been refuted (Hawkes 1990; Safford 1925a; Salaman 1985).

The central figure in the scientific world of the day was Carolus Clusius (Roze 1890), who in his monumental *Rariorum plantarum historia* provided a botanical description and two woodcut illustrations (Clusius 1601). In 1601 Clusius wondered why the knowledge of the potato had come so late to him. He first heard of it, whilst at Vienna in early 1588 when he received two tubers from Philip de Sivry, Prefect of the city of Mons, Belgium. De Sivry had received the tubers from a friend of the Papal Legate in Belgium, who had brought them from Italy under the name of *Taratouffli*. Clusius wondered why he had not heard of the potato before because by this time it was so common and frequent in certain parts of Italy where the tubers were boiled with mutton and eaten like turnips and carrots, and even fed to swine. It was also surprising to him that the potato was unknown at the prestigious university of Padua. However, Gentilcore (2012) found evidence that by 1601 the botanic garden in Padua had had potatoes in its collection for at least ten years! Clusius (1601) tried the potato himself. He peeled and boiled them and considered them equal in taste to turnips but when raw he thought they were excessively rough and flatulent. It was usually reported if a plant caused flatulence because that was considered to encourage lust (Salaman 1985).

Obstacles in Adaptation and Acceptance as a Food Crop

The potato eventually disseminated in Western Europe; by the middle of the eighteenth century it had reached the Scandinavian countries (Brown 1993). There were several reasons for the slow acceptance of the potato as a food crop in Europe.

- a. Lack of awareness of the impact of the crop on Inca society on the part of European chroniclers

When the Spanish conquered the Inca Empire they considered the natives backward and destroyed much of their intricate agricultural system. Native crops such as the potato initially received little attention from the Spanish who sought to replace them by European crops such as wheat and barley, a form of “botanical colonialism” (Davidson 1992; National Research Council Panel on Lost Crops of the Incas 1990). The first European to report on the potato was probably De Castellanos (1886). He was a member of the infamous expedition led by Gonzalo Jiménez de Quesada into current Colombia. In early 1537 the expedition entered the Andean village of Sorocotá. The natives had already fled but De Castellanos’ report mentions that the houses were furnished with various foods including what he called *turmas* (truffles). From his subsequent description it is certain that De Castellanos was referring to potatoes. This report was not published until 1886. Another early report was by the Spanish author Pedro De Cieza De León (1553), who travelled extensively through the former Inca Empire. He described in detail the customs and beliefs of the Indians as well as the fertility of the land and the riches of the silver mines of Potosí but, like De Castellanos, only paid scant attention to agriculture in general or to the potato (Reader 2008).

Felipe Guamán Poma de Ayala (also written as Felipe Huamán Poma de Ayala), a native Andean, wrote from a very different perspective than the above mentioned European chroniclers. He described in great detail life in Peru under the Spanish rule. Included in his *Nueva Corónica y Buen Gobierno* are descriptions of injustices committed by the Spanish rulers on the Indians as well as the various agricultural activities by the Incas in each month of the year. For the month of December he described the planting of potatoes and for June he depicted the potato harvest (Fig 5). He probably prepared this document between 1567 and 1615 and sent it to the king of Spain (Philip III). Apparently the king never received it; somehow it ended up in the Royal Library of Denmark where it was discovered in 1908 (Brown 1999; Dilke 1978; Guamán Poma de Ayala).

Another reason for the paucity of information in Europe about the role of the potato in Andean agriculture was the rivalry between England and Spain. Virtually all reports about the New World were considered military secrets. As a result free dissemination of the diets, clothing and technology of the people of South America did not occur for several more centuries (Brown and Henfling 2014).

- b. Superstitions and diet cults

The potato was, at various times, considered to be poisonous and suspected of causing various diseases. This was, at



Fig. 5 Potato harvest by Incas. Original drawing by F. Guamán Poma de Ayala. © International Potato Center

least in part, due to the widespread *Doctrine of Signatures*, which held that God marked objects with a sign, or signature, for their purpose. For example, since walnuts resemble brains, they were prescribed as a cure for problems with the brain. But in the case of the potato this doctrine seems to have been invoked to claim the reverse. Potatoes were at one time thought to cause leprosy, presumably because the rough and irregular shape of the tubers in those days reminded people of the deformed hands and feet of leprosy patients. Since the fruits of the potato plant resemble the fruits of the poisonous nightshades, it was speculated that the tubers of the potato plant must also be poisonous. Others frowned upon the potato because it was not mentioned in the Bible (Reader 2008; Salaman 1985). Today various misconceptions are still being propagated especially in Western Europe and North America in “low-carbohydrate diets” where the potato is often maligned and considered “fattening” (Fitzgerald 2014).

c. Three-field crop rotation system

There were also agricultural obstacles standing in the way of widespread potato cultivation. One of these was the three-year crop rotation system that was practiced over much of Europe. This system had been introduced by the Romans and lasted until about the end of the eighteenth century. The basic pattern was in the first year to plant winter cereal such as wheat or rye, in the second spring to plant oats or beans and to fallow the land in year three. One advantage of this system

was that, if the first winter cereal crop failed, possibly as result of unfavorable winter weather conditions, then another spring crop could still be planted the following spring. The one year of fallow gave the land rest and a chance to recuperate. In many countries, the village land was divided into three parts with each farmer having a share in each of the three parcels. This meant that an individual farmer was unable to change the crop rotation of his allotment even if he wanted to. Since potatoes did not fit into this system, they could not be cultivated widely until the crop rotation system itself was eventually changed. That occurred when the farming system switched from allowing the cattle to graze on community pastures to keeping them in stables or barns. The resulting production of manure at the stable was then available to fertilize the crop land. The manuring eliminated, at least in part, the need for a year of fallow and thus allowed for the insertion of potatoes and other crops in the rotation system (Reader 2008).

Religion, Politics, War, and Trickery

The potato appeared on the European scene shortly after the beginning of the Reformation. Thus it is no surprise that it got caught up in several of those turbulent events. This has been described in detail in a Dutch book of which the translated title is: *The bread of the poor. The history of the potato amidst heretics, monks and church princes* (Oliemans 1988). This author suggests that the areas in Italy which Clusius (1601) reported to be producing potatoes were the valleys in the Piedmont region of northern Italy where the religious group known as *Waldensians* had already been farming since shortly after the Reformation. This group was founded in France in the Middle Ages and was severely persecuted because they displeased the Roman Catholic Church authorities. Oliemans (1988) contended that, especially in the period 1590–1620, there was a “disconnect” between the scientists (herbalists) and the practical farmers (such as the Waldensians and others) and that it was the farmers rather than the scientists who appreciated the potential of the potato as a food crop and disseminated it to various parts of Europe.

In France some progressive Protestant citizens (*Huguenots*) had developed several technologies in industry and agriculture including the cultivation of the potato. The Huguenots were protected by the Edict of Nantes which was issued in 1598, a major milestone in granting Protestant groups tolerance in a predominantly Roman Catholic country. However, under the slogan *one king, one law, one faith* the Edict of Nantes was eventually revoked in 1685 and the subsequent persecution of the Huguenots and other Protestant groups resulted in a mass emigration of some of the best French industrialists, farmers and their agricultural know-how to the Netherlands, Germany and several other countries (Poole 1880). The tolerant countries they moved to benefited at the expense of France. It

would take another century and the promotional efforts of Parmentier (see below), before the potato was again recognized for its value in France (Oliemans 1988).

Eventually the potato received help from several governments of the day. In Prussia in 1744 Frederick the Great ordered his subjects to grow and eat potatoes (Laufer 1938; Wollner 1970). It was during the Seven Years War (1756–1763), also known as *Kartoffelkrieg* (“Potato War”) which pitted Prussia against France that the advantages of potato became more apparent. Unlike cereal crops that could be burned or trampled by marauding armies, the potato crop remained in the ground to be harvested after the armies had left (Salaman 1985). Thus the spread of potatoes to European gardens and fields radically changed the destructive consequences of warfare (McNeill 1999).

The value of the potato was not lost on the French pharmacist Antoine-Augustin Parmentier who had been a prisoner of war in Prussia for several years during the Seven Years War. Parmentier credited the potato for his survival and upon his return to France in 1763 used every opportunity to promote the potato. He wrote several articles and tracts, including a prize-winning essay in which he extolled the virtues of the potato that, in times of need, could be substituted for the more usual foods, such as grains. He expanded this essay in his *Examen chymique des pommes de terre* (Parmentier 1773). In the turbulent years leading up to the French revolution, he was an influential figure at the court of Louis XVI and Marie Antoinette. Potatoes were on the royal menu. Parmentier also obtained the King’s permission to plant a field on the edge of Paris with potatoes. As harvest time approached, he shrewdly had the field guarded by soldiers during the day. This predictably raised the profile of this crop in the minds of the local population. The curiosity created during the day led to the intended thievery at night when the guards were withdrawn (Reader 2008).

The Potato and Europe’s Population Growth 1750–1850

Between 1750 and 1850 the European population grew from 140 million to 266 million. This increase was in large measure the result of a substantial increase in food supply due primarily to two new American crops: maize in southern Europe and potato in the north (Langer 1975). By this time the potato had moved from the botanical gardens to farmer’s fields in the vast northern European plain which extended from France through Belgium, the Netherlands, Germany, Denmark, Poland and into Russia. In France it was Parmentier who had taken the lead in promoting the potato; in Germany it was Frederick the Great and in Russia Catherine the Great had undertaken steps to popularize the potato.

At the same time the changeover from the three-field crop rotation system to include potatoes meant a great increase in food production. Prior to 1750 there had been many famines in Europe. In France alone there had been 40 nationwide famines between 1500 and 1800, more than one per decade. In addition there were hundreds of local famines. Other countries in Europe experienced similar situations. Unsurprisingly epidemics naturally broke out in populations which had been weakened by famine (Braudel 1817). Mann (2011) calculated that in Europe the elimination of the three-field crop rotation system (which meant that one third of the land was left fallow) along with the diffusion of the potato resulted, in terms of calories, in a doubling of the food supply. Adam Smith (1776) correctly predicted that if the potato should ever become popular in Europe like rice in some other countries the same quantity of land would be able to maintain a much greater number of people and populations would increase.

In addition to providing more calories, the potato also provided another unexpected advantage. Prior to the use of the potato as a major food crop, grains were the major source of calories. Grains were often contaminated with several fungal toxins (such as ergot in rye) which were difficult to remove, especially after they were milled into flour or baked into bread. A greater reliance on potatoes meant less dependence on grain and thereby reduced exposure to fungal toxins (Nolte and Taylor 1991).

Yet it often still took some trickery before the potato was accepted as a staple food. Sir Benjamin Thompson, Count Rumford (Rumford 1796) after tricking the poor in a workhouse in Munich, Bavaria to, unbeknownst to them, eating potatoes reported: *the Poor soon found that their soup was improved in its qualities; and they testified their approbation of the change that had been made in it so generally and loudly, that it was at last thought to be no longer necessary to conceal from them the secret of its composition, and they are now grown so fond of potatoes that they would not easily be satisfied without them.*

Vandenbroeke (1971) in summarizing the European situation at the end of the eighteenth century noted that: *It can therefore be stated emphatically that the diffusion of the potato-growing meant that, for the first time in the history of Western Europe, a definitive solution had been found to the food problem.* Furthermore, the diffusion of the potato was not only responsible for a significant portion of the increase in population but also resulted in an increase in urbanization during the 18th and 19th centuries (Nunn and Qian 2009). In this way the potato contributed to economic development by underpinning the Industrial Revolution in England in the nineteenth century. The potato provided cheap and plentiful food for the laborers and thus enabled industrialists to keep wages down and produce goods at prices low enough to capture the vast foreign markets on which the entire enterprise depended (Reader 2008). McNeill (1999) argued that the

potato in northern Europe, by feeding rapidly growing populations, permitted a handful of European nations to assert dominion over most of the world between 1750 and 1950. Weatherford (1988) mused that: *It is difficult to imagine what Ireland would be today without the potato. What would the Russians, the Germans, the Poles and the Scandinavians eat? Without the potato the Soviet Union might never have come to become a world power, Germany would not have fought two world wars, and northern Europe and the Benelux countries would not have one of the world's highest standards of living.*

The Potato in Ireland

It was in Ireland where the potato was most rapidly adapted. This was due to both favorable climatic as well as socio-economic conditions. Absentee landowners, many of whom lived in England, owned much of the best Irish agricultural land. With the decisions about what to grow in Ireland being made in England, Ireland was in effect an agricultural colony of England (Hobhouse 1987). The primary crop grown in Ireland was grain much of which was exported (Bourke 1993). After its introduction into Ireland the potato quickly became the main food for the large Irish families who only had a very small amount of land from which to extract a living. The potato became so interwoven with the lives of the Irish that around the world it became known as the *Irish potato*. In no other European country did the potato have a greater impact on the national cuisine than in Ireland where the diet, especially among the poor, changed completely after the introduction of the potato (Linnane 2000). The population of Ireland increased even more rapidly than that on the continent. Here it nearly tripled from about 3 million in 1750 to over 8 million in 1841 (Reader 2008; Langer 1975; Salaman 1985; Zuckerman 1998).

The dependence of the Irish population on the potato had become so great that when the late blight disease attacked the crop for several successive years in the 1840s, the result was the catastrophic Irish Potato Famine – *An Gorta Mór* – The Great Hunger (Bourke 1993; Woodham-Smith 1962). At the time British economic policy was dominated by a *laissez-faire* philosophy which in turn delayed relief efforts. The famine resulted in the death of more than one million from starvation and associated diseases such as cholera and typhus. The tragedy of the famine led to the repeal of Britain's Corn Laws which restricted imports of grain in order to protect the (powerful) domestic grain producers. The need to import grain to relieve the disastrous situation in Ireland forced the British government, after much debate and political upheaval, to remove these laws and eventually to embrace free trade. The Duke of Wellington summed up the cause of the turnaround in Britain's trade policy: *Rotten potatoes have done it all* (Anonymous 2008; Salaman 1985).

The impact of the famine was felt far beyond Ireland. At least a million Irish refugees emigrated, mostly to North America where they have left a great legacy (Hobhouse 1987). The American rail system was built on the backs of large populations of ethnic groups including the Irish (Baldwin 2014). Today Irish descendants are one of North America's biggest ethnic groups and Saint Patrick's Day is widely celebrated in the USA and Canada. Famous people who trace their ancestry to the potato famine include President John F. Kennedy (Taha 2012).

The famine monument in Dublin (Fig 6) is one of many memorials around the world that commemorate An Gorta Mór and the brave Irish people. The famine also had a major impact on science. The debate among scientists about the cause of this plant disease led to the birth of modern plant pathology (Carefoot and Sprott 1967; Large 1940).

Gaining a Foothold in North America and Back to Europe

In 1685, William Penn, describing Pennsylvania for potential immigrants, included potatoes in a long list of crops that did well there. In 1719, a group of Scottish Presbyterian immigrants from Northern Ireland settled in Londonderry, New Hampshire, and among the goods they brought with them was the potato. This event is often credited with the introduction of the potato to North America but it appears from the above that they may not have been the first. George Washington planted potatoes in 1767 and Jefferson used it as a vegetable at Monticello in 1772 and listed them in his farm journal for 1794 (Wilson 1959; Zuckerman 1998). When in 1755 Britain expelled the Acadians from what are now the Canadian Maritime Provinces several Acadian refugees returned to France where they introduced the potato to their new settlements in Bretagne (Sulte 1893), well before Parmentier popularized it in that country.

Elbert Carman, editor of the *Rural New Yorker*, promoted the growing of the potato by holding contests (Carman 1891). In 1837 Henry Spalding was the first to grow potatoes in Idaho. After a poor first crop things improved the following year; eventually Idaho became the "Potato State." Several factors contributed to the success of the potato in Idaho including: (a) soon after the industrious Mormon pioneers had settled in the Salt Lake Valley in Utah their search for more land brought them to Idaho, (b) the discovery of gold in Idaho in 1860 and the subsequent influx of gold diggers was a boon to local potato producers, (c) as early as 1875 the Mormons were shipping potatoes (labelled as "Brigham's Potatoes") to California thus establishing very early a reputation for high quality potatoes, and (d) the suitability of the 'Burbank' (and subsequently 'Russet Burbank') cultivar to the Idaho growing environment (Davis 1992). On the West coast potatoes have



Fig. 6 Memorial to the Irish Potato Famine in Dublin. Source: Debbie and Hamish Jones (<http://www.traveljournals.net/pictures/229880.html>). Accessed Feb. 27, 2014

been grown for more than two centuries by the Makah nation in northwest Washington where they were probably introduced by Spanish explorers who brought them north from Mexico (Brown and Henfling 2014).

Potato Mania

In the decades following the famine there was a flurry of activity in finding new cultivars in Europe and North America which would be resistant to late blight. As new cultivars came to the market, there were unrealistic expectations that they would deliver great results to the farming community. This in turn drove up the price of seed potatoes of new cultivars to the point that in the USA by 1868/69 one new cultivar ('King of the Earlies') fetched fifty dollars per tuber. Henry Ward Beecher, who described this potato mania, mused that: *Prospectors, with pick and pan, may do very well in the Rocky Mountains, but the true way to dig for gold in New York State, is to let your potatoes do it for you* (Beecher 1870). A similar situation developed in Great Britain where, during the "potato boom" of 1902–1903, some of Findlay's new varieties such as 'Eldorado', were sold at prices up to £160 per pound or even their weight in gold (Salaman 1985; Wilson 1993).

However, not all potato breeders became wealthy. Rev. Chauncey Goodrich, whom Beecher called *the pioneer and patriarch of the New Kingdom of Potatoes* died a pauper. He was completely devoted to finding a cure for the late blight disease and spared no effort or expense towards this end. One of his seedlings, 'Garnet Chili', features prominently in the

pedigrees of most North American and many European cultivars. For example, 'Early Rose', an offspring from 'Garnet Chili,' is the female parent of 'Russet Burbank' (Plaisted and Plaisted and Hoopes 1989).

War and Potato Processing

In the history of mankind wars have often driven technological developments which were subsequently used in peacetimes. This includes potato processing, beginning with the development of chuño by the ancient Andean societies. More recently dried potatoes were used as ships' provisions and military rations in the Franco-German wars, the Napoleonic Wars, in the Crimea, and in the Civil War in the U.S. Both world wars generated widespread development of potato dehydration (Willard 1993). At the beginning of World War II scientists at Oregon State University developed "Victory Potatoes," a product made from shredded dehydrated compressed potatoes (Fig 7).

During World War I American soldiers stationed in Europe discovered a new potato treat being sold on the street corners of Belgium. They called this new product "french fries" because the Belgians preparing the product spoke French. Since then french fries have become the largest worldwide outlet for potatoes: retail and institutional frozen fried products. (Willard 1993).

Global Shift in Potato Production

The past 50 years have seen major changes in potato production on a global scale. The world potato production rose from an average of 264 million tons in 1961–1963 to 369 million tons in 2011–2013. Much of this increase has occurred in China, India and other Asian countries (Scott and Suarez 2012a). In China the annual potato production rose from an average of 13 million tons in 1961–1963 to 88 million tons in 2011–2013. During the same periods the potato production in India rose from about 3 to 43 million tons while the combined production of Germany and Poland dropped from about 29 % of the world's total production to about 5 % whereas the combined production of China and India rose from about 6 % of the world's total to about 35 % (FAOSTAT 2013).

There are several factors which have a bearing on this massive global shift. In general the per capita consumption of potatoes in Western Europe and North America has been relatively high. Rising incomes and other factors in these regions have resulted in changes in consumption patterns (see below) and in a reduction in per capita potato consumption. This in turn has resulted in a stagnation or decline in potato production in Western Europe and North America (Scott 2002). The fundamental driving force behind the growth in potato

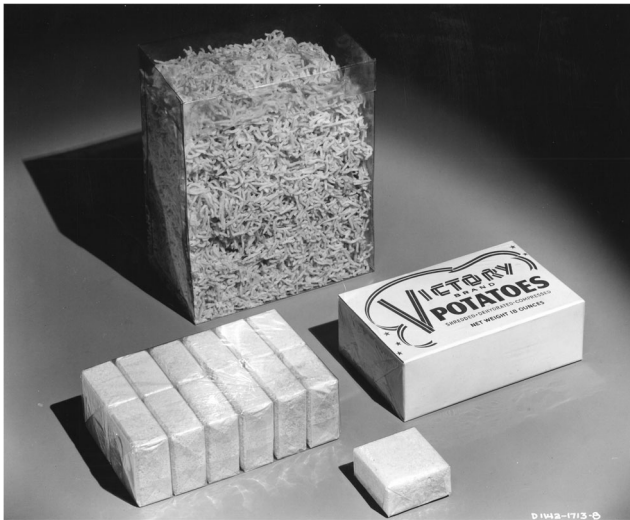


Fig. 7 Shredded dehydrated potatoes, ca. 1940. Source: Food Science and Technology Department Photographic Collection (P 142:389), Special Collections & Archives Research Center, Oregon State University Libraries

production in many developing countries in Asia, including China and India, has been the shift in consumption patterns away from cereal-based diets and less preferred vegetables toward other food commodities such as dairy products, fruit, and other vegetables including potatoes (Scott and Suarez 2012b). This is further facilitated by the role which their respective governments have taken. In the centrally planned economy of China this development resulted from changes in policies on land possession and incentives to production (Ezeta 2009). In the case of India there has been a synergy between government (including expanding irrigation infrastructure and public-sector supported agricultural research) and private sector investment such as large cold storage facilities (Walker et al. 1999).

The Potato and Changing Lifestyles and Consumption Patterns

During the course of its history society has impacted on the ways potatoes are being consumed. The preparation and use of chuño by Andean societies was described above. For much of the rest of the world the potato has primarily been consumed fresh as a staple food which was prepared domestically. This pattern is gradually changing, especially in developed countries where increasingly 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 income, the diversification of diets and lifestyles as well as an increased number of women in the labor force that leaves less time for preparing fresh product for consumption (FAO 2008c; Guenther 2010).

Especially in North America but also in Western Europe these changes have resulted in an erosion of the traditional family meal, the cornerstone of family life. The decline of the family dinner has the potential to lead to a less nutritious diet among older children and adolescents (Gillman et al. 2000). The shift towards consuming more potatoes in a processed form in turn has an impact on the cultivars being grown. For example in Canada the rise and fall of several major cultivars can, to a large extent, be attributed to market demand; cultivars which are suitable for processing into french fries and chips are replacing those which are not (Veilleux and De Jong 2007).

In Asia the strong trend toward urbanization in has resulted in a “westernization” of diets such as a rising popularity of temperate zone food products, convenience food and beverages (Pingali 2004) and an increased consumption of processed potatoes, especially chips (Ezeta 2009). In China potato processing has traditionally focused on starch and noodle production; $\geq 20\%$ of the potato crop is used for the production of starch and other products. However, as a result of urbanization and rising incomes there is an increasing demand for processed products common in western societies such as french fries and other frozen products, chips, and dehydrated potatoes (Jansky et al. 2009).

In India the potato’s role in the diet is most commonly that of a complementary vegetable. An exception is that in the major potato growing region at the peak of harvest potatoes can become a “seasonal staple” for the very poor and/or migrant laborers (Scott and Suarez 2011). The current demand for processing potatoes in India is about 8 % of the national crop. As elsewhere, this demand is driven by urban areas with relatively higher incomes than rural areas (Rana et al. 2010).

Impact of the Potato on Global Food Security

Throughout its history, time and again, the potato has provided bread for the poor. It continues in this role today on a global scale. After the collapse of the former Soviet Union in the 1990s the potato was a key factor in subsistence throughout the “post-socialist” countries by growing them in home gardens and is still embedded in the historical memory of the people (Ries 2009). In 2011 six of the top ten per capita potato consuming countries were former soviet republics (Helgi Library 2015).

Its nutritional quality, adaptability to different climates and cultivation methods makes the potato uniquely suitable for this purpose (DeFauw et al. 2012; Devaux 2014; Devaux et al. 2014; FAO 2008b; Niederhauser 1993). Today the potato is grown in environments that differ vastly with regard to latitude, altitude, day length and temperature from the Andean highlands where it was first domesticated (Hijmans 2001). The potato contributes in two different ways to the

livelihoods of the poor. In some areas it is a staple grown and eaten by the poor where it contributes directly to hunger reduction. Elsewhere the potato is a high value crop which contributes principally to poverty reduction by increasing income or creating employment (Thiele et al. 2010).

Great efforts are currently being made in using the potato as a source of food security in China (Baroke 2015; Frederick and Lei 2015; Qu and Xie 2008), India (Singh and Rana 2013), Bangladesh (Azimuddin et al. 2009) as well as on a global scale by the International Potato Center (Devaux 2014; Devaux et al. 2014). In Bangladesh during the period of 1993–2013 the area planted to potatoes nearly quadrupled and the per capita consumption increased five-fold from 9.7 to 46.4 kg/capita per year. In the Democratic People's Republic of Korea, after the 1990s famine, a potato revolution has taken place. During the period of 1993–2013 the area of potato cultivation in the DPRK has more than quadrupled to 144,000 ha; the per capita consumption has also more than quadrupled from 11.5 to 49.0 kg. per year (FAOSTAT 2013).

A gradual increase in potato production combined with modern technology in developing countries can not only improve food security and nutrition but also enhance rural incomes and reduce poverty (Scott 2002; Scott and Suarez 2012b; Sullivan 2010). The genomics era is accelerating our understanding of the key genes and mechanisms underlying potato development, physiology, water and nutrient use efficiency and resistance to biotic and abiotic stresses. Genomics technologies provide the potential for more rapid, marker-assisted breeding strategies, and afford the opportunity for biotechnological approaches, particularly in the case of major gene resistance to pests and diseases. Continued review of GM policies and regulations, and associated social and political opinions, are needed to guide and determine the safest and most productive routes to potato improvement (Birch et al. 2012).

Impact of the Colorado Potato Beetle

The Colorado potato beetle had a major impact in many countries (Alyokhin 2009). It was first discovered in 1811 in the Rocky Mountains where it was feeding on buffalo-bur. Its appetite for potatoes was not known until 1859 when it started devouring potatoes in the state of Nebraska, planted there by early settlers. It then started its march eastwards, often hitchhiking along the newly built railroads. On average, it moved about 130 km per year. By 1874 it had reached the east coast of the USA. In 1870, it crossed the Detroit River into Canada and by 1883, it had reached Prince Edward Island. Several insecticides were evaluated in the 1860s and 1870s. Eventually a dusting of Paris Green (a copper-arsenic compound) was found to be effective (Riley 1877). This was

in essence the first large-scale use of an insecticide on an agricultural crop. In the 1870s the adult beetle had such a high profile in American society that for a few years black and yellow-striped evening gowns were fashionable (Potato Museum n.d.).

During or immediately after World War I the beetle became established around American military bases near Bordeaux, France. By World War II it had spread across much of Europe. During WWII, both the Allies and the Germans considered dropping Colorado potato beetles on each other's potato fields. The German government claimed that American planes were dropping "Yankee beetles" over German potato fields and set up the "Potato Beetle Defense Service." After the war, the East German government, under Soviet occupation, also blamed the Americans for dropping potato beetles. The propaganda was reinforced by the publication of a large number of posters and tracts (Alyokhin 2008). Although research was conducted by several governments on how to use the beetle in entomological warfare, there is no evidence that it was ever used to attack the food supplies of enemy nations. In less than a century, the beetle established itself around the globe but it did so without the aid of warring armies (Garrett 1996).

The Potato in Art and Literature

There are many examples of the depiction of the potato in art and literature (Voelksen 1975). This is especially the case in Ireland where the potato has held a central place in the diet, and in the culture including place names, folklore, and literature (Mac Con Iomaire and Gallagher 2009). McKay's (1961) *Anthology of the Potato* includes many poems praising the potato. An example is the following chorus:



Fig. 8 Vincent Van Gogh 1885. *The Potato Eaters*. Source: https://en.wikipedia.org/wiki/The_Potato_Eaters. Accessed Jan. 15, 2016. In public domain

*Dear praties we can't do without them
They grow in our fields and our men they employ,
Talk as you will, you must say this about them,
That a fine mealy pratie's an Irishman's joy.*

The potato's depiction on postage stamps demonstrates the esteem in which it is held worldwide (De Jong 2003; Henseler 2001; International Potato Center 1993).

The earliest recorded painting of potatoes thus far dates back to 1650 (Zeven 1992). There are many paintings where the potato is the focus. In others, it is part of the background where the respective artist describes the rural way of life. An example of this is Vincent Van Gogh who painted several works which displayed the struggle for existence among the poor and thus stirred the conscience of society to improve their lot. Since the potato played such a dominant role in the lives of the poor, it is no surprise that many of Van Gogh's paintings involve the potato (Van Gogh Gallery n.d.). His paintings include virtually all aspects of the potato such as planting, digging, storing, marketing, and his classical masterpiece of demonstrating providing bread for the poor in *The Potato Eaters* (Fig 8).

Enjoyment of Eating Potatoes

In addition to its adaptation to growing in many different environments and its nutritional value, another major reason for its rise to its status as the world's third major food crop is the fact that potatoes are delicious and extremely versatile in their use in many different contexts around the world. The potato's great palatability facilitated it becoming embedded in so many cultures around the world. It has been suggested that, at least in the Netherlands, the potato may even have had an impact on the eating culture. In this country the introduction of the fork as an eating utensil appears to have been stimulated by the eating of potatoes. Boiled potatoes are easier to eat with a fork than with a spoon (Van der Zaag 1999).

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