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Maturation of *Physalis peruviana* L. seeds according to flowering and age of the fruit[1]

Maturação das sementes de *Physalis peruviana* L. em função do florescimento e da idade dos frutos

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ABSTRACT - It is important to understand the seed maturation process to determine the time point at which the seeds achieve optimum quality and the ideal time for harvest. This study aimed to study the maturation of *Physalis peruviana* L. seeds, based on flowering time and age of the fruit. This study was conducted from March to October of 2016 and 2017, in the city of Piracicaba, São Paulo. The plants were cultivated in four blocks using four stems, with spacing of 1.0 m between the plants and of 2.5 m between the rows. As experimental treatments, two flowering time points were defined: 55 and 105 days after transplanting (DAT); in each period, the flowers were marked at the anthesis and the respective fruits and seeds were evaluated at 45, 60, 75, and 90 days after anthesis (DAA). Characteristics during fruit development, such as age (days after anthesis) and changes in color, mass, and flavor, are parameters indicating the physiological maturity of fruits and seeds. The flowering time of the plant and the stage of fruit development influence the maturation of seeds, which present higher germination and vigor when obtained from fruits harvested at 75 DAA (55 DAT) and 60 DAA (105 DAT), after mass maturity.

Key words: Cape gooseberry. Physiological maturity. Germination. Anthesis. Harvest.

RESUMO - O entendimento do processo de maturação das sementes é imprescindível para a identificação do momento que a alta qualidade é alcançada, bem como, do ponto ideal para a colheita. Objetivou-se estudar a maturação de sementes de *Physalis peruviana* L., segundo o momento do florescimento da planta e a idade dos frutos. O trabalho foi realizado entre março e outubro, nos anos de 2016 e 2017, Piracicaba, São Paulo. As plantas foram cultivadas em quatro blocos, dispostas em espaçamento 2,5 x 1,0 m e conduzidas com quatro hastes. Como tratamentos experimentais, foram distinguidos dois momentos de florescimento das plantas, 55 e 105 dias após o transplante (DAT), em cada período, as flores foram marcadas por ocasião da antese e os respectivos frutos e sementes avaliados aos 45, 60, 75 e 90 dias após a antese (DAA). As características durante o desenvolvimento do fruto como a idade (em dias após a antese) e as modificações da cor, da massa e do sabor são parâmetros indicativos da maturidade fisiológica do fruto e das sementes. O momento do florescimento da planta e o estádio de desenvolvimento do fruto influenciam a maturação das sementes, as quais apresentam maior germinação e vigor quando obtidas dos frutos colhidos a partir dos 75 DAA (55 DAT) e 60 DAA (105 DAT), posteriores à maturidade de massa.

Palavras-chave: Fisális. Maturidade fisiológica. Germinação. Antese. Colheita.

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INTRODUCTION

The knowledge regarding the nutritional and functional properties and the organoleptic characteristics of the fruit of *Physalis peruviana* L. (*Solanaceae*) has resulted in increases interest in the consumption of this product, thereby making its culture as an alternative for cultivation in the segment of small fruits business in Brazil (FISCHER; ALMANZA-MERCHÁN; MIRANDA, 2014; RAMADAN, 2011). However, studies on seed technology remain limited. Although it can be asexually propagated, seed is the primary requirement for the propagation of this species (MUNIZ *et al*., 2014).

Studies on the process of seed maturation are essential, as knowledge resulting from such studies will enable us to determine the time point at which the seeds achieve optimum quality and the ideal time for harvest. The stage of optimum quality varies with species, and in species with seeds that develop into fleshy fruits, the seeds usually exhibit maximum germination and vigor, when they reach maximum accumulation of dry mass or when physiological maturity is reached (FIGUEIREDO NETO *et al*., 2015; VIDIGAL *et al*., 2011). In species of fleshy fruits, such as *P. peruviana*, a correlation has been observed between fruit aspects, such as age, color, and physiological maturity of seeds, and the harvest time (ARANTES *et al*., 2018; PEREIRA *et al*., 2014).

P. peruviana has indeterminate growth, with uninterrupted flowering and fruiting (FISCHER; ALMANZA-MERCHÁN; MIRANDA, 2014) in the same plant and fruits in different stages of maturation, which makes it difficult to determine the physiological maturity of the seeds and the best time for harvest, similar to other *Solanaceae* such as *Capsicum* spp. (ABUD *et al*., 2013) and *Solanum melongena* L. (MARTINS *et al*., 2012).

However, to determine whether the fruits are ready for consumption, the calyx color associated with the qualitative characteristics of the fruits are the primary indicators of maturation and harvest time of *P. peruviana* (FISCHER; MARTÍNEZ, 1999), although some of the parameters that characterize fruit maturity may vary throughout the plant cycle (LIMA *et al*., 2012).

Similarly, variations may also occur in seed maturation, for instance, variations in the time of physiological maturity of the seed from a given species, depending on the genotype, position of the fruit in the plant, position of the seed inside the fruit, plant development stage, and environmental conditions (CARVALHO; NAKAGAWA, 2012).

Till date, no studies have been reported in the literature regarding the possible relationships among flowering time, the age of the fruit, and the physiological maturity of *Physalis peruviana* seeds. Thus, in this study, seed maturation as a function of the time of flowering and the age of the fruit were analyzed under the edaphoclimatic conditions of the city of Piracicaba, in the State of São Paulo.

MATERIAL AND METHODS

This study was conducted from March to October of 2016 and 2017, and the plants were grown in the Horticulture Sector (22°42’32.01”; 47°37’ 41.03”W, 546 m). The fruits and seeds were analyzed at the Laboratories of Post-Harvesting of Horticultural Products (LPCPH) and Seed Tests (LAS) of the Department of Plant Production, School of Agriculture Luiz de Queiroz, University of São Paulo (USP, ESALQ), located in Piracicaba, São Paulo.

The seedlings were grown in 50-cell polyethylene trays containing Basaplant® substrate with added subsoil and coconut fiber in proportion of 3:2:1 v/v, maintained in a nursery with 50% shadowing, and were transplanted at 60 days after sowing, when they were 15 cm tall and had three pairs of leaves. The soil of the experimental area was Red Nitosol, with clay texture, and it was previously prepared with two harrows and fertilized according to the results of the soil analysis. The spacing between the plants was 1.0 m and between the rows 2.5 m. Each row of 14 plants represented a block, totaling four blocks. Between the blocks, lines with identical number of plants were set, which were considered borders of the experimental plot. The plants were grown in an X system, where four main branches were defined and grown up till the height of 1.6 m high. Drip irrigation was used. Thinning of side branches and roguing were performed to eliminate plants with disease symptoms.

Meteorological data were recorded during cultivation, and the temperature measurements were used to calculate the thermal sum (accumulated degrees-day, DD). The interval from flower anthesis to the respective fruit harvests was noted, according to the method described by Salazar *et al*. (2008). Two flowering time points were considered: 55 and 105 days after transplanting (DAT). At each of these time points, the flowers were labeled at the anthesis and the fruits harvested at 45, 60, 75, and 90 days after anthesis (DAA). After the preset periods, 30 fruits from each block were harvested, 15 of which were used in fruit characterization and the remaining 15 for the extraction of the seeds.

Immediately after harvest, fruit mass with calyx (MFC) and without calyx (MFSC) was weighted using a digital scale of 0.01 g resolution. The color of the calyx and the fruit epidermis were obtained from readings at

opposite sides of the equatorial region of the calyx and the epidermis of the fruit, using a Minolta® colorimeter (Model CR-300) which registered the hue ($h°$) angle. The digital refractometer Atago PR-101, Palette was used to measure the soluble solids (SS), and the results were presented in °Brix at 20 °C. The titratable acidity (TA) was determined by titration with 1 N NaOH solution; the results are presented as a percentage of citric acid in one hundred grams of the juice; based on these values and that of SS, the SS/TA ratio was calculated.

Seed extraction was performed manually using a sieve and running water, and the seeds of lower density, i.e., supernatant, were discarded. Immediately after removal of the superficial water of the seeds with a paper towel, a portion of the sample was divided into eight replicates of 100 seeds (two samples from each block) and the water content (WC) was calculated based on the wet mass (BRASIL, 2009). To determine the average number of seeds per fruit (NSF), seeds were removed from two fruits of each replicate and counted.

Subsequently, the seeds were dried in an air-circulating oven at 33 °C for 24 h (based on pre-testing). After that, the WC and the weight of one thousand seeds were determined, adjusted to 7% of WC, and seedling germination and emergence tests were conducted. The germination test was conducted with four replicates of 50 seeds each, distributed on two sheets of blotting paper, moistened at the ratio of 2.3 times their dry mass and stored in transparent plastic boxes (11.0 × 11.0 × 3.0 cm). The boxes were kept in a germinator with a photoperiod of 8 h, at 25 °C, according to preliminary tests. Seedling emergence testing was also performed with four replicates of 50 seeds each, in expanded polystyrene trays containing Basaplant® substrate. In both tests, daily evaluations of the number of germinated, emerged, and normal seeds were conducted until the numbers stabilized. The results were presented in percentage (BRASIL, 2009), speed index (MAGUIRE, 1962), and mean germination and emergence times (days) (LABOURIAU, 1983).

The experimental design was randomized blocks, with four replications. The treatments were arranged in a 2 × 4 factorial scheme, represented by the two flowering time points (55 and 105 days DAT) and four levels of the age of the fruit (45, 60, 75, and 90 DAA). The data were subjected to analysis of variance and the comparisons between the means were performed by the Tukey's test ($p<0.05$).

RESULTS AND DISCUSSION

Results from fruit evaluations were significantly and interactively influenced by the treatments (flowering time and age of the fruit) in the two-year cultivation period (Figures 1 and 2). Changes were observed in the color of the calyx and the fruit epidermis, with the progress of maturation, i.e., fruits at 45 DAA had green calyx and epidermis; at 60 DAA, fruits had green-yellow calyx and yellow-greenish epidermis; at 75 DAA, both were completely yellow; whereas at 90 DAA, the fruit calyx was pale yellow and the epidermis was yellow-orange (Figure 3).

The color change is noticeable by visual inspection and confirmed by decreasing values of the hue ($h°$) angle. Starting at 75 DAA (55 DAT), the fruits presented the values of $h° \leq 82.0$ for the calyx and $h° \leq 78.4$ for the fruit epidermis, whereas the fruits from the second flowering time (105 DAT) presented lower values of $h°$ at 60 DAA. In addition, mean values of $h°$ of the fruit epidermis are lower than the mean values of $h°$ of the calyx, particularly in the fruits at 60 DAA. These observations suggest that the fruits resulting from the flowering at 105 DAT exhibit color change earlier, which initiates in the fruit epidermis first and later in the calyx.

The fruits, with and without calyx, harvested at 75 DAA and originating from the flowers at 55 DAT, had the largest masses, whereas those from the flowers at 105 DAT, the largest masses were obtained from 60 DAA. However, the mass values of fruits from the second flowering time are lower than those of the fruits from the first flowering time, particularly in 2017 (Figures 1 and 2).

As fruits matured, the SS and the *ratio* increased, and the titratable acidity decreased (Figures 1 and 2). Fruits harvested at 75 DAA (55 DAT) and 60 DAA (105 DAT) had the characteristics and standards indicative of maturity, which are required for harvesting and trading, as stated in the Colombian standards (INSTITUTO COLOMBIANO DE NORMAS TÉCNICAS Y CERTIFICACIÓN, 1999). The Colombian standards refer that the commercialization of the fruit of *Physalis peruviana* should be done when the content of SS is of minimum 14 Brix, the SS/TA ratio ≥ 6.0, and the titratable acidity of ≤ 2.34. The fruits from the second flowering time (105 DAT) exhibited higher amount of SS contents and, consequently, the ratio higher than those observed in the fruits harvested at the beginning of flowering (55 DAT).

These results are similar to those obtained by Fischer and Martínez (1999), who reported that as the *P. peruviana* fruit grows, increase in size, weight, and the relationship between SS and TA (ratio) are observed, reaching maximum concentrations of SS and β-carotene when the epidermis is orange, and this stage called phase 4 characterizes the physiological maturity of the fruit. To a certain extent, these findings are similar to the conclusions of Lima *et al*. (2009) and Rodrigues *et al*. (2012), who

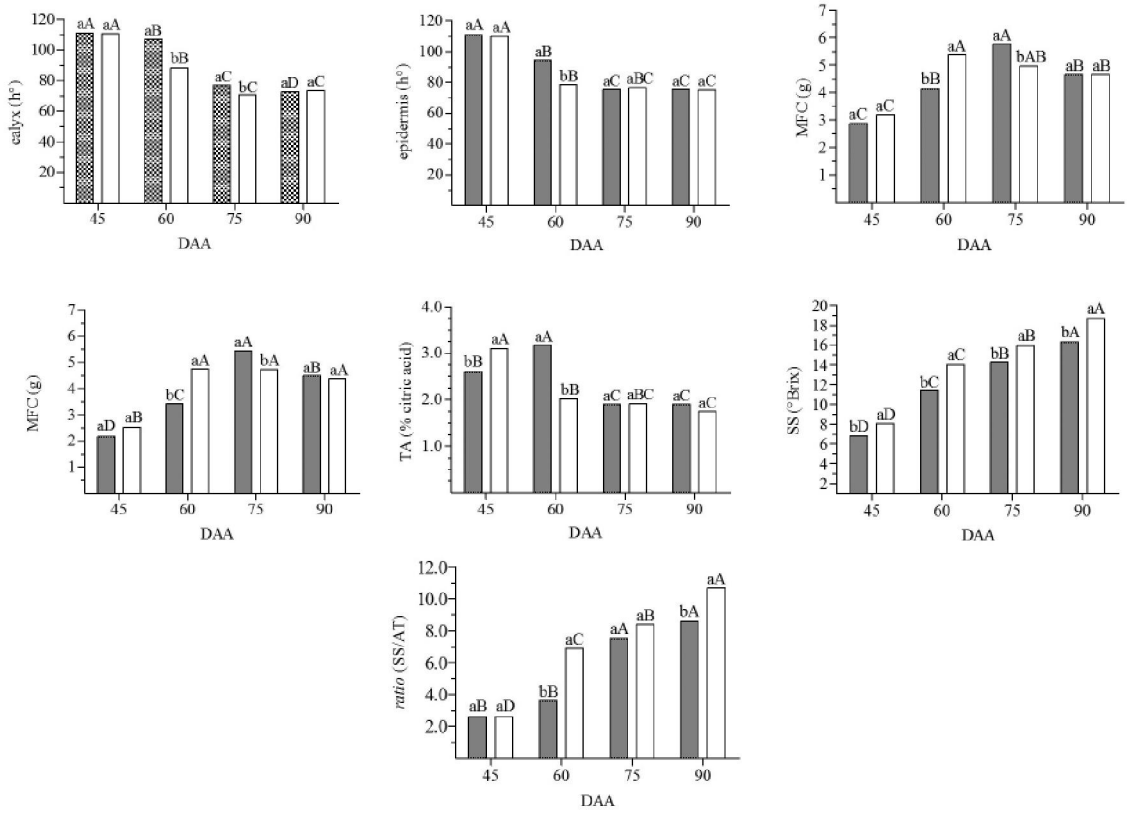
indicated that fruits can be harvested when the calyx presents a yellow-greenish to yellow-brownish color and have the highest masses, the largest diameters, and the maximum total SS and ratio.

The sum of thermal units in accumulated DD, corresponding to the period from the anthesis to the respective harvests, allowed the characterization of the fruit maturation stages. Considering that the physiological maturity of fruits is reached at 75 DAA (55 DAT) and 60 DAA (105 DAT), the corresponding thermal accumulation ranged from 880 to 892 DD and from 709 to 779 DD, respectively (Table 1). In field conditions, in the municipality of Capão do Leão, Rio Grande do Sul, Betemps *et al*. (2014), although they did not mark the flowers to determine the age of the fruit, they observed that flowering took place at 54 DAT and the fruit harvesting was done at 42 days after the emergence of the flowers, when the calyx color was yellow-greenish and with 624.9 DD of thermal accumulation.

The fruits from the second flowering time reached maturity, in less number of days and with lower thermal accumulation than the fruits from the first flowering time, regardless of the cultivation year. This difference may be related to the influence of temperature on fruit development in the different months of the year. During the development period of the fruits that were harvested at 75 DAA (55 DAT), average temperatures were 17.4 °C in 2016 and 17.6 °C in 2017, whereas during the development period of the fruits harvested at 60 DAA (105 DAT), the average temperature was 18.7 °C in both 2016 and 2017. Rainfall in the first year was 377.3 mm, which was lower than that in the second year (420.4 mm), but the relative humidity in the two years was similar (72%).

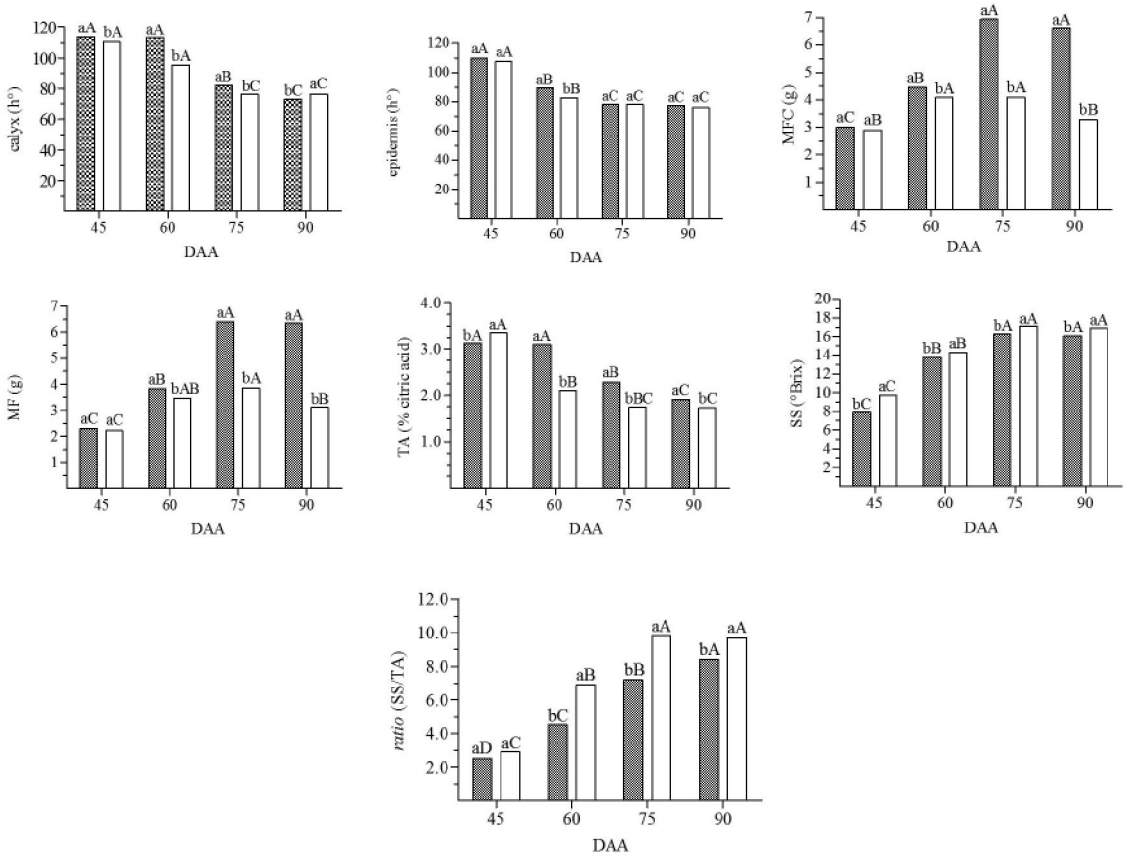
Regarding the seed maturation process in the 2016 experiment (Table 2), seeds extracted from the fruits harvested at 45 DAA and 60 DAA had the highest WC (30.8 and 29.2%, respectively), which stabilized at 75 DAA (28.2–28.4%). The lowest weight of one thousand

Figure 1 - Mean values of the hue (*h*°) angle for the calyx and the epidermis, fruit mass with calyx (MFC) and without calyx (MF), titratable acidity (TA), soluble solids (SS), and *ratio* (SS/AT) of *Phvsalis peruviana* L. fruits harvested at 45, 60, 75, and 90 days after anthesis (DAA), at two flowering time points: 55 ▩ and 105 □ days after transplanting (DAT). Year: 2016



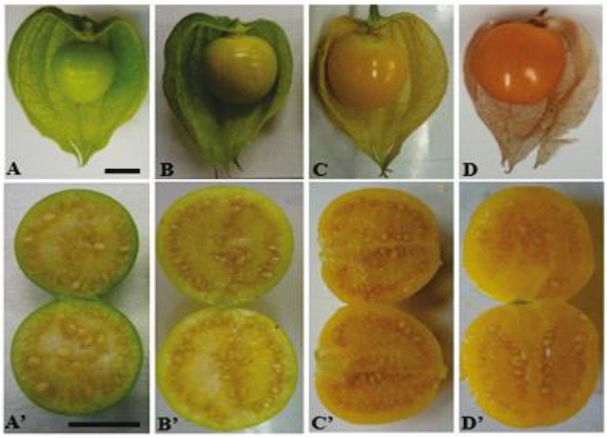
Means followed by the same letters, lowercase (compare flowering time points, DAT) and uppercase (compare the age of the fruit, DAA), do not significantly differ by the Tukey's test ($p<0.05$)

Figure 2 - Mean values of the hue (*h*°) angle for the calyx and the epidermis, fruit mass with calyx (MFC) and without calyx (MF), titratable acidity (TA), soluble solids (SS), and), and *ratio* (SS/AT) of *Phvsalis peruviana* L. fruits harvested at 45, 60, 75, and 90 days after anthesis (DAA), at two flowering time points: 55 ▩ and 105 ▭ days after transplanting (DAT). Year: 2017



Means followed by the same letters, lowercase (compare flowering time points, DAT) and uppercase (compare the age of the fruit, DAA), do not significantly differ by the Tukey's test ($p < 0.05$)

Figure 3 - Fruits of *Physalis peruviana* L., inside the calyx (A, B, C, and D) and sectioned in half, in a cross-section in relation to the fruit length, exposing the seeds (A', B', C,' and D'), harvested at 45, 60, 75, and 90 DAA, respectively. (Bars = 1 cm)



seeds at 7% of WC was found in the seeds collected from fruits harvested at 45 DAA (0.959 g), whereas the seeds collected from fruits harvested at 60 DAA showed no change in weight, remaining at approximately 1.0 g.

Analysis of the flowering time points (Table 2) revealed that the seeds of the fruits from the plants flowering at 55 DAT presented both WC and the weight of one thousand seeds higher than those of seeds of the fruits from the plants flowering at 105 DAT. However, the NSF did not change with the age of the fruit, although it was higher in the fruits from plants flowering at 105 DAT. Here, at the second flowering time there was an increase in the NSF and reduced seed mass.

In the second experiment (Table 3), the WC of the seeds decreased during fruit maturation, showing the lowest percentage at 75 DAA (26.2%–26.7%). The weight of one thousand seeds increased at 75 DAA, particularly in the fruits whose flowers emerged at 55 DAT. With

Table 1 - Degrees-day (DD) accumulated between the anthesis and the harvest of the fruits of *Physalis peruviana* L. at 45, 60, 75, and 90 days after anthesis (DAA), at two flowering time points: 55 and 105 days after transplanting (DAT). Years: 2016 and 2017

Florescimento	(DAA)			
	45	60	75	90
..... (2016)				
55 DAT	488	684	880	1.065
105 DAT	618	779	1.031	1.195
..... (2017)				
55 DAT	507	670	892	1.080
105 DAT	535	709	994	1.201

Table 2 - Means of water content (WC), weight of one thousand seeds (WOTS), and number of seeds per fruit (NSF) of *Physalis peruviana* L. obtained from fruits harvested at 45, 60, 75, and 90 days after anthesis (DAA), at two flowering time points: 55 and 105 days after transplanting (DAT). Year: 2016

Flowering	(DAA)				Mean
	45	60	75	90	
..... WC (%)					
55 DAT	33,0	30,0	28,0	28,7	29,9 a
105 DAT	28,6	28,4	28,4	28,0	28,3 b
Mean	30,8 A	29,2 AB	28,2 B	28,4 B	-
..... WOTS (g)					
55 DAT	0,992	1,065	1,040	1,032	1,032 a
105 DAT	0,927	0,941	0,987	0,967	0,955 b
Mean	0,959 B	1,003 AB	1,013 A	1,000 AB	-
..... NSF (unt)					
55 DAT	265	252	260	259	259 b
105 DAT	323	308	306	327	316 a
Mean	294 A	280 A	283 A	293 A	-
C.VWC = 6,4%; C.VWOTS= 3,2%; C.VNSF = 9,0%					

Means followed by the same letters, lowercase in columns and uppercase in rows, do not differ significantly by the Tukey's test ($p < 0.05$); C.V. = coefficient of variation

flowering at 105 DAT, the age of the fruit did not change, with one thousand seeds weighting from 0.954 to 0.999 g. There was no variation in the number of seeds extracted per fruit, regardless of the flowering time and the fruit development stage.

As a result of the composition of the pulp of fleshy fruits, the seeds had a high WC, even at physiological maturity, as already found for the seeds of other fleshy fruits such as *malagueta* pepper and *biquinho* pepper, which had 39% and 36% water, respectively, at 70 DAA (ABUD *et al*., 2013), and for pumpkin seeds which had 34.5% water at 60 DAA (FIGUEIREDO NETO *et al*., 2015).

Seeds extracted from fruits harvested at 75 DAA (55 DAT) and 60 DAA (105 DAT) had the weight of one thousand seeds similar to that obtained by Sbrussi *et al*. (2014), but these authors did not report a significant increase in weight as the maturation progressed, i.e., the weight of the seeds extracted from the fruit of green color was similar to the weight of the seeds obtained from the fruit of yellow color.

The NSF was equivalent to that reported by Fischer, Almanza-Merchán and Miranda (2014) ranging from 150 to 300 seeds, whereas Betancourt *et al*. (2008), morphologically characterized 24 accessions of *Physalis peruviana* that had 111–233 seeds per fruit. However,

Table 3 - Means of water content (WC), weight of one thousand seeds (WOTS), and number of seeds per fruit (NSF) of *Physalis peruviana* L. obtained from fruits harvested at 45, 60, 75, and 90 days after anthesis (DAA), at two flowering time points: 55 and 105 days after transplanting (DAT). Year: 2017

Flowering	(DAA)				Mean
	45	60	75	90	
..... WC (%)					
55 DAT	33,4	27,8	26,2	27,0	28,6 a
105 DAT	32,3	28,8	26,1	26,5	28,4 a
Mean	32,8 A	28,3 B	26,2 C	26,7 C	-
..... WOTS (g)					
55 DAT	0,931 bC	0,997 aB	1,015 aAB	1,048 aA	0,998
105 DAT	0,976 aA	0,976 aA	0,977 bA	0,949 bA	0,970
Mean	0,954	0,987	0,996	0,999	-
..... NSF (unt)					
55 DAT	277	286	259	246	267 a
105 DAT	266	260	271	241	260 a
Mean	271 A	273 A	265 A	243 A	-
C.VWC = 3,5%; C.VWOT S= 2,0%; C.VNSF = 9,3%					

Means followed by the same letters, lowercase in columns and uppercase in rows, do not differ significantly by the Tukey's test ($p < 0.05$); C.V. = coefficient of variation

the NSF is determined by the genotype, whereas the seed mass is due to the accumulation of reserve material during development.

After drying the seeds, the average WC was 7.0% and the percentage of germination increased depending on progress of fruit maturation, with the highest values starting from 60 DAA, consolidating at 75 DAA, regardless of the flowering time and the year of cultivation (Tables 4 and 5). Similar observations were noted with respect to the speed index and the mean germination time as the seeds extracted at 75 DAA exhibited a higher percentage of germination in the shortest time interval.

Apparently, drying the seeds did not induce a harmful effect on germination. Barroso *et al*. (2017), when studying the maturation of *Physalis ixocarpa*, found that the germination capacity was not affected after drying the seeds in advanced stages of development. However, tolerance to seed desiccation, besides varying among species, depends on the degree of maturity and environmental conditions during seed development and the time of seed dispersal (BARBEDO *et al*., 2013; LAMARCA *et al*., 2016).

The results of the germination test confirm an increase in germination percentage and germination speed with fruit maturation; however, Sbrussi *et al.* (2014) reported that fruit ripening stages do not influence the quality of *P. peruviana* seeds, as the seeds of green fruits exhibited the same germination and vigor as the seeds of yellow fruits.

The results presented by Criollo and Ibarra (1992) are similar to those obtained in this study, with lower percentage of germination of *P. peruviana* seeds observed in green fruits, as reduced germination was attributed to embryo immaturity, which can be affected by fruit maturation. Mazorra *et al*. (2003) reported that *P. peruviana* seeds extracted from fruits aged >30 days germinate and reach physiological maturity at 50 DAT, when the green-yellow colored calyx and yellow-greenish colored epidermis are observed, whereas the results reported by Ali and Singh (2015) show high percentage of seed germination and more vigorous seedlings of seeds obtained from fruits aged 56 days, declining at 63 days after the anthesis.

Seedling emergence was exclusively influenced by the age of the fruit, reaching the highest percentages at 60 DAA (Tables 6 and 7), similar to germination values under controlled test conditions. In the first year of this study, significant interactions of the treatments in

relation to the speed index and the mean time of seedling emergence were found; nevertheless, the best results were obtained with the seeds from the fruits harvested at 75 DAA (55 DAT) and 60 DAA (105 DAT).

Table 4 - Mean values of germination (G), germination speed index (ISG) and mean germination time (MGT) of *Physalis peruviana* L. seeds obtained from fruits harvested at 45, 60, 75, and 90 days after anthesis (DAA), at two flowering time points: 55 and 105 days after transplanting (DAT). Year: 2016

Flowering	(DAA)				Mean
	45	60	75	90	
..... G (%)					
55 DAT	9 bB	71 aA	72 bA	77 aA	57
105 DAT	39 aB	52 bB	89 aA	81 aA	65
Mean	24	62	80	79	-
..... ISG					
55 DAT	0,084 bC	1,412 aB	1,481 aAB	1,802 aA	1,195
105 DAT	0,515 aC	1,034 bAB	0,901 bB	1,329 bA	0,945
Mean	0,300	1,223	1,191	1,565	-
..... MGT (day)					
55 DAT	25,8 aA	12,8 aB	12,3 aB	11,8 aB	15,6
105 DAT	19,8 bA	13,0 aB	12,8 aB	11,8 aB	14,3
Mean	22,8	12,9	12,5	11,8	-
C.VG = 15,4%; C.VISG = 17,4%; C.VMGT = 8,6%					

Means followed by the same letters, lowercase in columns and uppercase in rows, do not differ significantly by the Tukey's test ($p < 0.05$); C.V. = coefficient of variation

Table 5 - Mean values of germination (G), germination speed index (ISG) and mean germination time (MGT) of *Physalis peruviana* L. seeds obtained from fruits harvested at 45, 60, 75, and 90 days after anthesis (DAA), at two flowering time points: 55 and 105 days after transplanting (DAT). Year: 2017

Flowering	(DAA)				Mean
	45	60	75	90	
..... G (%)					
55 DAT	14 bC	61 bB	86 aA	71 aAB	58
105 DAT	47 aB	85 aA	87 aA	75 aA	73
Mean	30	73	87	73	-
..... ISG					
55 DAT	0,143 bC	0,935 aB	1,649 aA	1,554 aA	1,070
105 DAT	0,652 aC	1,108 aB	1,638 aA	1,498 aA	1,224
Mean	0,397	1,021	1,644	1,526	-
..... MGT (day)					
55 DAT	24,0 aA	18,5 aB	13,5 aC	11,8 aC	16,9
105 DAT	19,0 bA	19,5 aA	13,5 aB	12,8 aB	16,2
Mean	21,5	19,0	13,5	12,3	-
C.VG = 15,9%; C.VISG = 16,9%; C.VMGT = 7,4%					

Means followed by the same letters, lowercase in columns and uppercase in rows, do not differ significantly by the Tukey's test ($p < 0.05$); C.V. = coefficient of variation

Table 6 - Means of seedling emergence (SE), seedling emergence speed index (SESI), and mean seedling emergence time (MSET) of *Physalis peruviana* L. seeds obtained from fruits harvested at 45, 60, 75, and 90 days after anthesis (DAA), at two flowering time points: 55 and 105 days after transplanting (DAT). Year: 2016

Flowering	(DAA)				Mean
	45	60	75	90	
..... SE (%)					
55 DAT	33	95	96	98	80 a
105 DAT	36	91	90	98	79 a
Mean	35 B	93 A	93 A	98 A	-
..... SESI					
55 DAT	0,671 aC	2,724 bB	3,309 aA	3,042 bAB	2,436
105 DAT	0,943 aC	3,291 aAB	3,155 aB	3,613 aA	2,750
Mean	0,807	3,007	3,232	3,327	-
..... MSET (day)					
55 DAT	25,3 aA	18,0 aB	14,5 aC	16,3 aBC	18,5
105 DAT	20,3 bA	15,0 bB	15,0 aB	14,0 bB	16,1
Mean	22,8	16,5	14,8	15,1	-
C.VSE = 9,0%; C.VSESI = 8,4%; C.VMSET = 8,9%					

Means followed by the same letters, lowercase in columns and uppercase in rows, do not differ significantly by the Tukey's test ($p < 0.05$); C.V. = coefficient of variation

Table 7 - Means of seedling emergence (SE), seedling emergence speed index (SESI), and mean seedling emergence time (MSET) of *Physalis peruviana* L. seeds obtained from fruits harvested at 45, 60, 75, and 90 days after anthesis (DAA), at two flowering time points: 55 and 105 days after transplanting (DAT). Year: 2017

Flowering	(DAA)				Mean
	45	60	75	90	
..... SE (%)					
55 DAT	46	87	94	94	80 a
105 DAT	38	84	88	92	76 a
Mean	42 B	86 A	91 A	93 A	-
..... SESI					
55 DAT	0,994	2,464	2,603	2,897	2,239 a
105 DAT	0,837	2,712	2,570	2,580	2,175 a
Mean	0,915 B	2,588 A	2.586 A	2,739 A	-
..... MSET (day)					
55 DAT	23,3	18,0	18,3	16,8	19,1 a
105 DAT	23,3	16,0	15,8	15,5	17,6 b
Mean	23,3 A	17,0 B	17,0 B	16,1 B	-
C.VSE = 9,8%; C.VSESI = 10,5%; C.VTMEP = 5,2%					

Means followed by the same letters, lowercase in columns and uppercase in rows, do not differ significantly by the Tukey's test ($p < 0.05$); C.V. = coefficient of variation

No significant interaction of the treatments in relation to seedling emergence was found in 2017, contrary to that in 2016. The fruit development stage, whose seeds had the highest speed indices, also provided the highest percentages of germination and the shortest mean emergence times (60 DAA), which was favored in

seeds collected from fruits whose flowers emerged at 105 DAT.

In general, germination test results suggest that seeds from fruits harvested at 75 DAA (55 DAT) and 60 DAA (105 DAT) and later exhibit higher quality, whereas in seedling emergence tests, favorable results were obtained at 60 DAA and later. At these stages, the seeds still had a high WC, maximum germination, and maximum vigor, following the maximum accumulation of dry mass.

Although the dry mass is the ideal indicator of the seed development stage, this characteristic should not be used as the only parameter because physiological and biochemical changes in the seed may occur, even after the maximum content of dry mass is reached. In some species, the maximum physiological parameter is reached after the maximum dry mass accumulation (CARVALHO; NAKAGAWA, 2012).

Throughout the development process, the changes in color, from green to yellow, as well as an increase in mass and sugar content and reduced acidity were evident, which characterized the maturity of fruits harvested at 75 DAA (55 DAT) and 60 DAA (105 DAT), whose seeds presented the best results of seed germination and seedling emergence.

The effect of the flowering time on the fruit and seed maturation process was also evident, as such influence is related to the temperature during these phenological phases, as demonstrated by Demir, Ashirov, and Mavi (2008) who, when growing tomato plants in a greenhouse for two seasons, concluded that the seeds reached maximum dry mass and seedling emergence at 50 and 60 DAA in spring and 80 and 115 DAA in autumn, respectively. They attributed these maturation differences to the environmental conditions during seed development, as temperatures in spring are higher than in the fall.

Tomato seeds produced during the rainy season reached physiological maturity at 50 DAA; however, during winter, a 10-day maturity delay was noted. Singkaew *et al*. (2017) attributed this delay to the higher luminous intensity (7.4 $W.m^2$), higher temperature variation between day and night (12.9 °C), and lower relative humidity (64.1%), in relation to the rainy season (2.4 $W.m^2$, 6.2 °C, and 79.2%, respectively). Therefore, these results help justify the difference (in the number of days) of maturation of *P. peruviana* seeds produced at different time points of plant development.

CONCLUSIONS

1. Characteristics during fruit development, such as age (in DAA) and changes in color, mass, and flavor are parameters that indicate the physiological maturity of the *P. peruviana* fruits and seeds;
2. The maturation of *P. peruviana* seeds is influenced by the fruit development stage and the flowering time point of the plant;
3. The seeds of *P. peruviana* showed higher germination and vigor when obtained from fruits harvested at 75 DAA (55 DAT) and 60 DAA (105 DAT), following mass maturity.

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