Revista Brasileira de Ciências Agrárias
ISSN (on line) 1981-0997
v.17, n.3, e161, 2022
Recife, PE, UFRPE. www.agraria.pro.br
DOI: 10.5039/agraria.v17i3a161 - Protocol 161
Subm. 26/01/2021 • App. 28/06/2022 • Pub. 24/08/2022

Maturation and determination of the harvest point of *Capsicum chinense* Jacq. ('biquinho' pepper)

Carine Borges Batista[1]*, Francis Júnior Soldateli[2], Shirlei Pezzi Fehndrich[1], Matheus Noronha Bittencourt[1], Lucas Santos da Silva[1], Luciana Zago Ethur[1]

[1] Universidade Federal do Pampa, Itaqui, RS, Brasil. E-mail: carinebatista.aluno@unipampa.edu.br; shirleip.f@hotmail.com; matheus.nb7@gmail.com; lucastricolor9912@gmail.com; luethur@gmail.com
[2] Universidade Federal de Santa Maria, Santa Maria, RS, Brasil. E-mail: francisjrsoldateli@gmail.com

ABSTRACT: The objective of this study was to evaluate the physicochemical characteristics of *Capsicum chinense* Jacq. ('biquinho' pepper) at different stages of maturation and to determine the ideal harvest point of the fruits according to the coloration of the epidermis. The treatments consisted of five maturation stages, characterized as: green, orange-green, orange, red-orange, and red. Fresh mass, vertical and horizontal diameters, pericarp thickness, cracked fruit, luminosity, chroma, hue angle, pH, soluble solids, acidity, and ratio were evaluated. The fresh mass, vertical and horizontal diameter, and pericarp thickness increased with the stages of maturation until reaching an red-orange color. The highest incidence of cracked fruit occurred at the red stage. There was a reduction in pH while soluble solids, acidity, and ratio increased with maturation. The highest chroma values occurred intermediate stages, while the hue angle and luminosity decreased with advancing of the stages of maturation. Thus, the ideal harvest point for consumption is the red-orange stage, because the fruits are larger, with a lower incidence of cracking compared to the more advanced stage of maturation, and their chemical characteristics indicate a soft fruit.

Key words: fruit development; physicochemical characterization; skin color; *Solanaceae*

Maturação e determinação do ponto de colheita de *Capsicum chinense* Jacq. (pimenta biquinho)

RESUMO: O objetivo deste estudo foi avaliar as características físico-químicas de *Capsicum chinense* Jacq. (pimenta biquinho) em diferentes estádios de maturação e determinar o ponto de colheita ideal dos frutos de acordo com a coloração da epiderme. Os tratamentos consistiram em cinco estádios de maturação, caracterizados como: verde, verde-alaranjado, laranja, vermelho-alaranjado e vermelho. Foram avaliados, massa fresca, diâmetros vertical e horizontal, espessura do pericarpo, frutos rachados, luminosidade, croma, ângulo hue, pH, sólidos solúveis, acidez e ratio. A massa fresca, diâmetro vertical e horizontal, e espessura de pericarpo aumentaram conforme os estádios de maturação até atingir a coloração vermelho-alaranjado. A maior incidência de frutos rachados ocorreu no estádio vermelho. Houve redução do pH enquanto sólidos solúveis, acidez e ratio aumentaram conforme a maturação. Os maiores valores de croma ocorreram em estádios intermediários, já ângulo hue e luminosidade decresceram com o avanço dos estádios de maturação. Assim o ponto de colheita ideal para consumo é o estádio vermelho-alaranjado, pois os frutos apresentam-se maiores, com menor incidência de rachaduras em relação ao estádio mais avançado de maturação, e suas características químicas indicam um fruto suave.

Palavras-chave: desenvolvimento de frutos; caracterização físico-química; cor da epiderme; *Solanaceae*

* Carine Borges Batista - E-mail: carinebatista.aluno@unipampa.edu.br (Corresponding author)
Associate Editor: Ana Carolina Silva Siquieroli

Introduction

The peppers are inserted in the genus *Capsicum*, in which there are approximately 25 species belonging to the Solanaceae family (Acunha et al., 2017). Among the various fruits that make up this group, *Capsicum chinense* Jacq. ('biquinho' pepper), is relevant in the human diet, with small fruits, being characterized as tasty, aromatic, and crunchy (Heinrich et al., 2015). Besides, differently of most species of the *Capsicum genus*, the fruits of the *C. chinense* Jacq. do not have pungency, which gives them a mild flavor and makes them more accepted in certain markets (Domenico et al., 2012). In this way, this pepper can be consumed in the form of jellies, sauces, pickled, and fresh (Ribeiro et al., 2018).

However, because they are non-climacteric fruits, peppers are harvested at maturity for consumption, which makes them highly perishable and reduces the commercialization period (Bernardo et al., 2015). In addition, due to the indeterminate growth habit, peppers simultaneously present flower buds, flowers, and fruits at different stages of maturation (Gomes et al., 2017). Therefore, at the same time, the plants have green fruits, which are immature, orange fruits, which are in the maturation phase and red fruits, matured and in ripening, causing problems related to the harvest due to the complete unevenness of fruit development (Araújo et al., 2018). Thus, determining the appropriate harvest period is essential to reduce losses and provide a longer commercialization period by increasing the shelf-life of the fruits (Rodrigues et al., 2012).

The fruit maturation is evaluated according to the physicochemical characteristics, mainly based on skin color (Chaki et al., 2015). Also, the maturation process is characterized by different stages, amongst them growth and development of the fruits and lastly ripening, and in this last stage the fruits undergo a sequence of physiological and biochemical alterations making the fruit more attractive and tastier (Villa-Rivera & Ochoa-Alejo, 2021). Thus, during ripening, the color of the peppers is altered due to the degradation of chlorophyll and the synthesis of carotenoids, giving different shades of colors to the epidermis, being the main color used as an indicator of ripening the red color (Rêgo et al., 2011). In addition to color change, other parameters are altered during fruit ripening, affecting the dimensions, cell wall composition, synthesis of aromatic compounds, conversion of starches to sugars, and the ratio of sugars to acids, which provide texture, aroma, and flavor to the fruit (Pereira et al., 2014; Soethe et al., 2016; Villa-Rivera & Ochoa-Alejo, 2021).

However, the characteristic coloration of fruit ripeness varies according to species and cultivar (Domenico et al., 2012; Ribeiro et al., 2018), therefore it cannot be extrapolated as a standard for all genotypes. In 'dedo-de-moça' pepper (*Capsicum baccatum* L.), the harvest should be performed when the fruits present a predominant red coloration, being related to the maximum content of soluble solids and adequate acid content (Soethe et al., 2016). In 'malagueta' peppers (*Capsicum frutescens* L.), characterized by high pungency, the harvest can still be performed when the fruits present green color (Fayos et al., 2017). Nevertheless, works evaluating the harvest point of *C. chinense* Jacq. for consumption are scarce, being limited to determining the best harvest period for seed collection (Abud et al., 2013; Pereira et al., 2014; Araújo et al., 2018; Jorge et al., 2018).

The objective of this study was to evaluate the physicochemical characteristics of the *C. chinense* Jacq. at different stages of maturity and to determine the ideal harvest point of the fruits according to the coloration of the epidermis.

Materials and Methods

The study was conducted in the experimental area of the Universidade Federal do Pampa, Itaqui, Rio Grande do Sul, Brazil (coordinates 29° 9' 21.68" S; 56° 33' 2.58" W, altitude 74 m). The soil was classified as dystrophic Argiluvic Plinthsol (Embrapa, 2018) and, according to the Köppen classification, the climate of the region is of type Cfa, subtropical without defined dry season (Kuinchtner & Buriol, 2001).

To produce seedlings, pepper seeds of the Iracema cultivar (Isla®) were sown in expanded polystyrene trays with 128 cells, containing the Mecplant® commercial substrate, with one seed per cell at a depth of 0.4 cm. The trays were placed on iron benches at one meter high and kept in a greenhouse, covered with 120-micron transparent polyethylene. The transplantation was performed when the plants had approximately four expanded leaves and arranged in beds made in east-west direction, with 1.5 × 0.4 m spacing between beds and between plants, respectively.

In the planting area, pH correction was performed according to the need for corrective material indicated by the soil analysis (Table 1). The fertilization recommendation was made using the indicated for the bell pepper culture. The basic fertilization consisted of 20 kg ha^{-1} of N, 280 kg ha^{-1} of P_2O_5, and 40 kg ha^{-1} of K_2O in the forms of urea (45% N), triple superphosphate (41% P_2O_5) and potassium chloride (58% K_2O), respectively. The cover fertilization consisted of 140 kg ha^{-1} of N and 180 kg ha^{-1} of K_2O, in the forms of urea and potassium chloride, respectively, being divided into two applications, performed at 30 and 60 days after transplantation.

The experiment was conducted in a completely randomized design, with five treatments and four repetitions, with each sample formed by 40 fruits. The treatments consisted of five stages of maturation according to the skin color, characterized

Table 1. Chemical composition of the soil in the cultivation area.

Clay	O.M.	V	pH	Index	P	K	Al	Ca	Mg	H + Al	CTC
	(%)		water	SMP	(mg dm^{-3})			(cmol$_c$ dm^{-3})			pH$_7$
22.0	1.2	41.6	4.9	5.7	3.6	11.0	1.0	3.1	1.3	6.2	10.5

Figure 1. Maturation stage of the *C. chinense* Jacq. according to the coloration: green (1), orange-green (2), orange (3), red-orange (4), and red (5).

as: (1) green, (2) orange-green, (3) orange, (4) red-orange, and (5) red (Figure 1). The fruits were harvested at 150 days after transplantation and immediately transported to the laboratory where the classification was carried out, in order to remove the fruits with incidence of damage and homogenize the samples.

The evaluations of the physical parameters of fruits consisted of determining the fresh mass, vertical and horizontal diameters, pericarp thickness, cracked fruit, luminosity, chroma, and hue angle. The fresh mass of fruits was obtained by weighing each fruit individually on a precision analytical balance and the values expressed in grams. The vertical and horizontal diameters and the pericarp thickness were obtained by measuring with a digital caliper and the values expressed in millimeters. The incidence of cracked fruit was determined visually by counting fruits that showed cracking, expressed as a percentage. A digital colorimeter was used to determine the luminosity, chroma, and hue angle, and the analysis was performed in the equatorial region of the fruits (Ribeiro et al., 2017).

The fruits were crushed in a juice extractor centrifuge and chemical evaluations were performed to determine the pH, total soluble solids, titratable acidity, and ratio (Adolfo Lutz Institute, 2008). The pH values were obtained by direct reading in a potentiometer. Total soluble solids were determined by refractometry, in which 1 mL of juice was placed over the prism of the digital refractometer and the values expressed in °Brix. The titratable acidity was obtained by diluting a 10 mL aliquot of juice in 100 mL of distilled water and titrating with a 0.1 M NaOH solution until the turning point using the phenolphthalein reagent, expressed as citric acid percentage. The ratio was obtained by the ratio between soluble solids and titratable acidity.

The results were submitted to the analysis of normality, by the Shapiro-Wilk test, and homogeneity of variances by the Bartlett test. Subsequently, the results were subjected to analysis of variance, and the means were compared using the Tukey test at 5% probability. The results were submitted to the determination of the correlation coefficients of Pearson and were also subjected to analysis of the principal components using the Past® program to show an overview of the results. Before the multivariate analysis, the data matrix of each variable was automatically scaled to obtain the same weight for all variables (mean = 0 and variation = 1).

Results and Discussion

The dependent variables were changed according to the factors evaluated, being emphasized through multivariate analysis (Figure 2). The principal components one (PC I) (Figure 2A) and two (PC II) (Figure 2B) explained 91.82% of the total variation between the variables. While PC I show the changes that occurred during maturation and ripening, PC II distinguishes fruits in the maturation process from immature and ripened fruits. From the evaluations carried out, there was an increase in the weight and fruit size, in addition to an increase in the hue angle, giving red color to the skin and an accumulation of sugars and acids in the fruits as the maturation stage increased. However, there was also an increase in the number of fruit cracking which can limit the period of commercialization and consumer acceptance as the maturation progressed and with the increase of fruit dimensions.

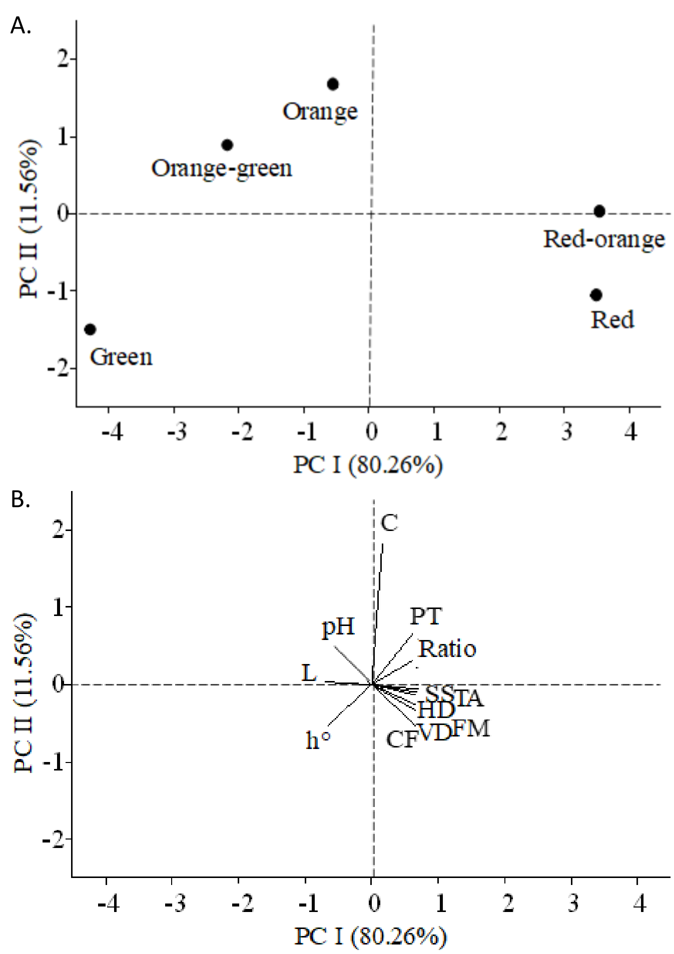

Figure 2. Analysis of the principal components between the maturation stages (A) and the relationship with dependent variables (B), fresh mass (FM), vertical diameter (VD), horizontal diameter (HD), pericarp thickness (PT), cracked fruit (CF), pH, soluble solids (SS), titratable acidity (TA), ratio, luminosity (L), chroma (C), and hue angle (h°) of *C. chinense* Jacq.

The fresh mass of the fruits increased according to the stages of maturation, with a maximum value at the red-orange stage, reducing significantly in the red stage (Table 2). The lowest values were found in the green stage, not differing from the orange-green- and orange-colored fruits. The reduction of fresh mass observed in the red stage was also verified by Biles et al. (1993) when evaluating the ripening of certain Mexican peppers. However, the values analyzed in this study are above those verified by Domenico et al. (2012) regardless of the maturation stage, since they found an average fruit mass of 1.40 g of *C. chinense* Jacq. Similarly, the results found from the analysis process are also above the average values analyzed by Reis et al. (2015) in the characterization of *C. chinense* Jacq., 1.51 g in the red stage. During the maturation process the fruits grow linearly until they become ripe, this fact can be attributed to the constant movement of water and carbohydrates that are sent from the stem. However, at the stage of fruit ripening there is a limitation of these inflows, due to the formation of a zone of abscission in the pedicel, ceasing its development (Dominguez et al., 2012). Thus, the mass of the fruit is closely related to its degree of ripeness and development, with fresh mass being highly correlated to fruit size (Figure 3). Similarly, Reis et al. (2015) also found a high correlation between fruit weight and vertical and horizontal diameter. Also, Biles et al. (1993) found that fruit mass is also highly correlated with fruit firmness and water content.

In the same way, the diameters (vertical and horizontal) increased according to the stages of maturation, with the highest values being observed in the red-orange and red stage (Table 2). These results may be due to the increase in the accumulation of water, which intensifies during the fruit maturation, contributing to the increase of the internal pressure, and consequently, to the increase of the turgidity, leading to the expansion of the fruit size (Dominguez et al., 2012; Jorge et al., 2018). There are few studies in the literature evaluating the growth of *C. chinense* Jacq. during maturation. Domenico et al. (2012) evaluating the physicochemical characteristics of pepper accessions, found values of 23 and 11 mm for vertical and horizontal diameter, respectively, for *C. chinense* Jacq. harvested with red color. The results of this study also coincide with those of Heinrich et al. (2015), who when analyzing the physicochemical characteristics of 'biquinho-salmon' pepper progenies at the harvest found variations between 28.5 to 19.8 mm, and 16.6 to 12.1 mm for vertical and horizontal diameter, respectively.

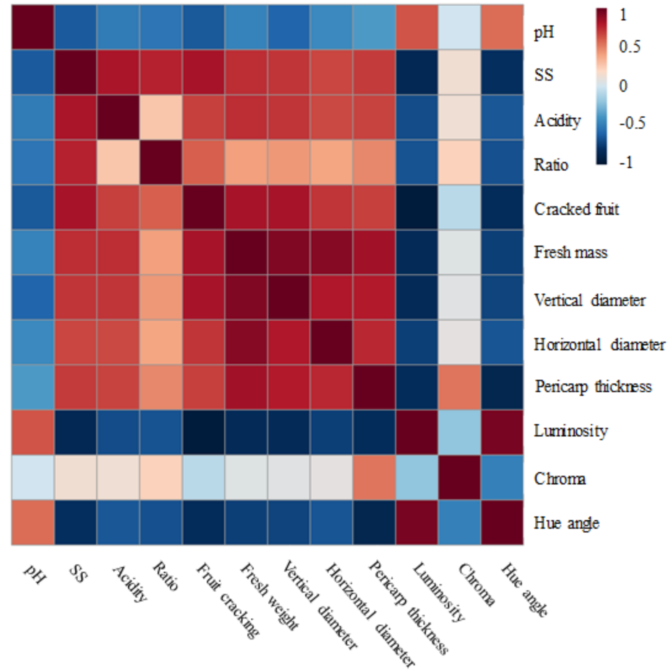

Figure 3. Heat map of Pearson correlation between physicochemical attributes of *C. chinense* Jacq.

Regarding the pericarp thickness, it was found that fruits in the red-orange stage had the largest dimensions (Table 2). The green stage expressed the lowest value, with a reduction of 39.5%, when compared to the red-orange maturation stage. In addition, there was a reduction in the pericarp thickness and in the dimensions of the fruit in the red stage, indicating that high mass loss may have occurred due to the metabolic changes that intensify during ripening and also due to the increase in the incidence of cracks (Figure 3), thus reducing its use and appreciation (Farias et al., 2011). These results corroborate those obtained in pepper accessions by Lannes et al. (2007), where values between 1.57 to 3.39 mm were observed, and the greater the thickness of the pericarp, the greater the dimensions of the fruit and the yield of pulp. The results found by Jorge et al. (2018) also coincide with this study, being verified the lowest values for the green stage 1.30 and 2.04 mm for the stage with more advanced maturity, however without having reached full maturity. Based on this, the thickness of the pericarp becomes a commercially interesting characteristic, because fruits with thicker pericarp have greater firmness, are more resistant to postharvest injuries,

Table 2. Fresh mass (FM), vertical diameter (VD), horizontal diameter (HD), pericarp thickness (PT), and cracked fruit (CF) of *C. chinense* Jacq. at different stages of maturation.

Stages of maturation	FM (g)	VD	HD (mm)	PT	CF (%)
Green	1.63 cd	20.97 c	15.04 bc	1.77 d	0.00 d
Orange-green	1.52 d	21.20 c	14.32 c	2.13 c	3.75 d
Orange	1.67 c	21.50 c	15.13 b	2.54 b	11.25 c
Red-orange	2.06 a	24.25 a	16.19 a	2.93 a	40.00 b
Red	1.89 b	23.36 b	15.45 ab	2.49 b	56.88 a
CV (%)	17.18	9.68	12.84	8.79	12.49

* Averages followed by the same letter in the column do not differ from each other by the Tukey test (p ≥ 0.05).

also contributing to increase the period of commercialization and consumption *in natura* form (Finger & Pereira, 2016).

The fruit cracking showed a significant difference between the stages of maturation, increasing progressively according to the harvest stages, with the highest percentage corresponding to red stage (Table 2). The main cause of the fruits cracking is their inadequate water balance, showing that the cuticle division occurs as a result of the high turgor pressure in the underlying pericarp and in the layers of epidermal cells (Aloni et al., 1998).

The increase in water content occurs during the night and the decrease during the day, this variation causes the cuticle to weaken and leads to its rupture. It is possible to confirm this with the correlation of split fruits with fruit weight and size and the inverse relationship with the color parameters (Figures 2 and 3), showing that as the fruits advance in maturity, there is a tendency of rupture occurrences. Such factor may also be associated with cuticle thickness, as according to Vieira et al. (2020) when analyzing tomatoes at different stages of maturation, found that cuticle thickening increases during development and decreases in fully ripe fruits. This is due to the fact that cuticle deposition ceases before complete ripening of the fruits, so that ripe fruits have less cuticle per surface unit, meaning, thinner cuticle. And thus, so many fruits in full maturity suffer from degradation of cell wall components. Since fruit cracking occurs only after it reaches its maximum size and red coloration, there is the indication that immature peppers can suffer elongation with the increase of turgidity without causing ruptures (Aloni et al., 1999). The loss of water, either by the decrease of turgidity due to cracks or by the increase of respiratory activity, is one of the main problems of postharvest, resulting in the loss of luminosity, weight and shrinkage of the fruits (Figure 3), causing the useful life of pepper fruits to be reduced (Aloni et al., 1999; Finger & Pereira, 2016). Therefore, the thicker the cuticle is at the harvest stage, the longer will be the durability of this fruit (Vieira et al., 2020). Thus, it is important that the fruit harvest is performed at the optimal maturity stage to minimize water losses during storage and the marketing period (Lufu et al., 2020).

Regarding the fruit color, the chroma varied significantly depending on the maturation stages. The highest averages were observed in the orange stage, while the lowest averages were seen in the green stage (Table 3). On the other hand, the luminosity and the hue angle showed a decrease along the stages of maturation, with the highest values observed in the green stage and the lowest values in the red stage (Table 3). These results coincide with those of Soethe et al. (2016), who found a decrease in the values of luminosity and hue angle with the maturation of 'dedo-de-moça' peppers.

Table 3. Luminosity (L*), chroma (C*), and hue angle (h°) of *C. chinense* Jacq. at different stages of maturation.

Stages of maturation	L*	C*	h°
Green	74.68 a	31.60 e	111.20 a
Orange-green	68.50 b	39.04 b	67.99 b
Orange	63.64 c	41.00 a	53.56 c
Red-orange	54.94 d	37.89 c	37.24 d
Red	50.99 e	34.68 d	29.57 e
CV (%)	2.75	6.57	7.93

* Averages followed by the same letter in the column do not differ from each other by the Tukey test (p ≥ 0.05).

Immature pepper fruits contain a high concentration of chlorophyll, giving it a green color. During the maturation process, chlorophyll degradation occurs and fruit color changes due to changes in the accumulation of carotenoids caused by the ethylene, thus, ripe fruits have great concentration of carotenoids, which can give peppers a yellow, orange or red coloration (Biles et al., 1993; Finger & Pereira, 2016). However, the harvests for 'chili' peppers are made considering only visual aspects such as color, and it is important to point out that as the luminosity and hue angle decreased, giving the red color, there was an increase in the parameters fruit mass and size, pericarp thickness and soluble solids. Still, there was also an increase in the incidence of cracked fruit, which may limit their commercialization (Figure 3).

The pH was shown to be decreasing throughout the maturation stages, with the highest values obtained in fruits in the green stage being significantly higher than the fruits in the red stage (Table 4). These results are lower than those verified by Borges et al. (2015), who when evaluating the physicochemical characteristics of peppers, found average pH values of 5.45. In the same way, Acunha et al. (2017) when evaluating the bioactive compounds of a pepper collection, found a variation of 5.2 to 6.5 in the pH values. Thus, the results found in the present study describe fruits with slightly more acidic pH. This result can be considered a commercially beneficial aspect, since fruits with a more acidic pH are more stable to deterioration when compared to foods that have a pH close to neutrality, thus offering less risk of contamination by microorganisms harmful to human health (Borges et al., 2015).

Table 4. pH, soluble solids (SS), titratable acidity (TA), and ratio of *C. chinense* Jacq. at different stages of maturation.

Stages of maturation	pH	SS (°Brix)	TA (% citric acid)	Ratio
Green	4.74 a	2.45 b	0.43 b	3.35 b
Orange-green	4.71 ab	2.58 b	0.50 ab	5.20 ab
Orange	4.69 ab	2.95 ab	0.50 ab	5.97 ab
Red-orange	4.64 ab	3.90 ab	0.68 a	5.82 ab
Red	4.54 b	4.20 a	0.63 a	6.73 a
CV (%)	1.97	22.7	16.58	24.24

* Averages followed by the same letter in the column do not differ from each other by the Tukey test (p ≥ 0.05).

The content of soluble solids increased progressively in accordance with the stages of maturation, reaching a maximum value in the red-orange and red stages, with a significant difference for the green-orange and green stages (Table 4). Similarly, Rathnayaka et al. (2020) also verified an increase in the soluble solids content in pepper cultivars as the fruits matured. Still, these results corroborate those obtained by Tsegay et al. (2013) who evaluated the stages of maturation of sweet pepper fruits (*Capsicum annuum* L.) and found a progressive increase with fruit maturation, which may have occurred due to the dissociation of some structural organic molecules from soluble compounds. As the stages of maturation increase there is a decrease in the starch content due to hydrolysis, which results in the degradation of carbohydrates in several precursors to the metabolic pathways, as well an increase in the content of sugars, such as sucrose, glucose, and fructose (Aizat et al., 2014). In addition, during the maturation process there is a loss of fruit weight due to water loss, which results in an increase in the concentration of sugar within the tissues (Lannes et al., 2007; Rodrigues et al., 2012). Considering that the peppers are mainly consumed in fresh form, the sugar content is an important parameter to define the ideal stage of maturation for harvest (Pereira et al., 2008), in order to prolong the durability of the fruits.

In the same way, the acidity varied according to the stages of maturation, with fruits in red-orange stage presented the highest value, although differing only from the green stage (Table 4). These results coincide with those obtained by Acunha et al. (2017), who found a variation between 0.1 to 0.6% of citric acid, proving to be inversely proportional to the pH. According to the authors, this process occurs due to the dissociation of acids from potassium salts, so as the pH decreases the acidity increases, showing a negative correlation (Figure 3). These results also corroborate those obtained by Tsegay et al. (2013), who found an increasing trend in the values of titratable acidity as the maturation increased, until the intermediate maturation, decreasing later with ripening. This increase in titratable acidity values may be associated with an increase in the pectin methyl esterase enzyme activity that causes the degradation of pectin, as the hydrolysis of pectin methyl ester groups results in galacturonic acid residues, thus increasing acidity. On the other hand, the reduction in the values of titratable acidity in fruits harvested with more advanced maturation may be due to the use of organic acids in respiratory reactions or their conversion into sugars (Anthon & Barrett, 2012).

The ratio between soluble solids and titratable acidity increased with advancing maturation stages. The red stage obtained the maximum value but differed only from the green stage (Table 4). Similar results were verified by Soethe et al. (2016), who found that fruits in more advanced stages of maturation reached the highest ratio, due to the high content of soluble solids. According to Almeida & Durigan (2006) the flavor is constituted by the relationship between the sugar content and the acidity, so that the perception of a sweeter taste reflects a higher content of soluble solids and a more acidic taste is due to acidity. Considering that the *C. chinense* Jacq. is characterized by its mild flavor, and consumed mainly in fresh form, this balanced ratio of soluble solids with acidity is an important aspect to be considered by producers for the harvest of fruit in the ideal stage of maturation according to the destination and commercialization period.

Conclusions

As the stages of maturation advanced, the dimensions and fresh mass of the fruit increased, as did the incidence of cracked fruit, strictly related to fruit expansion. The soluble solids, acidity and ratio also increased and the pH decreased as the fruit ripened. Regarding color, the hue angle and luminosity showed a decreasing behavior with the advance of fruit maturation, giving red coloration to the fruit epidermis.

Therefore, *C. chinense* Jacq. should be harvested when the fruits present an red-orange color, because at this stage the fruits show larger dimensions, less incidence of cracks when compared to fruits at a more advanced stage of maturation, in addition to an adequate content of acids and sugars, giving them a smooth and balanced flavor, but still without having triggered all their metabolic reactions, which can contribute to increase their shelf life.

Compliance with Ethical Standards

Author contributions: Conceptualization: CBB, FJS; Investigation: CBB, FJS, SPF, MNB, LSS, LZE; Methodology: CBB, FJS, SPF, MNB, LSS; Resources: CBB, FJS, SPF, MNB, LSS, LZE; Supervision: LZE; Validation: CBB, FJS, SPF, MNB, LSS, LZE; Visualization: CBB, FJS, SPF, MNB, LSS, LZE; Writing – original draft: CBB; Writing – review & editing: CBB, FJS, SPF, MNB, LSS, LZE.

Conflict of interest: The authors declare that there is no possible conflict of interest that may influence the article.

Financing source: There were no funding sources.

Literature Cited

Abud, H.F.; Araujo, E.F.; Araujo, R.F.; Araujo, A.V.; Pinto C.M.F. Qualidade fisiológica de sementes das pimentas malagueta e biquinho durante a ontogênese. Pesquisa Agropecuária Brasileira, v.48, n.12, p.1546-1554, 2013. https://doi.org/10.1590/S0100-204X2013001200003.

Acunha, T.S.; Crizel, R.L.; Tavares, I.B.; Barbieri, R.L.; Pereira, C.M.P.; Rombaldi, C.V.; Chaves, F.C. Bioactive compound variability in a Brazilian *Capsicum* pepper collection. Crop Science, v.57, n.3, p. 1611-1623, 2017. https://doi.org/10.2135/cropsci2016.08.0701.

Aizat, W.M.; Dias, D.A.; Stangoulis, J.C.R.; Able, J.A.; Roessner, U.; Able, A.J. Metabolomics of capsicum ripening reveals modification of the ethylene related-pathway and carbon metabolism. Postharvest Biology and Technology, v.89, p.19-31, 2014. https://doi.org/10.1016/j.postharvbio.2013.11.004.

Almeida, G.V.B.; Durigan, J.F. Relação entre as características químicas e o valor dos pêssegos comercializados pelo sistema veiling frutas Holambra em Paranapanema-SP. Revista Brasileira de Fruticultura, v.28, n.2, p.218-221, 2006. https://doi.org/10.1590/S 0100-29452006000200014.

Aloni, B.; Karni, L.; Moreshet, S.; Yao, C.; Stanghellini, C. Cuticular cracking in bell pepper fruit: Effects of fruit water relations and fruit expansion. The Journal of Horticultural Science and Biotechnology, v.74, n.1, p.1-5, 1999. https://doi.org/10.1080/14620316.1999.11511062.

Aloni, B.; Karni, L.; Rylski, I.; Cohen, Y.; Lee, Y.; Fuchs, M.; Moreshet, S.; Yao, C. Cuticular cracking in pepper fruit: Effects of night temperature and humidity. The Journal of Horticultural Science and Biotechnology, v.73, n.6, p.743-749, 1998. https://doi.org/10.1080/14620316.1998.11511042.

Anthon, G.E.; Barrett, D.M. Pectin methylesterase activity and other factors affecting pH and titratable acidity in processing tomatoes. Food Chemistry, v.132, n.2, p.915-920, 2012. https://doi.org/10.1016/j.foodchem.2011.11.066.

Araújo, R.F.; Abud, H.F.; Silva, L.J.; Araujo, E.F.; Pinto, C.M.F.; Silva, F.W.S. Alterações fisiológicas e atividade de enzimas antioxidantes em sementes de pimentas *Capsicum chinense* Jacq. e *Capsicum frutescens* L. durante o processo de maturação. Revista Ceres, v.65, n.6, p.534-545, 2018. https://doi.org/10.1590/0034-737x201865060009.

Bernardo, C.O.; Martins, I.B.A.; Pinto, C.M.F.; Pinto, C.L.O.; Bittencourt, F.; Martins, M.L.; Martins, E.M.F. Desenvolvimento de extrato de pimenta-biquinho como forma de conservação pós-colheita. Revista Brasileira de Agropecuária Sustentável, v.5, n.2, p.29-37, 2015. https://doi.org/10.21206/rbas.v5i2.297.

Biles, C. L.; Wall, M. M.; Blackstone, K. Morphological and physiological changes during maturation of new Mexican type peppers. Journal of the American Society for Horticultural Science, v.118, n.4, p.476-480, 1993. https://doi.org/10.21273/JASHS.118.4.476.

Borges, K.M.; Vilarinho, L.B.O.; Melo Filho, A.A.; Morais, S.B.; Rodrigues R.N.S. Caracterização morfoagronômica e físico-química de pimentas em Roraima. Revista Agro@mbiente On-line, v.9, n.3, p.292-299, 2015. https://doi.org/10.18227/1982-8470ragro.v9i3.2766.

Chaki, M.; Morales, P.A.; Ruiz, C.; Begara-Morales, J.; Barroso, J.B.; Corpas, F.J.; Palma, J.M. Ripening of pepper (*Capsicum annuum*) fruit is characterized by an enhancement of protein tyrosine nitration. Annals of Botany, v.116, n.4, p.637-647, 2015. https://doi.org/10.1093/aob/mcv016.

Domenico, C.I.; Coutinho, J.P.; Godoy, H.T.; Melo, A.M.T. Caracterização agronômica e pungência em pimenta de cheiro. Horticultura Brasileira, v.30, n.3, p.466-472, 2012. https://doi.org/10.1590/S0102-05362012000300018.

Dominguez, E.; Fernandez, M.D.; Hernandez, J.C.L.; Parra, J.P.; España, L.; Heredia, A.; Cuartero, J. Tomato fruit continues growing while ripening, affecting cuticle properties and cracking. Physiologia Plantarum, v.146, n.4, p.473-486, 2012. https://doi.org/10.1111/j.1399-3054.2012.01647.x.

Empresa Brasileira de Pesquisa Agropecuária - Embrapa. Sistema brasileiro de classificação de solos. 5.ed. Rio de Janeiro: Embrapa, 2018. 356p.

Farias, J.F.; Araújo Neto, S.E.; Álvares, V.S.; Ferraz, P.A.; Furtado, D.T.; Souza, M.L. Maturação e determinação do ponto de colheita de frutos de envira-caju. Revista Brasileira de Fruticultura, v.33, n.3, p.730-736, 2011. https://doi.org/10.1590/S0100-29452011005000100.

Fayos, O.; Aguiar, A.C.; Jiménez-Cantizano, A.; Ferreiro-Gonzáles, M.; Garcés-Claver, A.; Martínez, J.; Mallor, C.; Ruiz-Rodríguez, A.; Palma, M.; Barroso, C.G.; Barbero, G. Ontogenetic variation of individual and total capsaicinoids in malagueta peppers (*Capsicum frutescens*) during fruit maturation. Molecules, v.22, n.5, p.1-12, 2017. https://doi.org/10.3390/molecules22050736.

Finger, F.L.; Pereira, G.M. Physiology and postharvest of pepper fruits. In: Rêgo, E.R.; Rêgo, M.M.; Finger, F.L. (Eds.). Production and breeding of chilli peppers (*Capsicum* spp.). Cham: Springer, 2016. Chap. 2, p.27-40.

Gomes, G.P.; Junior, C.V.D.; Costa, D.S.; Queiroz, R.A.; Baba, V.Y.; Takahashi, L.S.A.; Gonçalves, L.S.A. Harvest season and seed physiological potential of 'dedo-de-moça BRS Mari' hot peppers. Semina: Ciências Agrárias, v.38, n.6, p.3897-3906, 2017. https://doi.org/10.5433/1679-0359.2017v38n6p3897.

Heinrich, A.G.; Ferraz, R.M.; Ragassi, C.F.; Reifschneider, F.J.B. Caracterização e avaliação de progênies autofecundadas de pimenta biquinho salmão. Horticultura Brasileira, v.33, n.4, p.465-470, 2015. https://doi.org/10.1590/S0102-053620150000400010.

Instituto Adolfo Lutz - IAL. Normas Analíticas do Instituto Adolfo Lutz. Métodos físico-químicos para análises de alimentos. 4.ed. (1.ed. digital). São Paulo: Instituto Adolfo Lutz, 2008. 1020p. https://wp.ufpel.edu.br/nutricaobromatologia/files/2013/07/NormasADOLFOLUTZ.pdf. 07 Dec. 2020.

Jorge, E.V.C.; David, A.M.S.S.; Figueiredo, J.C.; Bernardino, D.L.M.P.; Silva, R.A.N.; Alves, R.A. Estádio de maturação e repouso pós-colheita dos frutos na qualidade de sementes de pimenta biquinho. Revista de Ciências Agrárias, v.61, p.1-7, 2018. https://doi.org/10.22491/rca.2018.2725.

Kuinchtner, A.; Buriol, G.A. Clima do Estado do Rio Grande do Sul segundo a classificação climática de Köppen e Thornthwaite. Disciplinarum Scientia, v.2, n.1, p.171-182, 2001. https://periodicos.ufn.edu.br/index.php/disciplinarumNT/article/view/1136. 07 Dec. 2020.

Lannes, S.D.; Finger, F.L.; Schuelter, A.R.; Casali, V.W.D. Growth and quality of Brazilian accessions of *Capsicum chinense* fruits. Scientia Horticulturae, v.112, n.3, p.266-270, 2007. https://doi.org/10.1016/j.scienta.2006.12.029.

Lufu, R.; Amba, W.A.; Opara, U.L. Water loss of fresh fruit: Influencing pre-harvest, harvest and postharvest factors. Scientia Horticulturae, v.272, e109519, 2020. https://doi.org/10.1016/j.scienta.2020.109519.

Pereira, F.E.C.B.; Torres, S.B.; Silva, M.I.L.; Grangeiro, L.C.; Benedito, C.P. Qualidade fisiológica de sementes de pimenta em função da idade e do tempo de repouso pós-colheita dos frutos. Revista Ciência Agronômica, v.45, n.4, p.737-744, 2014. https://doi.org/10.1590/S1806-66902014000400011.

Pereira, G.M.; Finger, F.L.; Casali, V.W.D.; Brommonschenkel, S.H. Influência do tratamento com etileno sobre o teor de sólidos solúveis e a cor de pimentas. Bragantia, v.67, n.4, p.1031-1036, 2008. https://doi.org/10.1590/S0006-87052008000400027.

Rathnayaka, R. M. S. M. B.; Minami, M.; Nemoto, K.; Prabandaka, S. S.; Matsushima, K. Relationship between water supply and sugar and capsaicinoids contents in fruit of chili pepper (*Capsicum annuum* L.). The Japanese Society for Horticultural Science, v.90, n.1, p.58-67, 2020. https://doi.org/10.2503/hortj.UTD-217.

Rêgo, E.R.; Rêgo, M.M.; Matos, I.W.F.; Barbosa, L.A. Morphological and chemical characterization of fruits of *Capsicum* spp. accessions. Horticultura Brasileira, v.29, n.3, p.364-371, 2011. https://doi.org/10.1590/S0102-05362011000300018.

Reis, D. R.; Barbosa, C. M. D.; Silva, F. S.; Porto, A. G.; Soares, E. J. O. Caracterização biométrica e físico-química de pimenta variedade biquinho. Enciclopédia Biosfera, v.11 n.21, p.454-460, 2015. https://conhecer.org.br/ojs/index.php/biosfera/article/view/1765. 07 Dec. 2020.

Ribeiro, C. S. C; Soares, R. S.; Gomes L. M.; Coelho, L. G. F.; Reifschneider, F. J. B. Breeding Calabrian pepper lines for Brazilian agriculture from sui generis introduction of germplasm. Horticultura Brasileira, v.35, n.2, p.195-202, 2017. https://doi.org/10.1590/S0102-053620170207.

Ribeiro, C.S.C.; Carvalho, S.I.C.; Heinrich, A.G.; Reifschneider, F.J.B. BRS Tui: a new biquinho-type pepper cultivar released by Embrapa. Horticultura Brasileira, v.36, n.4, p.526-528, 2018. https://doi.org/10.1590/s0102-053620180417.

Rodrigues, F.A.; Penoni, E.S.; Soares, J.D.R.; Pasqual, M. Caracterização do ponto de colheita de *Physalis peruviana* L. na região de Lavras-MG. Bioscience Journal, v.28, n.6, p.862-867, 2012. http://www.seer.ufu.br/index.php/biosciencejournal/article/view/14039. 10 Jan. 2021.

Soethe, C.; Steffens, C.A.; Mattos, L.M.; Ferreira, N.A.; Mayer, D.M. Postharvest quality and functional compounds in ‘dedo-de-moça’ ‘BRS Mari’ pepper fruit at different stages of maturity. Ciência Rural, v.46, n.8, p.1322-1328, 2016. https://doi.org/10.1590/0103-8478cr20141795.

Tsegay, D.; Tesfaye, B.; Mohammed, A.; Yirga, H.; Bayleyegn, A. Effects of harvesting stage and storage duration on postharvest quality and shelf life of sweet bell pepper (*Capsicum annuum* L.) varieties under passive refrigeration system. International Journal for Biotechnology and Molecular Biology Research, v.4, n.7, p.98-104, 2013. https://doi.org/10.5897/IJBMBR2013.0154.

Vieira, D. A. P.; Caliari, M.; Souza, E. R. B. Quantitative cellular evaluation and anatomical organization of the external region of different genetic materials and maturation stages of tomato processing. Brazilian Archives of Biology and Technology, v.63, e20190348, 2020. https://doi.org/10.1590/1678-4324-2020190348.

Villa-Rivera, M. G.; Ochoa-Alejo, N. Transcriptional regulation of ripening in chili pepper fruits (*Capsicum* spp.). International Journal of Molecular Sciences, v.22, n.22, e12151, 2021. https://doi.org/10.3390/ijms222212151.