

ลักษณะการเจริญเติบโตของผลแก้วมังกร และปัจจัยบางประการที่มีผลต่อคุณภาพผล

Fruit growth characteristics of pitaya fruit and some factors effecting on fruit qualities

สุภัทร์ อิศรางกูร ณ อยุธยา^{1*} และ พรศุณี อิศรางกูร ณ อยุธยา²

Supat Isarangkool Na Ayutthaya^{1*} and Pomsulee Issarangkool Na Ayutthaya²

บทคัดย่อ: การศึกษานี้ต้องการศึกษาลักษณะการเจริญเติบโตของผลแก้วมังกรที่ปลูกในเขตพื้นที่สูง และผลของช่วงเวลาออกดอก ขนาดผล อายุผล ต่อคุณภาพผลแก้วมังกร โดยทำการคัดเลือกแก้วมังกรจำนวน 20 ต้น ซึ่งปลูกด้วยค้างเดี่ยวสูง 1.5 เมตร ทำการติดเครื่องหมายวันที่ดอกบานในแก้วมังกรจำนวน 120 ดอก ซึ่งมีการออกดอกสองช่วง คือ กลางเดือนกรกฎาคม และต้นเดือนสิงหาคม ทำการสุ่มเก็บตัวอย่างผลที่อายุต่างๆ ต่อเนื่องโดยห่างกันประมาณ 4-7 วัน ตั้งแต่ผลมีอายุ 7 วัน จนถึง 41 วันหลังดอกบาน พบว่าการเจริญเติบโตของผลแก้วมังกรจากการประเมินด้วยน้ำหนักผลรวมและน้ำหนักเนื้อเป็นการเจริญแบบ simple sigmoid curve ส่วนการศึกษาลักษณะการเจริญเติบโตด้วยความกว้างและความยาวผลเป็นการเจริญแบบ double sigmoid curve ซึ่งแก้วมังกรที่ปลูกในเขตพื้นที่สูงควรเก็บเกี่ยวเมื่อผลมีอายุ 33-35 วันหลังดอกบาน การเก็บเกี่ยวแก้วมังกรที่ 40 วันหลังดอกบาน พบว่าเนื้อแก้วมังกรมีปริมาณ (total soluble solid, TSS) เพิ่มขึ้น และปริมาณ (titratable acidity, TA) ลดลง แต่ลักษณะเนื้อมีการฉ่ำน้ำไม่เหมาะกับการรับประทาน การเปรียบเทียบขนาดผลที่มีผลต่อคุณภาพผล พบว่าผลแก้วมังกรที่มีน้ำหนักมากกว่า 600 กรัมมีปริมาณ TSS และ TA สูงกว่าผลขนาดอื่นๆ นอกจากนี้การศึกษากำหนดผลต่อกิ่งพบว่าผลที่ได้จากกิ่งที่มีผลเดียวมี TA น้อยกว่าผลที่มาจากกิ่งที่มีสองผล

คำสำคัญ: แก้วมังกร อายุผล ขนาดผล ดัชนีชี้วัดการเก็บเกี่ยว

ABSTRACT: The aim of this study was to investigate the fruit growth pattern of pitaya (*Hylocereus undatus*) fruit planted in the semi-highland zone and effect of flowering period, fruit size and fruit age on fruit qualities. The 20 plants which planted from cuttings and trained on a 1.5 m-high vertical pole were selected. The 120 flowers of 2 periods of flowering had been tagged on mid-July and early August. Sample fruits were harvested randomly with 4 to 7 days interval from 7 to 41 days after blooming. The result showed that the flowering period had a little effect on some fruit qualities. The fruit growth pattern revealed by weighting that the whole fruit was a simple sigmoid curve growth

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¹ สาขาวิชาพืชสวน คณะเกษตรศาสตร์ มหาวิทยาลัยขอนแก่น

Department of Horticulture, Faculty of Agriculture, Khon Kean University

² ศูนย์วิจัยและพัฒนาการเกษตรในที่สูง สำนักวิจัยและพัฒนาการเกษตรเขตที่ 4 กรมวิชาการเกษตร

Non Sung Research and Development Center, Bureau of Agricultural Research and Development Region 4, Department of Agriculture

* Corresponding author. isupat@kku.ac.th

pattern, while a change of pulp width and length seemly expressed by a double growth curve. The optimum harvesting period of pitaya planted in highland zone was 33-35 days after bloom. On the over-ripening stage (40 days after bloom), the fruit had the highest in total soluble solid (TSS) and the lowest in titratable acidity (TA), but the pulp expressed more mucilage closely to injury. In comparison of fruit size effect on fruit quality found that the bigger fruit (>600 g) had the highest in both TSS and TA. Moreover, the number of fruit on the branch revealed that the single fruit on branch was lower in TA than the double fruit on branch.

Keywords: dragon fruit, fruit age, fruit size, harvesting index

INTRODUCTION

Pitaya or dragon fruit (*Hylocereus undatus*) is a tropical fruit in the climbing vine cactus species and it also is called “small exotic fruit” (Le Bellec et al., 2006). It originated from the tropical region of Latin America. Nowadays, it is being grown commercially in Israel, Vietnam, Taiwan, Australia, United States and also Thailand (Nerd et al., 1999; Merten, 2003; Wall and Khan, 2003; Le Bellec et al., 2006; Esquivel et al., 2007; Gunasena et al., 2007) and occupies a growing niche in the European exotic fruit market (Nerd et al., 1999; Le Bellec et al., 2006) and in the producer countries domestically.

The fruit-growth characteristic of all plants is naturally separated in to 2 types: 1) single sigmoid curve for the fruit without a hard endocarp, and 2) double sigmoid curve for the fruit with a hard endocarp. For pitaya, Nerd et al. (1999) reported that according to fruit age, the fruit-growth characteristic of the white-pulp pitaya planted in Israel is a simple sigmoid curve, which was considered by continuous fruit weight, fruit length and fruit diameter. These parameters are the entire fruit investigation for a fruit characteristic study. However, the focusing pattern of pulp growth is limited which could have a different pattern from a whole fruit study. Generally, the pitaya plantations are in

tropical areas. The optimum temperature for growing is 20-30 oC (Gunasena et al., 2007). In this condition, 32-35 days from flowering is recommended for harvesting (Nerd et al., 1999). The average weight is between 350-460 g (Nerd et al., 1999; Merten, 2003; Hoa et al., 2006). Other qualities of fruit at the harvesting stage are minimum firmness, acidity and total soluble solid (TSS) which is about 14%. Also, the ratio of TSS and total titratable acidity (TA) of around 40 has been suggested as a harvesting index (Nerd et al., 1999). Nevertheless, there was a small number of works paid on harvesting index of pitaya in Asia.

Moreover, the flowering process of pitaya in Thailand eventually produces two sets in the same tree during July and August. The period gap between first and second flowering sets is around 15 to 20 days. Yet, there was no work paid on the evaluation of fruit qualities in these flowering groups. Additionally, consumers are believed that a small fruit had a better taste than a big fruit due to the effect of size to taste of pulp. Also, ripening levels should have been affected on fruit quality. For example, the fruit firmness and acidity should have decreased in the over-ripening stage. This information should provide some practices for control the fruit quality.

Lastly, the crop load affect to fruit quality is attractive for premium grade

production. The thinning activity might be required for this objective, several works found that the reduction of fruit numbers on plant or tree can improve the fruit size and fruit quality (Corelli-Grappadelli and Coston, 1991; Rab et al., 2012). Commonly, pitaya producers paid little attention to fruit thinning; therefore, if the number of fruit on branch has an effect on fruit quality, the thinning process should be used for a higher quality production.

Consequently, this work was to study 1) the fruit qualities in 2 differing flowering periods in the same tree, 2) patterns of white pulp pitaya fruit-growth by considering the whole fruit weight and pulp components, 3) the harvesting index for pitaya in semi-highland and 4) the vast fruit sizes and ripening level effecting on fruit qualities. Additionally, the possibility for improving the fruit quality process, the comparisons between different numbers of fruits on branches was done.

Materials and Methods

Field site and plant materials

The experiment had been conducted in the seasonal flowering during July to September 2011 at the Experimental and Training Station in Agriculture (N16°32' 07" E101°38' 18"), Khon Kaen University, Chulabhorn Dam, Chaiyaphum province, (around 800 meters above sea level). The minimum and maximum temperatures in this period were 21.0 °C and 30.5 °C, respectively. The 20 plants which were planted from cutting and were trained on a 1.5 m-high vertical pole were selected. The 120 flowers of 2 sets of flowering were tagged on the 21st of July and the 6th of August 2011, the flower number in each set was around 60 flowers. Then, the flowers

were opened pollination. Sample fruits were harvested randomly with 4-7 days interval from 7 to 41 days after blooming.

Fruit quality in 2 flowering periods

The fruit qualities of 2 sets of flowering, firstly on 21st July 2011 and secondly on 6th August 2011 were compared at fruit age of 25 days old after blooming. The comparison was done by 5-fruit samplings in each flowering set.

Fruit growth pattern

The growth patterns of whole fruit and pulp weights in all growth stages were fitted with 5 parameters of single sigmoid curve pattern and the peel weight was fitted with 3 parameters of peak curve by SigmaPlot 10.0 (Systat Software, Inc., wpcubed GmbH, Germany). Other growth changes were plotted with average value.

Fruit age effect on fruit quality

The age of harvested fruits was divided into 3 groups: 35, 36 and over 40 days after bloom. The 10 sample fruits were randomized for each group. Also, this part was the clarification for the optimum harvesting period.

Fruit size effect on fruit quality

The fruit sizes of pitaya were separated into 3 groups: <500, 500-600 and >600 grams fruit weight. The comparison of fruit quality was completed by 8 fruits at edible stage (35-36 days after blooming) in each group.

Number of fruit on branch on fruit Quality

Two types of fruit on branch were separated: 1) single and 2) double fruit on branch. The 5 sample fruits at 35 days old after blooming in each type were used to analyze fruit quality.

Fruit quality analysis

Each sample fruit was physically analyzed in whole fruit weight, pulp and peel weight, pulp diameter and pulp length. The firmness was determined at two opposite points on equator after length-half cut of each fruit with a 4 mm diameter of plunger of penetrometer. TSS was measured in sap pressed from the pulp by a hand refractometer (range 0-32°Brix, ERMA, Japan). TA was determined with 10 g of pulp macerated in 10 ml of distilled water and titrated with 0.01-0.1M NaOH using phenolphthalein as an indicator (AOAC, 1990).

Statistical analysis

The comparisons of means were performed using SPSS 17.0 (SPSS Inc., New York, NY, USA).

Results and discussion

Comparing of 2 flowering periods

The fruit quality comparison between 2 flowering periods (Table 1), the first flowering period was on the 21st July 2011 and the second flowering period was on the 6th August 2011, it was found that fruit weight, pulp weight, peel weight, pulp width, pulp length, TA and ratio TSS/TA had no difference. While, the firmness and TSS of fruit from second flowering period set on the 6th August 2011 showed slight softness and sweetness ($p < 0.01$). The cause of softness and sweetness may result from day and night temperatures during fruit development. The softness and sweetness of the second flowering period was 1 to 2°C slightly lower than the first flowering period for day temperature and 0.5°C for night temperature. Relatively with Wang and Camp (2000) who also reported that the decreasing of temperature around 5-10 °C during fruit growth of strawberries increases the fruit quality.

$$WF = 42.84 + 652.20 / (1 + \exp(-(A - 33.61)/1.63))^{0.09} \quad (1)$$

$$PF = 37.72 + 506.79 / (1 + \exp(-(A - 32.66)/3.93))^{0.86} \quad (2)$$

Pattern of fruit growth

The changes of whole fruit weight ($r^2 = 0.85$; Figure 1A) and pulp weight ($r^2 = 0.89$; Figure 1B) exhibited a simple sigmoid pattern, while peel weight ($r^2 = 0.71$; Figure 1C) exposed a peak pattern ($n = 98$). The whole fruit weight showed stable patterns during 33 to 41 days after blooming (Figure 1A), while the pulp weight growth pattern apparently did not stop growing after the whole fruit stabilized (Figure 1B).

The peel showed higher growth in the first period (0 to 25 days after blooming), and then showed the decreasing of peel weight. The pulp had stable weight between 0 to 17 days after blooming and had dramatic weight increase between 18 to 30 days. The relationship of whole fruit and pulp weight with age were revealed by equation 1 and 2, respectively.

Where WF, PF and A represent whole fruit weight, pulp weight and age of fruit, respectively.

Clearly, the pulp and the peel growth in each fruit growth stage designated the relationships showed in Figure 1D. These relationships indicated that the first stage of fruit growth was the developing of peel, followed by the pulp which showed high increases after 25 days after blooming. This evidence thus, was likely expressed by Litchi (Huang and Xu, 1983; Huang and Qiu, 1987), Longan (Ke et al., 1992) and Pummelo (Pundee et al., 2008).

Contrary, the pulp growth investigation by size, width and length of pulp, found that the patterns seemly were double growth curves (Figure 1E, 1F). This evidence should be from the effect of seed development because of the seed of pitaya changing from white seed coat to black seed coat around 25 days after blooming. Thus, the increasing of pulp weight (Figure 1B) while the pulp size, pulp width and length, were nearly stable during the stage of 15-25 days after blooming (Figure 1E) should cause by seed developing as same as fruit with hard endocarp (double growth curve).

Fruit quality changing during fruit growth

The investigation of fruit qualities including TSS, TA, TSS/TA ratio and firmness had found that the TSS increased according to fruit age (Figure 2A), while TA exposed the peak at 30 days after blooming (Figure 2B). The evidence of the peak of TA should be related to the 25-day development of black seed after blooming, and also related

with outside peel color change (Nerd et al., 1999). Therefore, the TSS/TA ratio apparently expressed the lowest value at 30 days after blooming. However, the TSS/TA ratio dramatically increased in the over ripening stage which was around 40 days after blooming (Figure 2C, Table 2). Additionally, the firmness exhibited the gradual changing; it was decreased when the fruit age was increased (Figure 2D).

Optimum harvesting period

From the whole fruit growth pattern (Figure 1A, Equation 1) indicated that the optimum harvesting period was 33 to 35 days after blooming, because of the fruit weight stability in that period. In spite of the consideration of pulp growth after 35 days (over-ripening stage) found that the pulp weight (Figure 1B) and percentage of pulp (Table 2) increased relating to the decreasing of peel weight (Figure 1C, Table 2). It meant that peel weight partially turned to pulp weight after fruit maturity stage (around 35 days). Reasonably by this observation, the peel of fruit at 40 days was thinner than the peel of fruit at 35 and 36 days; also, the ratio of pulp/peel increased (Table 2). Though, the over-ripening stage of the pulp presented highly juicy or mucilage closely with injury, the palatability should be decreased. Nerd and Mizrahi (1999) explained the evidence of the increasing of water in pulp during storage; it was translocated from peel to pulp.

More consideration in fruit chemical composition for optimum harvesting period, our work showed that the TSS and TA remained relatively unchanged during 33 to 35 days after

blooming (Figure 2A, 2B). Incidentally, they were related to the stable of fruit weight and internal fruit size (Figure 1A, 1E, 1F). Several works explained that these expressions are the criteria of the optimum harvesting period (Nerd et al., 1999; Nerd and Mizrahi, 1999; Merten, 2003). More data on an over-ripening stage found that the TSS was increased while TA was decreased (Table 2) but the pulp expressed the starting of high mucilage which close to injury, thus it was over the optimum eating stage. Therefore, the condition of 27 to 30°C for maximum temperature and 19 to 21°C for minimum temperature harvesting period of pitaya was 33-35 days after blooming.

Comparing the fruit weight at harvesting stage of *Hylocereus undatus* in recent works showed that the average fruit weight was 585g (ranged from 390 to 820 g) higher than the fruit weight that was reported from previous work (350 g) in Israel (Nerd et al., 1999) and 462 g in Vietnam (Hoa et al., 2006). It should had partially affected from the planting area of pitaya in this experiment was in semi-highland area with lower temperature condition.

Effect of fruit size on fruit quality

The effect of fruit size on fruit quality exposed that the increasing of fruit weight increased all of pulp weight, peel weight, pulp width and pulp length ($p < 0.01$), but the ratio of pulp per peel, percentage of pulp and percentage of peel had no change (Table 3). The investigation of fruit chemical components found that the biggest fruit (>600 g) had the highest in both TSS and TA ($p < 0.05$), but all fruit sizes had no differences on TSS/TA ratio. In

Thailand, the consumers generally believe that the smaller fruit has a better taste than the larger fruit. Therefore, it maybe from the TA in the bigger fruits (>600 g) which was higher than smaller fruits, this could have an effect on the taste of pulp of pitaya. The comparison of the increasing between TSS and TA from the fruit size <500 g to fruit size >600 g expressed that the TSS increased by 14%, while TA increased by 24%. This meant that the bigger fruit had a more sour taste than smaller fruit.

Effect of fruit number on branch on fruit quality

The comparison of fruit quality of single or double fruit on the branch at age 35 days after blooming found that the single fruiting on the branch had pulp/peel ratio, percentage of pulp and TSS/TA ratio higher than the double fruit branch, while TA was lower (Table 4). It indicated that the number of fruit on the branch had an effect on fruit components mainly in fruit chemical; but, there was a not significant difference on fruit weight and internal size. However, the fruit from one fruit on the branch tended to be bigger than the fruit from two fruits on the branch. Moreover, the taste of fruit from one fruit per branch should be better than the fruit from two fruit per branch, because of the lower TA. Corelli-Grappadelli and Coston (1991) and Rab et al. (2012) expressed that the reduction of fruit numbers on plants or trees can improve the fruit size and fruit quality. This suggests that the fruit thinning for single fruit on branch maybe needs to be practiced for premium grade production. Therefore, the interesting anticipated work in the future would be the thinning period on

fruit quality of pitaya.

Conclusion and Suggestions

Conclusively, the pitaya fruit-growth pattern which was considered by whole fruit weight was a simple sigmoid curve, but the pulp growth pattern by width and length measurements seemly was a double growth curve. The optimum harvesting period of pitaya planted in the condition of 27-30°C for maximum temperature and 19 to 21°C for minimum temperature was 33 to 35 days after blooming. The flowering period had a slight effect on chemical property (TSS). The chemical property of larger fruit (>600g) compared with smaller fruit was the highest of both TSS and TA. The number of fruit on the branch had an effect on some fruit quality.

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Table 1 Effect of flowering periods on fruit quality of pitaya at age 25 days old after bloom (n = 5)

Flowering period	Fruit weight (g)	Pulp weight (g)	Peel weight (g)	Pulp width (cm)	Pulp Length (cm)	Firmness (kg)	TSS (°Brix)	TA (%)	TSS/TA	Pulp/peel	% pulp	% peel
(Date at bloom)	(g)	(g)	(g)	(cm)	(cm)	(kg)	(°Brix)	(%)		peel		
21-Jul-11	311.7±24.07	96.7±11.2	215.0±13.8	5.02±0.27	6.68±0.24	3.31±0.17	3.84±0.15	0.24±0.02	16.07±1.01	0.45±0.03	30.74±1.39	69.26±1.39
6-Aug-11	316.8±22.82	110.8±6.3	206.0±17.2	5.50±0.10	6.52±0.24	2.63±0.10	4.56±0.11	0.27±0.01	17.39±1.18	0.54±0.03	35.17±1.16	64.83±1.16
F-test	NS	NS	NS	NS	NS	**	**	NS	NS	*	*	*

Values are means (± standard error). NS, * and ** indicate non-significant and significant at p<0.05 and p<0.01, respectively. Means in the same column with the different letters are significantly different by DMRT.

Table 2 Effect of fruit age at ripening and over-ripening stage on fruit quality of pitaya (n = 10)

Days after bloom	Fruit weight (g)	Pulp weight (g)	Peel weight (g)	Pulp width (cm)	Pulp Length (cm)	Firmness (kg)	TSS (°Brix)	TA (%)	TSS/TA	Pulp/peel	% pulp	% peel
	(g)	(g)	(g)	(cm)	(cm)	(kg)	(°Brix)	(%)				
35 days	627.8±19.15	413.6±15.64	214.2±12.27a	8.98±0.11	9.49±0.11	0.35±0.02a	11.10±0.35b	0.39±0.03a	29.43±1.92b	1.99±0.12b	65.92±1.60b	34.08±1.60a
36 days	615.9±39.32	422.4±33.47	193.5±8.68a	8.99±0.23	9.68±0.25	0.41±0.03a	11.37±0.38b	0.35±0.02a	33.97±2.28b	2.18±0.14b	68.04±1.28b	31.96±1.28a
Overripe (40 days)	610.1±30.56	491.5±29.57	118.6±5.79b	9.29±0.23	9.63±0.17	0.20±0.01b	12.36±0.27a	0.16±0.01b	79.78±3.80a	4.23±0.31a	80.18±1.33a	19.82±1.33b
F-test	NS	NS	**	NS	NS	**	*	**	**	**	**	**

Values are means (± standard error). NS, * and ** indicate non-significant and significant at p<0.05 and p<0.01, respectively. Means in the same column with the different letters are significantly different by DMRT.

Table 3 Effect of fruit size on fruit quality of pitaya at eating stage (n = 8)

Fruit size	Fruit weight (g)	Pulp weight (g)	Peel weight (g)	Pulp width (cm)	Pulp Length (cm)	Firmness (kg)	TSS (°Brix)	TA (%)	TSS/TA	Pulp/peel	% pulp	% peel
<500g	432.9±12.08c	273.9±7.83c	159.0±4.78c	7.88±0.11c	8.29±0.13c	0.42±0.04	10.43±0.36b	0.34±0.01b	30.91±1.92	1.73±0.03	63.28±0.40	36.72±0.40
500-600g	570.9±9.60b	380.8±9.52b	190.1±9.24b	8.76±0.08b	9.45±0.08b	0.36±0.03	11.13±0.31ab	0.34±0.02b	33.08±1.72	2.04±0.11	66.72±1.39	33.28±1.39
>600g	706.0±21.79a	479.7±24.31a	226.4±13.94a	9.36±0.18a	9.95±0.19a	0.38±0.03	11.88±0.37a	0.42±0.03a	29.62±2.95	2.19±0.20	67.78±2.16	32.22±2.15
F-test	**	**	**	**	**	NS	*	*	NS	NS	NS	NS

Values are means (± standard error). NS, * and ** indicate non-significant and significant at p<0.05 and p<0.01, respectively. Means in the same column with the different letters are significantly different by DMRT.

Table 4 Effect of fruit number on branch on fruit quality (n = 5)

No. of fruit on branch	Fruit weight (g)	Pulp weight (g)	Peel weight (g)	Pulp width (cm)	Pulp Length (cm)	Firmness (kg)	TSS (°Brix)	TA (%)	TSS/TA	Pulp/peel	% pulp	% peel
1	449.1±39.92	286.8±26.43	162.3±13.59	8.02±0.26	8.54±0.26	0.45±0.06	9.66±0.47	0.36±0.00b	26.90±1.35a	1.76±0.03a	63.80±0.33a	36.20±0.33b
2	367.7±15.65	223.2±13.55	144.5±3.94	7.34±0.19	8.06±0.31	0.32±0.00	8.88±0.22	0.43±0.03a	21.13±1.33b	1.54±0.08b	60.53±1.25b	39.47±1.25a
F-test	NS	NS	NS	NS	NS	NS	NS	*	*	*	*	*

Values are means (± standard error). NS, * and ** indicate non-significant and significant at p<0.05, respectively. Means in the same column with the different letters are significantly different by DMRT.

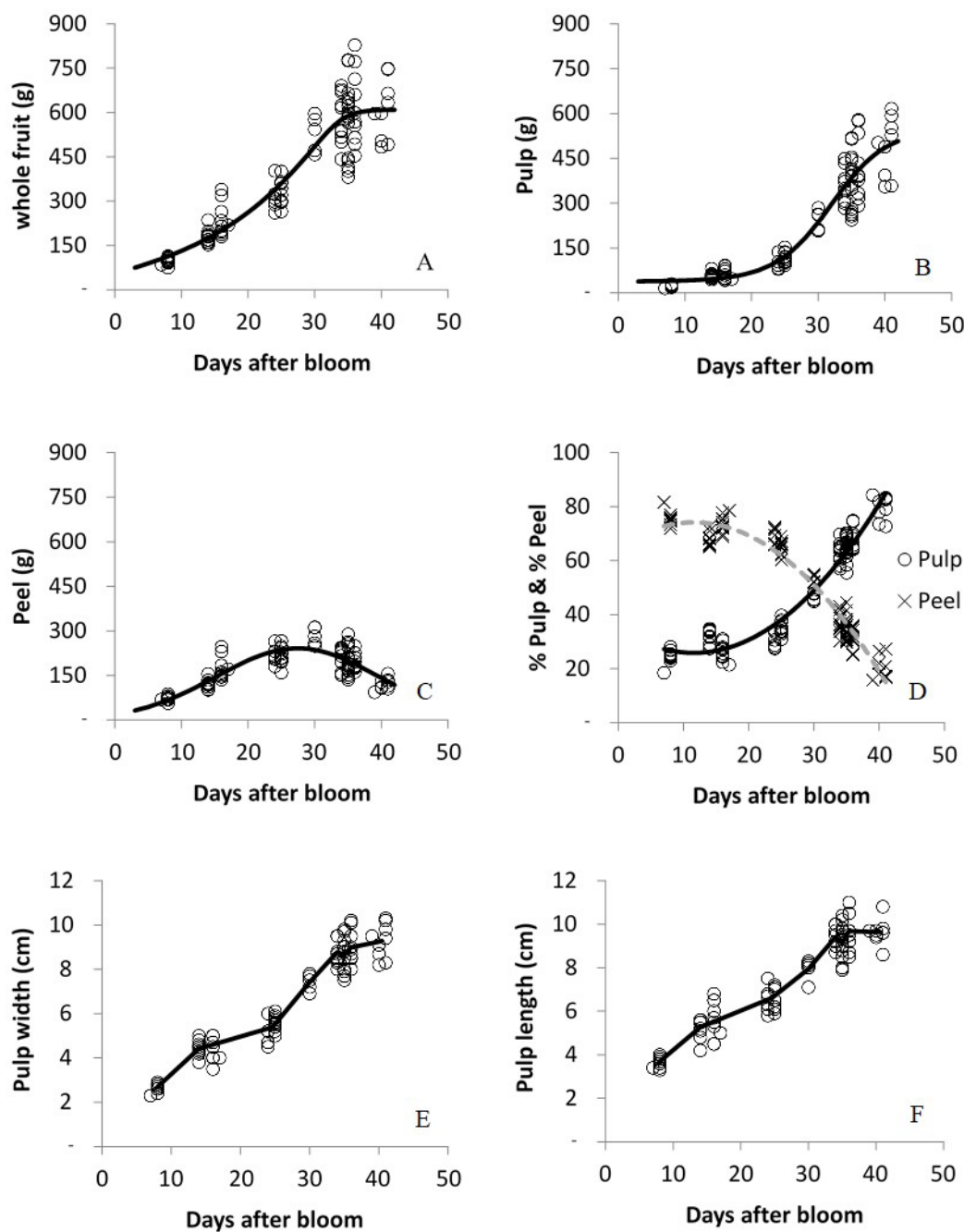


Figure 1 Fruit growth pattern of pitaya: A) whole fruit weight, B) pulp weight, C) peel weight, D) percentage of pulp and peel, E) pulp width and F) pulp length. (n = 98).

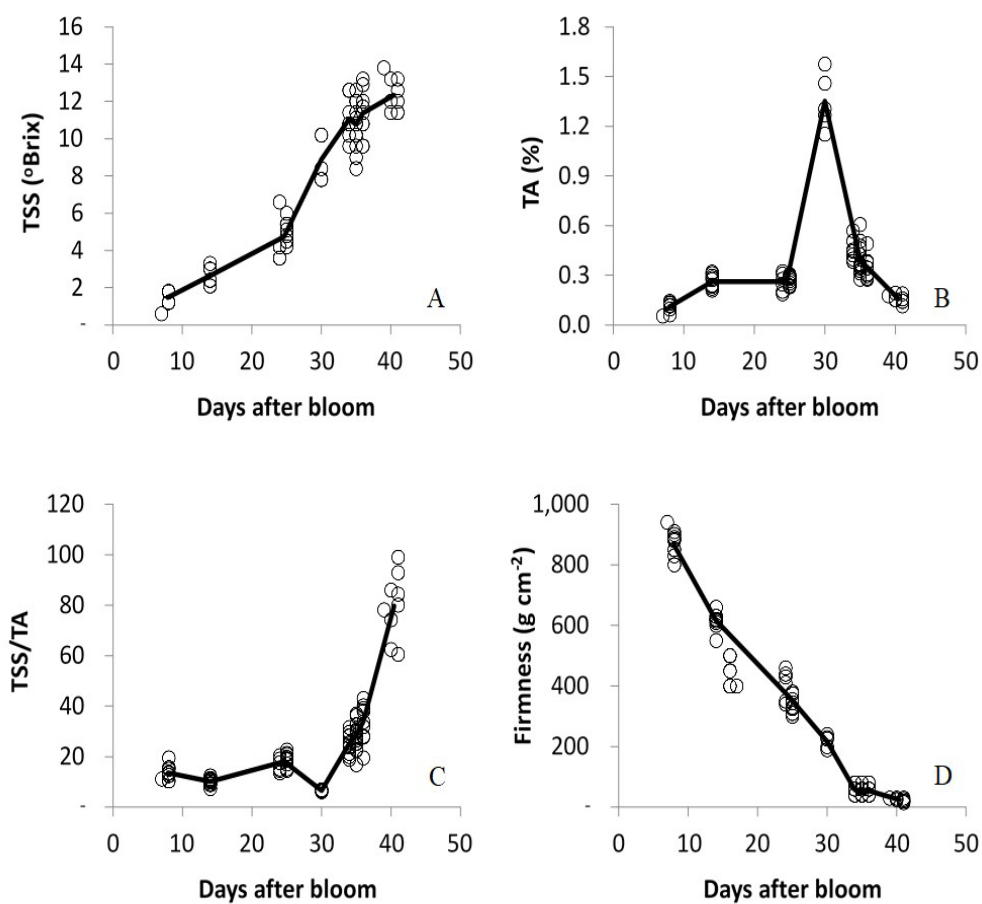


Figure 2 Fruit quality changing during fruit growth: A) total soluble solid (TSS), B) titratable acid (TA), C) TSS/TA ratio and D) pulp firmness.