

Chapter 2

Physiology and Postharvest of Pepper Fruits

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Abstract The *Capsicum* genus comprises a large and diverse group of cultivated and nondomesticated plants producing flesh fruits that vary from sweet to hot spicy taste. Fruits from the domesticated species of peppers, *Capsicum annuum*, *C. frutescens*, *C. baccatum*, and *C. chinense* present a nonclimacteric behavior for respiration and ethylene production. Nevertheless, harvested fruits show different degrees of sensitivity to exogenous ethylene regardless of the species. With Fruits in the same species, ethylene induces different intensity of changes for color, chlorophyll degradation, and total soluble solids content. Postharvest loss of fresh weight has different intensities, which is associated with the thickness of the pericarp, surface/volume ratio, and composition of waxy epidermis. Fruits with a thicker pericarp are more susceptible to wounding but less susceptible to shrinking under intense water loss. Regardless the species, fresh fruits are susceptible to develop chilling symptoms when stored below 10 °C, which can be reduced by wrapping the fruits with plastic film. The intensity of chilling seems to be related to the stage of ripening of the fruits and variety.

Keywords Respiration • Ethylene • Shelf life • Pigments • Water loss • Temperature

2.1 Introduction

The genus *Capsicum* comprises a large and diverse group of plants producing flesh fruits varying from sweet to hot. Originating from Latin American tropical regions, spreading from Chile to the southeastern United States, the *Capsicum* species are cultivated and appreciated around the world. Due to the unique flavor, spice uses, and presence of hot taste of the fruits, they are consumed fresh and in different forms of processed products.

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There are five domesticated species in the genus, with distinct characteristics and distribution. *Capsicum annuum* is the most popular and diverse species. The other four species, *C. frutescens*, *C. baccatum*, *C. pubescens*, and *C. chinense*, usually have their cultivation restricted to particular countries or regions. In Brazil, *C. baccatum* and *C. chinense* are very popular, because they are quite adapted to the climate conditions present in the equatorial and tropical regions of the country. In addition, their fruits have good culinary characteristics for in natura consumption as part of dishes or as fresh vinaigrette.

Peppers belong to a group of botanical species with unique characteristics, producing flesh fruits with a wide range of hot flavors in addition to sweet fruits with no capsaicin. The plant is perennial but cultivated as an annual crop. The plant looks like a bush with height of 120 cm with many lateral shoots, although small plants are also cultivated for ornamental purposes. It is autogamous but presents cross-pollination within and between species (Araujo 2005).

The market for the fruits is enormous with a wide range of processed products, as fresh fruits for both in natura consumption and ornamental purposes. Processed products include sauces, pickles, paprika, dry cracked pepper, whole dry fruits, jams, and medicinal products.

The diversity of color, format, and flavor of fruits are some of the reasons for their appreciation but the most important feature is their hotness, due to the presence of capsaicin secreted by the glands present in the fruit placenta. Pepper consumption helps digestion and is an important source of antioxidant substances, including vitamin C, carotenoids, and vitamin E.

The market for in natura consumption of fresh fruits is small when compared to other vegetables, mainly because they are used in small amounts as part of sauces, although sweet pepper can be used in large quantities as occur with the Buiquinho pepper (*C. chinense*) in Brazil. Its fresh fruits are largely used as pickles and as an important ingredient in salads. The market for fresh fruit is locally driven and requires patronization and a high quality product.

All around the world the market for pepper is growing because of its culinary acceptance in many dishes, industrial uses, medical properties, and in more recent years as an ornamental plant. The flesh fruits have relatively short shelf life because of the presence of several abiotic and biotic stresses:

- (a) Losses due to mechanical injury or presence of insects or diseases
- (b) Water loss by transpiration and respiration
- (c) Losses by exposition to low or high extremes of temperature, causing freezing or excessive dehydration
- (d) Development of physiological disorders such as chilling symptoms induced by low temperatures in the field or during storage
- (e) Losses of dry matter by the respiration process
- (f) Breakdown of vitamins

The expansion of the fresh market requires the improvement of postharvest handling, but little is known regarding the physiological reaction of the fruits to long-term storage and quality changes that occur during transportation and display at retail stores.

2.2 Physiology of Fruit Growth and Ripening

The flesh fruit shows a simple sigmoid pattern of growth and at the end of its increase in fresh matter, the fruits develop their ripe color, ranging from purple, yellow, orange, or red. The intensity of color in ripe fruit depends on the variety, stage of development at harvest, and climate conditions at the field. Mutations also can change the color of ripe fruits, usually in genes responsible for the synthesis of carotenoids.

The initial phase of growth is characterized by intense cell division followed by cell enlargement due to the uptake of water and photoassimilates. The later phase is responsible for the thickening of the pericarp giving the final fruit succulence and hardness. Fruits with thick pericarp are more suitable for fresh consumption because they are more hydrated than those with thinner pericarp. On the other hand, peppers with thinner pericarp usually have more soluble solids, thus are more suitable for the production of dry products such as paprikas, due to a faster dehydration and allowing less contamination by postharvest diseases (Lannes et al. 2007).

At the end of the growing phase the mature green fruits start to change color and develop some softening of the pericarp. The degradation of chlorophyll starts at the breaker stage of fruit color, after fruits reach the mature green phase, revealing the carotenoids or purple colored anthocyanins. In climacteric fruits, ripening is induced by a low concentration of ethylene (system I) simultaneously to the induction of climacteric respiration and autocatalytic production of ethylene by the fruit. Nevertheless, in nonclimacteric fruits, ethylene usually induces changes in both skin and flesh color without inducing ripening or autocatalytic synthesis of ethylene (system II). The response of nonclimacteric fruits to ethylene seems to be related to the advance on senescence instead the beginning of fruit ripening. Usually, the harvest of ripe peppers extends for several months, because the fruits are present at different stages of development, with immature, mature green, and ripe fruits in the same plant (Fig. 2.1). This fact can be evident in plants of *C. frutescens* known as Pimenta Malagueta, a common variety grown for fresh consumption and for sauce production.

Based on respiratory pattern and ethylene evolution during the ripening, peppers behave as nonclimacteric fruits. Following the growth and ripening of different domesticated *Capsicum* species no increase in respiration and ethylene production occurred when fruits were attached or detached from the plant. Pereira (2004), studying 16 accessions of the peppers from *C. annuum*, *C. chinense*, *C. baccatum*, and *C. frutescens*, applied 1000 mg L⁻¹ ethephon solution in mature green fruits. In the treated fruits, there was no increase in respiration and autocatalytic ethylene evolution. Nevertheless, in overripe fruits there were changes in respiration and ethylene production. These changes may reflect the advanced stage of senescence that follows fruit ripening. In previous works, Saltveit (1977) and Pretel et al. (1995) studied both respiratory and ethylene behavior in peppers treated with propylene, an analogue ethylene gas. Their conclusion was that the fruits responded like nonclimacteric fruits, inasmuch as no significant changes in respiration and ethylene production



Fig. 2.1 Maturity diversity of *Capsicum frutescens* variety Pimenta Malagueta fruits during plant production

were detected. In another experiment, Gross et al. (1986) evaluated the biochemical changes in the ripening of *C. annuum* cv. Choorachong harvested at the mature green stage. They determined a climacteric-like increase in respiration during ripening but ethylene production up to 18 h after being kept at 20 °C in closed flasks was not detectable. Also, the ethylene detected was not similar to an autocatalytic evolution, which is characteristic of any climacteric fruit. The peak of respiration occurred when the fruits had 50 % red color, which seems a symptom of senescence and not a climacteric peak of respiration.

Barrera et al. (2005) determined that pepper fruits of *C. annuum* and *C. frutescens* from the germplasm bank of the Amazon SINCHI (Instituto Amazônico de Pesquisa Científica—Colômbia) kept ethylene evolution always below $0.01 \mu\text{L L}^{-1}$ (a typical behavior of a nonclimacteric fruit) and absence of system II or autocatalytic ethylene production throughout the ripening. In another study, the related *C. annuum* sweet pepper treated with $100 \mu\text{L L}^{-1}$ ethylene determined the elevation of mitochondrial respiration in green sweet pepper, but the internal concentration of carbon dioxide within the fruits decreased when the ethylene was removed. This result clearly indicates that the increment in respiration depends on the presence of ethylene, a response that is present in nonclimacteric fruits.

Ethylene nevertheless was able to induce changes on some characteristics of fresh harvested fruit peppers. Dipping mature green fruits of different species of peppers for 30 min in a solution at concentration of 1000 mg L^{-1} ethephon, an enhancement to the development of red or yellow ripe fruit was observed (Table 2.1).

At the first stages of fruit development in both climacteric and nonclimacteric fruits, high rates of ethylene production are related with cell growth, followed by a period of sharp drop parallel to the cell expansion. The earlier and elevated production

Table 2.1 Means followed by the same letter, in a row and within each accession, are not significantly different according to F test (p 0.05)

Species	Color of ripe fruit	Control (Days to ripe fruit color)	Ethephon ¹
<i>C. annuum</i>			
Mirassol	Red	21.5a	11.8b
New Mexican	Red	20.3a	17.7a
<i>C. chinense</i>			
BGH 1716	Orange	7.8a	7.3a
BGH 1723	Red	14.8a	18.8a
<i>C. baccatum</i>			
BGH 4366	Red	13.0a	9.0a
BGH 6029	Yellow	5.3a	3.5b
<i>C. frutescens</i>			
BGH 4179	Red	12.8a	8.0b
BGH 4708	Red	16.3a	17.5a

of ethylene is related to cell division and radial growth of cells regardless of the climacteric or nonclimacteric nature of the fruit.

Two ethylene systems of production act at the same biosynthetic pathway. System I is responsible for the production of small quantities of ethylene, which is present at the preclimacteric phase of climacteric fruit or flowers, just before the increase in respiration. This system is also present in all vegetative tissues of plants. System II produces massive quantities of ethylene acting during ripening of climacteric fruits or senescence of climacteric flowers. The autocatalytic production of ethylene is due to the increase of RNA transcription and translation of the key enzymes ACC synthase and ACC oxidase. Some pepper fruits present an increase in ethylene and respiration but the climacteric nature of the rises remains to be determined. Villavincencio et al. (2001) suggest that some cultivars of *C. annuum* may present an intermediate climacteric pattern.

The importance of the fruit respiratory pattern is related to the strategies for handling the fresh produce after harvest. Little is known about the physiological behavior of pepper fruits, related to ethylene production and sensitivity in particular. Responses to ethylene treatment help to understand the changes in fruit metabolism and potential for storage. As mentioned previously, Pereira (2004) analyzed the responses of 16 pepper accessions under ethylene treatment. Ethylene reduced the number of days for the mature green fruits to reach the full red, orange, or yellow ripe color (Table 2.1). However, the response was dependent on the accession treated with ethephon, which showed different sensitivity to the hormone ethylene, enhancing the development of the ripe fruit color or having no effectiveness whatsoever. Two accessions of *C. chinense* were insensitive to ethylene, regarding the development of changes on carotenoid pigment accumulation.

In the same extended study of several accessions of hot peppers, conducted by Pereira (2004) in fruits from the species *C. annuum*, *C. chinense*, *C. baccatum*, and *C. frutescens*, it was found that the submersion of fruits in 1000 mg L⁻¹ ethephon

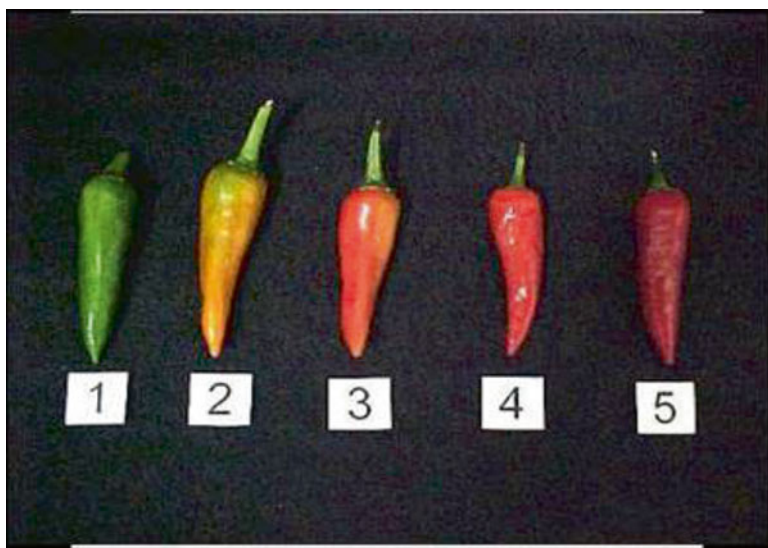


Fig. 2.2 Ripening of cultivar Ca 6 (*C. annuum*) fruit. (1) Mature green; (2) 25 % red; (3) 50 % red; (4) 75 % red; (5) 100 % red

harvested at the mature green stage induced changes in total soluble solids in only two accessions: the BGH 4366 (*C. baccatum*) and BGH 4708 (*C. frutescens*) held at the germplasm bank BGH/UFV. Nevertheless, the remaining 14 accessions did not respond to ethylene regarding the accumulation of total soluble solids. Furthermore, the changes in color were affected by the action of ethephon (Table 2.1). This work showed that the response to ethylene varies among the genotypes within the same species of pepper. This is an important characteristic, because the development of intense red color is important for the hot paprika industry production. The induction of carotenoid biosynthesis in this nonclimacteric fruit remains to be evaluated in future studies.

Hot peppers from *C. annuum* ripen well when attached to the plant as showed in Fig. 2.2. If detached from the plant at the mature green stage, the fruits must be treated with ethylene in order to induce more intense changes in color. In the absence of ethylene, color changes occur at a low rate and are related to an advanced stage of senescence.

As do other fruits, peppers have different degrees of response to ethylene, affecting the shelf life and quality. The handling of fruits requires knowledge of physiological changes during maturation and ripening, including changes in respiration and ethylene synthesis and sensitivity. The use of 1-methylcyclopropene (1-MCP), an ethylene action inhibitor, has profound effects on the ripening of climacteric fruits and reduces the rate of deterioration in some nonclimacteric fruits such as peppers. The use of 1-MCP in potted ornamental plants of *C. annuum* hot peppers prolongs the postproduction shelf life in indoor environments, indicating that vegetative tissues also respond to the action of ethylene in *Capsicum* plants. Thus, dur-



Fig. 2.3 Ripe fruits of *Capsicum chinense* genotypes from BGH/UFV

ing handling, shipping, and storage, pepper plants in wholesale and retail stores must be checked for the presence of concentrations of ethylene above $10 \mu\text{L L}^{-1}$, which has proved to affect the abscission of leaves, flowers, and fruits if the exposure is more than 24 h at room temperature. In cultivars with high sensitivity to ethylene such as Calypso fumigation with $1 \mu\text{L L}^{-1}$ 1-MCP for 6 h was able to prolong the post production shelf life by inhibiting the abscission of leaves induced by ethylene (Finger et al. 2015).

One of the main desirable attributes in fruits is the color and it is related to the stage of fruit development and the cultivar. The BGH/UFV germplasm bank of *C. chinense* has fruits with different intensities of red, yellow, and orange colors when ripe (Fig. 2.3). Intense red ripe fruits usually are suitable for processing as dry powder because they have high amount of carotenoid pigments, which define the final quality of dry processed pepper products.

One of the main changes during fruit ripening is the degradation of the pulp chlorophyll, but during the fruit growth phase there is a large increase in the chlorophyll synthesis. Mattos et al. (2008) found differences in the chlorophyll content among several varieties, and the so-called Pimenta de Bode had 60 % more chlorophyll than Dedo de Moça. In the same study, the ratio between chlorophyll a/b varied from 1.19 to 2.33, depending on the cultivar, indicating different degrees of chloroplast development in mature green fruits. Menichini et al. (2009) found that the composition of carotenoids in immature and mature fruits of cultivar Habanero increase when the fruits were at the mature green stage compared to immature green stage, but the phenols had an opposite behavior.

Fruit pungency is one of the most important quality of peppers in both in natura consumption and processing, especially for condiments and sauces of ethnic dishes around the world. During fruit growth there is a substantial accumulation of capsaicin and dihydrocapsaicin distributed at the placenta of the flesh fruit. The placenta contains glands that are responsible for the production of these alkaloids, which usually spread to all other portions of the fruit, including the seeds and pericarp.

The varieties used for cooking and processing have different capsaicinoid contents. The dry powder of paprikas have different contents of capsaicinoids, varying from 0.003 to 0.01 % known as sweet products, 0.05 to 0.03 % considered light dry powders, and finally, the hot powders ranging from 0.3 to 1 % of capsaicin (Araujo 2005).

The content of capsaicinoids depends on several factors, including the genetic factor, cultivar, and stage of development of the fruit (Bosland and Votava 1999). Furthermore, environmental conditions affect the accumulation of these alkaloids, mainly the temperature, light intensity (Estrada et al. 1999a; Tewksbury et al. 2006), water stresses (Estrada et al. 1999b), and plant nutrition (Estrada et al. 1998). Lannes et al. (2007) evaluated 49 accessions of *C. chinense* for capsaicin and dihydrocapsaicin contents and determined a wide range of hotness. The highest content was 14 mg g⁻¹ dry weight and the lowest content was 1.9 mg g⁻¹ for the light hot fruits. In addition, fruits were found that had only traces of capsaicinoids. Thus, 27 % of the accessions could be included as light hot fruits, while 2.5 % of the accessions had 12–14 mg g⁻¹ dry weight and were consider as hot paprikas.

Despite the fact that the biosynthesis of capsaicinoids is known, the degradation of capsaicin and dihydrocapsaicin is not completely understood. The enzyme peroxidase seems to be involved in the oxidation of capsaicinoids, because there is an increase in peroxidation during fruit ripening. The increase of peroxidase activity is related to the increased demand for phenylpropanoid intermediates for the synthesis of cell wall suberin and lignin, competing with intermediates needed for the synthesis of capsaicin and dihydrocapsaicin (Bernal et al. 1995). Pereira (2007) found a significant decrease for the capsaicinoids on the majority of hot *C. chinense* fruits during ripening. In the same work, it was observed that peroxidase activity was higher at the beginning of fruit ripening regardless of whether fruits were sweet or hot. Such behavior shows that during fruit ripening peroxidases are involved on the changes of cell wall metabolism as suggested before.

In addition to the contribution of capsaicinoids to the flavor, the presence of 102 different volatiles compounds when fruits of Habanero changed from mature green to ripe was observed. In a study, Pino et al. (2006) found alcohols, ketones, and aldehydes as the major volatiles that increased the flavor.

2.3 Postharvest Water Loss

The harvest interrupts the fruit water supply and the subsequent loss of water is responsible for the qualitative and quantitative losses on most of the varieties of fresh sweet and hot peppers. Excessive loss of water results on less shiny skin and

shrunken fruits, but the amount of water necessary to cause these problems depends on the variety and environmental conditions of storage. In addition to the above symptoms, the fruits are more susceptible to deterioration, including an increase in oxidative reactions, degradation of chlorophyll, and elevation of ethylene synthesis and action.

The total postharvest losses of fresh fruits results from both the water loss and the consumption of dry matter by respiratory activity, the former being the most relevant. Previous works have determined that weight losses from 3 to 5 % may cause shrinkage in most flesh fruits (Ben-Yehoshua 1987). Weight loss has a negative impact on shipping, storage, and sales at retail stores. Surveys on retail stores showed that loss of weight is the most important cause of postharvest losses of peppers in the majority of Brazil's local stores and large supermarkets. Unfortunately, most of the retail store owners do not apply any method to reduce the rate of water loss, which could be achieved by wrapping fruits with plastic bags and reduction of temperature. Because of that, the shelf life of most pepper varieties does not exceed three days.

The main barrier to determine the rate of water loss of fresh fruits is the waxy cuticle that covers the epidermal cells. This cuticle is formed by esterified lipids with a distinct composition and thickness, depending on the species and the variety. The integrity of the cuticle is a determining factor that affects the passage of water vapor and infection by pathogens. Previously, it was established that the cuticle chemical composition is more important than its thickness regarding the effectiveness in reducing the water loss. Lownds et al. (1994) determined a variation of 60 % on the rate of weight loss analyzing the influence of storage temperature and humidity on shelf life of several sweet pepper cultivars. The variation in the rate of weight loss among the cultivars was related to the permeability of the cuticle to water vapor.

Exchange of gases between the fruit and the storage environment is usually influenced by the surface/volume ratio (cm^2/cm^3). This ratio is determined by the size and format of the fruit. Higher losses of water are present on those fruits with elevated ratios. Assuming the fruit format is constant, the smaller fresh fruits are more susceptible to water loss than the larger ones during shelf life and processing as dry powder.

In ripe fruits of *C. chinense*, Cabral (2006) found a positive correlation between the surface/volume ratio and the rate of weight loss during storage at room temperature (Table 2.2). Fruits with elevated surface/volume ratio had a shorter shelf life at room temperature, due to a much higher rate of fresh weight loss. An increase of surface/volume ratio from 1.17 to 5.27 increased the weight loss from 0.9 % per day to 3.25 % per day, shortening the shelf life in these fruits by five days (Table 2.2).

In a previous analysis of several genotypes belonging to *C. chinense*, it was established that fruits with a thicker pericarp are more appropriate for fresh consumption due to the pericarp's higher resistance to wounding, firmness, and freshness. However, fruits with less thick pericarp had more dry matter and soluble solids, and were more suitable for processing as dry products.

During pepper fruit dehydration there is the activation of lipoxigenases changing the permeability of cell membranes. As a consequence of membrane damage, a

Table 2.2 Surface/volume ratio, weight loss, and days to chilled fruits in accessions of *Capsicum chinense* stored at 22 °C and relative humidity of 60 %

Accessions	Surface/volume ratio (cm ² /cm ³)	Weight loss (%/day)	Days to waste
BGH 6371	1.17	0.90	8
BGH 4213	2.78	1.73	5
BGH 1716	3.38	2.63	5
BGH 1723	5.27	3.25	3

cascade of catabolic reactions takes place, causing the deterioration of tissues. The leakage of electrolytes is an indicator that the membrane integrity is lost. Such behavior was observed in genotypes of hot peppers susceptible to elevated water loss compared to those cultivars less susceptible to dehydration during storage (Maalekuu et al. 2005).

In *C. annuum* cultivars, the activity of lipoxigenases is associated to the development of volatiles compounds and degradation of pigments throughout the different stages of ripening (Luning et al. 1995; Jaren-Galan and Minguéz-Mosquera 1999).

Maalekuu et al. (2006) verified a negative correlation between the lipids content in the membrane, electrolyte leakage, and lipoxigenases activity in 10 accessions of *C. annuum*. Thus, the genotypes susceptible to high rates of water loss presented lower quantities of total lipids in their membranes. Inverse behavior was observed in genotypes with low susceptibility to water loss. The differences among the genotypes seemed to be related to the cuticle wax composition, enzyme activity of cell wall degradation, and the integrity of cell membranes.

Lannes et al. (2010) found that hot peppers *C. chinense* with less thick pericarp had more dry matter and soluble solids. This fact may reflect a higher capacity of these plants to accumulate and translocate dry matter or due to dehydration of the fruit during ripening when attached to the plant. Such fruits would be more adequate to the paprika industry and dry pepper spices, because less water would be necessary to remove during processing, reducing the cost for dehydration. But fruits with thicker pericarp are more appropriate for fresh consumption due to higher resistance of the pericarp to the wounding, firmness, and freshness aspect of the fruits.

2.4 Temperature of Storage

Temperature is the most important factor regarding the postharvest shelf life of peppers. It is well known that length of shelf life is inverse to the elevation of temperature. However, the *Capsicum* species fresh fruits are sensitive to chilling injury determining their handling and extent of storage.

In general, the symptoms of chilling in fleshy fruits are the development of depressions and/or discolorations and further browning on the surface. In addition, the development of chilling has other effects on fruit quality, including lack of

ripening and higher incidence of postharvest diseases. According to Shewfelt (1993), tropical and subtropical fruits develop a series of reactions in response to low temperatures leading to an increase of leakage of electrolytes, increase of respiration, ethylene synthesis, accumulation of toxins, and finally cell collapse.

The development of chilling injury occurs when fruits are stored under temperatures above 0 and below 12 °C, for the majority of species. In most cases, temperatures closer to 5 °C are more effective in inducing symptoms of injury (Wills et al. 1998). Nevertheless, in order to develop permanent symptoms, the fruits must remain for a period under inducing chilling temperatures: the longer the periods under the stressing temperatures, the more intense are the symptoms. In general, fruits show symptoms under low temperature, but in some species, visible symptoms will develop only when they are moved to higher temperatures.

Reactive oxygen species (ROS) composed of superoxide, hydroxyls, peroxides, and oxygen singlet may contribute to the resistance to chilling injury development in pepper fruits. The resistance to chilling is related to the activation of the antioxidant system involved in the ROS metabolism. Peroxidases and catalase eliminate the accumulation of hydrogen peroxide delaying the appearance of chilling. In addition, there is an increase in the expression of the alternative oxidase pathway (AOX), associated with the reduction of ROS, detected in fruits of *C. annuum* stored under chilling inducing temperatures (Fung et al. 2004; Purvis 2002).

The fruit maturity stage at harvest is another important factor of the resistance to chilling. As in other fruits, immature and mature green fruits are more sensitive to develop chilling injury than fully ripe fruits. Furthermore, fruits originated from colder regions are less susceptible to chilling than fruits grown in warmer climates. No information is yet available on the degree of sensitivity from the different cultivated *Capsicum* species and cultivars.

The optimum temperature for storage of hot peppers is still to be determined for most of the species and cultivars. The general recommendation is to store between 7 and 10 °C. The hot pepper Pimenta Malagueta had 30 days of shelf life when stored under 12 °C of temperature and relative humidity of 80 %. Nevertheless, the fruit showed some shrinkage at the skin, which can be avoided by wrapping fruits in PVC or a PET plastic box, maintaining elevated humidity inside.

If fruits are stored in PET, it is desired to punch some holes in order to avoid excessive condensation inside the box and the development of fungi and bacterial diseases after 2–3 days if kept at room temperature. The storage of Pimenta Malagueta, De Cheiro, Cumari do Pará, Bode Vermelha, Bode Amarela, and Dedo de Moça wrapped with PVC film had a shelf life of 30 days at 8 °C. These pepper fruits had daily fresh weight of 2.5 % at 24 °C when stored without any PVC film to avoid excessive water loss. However, if wrapped with PVC plastic film, the weight loss was 0.9 % per day and only 0.2 % if stored at 8 °C protected with plastic film (Gravina et al. 2004).

Marques et al. (2005) stored seven *Capsicum* accessions (*C. baccatum*—BGH 1646, 4366, 6029; *C. chinense*—BGH 4213 and 6371; *C. annuum*—cultivars Mirassol and New Mexican) at 5 and 10 °C in PET perforated boxes. Except for

accessions BGH 6029 and Mirassol, all fruits from the others developed symptoms of chilling at both temperatures, with much more intensity at 5 °C. Chilled fruits had dispersed little pale spots at the surface of the pericarp. The first symptoms appeared in those fruits of BGH 4366 stored at 5 °C after 6 days. At 10 °C, the symptoms started to develop after 12 days in BGH 1646, also a *C. baccatum* accession.

Fruits from BGH 6029 (*C. baccatum*) and Mirassol (*C. annuum*) were resistant to chilling injury even after 1 month of storage at 5 or 10 °C. As a general recommendation, temperatures between 7 and 10 °C are more suitable and the relative humidity should stay between 90 and 95 %. Nevertheless, this humidity is hard to get in most refrigerated storage facilities when there is no humidity control. In this situation, it is recommended to use plastic films to avoid dehydration (Finger and Vieira 1997). Several works show that excessive postharvest water loss increases the susceptibility of fruits to chilling, which can be diminished by wrapping with any plastic film.

2.5 Conclusions

Fruits from the cultivated species *Capsicum annuum*, *C. frutescens*, *C. baccatum*, *C. pubescens*, and *C. chinense* behave as nonclimacteric fruits. All fruits are susceptible to intense water loss after harvest requiring immediate reduction of temperature and wrapping with plastic film to avoid dehydration and shrinkage.

Regardless of the domesticated species of hot peppers, the majority of the fruits are susceptible to develop chilling symptoms when stored below 10 °C of temperature, which can be reduced by wrapping the fruits with plastic film. For most cultivars, however, there is no information about the best postharvest temperature and humidity of storage.

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Production and Breeding of Chilli Peppers (*Capsicum*
spp.)

Ramalho do Rêgo, E.; Monteiro do Rêgo, M.; Finger, F.L.

2016, IX, 134 p. 25 illus., 2 illus. in color., Hardcover

ISBN: 978-3-319-06531-1