

Origin and Evolution of **Capsicum**

1.1 Introduction

What are chilli peppers? When we think about this term, most of us picture a small red fruit with a conical shape, no longer than our fingers, with a burning taste (Figure 1.1). Most people also imagine chilli peppers simply as a cooking ingredient. People also misidentify black pepper as a chilli pepper because the term “chilli pepper” is often wrongly used to denote any hot or spicy pepper. The American English term “chili” comes from the name “chilli”, a Nahuatl word from the Aztec civilisation, which was used specifically for hot *Capsicum* peppers. This name became more popular as *Capsicum* spread around the world and gained several translations. The term “chilli pepper” is one of more than 200 common names given to the hot species of the genus *Capsicum*.¹

Capsicum encompasses so much more than “chilli peppers”. The genus contains a huge biodiversity within its nearly 40 species and they have many more applications than just cooking spicy foods. It is estimated that *Capsicum* made an appearance in human history around 7500 BC and started to be cultivated between 5200 and 3400 BC.² *Capsicum* was not only used for its taste, but also had other ethnobotanical usages. Records dating back to the sixth century report the use of *Capsicum* fruits in medicinal preparations. Chilli peppers are used to treat wounds, relieve pain (*e.g.* stomach aches, headaches and indigestion), reduce fever, as an anti-infective agent and to treat hypertension when chewed. Chilli pepper smoke was used as a punishment for children and as a weapon in hunting and warfare. The smoke of chilli peppers causes the same burning sensation

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Chemistry and Nutritional Effects of Capsicum

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Figure 1.1 The conical fruits known as chilli peppers. Image Credit: Carlos Magno da Silva Antonio.

in the eyes, lungs, throat, nose and skin as occurs in the mouth when eaten.^{3,4} Can you imagine how painful this could it be? Nowadays, the use of chilli peppers as a weapon is restricted, as discussed in Chapter 10.

In addition to these ancient uses of *Capsicum*, modern society still uses peppers as a source of bioactive compounds for drug development and as food additives. Which brings us to the question: how did *Capsicum* become such a remarkable source of bioproducts worldwide? It received attention because of its flavour and its use in treating ailments. However, the Age of Discovery and the expeditions of Christopher Columbus were defining points in the spread of chilli peppers across the world and their worldwide commercialisation. In the pre-Columbian era, *Capsicum* was dispersed by both birds (which also like the taste of chilli peppers) and humans, including the Inca and Aztec civilisations.¹ Despite the pre-Columbian exchange of chilli peppers by different civilisations, there is no consensus about how *Capsicum* was introduced to Asia, although archaeological records confirm the origin of *Capsicum* in the Americas.^{4,5}

Origin is an important issue in everything with which we interact. For instance, a known origin can aid in understanding how a plant interacts and evolves in the environment and enables us to develop the best technology to exploit and preserve it. We would therefore like to take you on a trip back to the origin of chilli peppers.

1.2 *Capsicum*, Chili or Chilli?

The terminology used to refer to the *Capsicum* species includes more than 200 names, including common names, botanical terminology and variety

identification. Some of these (e.g. the terms “chilli peppers”, “ají”, “paprika”, “pepper” and “chili”) are more common and are used synonymously to define any pungent or powdered fruit. Nowadays, two terms are popularly used to distinguish pungent from non-pungent *Capsicum* species, which are, respectively, chilli peppers and sweet bell peppers (Figure 1.2).

The name *Capsicum* was first suggested as a botanical term to define the genus in 1543. The term was derived from the Latin word “capsa” and the Greek term “kapto”, which mean “box” and “to bite”. Both terms are believed to have been chosen because they allude to the shape of the fruit and the pungency of a bite. Between 1543 and 1753, several attempts were made to taxonomically describe *Capsicum* species, as highlighted in Morrison’s *Plantarum Historiae Universalis Oxoniensis* (1699), which described 33 different peppers, and Tournefort’s description in 1700, which is considered to be responsible for the consolidation of the term “*Capsicum*” to define the genus. Linnaeus (1753 and 1767) and Diószegi and Fazekas (1807) gave the first concise taxonomic descriptions of the five domesticated species of *Capsicum*.^{6,7}

The other terms used to describe *Capsicum* species are derived from their local popular names. For instance, the term “ají” comes from the word “axi” in an extinct Arawak dialect, whereas the term “chilli” is originally from the Nahuatl Aztec dialect, which has been translated into several languages, gaining the variations “chili” and “chile”. The removal of one “l” was an adaptation of the word for American English, while the additional “e” is



Figure 1.2 *Capsicum* peppers with a bell shape: the sweet bell peppers. Image Credit: Bárbara Elisabeth Teixeira Costa.

related to the Hispanic spelling. Some varieties, such as chiltepin (*C. annuum* var. *glabriusculum*), also have popular names derived from extinct dialects. Chiltepin comes from the words “chil” and “tepin” of the Nahuatl Aztec dialect. In addition, the term “pepper”, which follows “chili”, is derived from the Sanskrit “pippali”, the same name given to *Piper longum* (black pepper). The use of “pepper” for either *Capsicum* and *Piper* is based on their similar taste properties: the burning feeling.

1.3 The Age of Discovery: Routes for the Dissemination of Peppers

Humans have always sought different ways to season their food and the Indian region was the origin of the spices most widely used today. Some of these spices were known by the Greeks, whereas others were only discovered by Europeans at the time of the Crusades (1096–1291).^{8,9} We start our journey in the Middle Ages and then travel through one of the most beautiful times in human history: the Renaissance and the discovery of the New World.

After the end of the Crusades, several of the supply chains that had been paved to transport and trade goods to fighting armies enabled commerce between Europe and the Middle East, including faraway countries such as India and China. Crossing the Middle East to reach Europe, the Spice Route (Figure 1.3) brought precious products to the northern countries. With the fall of Constantinople on 29 May 1453, the whole world changed. Several waves of migration of writers, poets, lecturers, musicians and artists left the city to move west. This marked the end of the Middle Ages and led to the Renaissance. Architects, geographers, academics and astronomers brought the finest maps from Africa and Asia to Europe and also technologies from

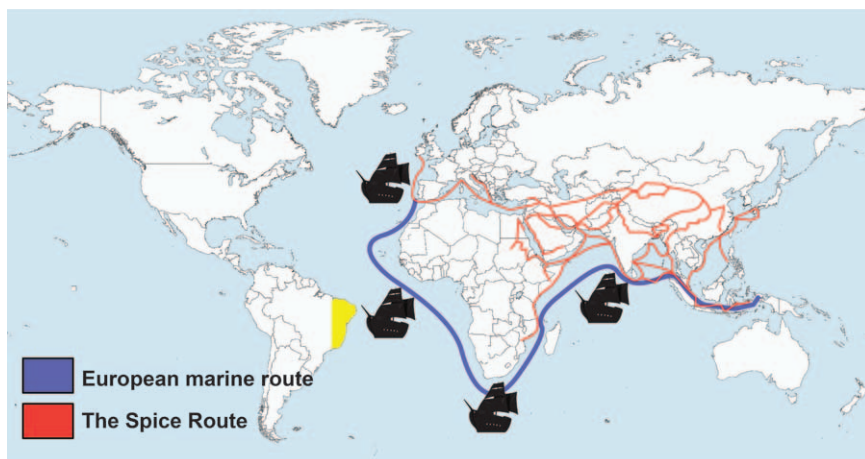


Figure 1.3 Map of the Spice Route and the European marine route for spices. Image Credit: Carlos Magno da Silva Antonio.

Ancient Greece and the Orient. This brought a new wave of knowledge in the second half of the fifteenth century. As Arabs started controlling the Spice Route, Venice, the centre of European commerce, saw prices soaring and Indian products became much more expensive.^{10,11} This included the spices sold in macerated, dried and powdered forms, which were indispensable in European cuisine. An alternative route to India was devised: across the ocean.

Portugal, facing out to the Atlantic Ocean, became a Kingdom in 1139. At the beginning of the fourteenth century, the nautical sciences in Iberia were superior to any other region of the globe. Portugal began to improve its sailing ships (caravels) and conquered several Atlantic islands, such as the archipelagos of Madeira in 1419 and the Azores in 1427, and the west coast of Africa from 1434, including the Cabo Verde archipelago in 1460.

Launching their ships in pursuit of new sea trade routes was a natural path for the Portuguese and Spanish kingdoms. They had conquered several overseas colonies and were enriched by commerce, achieved through their enhanced navigational knowledge of the Atlantic Ocean and new maps from Africa obtained from Middle Eastern astronomers and geographers. This resulted in the discovery of the Americas by Christopher Columbus in 1492, the maritime route to India bypassing Africa by Vasco da Gama in 1498, and the first circumnavigation of the world by Fernão de Magalhães and Juan Sebastián Elcano in 1522. The new routes to India and the discovery of the Americas and many Indonesian islands enabled the establishment of a strong and exclusive commercial path to the Iberian countries, generating long-lasting empires in Asia and the Americas (Figure 1.3).

In addition to the known Indian, Chinese and Indonesian peppers and cinnamons, many other new products were brought to Europe and spread throughout the world. From the Americas, the world was introduced to maize, avocado, potato, cotton, rubber, chicle, coca, tobacco, peanuts, guarana, *açaí* fruit, pineapple, blueberry, guava, chilli peppers and other *Capsicum* species. Portuguese and Spanish navigators also found the known Indian black pepper (*P. nigrum*) in the tropical Americas, as well as other peppers from the genus *Capsicum* that were unique to the New World.^{9,12,13} These species were sent to Europe by the first explorers and were introduced to Spain by Christopher Columbus in 1493. In the same year, an entry from Christopher Columbus' diaries from his last day in Haiti states: "There is also a lot of axi, which is their pepper, of a kind as precious as pepper, and none of the natives eat anything without it, because they find it very sound. Fifty caravels could be loaded with it each year in Haiti".

Diego Álvarez Chanca, a doctor onboard the Columbus expedition, shipped the first *Capsicum* plants to Spain in 1494 with a letter describing their medicinal effects. Chanca's letter also included the following statement: "They use, to season it, a vegetable called aji, which they also employ to give a sharp taste to the fish and such birds as they can catch, of the infinite variety there are in this island, dishes of which they prepare in different ways".

Peppers from *Capsicum* genus were taken by the Portuguese from South America to Europe, Africa and Asia and, in 1542, they were cultivated in India, where they were promptly adopted for consumption. In the sixteenth century, a variety of pepper grown in Goa, India was called pernambuco (named after a state in northeastern Brazil), documenting its origin and intensifying the relationship between European populations and indigenous peoples. The cultivation of this pepper was later recorded in China in 1700.^{8,9,14,15}

In the period between 1492 and 1600, shipping routes allowed pepper species to travel the world, especially from Brazil to Portugal, Africa and, later, Asia. There was a broad distribution of the genus *Capsicum* from the Mediterranean region to England in 1548 and to Central Europe, where it was immediately accepted. After its introduction to Europe, the genus was dispersed to various parts of the world, including North America. This new condiment was incorporated almost instantaneously into the cuisine of countries in Europe, Africa and Asia. Even in the East, despite being the land of spices, where it might have been difficult to accept a new spicy substance, *Capsicum* became widespread. It was called “poor pepper” because it was incomparably cheaper than black pepper and had a similar burning, spicy taste. Five centuries after the discovery of the Americas, peppers came to dominate the spice trade in both tropical and temperate regions.

1.4 Archaeological Records and Historical Usage

Latin America can be considered as the centre of origin for species of the genus *Capsicum*.¹⁶ Long before the arrival of Columbus in the Americas, *Capsicum* were widely used in Central and South America, the Caribbean and Mexico, with at least 27 reported species. The origin and history of the *Capsicum* genus is complex due to its worldwide dispersion by humans. The origin of the genus is usually studied over the five species that are the most cultivated today: *Capsicum annuum*, *Capsicum baccatum*, *Capsicum frutescens*, *Capsicum chinense* and *Capsicum pubescens*. Several archaeological records indicate that these peppers were consumed in the Andean regions of Peru and in Mexico from at least 8600–5600 BC.¹⁷

Archaeological finds are either illustrations created by ancient civilisations, remains of fruit parts in human artefacts or preserved plant parts. In the Codex Mendoza, which contains records of Aztec civilisations, there are several illustrations of their tribute system that include pictures of chilli peppers. The Aztec civilisation is known to have used chilli peppers to spice up a cocoa bean drink known as tchocoatl, a precursor of chocolate, and pottery and embroidery adorned with chilli peppers dating back to 500 AD has been found in Peru.

The first proof of the presence of peppers in the human diet, estimated to be from 7500 BC, was found in Tehuacán, Mexico (Figure 1.4). The discovery was in Coxcatlán cave, an archaeological site considered to be key to our understanding of the early history of plant domestication. Several remains of



Figure 1.4 Archaeological sites with the most ancient *Capsicum* fossils. Image Credit: Carlos Magno da Silva Antonio.

C. annum fruits were discovered in the cave, along with maize and agave. *C. annum* is currently the most commercialised *Capsicum* species, with its centre of diversity thought to be Central America and Mexico.

Another finding from the transition from gathering to a cultivation-based economy was made in Guitarrero cave, Peru. The cave is another famous archaeological site with evidence of humans dating back to about 8000 BC. The *Capsicum* spp. fossil found in Guitarrero cave was a whole fruit with its calyx estimated to date back to nearly 6500 BC. The fossil had a layer just after its calyx that indicated it was a fully domesticated variety.

Peru has several archaeological sites from this transitioning economy. Sites such as Huaca Pietra have the oldest records of plant domestication, including one of the oldest fossils of maize in South America. Huaca Pietra contained seeds of *Capsicum*, mainly of *C. baccatum*, dating from 9300 to 3800 BC. The evidence from archaeological sites in Peru indicate that *Capsicum* were domesticated by humans as early as 10 000 BC (Figure 1.4).^{8,18} The Huaca Pietra site and others along the Andean coast are related to the Inca empire. According to historians, chilli peppers were of more value than money in commerce and were considered to be holy plants in Inca creation myths. There is a tale in Inca mythology known as Brother Chile Pepper, which retells the origin and ascension of the Inca empire through the story of four very strong brothers. The brother representing chilli peppers was Agar-Uchu and the association with the spicy fruit that gives taste to many of

the dishes in their cuisine represents the joy and contentment in life after the creation of the Incan empire. Several varieties of cultivated chilli pepper were described by the major historian of the Inca empire, Garcilaso de la Vega, including: *rocot uchu*, the broad pepper, a *C. pubescens* variety; *kellu uchu*, the lemon drop, a *C. baccatum* variety; and *chinchu uchu*, a cherry-like pod fruit of *C. chinense*.

Huaca Pietra and the nearby Paredones site have archaeological evidence of *C. baccatum*, *C. pubescens*, *C. chinense* and *C. frutescens* dating back to 7600–6500 BC. However, the majority of samples were of *C. baccatum* dating to 4500 BC, representing the ability of the local civilisation to domesticate this species. Still in Peru, archaeological finds in Punta Grande and Ancón identified seeds and fruits of *C. baccatum* with morphological traits of domestication dating back to 2000–500 BC.^{19,20} *C. baccatum* was largely cultivated in the Andean coastal region. This species, referred to as “ají” in this region, is one of the most important ingredients in Bolivian and Peruvian cuisine. In Brazil, three varieties of these species are known: pepper-to-pepper (*C. baccatum*), coumari (*C. baccatum* var. *praetermissum*) and cambuci (*C. baccatum* var. *pendulum*).²¹ Despite its popularity in its centre of dispersion, *C. baccatum* was one of the least commercialised peppers during the Age of Discovery.

Fossils of *C. frutescens* fruits were found in Cahuachi, a site used by the Nazca people (southern Peru) during peregrination. Curiously, it was still possible to detect capsaicin, a pungent metabolite of *Capsicum*, in the fossils from this site. Pollen microfossils of *C. frutescens* were found in sediments from a drained agricultural field in La Tigra, Venezuela. The pollen samples date to 1000–450 BC and, because the field covered >35 ha, indicate the agricultural exploitation of chilli peppers.

The most ancient archaeological finds of *C. chinense* date to about 8600 BC from the Guitarrero cave.²⁰ Fossil remains of a domesticated *C. chinense* fruit were also found in the Casma Valley, Peru, along with remains of maize, beans and potatoes. Evidence of wild varieties of *C. chinense* were found in Roraima, Brazil, reinforcing the idea that *C. chinense* arrived in the Andean coastal region after domestication in Brazil. Despite the fact that most people believe the name *C. chinense* was given to suggest a possible Asian origin, this is not true. The archaeological finds corroborate that *C. chinense* is of Latin America origin and, more precisely, an Amazon basin species. Several of the famous *C. chinense* cultivars (e.g. habanero and biquinho) are native to Amazonia. The indigenous people of the Amazon basin had plenty of uses for this species and are currently considered to be responsible for its domestication.^{16,22}

Capsicum chinense is known among chilli peppers as the species that contains the hottest varieties. In 2010, an internet challenge emerged in which people shared videos of themselves biting a *C. chinense* variety known as bhut jolokia, one of the hottest peppers in the world. This variety has been cultivated in India for the last 7000 years. Such hot cultivars also have medicinal properties and can be used to heal wounds, treat intestinal disorders,

relieve muscle pain and toothache, and control arthritic pain; they are used by indigenous communities in the Amazon basin.^{4,23,24}

Other records that reconstruct the domestication of *Capsicum* in the pre-Columbian era were found in the buried remains of Cerén, El Salvador. This was a farming community that had a similar fate to Pompeii and was buried by volcanic ash. Remains of *C. annuum* seeds and pedicels, dating to about 1400 BC, were found at this site. Their locations within the site suggest that the fruits were being stored for further use. More recent evidence for the popularity of *C. annuum* was found in the archaeological site at En Bas Saline, Haiti, a Chican Ostionoid settlement. Seed and pedicel remains dating to 600 BC were found in positions within the settlement that indicate their possible use in trading and cultivation in home gardens.

As an ancient botanical species, chilli peppers have passed through human history with many applications. Archaeological finds of *Capsicum* are not only of fruit, flower and seed fossils, but also handmade artefacts, such as food receptacles and vessels.³ In Brazil, by the time of the arrival of Europeans, the cultivation of peppers was the most common practice among indigenous peoples. In fact, Central and South America were the birthplace of domesticated peppers. Reports of peppers cultivated by Brazilian indigenous peoples in the sixteenth century were made by the German Hans Staden. Reports also describe trade between indigenous peoples and French explorers, whose ships landed on the Brazilian coast in search of local products. Peppers were highly prized plants among the indigenous peoples, together with maize and cassava.

Expeditions during the sixteenth century in Brazil have several narratives regarding the importance of chilli peppers for the population at the time. Quotations include descriptions such as:²⁵ “Peppers in great quantity...” (Sylveira 1624) and peppers would be “...as indispensably necessary to the natives as salt for the whites” (Humboldt 1841). Among the first and foremost scientific records of peppers is the work of Leonhartus Fuchsius from 1543, named *Stirring History*. It presents a very detailed description and three drawings of a pepper tree.

In Europe, *Capsicum* arrived by the Spice Route, but not as a spice. The first samples that arrived in Europe were considered rare and expensive items and were taken by botanists and aristocrats. European nobles in the sixteenth century primarily used *Capsicum* spp. as ornamental plants in their gardens. As it started being cultivated in the countryside of Europe by farmers who could not afford Asian black pepper, it was no longer considered interesting as an ornamental plant and instead was known as “the poor people’s peppers”. Only in the eighteenth century were *Capsicum* peppers fully consolidated in Europe as a spice in several traditional recipes.²⁶

Capsicum spp. has many applications in our society, from ornamental plants to medicine. There are also some very peculiar ethnobotanic uses of this genus involving superstitions. Brazilian indigenous communities use chilli peppers to keep bad spirits away when entering forests. Indigenous people gift a new friend with a pepper to make the friendship last, but it

cannot be delivered by hand and must be placed in a location where the new friend will find it. In Europe and Mexico, chilli peppers are also used as a symbol of virility and as an aphrodisiac to “spice up” romantic relationships.^{25,26}

1.5 Geographical Distribution

The geographical distribution of the genus *Capsicum* has four major epicentres where the species originated naturally, all of them within the American continent (Figure 1.5).⁹ Nowadays, *Capsicum* is cultivated throughout the world.

The centre of origin of *Capsicum* is thought to be in the Andes region, with a clockwise expansion in South America to northeastern Brazil, southeastern Brazil, back to western South America and entering Central America with the most recent clade (Figure 1.5).^{9,13,27} As *Capsicum* expanded geographically,

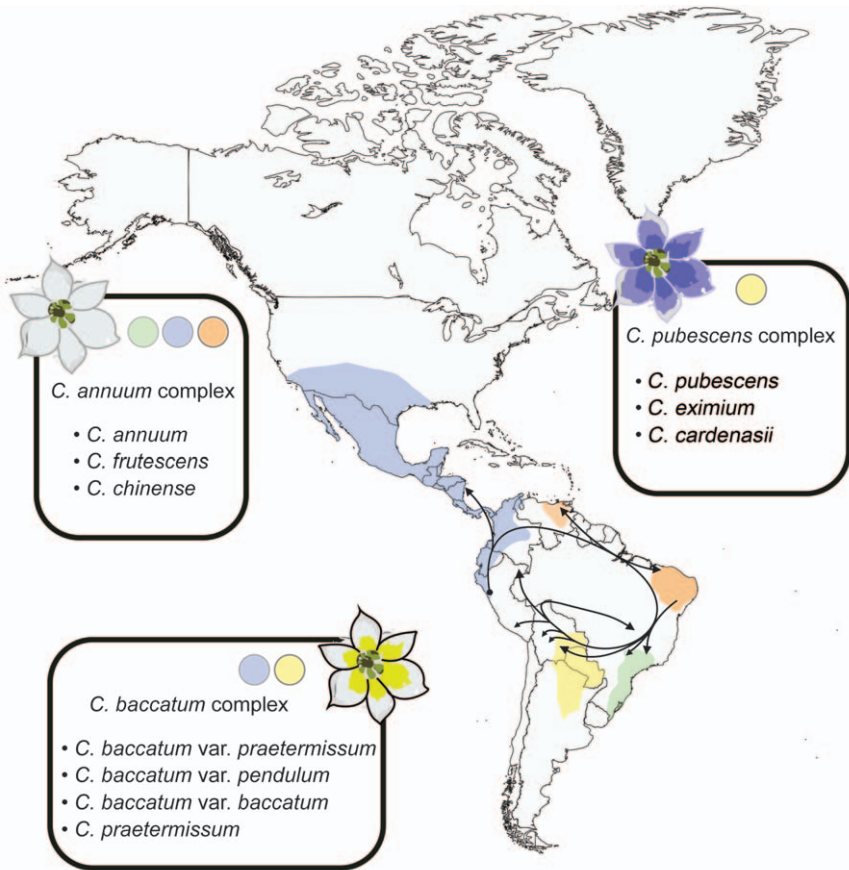


Figure 1.5 Natural epicentres of occurrence of *Capsicum*. Image Credit: Carlos Magno da Silva Antonio.

the distinct climatic conditions in each location promoted the development of species complexes – that is, groups of different species with very similar morphological features that often make it difficult to distinguish between them by eye. Three complexes were formed through gene crossing, which, coincidentally, can be morphologically characterised by the colour pattern of their flowers.^{27,28} These complexes are known as the *C. annuum* complex, the *C. baccatum* complex and the *C. pubescens* complex.

The first complex, known as the *C. annuum* complex, possibly originated in the lower tropical regions of South and Central America due to its affinity for wetter environments. This complex includes species such as *C. annuum* var. *annuum*, *C. annuum* var. *aviculare*, *C. annuum* var. *glabriusculum*, *Capsicum chacoense*, *Capsicum galapagoense*, *C. frutescens* and *C. chinense*. Morphologically, these species are similar with dull white flowers.^{27,29,30} There is some dispute as to whether *C. chacoense* is part of the *C. annuum* or the *C. baccatum* complex.^{29,30}

Interesting varieties of *C. annuum* include jalapeño, poblano and ancho. In addition, cayenne and paprika spices are derived from this species. Jalapeño peppers are used in the preparation of a less spicy variety of Tabasco sauce. This *C. annuum* species has cultivated forms that appear to have reached South America, possibly after the Spanish conquests.³¹ The centre of diversity of the cultivated form of *C. annuum* var. *annuum* includes Asia and Latin America.³² Wild populations of *C. annuum* are found from the southern USA and Mexico to Central America and northern South America.⁶ *C. annuum* var. *glabriusculum* is found in the southern USA, Mexico, the Antilles, Belize, Honduras, El Salvador, Panama, Costa Rica, Guatemala, Suriname, Venezuela, Colombia, Ecuador, Peru, and the north and northeast of Brazil. This species is popularly known as the American bird pepper, turkey pepper, cayenne pepper, chile-tepin and chiltepin.

Although the *C. annuum* complex has its epicentre in South America, its species each have their own centre of origin. For instance, the species *C. annuum* is thought to be originally from Mexico (a little bit far from the epicentre of the complex, but only because it is the youngest species).³³ By contrast, the centre of origin of *C. frutescens* is thought to be in Peru. *C. frutescens* wild cultivars are widely distributed in the tropical and subtropical Americas, whereas domesticated cultivars are grown in the USA, Mexico, South and Central America, Africa, India, China and Japan. The tabasco cultivar is the sole representative of this species commonly grown outside the tropics.^{32,34}

Capsicum chinense is the most widespread species of the *C. annuum* complex in tropical America. Its centre of origin is the Amazon basin, which currently holds its centre of biodiversity.²⁰ Some varieties of this species grown in Africa are reported to be the most pungent of all peppers.³⁴ *C. chinense* is the most commonly grown pepper in the West Indies, northern South America and the Amazon basin. In addition, some of its domesticated cultivars are grown in the USA, Mexico, Central America, Ecuador, Peru, Bolivia, Argentina, China and Japan.²² The limited global

popularity of the *C. chinense* species, compared with other *C. annuum* complex species, is most likely due to its discovery in South America after *C. annuum* had already been established on the European continent.³⁵

The *C. baccatum* complex has characteristics related to dry environments and therefore may have originated in the south-central regions of Bolivia and Peru and, based on archaeological evidence, was probably domesticated in Peru around 2500 BC. It is commonly consumed in South America,³⁶ but is little known outside this region.³⁴ Some wild species of *C. baccatum* can be found in Mexico, India and Hawaii.³⁵ This complex mainly consists of white-flowered species with yellow dots or lines on the petals. Among the species, *C. baccatum* var. *pendulum* is cultivated in the USA, Mexico, Costa Rica, Colombia, Ecuador, Peru, Brazil, Bolivia, Paraguay, Chile, Argentina and India, whereas *C. baccatum* var. *baccatum* is cultivated in Colombia, Peru, Bolivia, Paraguay, south and southeast Brazil, and northern Argentina. The varieties *pendulum* and *baccatum* are popularly known as *dedo de moça* and *cumari*, respectively. *C. baccatum* is mainly consumed and commercialised in Peru, Bolivia and Brazil.

The *C. pubescens* complex, sometimes called the *C. emixia* complex, originated in Bolivia and extended across northern Central America and Mexico.⁹ This complex consists of species such as *C. pubescens*, *Capsicum eximium* and *Capsicum cardenasii*, characterised by purple flowers.

The cultivation of *C. pubescens* (popular name *rocoto*), the only domesticated species in the complex, is centred in South America, Guatemala and southern Mexico at mid-elevations (1500–3000 m). Its most remarkable characteristic is that it requires a cold climate and can resist temperatures as low as -5°C .

1.6 Concluding Remarks

The genus *Capsicum* is one of the oldest and most cultivated crops worldwide. Known by many names, it was also one of the major spices of the Spice Route and the Inca empire. Long before the Common Era, brought about by the exploration of marine routes, *Capsicum* peppers had become domesticated in their centre of diversity. Peru and Mexico have many archaeological sites in which the economic and cultural importance of the genus is clear. Despite the great importance of the Age of Discovery in the worldwide spread of *Capsicum*, it was already a common product before that time. The commercial routes travelled by foot from the centre of origin of the species are still unclear and the extensive commercialisation of the species makes it difficult to trace the ancestor species with accuracy. The human influence in the dispersion of *Capsicum* is so important that its existence within the major products of the Spice Route may have defined the world economy we know today. As an essential ingredient in traditional dishes and part of the human diet, *Capsicum* has played a part in motivating marine expeditions. Its taste and medicinal properties are both remarkable and unique, as you will see as you read this book.

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