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Effect of time and storage conditions on the physical and physico-chemical characteristics of the pulp of yellow and purple passion fruit

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Abstract

The aim of this study was evaluate the physical and physico-chemical characteristics of extracted fruit pulp of passion fruit with different skin color (yellow, light and dark purple) under refrigeration temperatures and storage times. The extracted pulp of passion fruit was stored at different temperatures: 10 °C, 25 °C; - 30 °C and - 80 °C and at four different storage periods: 0; 10; 20 and 30 days. The following physical and physico-chemical characteristics of the fruit were evaluated: color of fruit peel, fruit weight, diameter, length and width of the fruit, peel thickness, peel mass, pulp mass, pulp color, juice yield, pH, soluble solids, titratable acidity and ratio. The physical and physico-chemical results indicate that all the passion fruit pulp, *in natura* as well as refrigerated, presented values in conformity to the identity and quality standards. The coloration of the fruit peel influenced the preservation of pulp color during the storage period and conditions. Purple fruits showed no change in the color of the pulp, even under different conservation procedures. The passion fruit pulp can be stored up to 30 days while preserving the physical and physico-chemical characteristics, similar to the pulp *in natura*.

Keywords: fruit pulp; *Passiflora*; pulp quality; storage time; refrigeration.

Practical Application: The preservation of the pulp for long periods while maintaining similar physical and physico-chemical properties as in fresh fruit is needed to meet the demands of consumers. The results presented in the paper showed that the pulp quality under freezing and ultra-freezing can be recommended without damaging the pulp quality up to 30 days.

1 Introduction

The passion fruit vine is an important fruit bearing plant in Brazil, the world's leading producer of the fruit (Instituto Brasileiro de Geografia e Estatística, 2016). Having origin in Tropical America, the passion fruit is considered an exotic species with attractive flavor and aroma (Jordan et al., 2002; Sandi et al., 2004). It can be grown in virtually all regions of Brazil and the vines reach productive age quickly. The crop is in high demand in the market both as fresh fruit and in processed foods and juices (Malacrida & Jorge, 2012).

In Brazil, the species that is cultivated the most is *Passiflora edulis* Sims f. *flavicarpa* Deg., known as yellow passion fruit, accounting for 95% of national output (Janzantti & Monteiro, 2014). Other varieties are also grown, with peel color that varies from orange to dark purple. Despite the predominance of the yellow variety in the national market, the sale of purple fruits is gaining space in the country, due to some organoleptic traits that please consumers, such as lower acidity and stronger aroma (Jesus et al., 2016a), making cultivation of this variety an additional option for farmers. Indeed, because of these traits the purple variety (*P. edulis* f. *edulis* Sims) is in particular demand as fresh fruit in the foreign market, mainly in European countries (Pinzón et al., 2007), in comparison with the yellow variety.

The seasonality of production and losses resulting from climate conditions, harvesting, transportation and perishability (since the fruits lose quality quickly after harvest when stored under ambient conditions) (Cerqueira et al., 2011) stimulate industrial production of pulp near to growing areas, since the pulp can be maintained in good quality during shipment to markets much more easily than the fresh fruit (Pongener et al., 2014).

The crucial point for success in producing high-quality pulp starts with the adoption of good practices in choosing the raw material and harvesting of the fruits (Nunes et al., 2015). Therefore, the fruits must be selected and the pulp prepared by technological processes that assure good quality of the physical and physico-chemical, nutritional and microbiological characteristics, from processing until sale to end consumers (Oliveira et al., 2014).

In recent years, a large number of studies have been conducted regarding the postharvest conservation of pulp of various fruits, such as pear (Arora & Aggarwal, 2009), mango, (Ahmed et al., 2005), umbu-caja (*Spondias* spp.) (Oliveira et al., 2015), apple (Muhammad et al., 2011), pineapple (Antoniolli et al., 2012), sugar-apple (Sravanthi et al., 2014) and tangerine (Bhardwaj & Urvashi, 2014), employing different techniques to prolong their

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shelf life, such as storage in controlled atmosphere, refrigeration, elevation of hydrostatic pressure, use of additives for conservation and use of special packaging, among others.

The use of chemical preservatives is the technique most commonly used to conserve fruit pulps, because it is the simplest and least expensive (Nasir et al., 2015). Nevertheless, this technique is coming under increasing commercial restrictions as a result of growing demand by consumers for foods that are free of chemical additives. In light of this trend, temperature reduction is increasingly being employed, since it slows the respiratory rate and consequently lowers the deterioration of some organoleptic traits, such as color, flavor, texture and aroma, among other quality characteristics (Prasad & Mali, 2000).

Although studies have been conducted showing the benefits of temperature reduction for postharvest conservation of passion fruit (Kishore et al., 2011; Bhardwaj & Urvashi, 2014; Maniwara et al., 2015), only a few works have investigated the association of temperature and storage period with the physical and physico-chemical characteristics of the pulp of passion fruit stored under refrigeration (Ciabotti et al., 2000; Maniwara et al., 2015).

In this context, because of the importance of preserving the pulp while maintaining similar physical and physico-chemical properties as in fresh fruit to meet quality demands of Brazilian consumers and sanitary regulations, the aim of this study was to evaluate the physical and physico-chemical characteristics of the pulp extracted from passion fruits with different peel color (yellow, light purple and dark purple) under different storage temperatures and times.

2 Material and methods

2.1 Experiment location and cultural practices

The study was carried out in the Embrapa Cassava and Fruits (12° 39' 25" S, 39° 07' 27" W, 222 m above sea level), located in Cruz das Almas, Bahia state, Brazil during March and April 2014. According to the Köppen classification, the region's climate is transition from Am to Aw (subhumid tropical to dry), with average yearly temperature of 23.8 °C, average annual rainfall of 1,224 mm, concentrated from June to August, and average relative humidity of 82.3%.

The seedlings were grown in a greenhouse and cultivated in polyethylene tubes with 12.5 cm × 3.0 cm, containing a sterile mixture of soil, cow dung and vermiculite (3:1:1, v:v), showing the following chemical characteristics: pH (water) 6.3; phosphorus (P) 700 mg dm^{-3}; potassium (K) 5.9; calcium (Ca) 6.5; magnesium (Mg) 3.3; hydrogen plus aluminum (H + Al) 6.9; sum of bases (SB) 16.9; T 23.2 $cmol_c$ dm^{-3}; base saturation (V) 70.0% and organic matter (M.O.) 69.3 g kg^{-1}. Ninety days after sowing, the transplanting to the field was performed.

The cultivation was conducted in spaulders of 2.0 m tall and a wire in 2.0 m × 1.0 m spacing, using additional drip irrigation. The cultural practices usually recommended for the cultivation of passion fruit followed the protocol established by Lima et al. (2011), except for the absence of any disease control on plants in the field.

2.2 Plant material

We evaluated 54 passion fruits from the hybrid HFOP-02 – resultant from the cross [(*P. edulis* (BGP025) x *P. edulis* (BGP043))], selected by Embrapa Cassava and Fruits for higher yield and desirable physico-chemical attributes. This hybrid produces fruits with different peel colors, classified as yellow (without anthocyanin pigmentation), light purple (weak or moderate anthocyanin pigmentation) and dark purple (strong anthocyanin pigmentation), as illustrated in Figure 1a-c.

2.3 Description of the experiment

Eighteen fruits were selected of each peel color classification (yellow, light purple and dark purple) were used for physico-chemical characterization of the fruits. The study was carried out in the Postharvest Laboratory of the Embrapa Cassava and Fruits. The physical analysis of the fruits was characterized at the moment of harvest before pulp and juice removal. While, physico-chemical

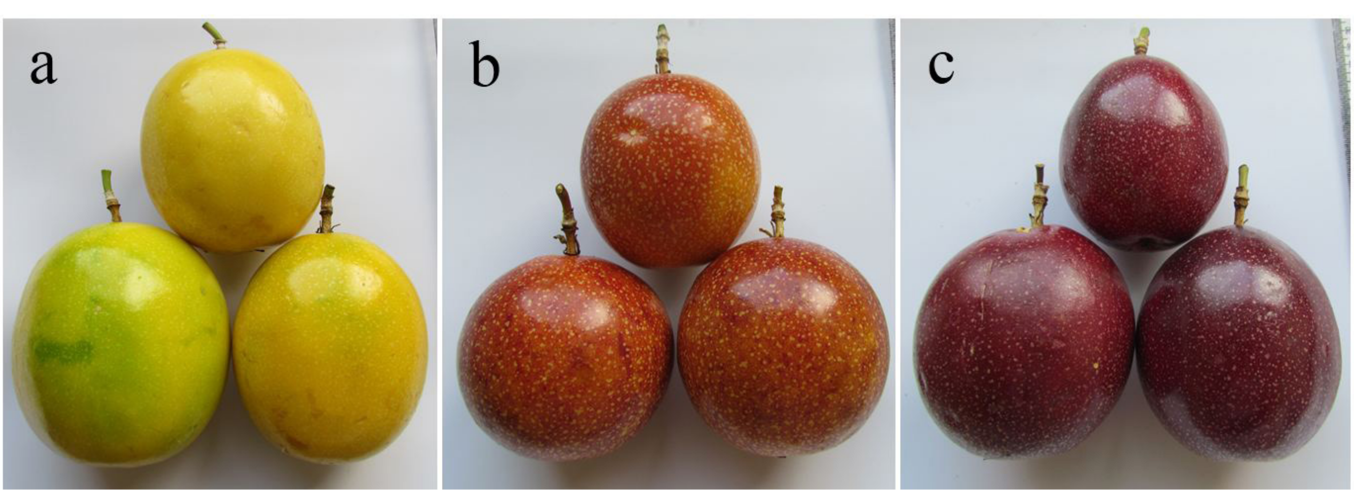

Figure 1. Hybrid general view HFOP-02 fruits with different peel colors: yellow; light purple; dark purple.

analysis of the pulp was made under five different temperature regimes: ambient (25 °C); refrigerator (10 °C); freezer (−30 °C); and liquid nitrogen freezing (−96 °C) followed by freezer (−30 °C) and ultrafreezer (−80 °C) storage, for four intervals: 0, 10, 20 and 30 days.

2.4 Physical analysis and physico-chemical

The following physical traits of the fruits were evaluated: peel color (PeC); fruit mass (FM), fruit length (FL), fruit diameter (FD), length/diameter ratio (FL/FD), peel thickness (PT), peel mass (PeM), pulp mass without seeds (PM), pulp color (PC) and juice yield (JY), given by PM divided by FM (expressed as a percentage). The pulp was classified by scale color (Jesus et al., 2016b). The samples submitted to the various storage regimes were defrosted, homogenized and left to reach ambient temperature (± 25 °C). Then the samples were subjected to the following physico-chemical: pH (potentiometer); soluble solids content (SS) (° Brix); titratable acidity (TA), expressed as the percentage of citric acid, measured by solution neutralization reaction (Association of Official Analytical Chemistry, 1995); titratable acidity (TA) and SS/TA ratio.

2.5 Statistical analysis

The experimental design was completely randomized in a 3 × 5 × 4 factorial scheme (peel color category x storage temperature regime x storage period), with three repetitions. Each experimental unit was composed of a Falcon tube with about 15 g of pulp. The data were submitted to analysis of variance and the means were compared by the Tukey test at 5% probability. When necessary, the data were transformed to arc sin ($\sqrt{x/100}$) for normalization and homogenization of variance, using the SAS program (SAS Institute Inc, 2010).

3 Results and discussion

With respect to the physical traits assessed, only the peel color variable showed a significant difference ($p \leq 0.05$), since the fruits were chosen based on peel color (Figure 1a-c; Table 1). This result was expected, since all the characteristics were evaluated using fruits from the same genotype (HFOP-02).

After storage, the pulp color was influenced by the peel color, storage temperature regime and storage time, as well as their interaction (Table 2). In the control sample (pulp immediately after removal, without storage), the color varied from 4.67 to 5.00 (light to dark orange) (Table 2). In the samples stored under refrigeration, the color of the pulp from the yellow fruits became less intense with increasing storage time, changing to light orange color (Table 2). On the other hand, the pulp samples from the purple fruits maintained their pre-processing color (orange), except for the pulp from the light purple fruits stored for 30 days, which became light orange.

It is noteworthy that the pulp samples from the fruits with dark purple peel color maintained their color under all the storage conditions, while the pulp samples from the yellow fruits were more sensitive to the low storage temperatures, passing from dark to light orange (Table 2). These results corroborate those

Table 1. Analysis of variance of the physical characteristics of passion fruit with different colorations of the fruit peel.

Source of variation	Physical characteristics[1]									
	PeC	FM	FL	FD	FL/FD	PT	PeM	PM	PC	JY
Peel color	527.9*	2.0^{ns}	0.6^{ns}	1.5^{ns}	1.4^{ns}	0.2^{ns}	2.7^{ns}	1.6^{ns}	13.4^{ns}	1.6^{ns}
Yellow	1.2 b	93.2 a	65.4 a	65.0 a	1.0 a	7.0 a	51.9 a	23.9 a	3.2 b	23.9 a
Dark purple	5.0 a	92.4 a	63.1 a	64.8 a	0.9 a	6.9 a	52.2 a	31.2 a	4.6 a	21.6 a
Light purple	4.7 b	113.7 a	65.9 a	68.1 a	0.9 a	6.9 a	62.4 a	22.6 a	3.6 b	26.1 a
CV (%)	9.7	34.9	12.4	9.7	7.3	22.5	27.0	59.0	20.3	31.2

*significant; ns = not significant ($p \leq 0.05$). [1]Means followed by the same letters in the column do not differ by the Tukey test ($p \leq 0.05$). PeC: peel color; FM: fruit mass; FL: fruit length; FD: fruit diameter; FL/FD: length/diameter fruit; PT: peel thickness; PeM: peel mass; PM: pulp mass without seeds; PC: pulp color; JY: juice yield.

Table 2. Passion fruit pulp color from fruit with different peel color in function of storage time and different storage temperatures.

Peel color	Storage time (days)[1]				
	0	10	20	30	
Yellow	5.00 aA	4.00 bB	4.00 bB	4.00 bB	
Dark purple	5.00 aA	5.00 aA	5.00 aA	5.00 aA	
Light purple	4.67 bB	5.00aA	5.00 aA	4.00 bC	
Peel color	Storage conditions				
	Ambiente	Freezer	Liquid nitrogen + Freezer	Refrigerator	Ultrafreezer
Yellow	5.00 aA	4.00 cB	4.00 cB	4.00 cB	4.00 cB
Dark purple	5.00 aA	5.00 aA	5.00 aA	5.00 aA	5.00 aA
Light purple	4.67 bA	4.67 bA	4.67 bA	4.67 bA	4.67 bA
CV (%) = 4.02					

[1]Means followed by the same lower-case letters in the column and upper-case letters in the row do not differ by the Tukey test ($p \leq 0.05$).

of Nasir et al. (2015), who also observed a change in the pulp color of apples with the treatment methods and storage periods analyzed. The authors attributed this change in apple pulp color during storage mainly to the action of the enzyme polyphenol oxidase, in which the polyphenols are converted into brown compounds, thus causing enzymatic darkening.

For the variable pH, an interaction was observed ($p \leq 0.05$) involving the peel color and storage time and temperature (Table 3). In relation to the peel color x storage time interaction, the pH has highest with ambient temperature storage, at 3.22, for light purple fruits. After storage for 30 days, the pulp pH of these fruits declined to 2.77 (Table 3). The pH of the pulp samples from the dark purple and yellow fruits did not change after storage. Similar behavior was observed in relation to peel color x storage temperature, where once again the pulp from the light purple fruits had higher pH (3.22) at room temperature, which declined when submitted to refrigeration (Table 3). Ciabotti et al. (2000) also observed changes in the pH of passion fruit pulp due to refrigeration temperature, storage time and the interaction between the two, although the authors considered the pH differences to be chemically negligible. Gomes et al. (2006), analyzing passion fruit pulp immediately after extraction from the fruit, found pH values between 2.54 and 2.58, lower than those found in our study.

For the soluble solids (SS) trait, there was a significant interaction with peel color and storage time and storage conditions x peel color (Table 4). The highest SS content in the fresh pulp was from the fruits with light purple peels (13.93 °Brix), although it did not differ from treatments with 10 and 20 days after storage and the lowest was from the yellow fruits after storage for 30 days (11.82 °Brix) (Table 4). The table also shows that the storage time influenced in °Brix level for all the peel colors, and that after 30 days' storage, the SS content declined significantly in relation to the control treatment. Likewise, Antunes et al. (2003) observed a decrease in SS values during storage of black raspberries (*Rubus* spp.).

Considering the interaction of storage temperature and peel color, the pulp samples stored under refrigeration presented lower soluble solids levels than the samples in the other treatment groups (Table 4). This behavior was common to all three peel colors. Other authors have also reported a reduction in the soluble solids content in passion fruit pulp subjected to cold storage (Goldenberg et al., 2012; Matta et al., 2006).

Table 3. Evatuation of the pH of passion fruit pulp with different peel colors in function of storage time and different storage temperatures.

Peel color	Storage time (days)[1]				
	0	10	20	30	
Yellow	2.78 bA	2.74 aA	2.79 abA	2.80 abA	
Light purple	3.22 aA	2.73 aB	2.74 bB	2.77 bB	
Dark purple	2.82 bA	2.75 aA	2.87 aA	2.88 aA	
Peel color	Storage conditions				
	Ambient	Freezer	Liquid nitrogen + Freezer	Refrigerator	Ultrafreezer
Yellow	2.78 bA	2.78 aA	2.74 aB	2.78 abA	2.77 aA
Light purple	3.22 aA	2.74 aB	2.78 aA	2.74 bB	2.77 aB
Dark purple	2.82 bA	2.80 aA	2.85 aA	2.87 aA	2.80 aA
CV (%) = 3.92					

[1]Means followed by the same lower-case letters in the column and upper-case letters in the row do not differ by the Tukey test ($p \leq 0.05$).

Table 4. Evatuation of the soluble solids content (SS) of passion fruit pulp with different peel colors in function of storage time and different storage temperatures.

Peel color	Storage time (days)[1]				
	0	10	20	30	
Yellow	13.00 bA	12.28 bB	12.35 bB	11.82 cB	
Light purple	13.93 aA	13.45 aA	13.36 aA	12.73 aB	
Dark purple	13.33 abA	13.27 aA	11.98 bB	12.25 bB	
Peel color	Storage conditions				
	Ambient	Freezer	Liquid nitrogen + Freezer	Refrigerator	Ultrafreezer
Yellow	13.00 bA	12.96 bA	13.11 bA	9.64 cB	12.89 bA
Light purple	13.93 aA	13.64 aA	13.82 aA	11.54 aB	13.71 aA
Dark purple	13.33 abA	13.20 abA	13.22 bA	10.40 bB	13.18 bA
CV (%) = 3.28					

[1]Means followed by the same lower-case letters in the column and upper-case letters in the row do not differ by the Tukey test ($p \leq 0.05$).

A high SS value is an important trait for the food processing industry, since about 11 Kg of fruit with SS between 11 and 12% is necessary to obtain 1 Kg of concentrated juice at 50 °Brix (Neves et al., 2013). The higher the SS level is, the lower the quantity of fruit necessary to make concentrated juice (Nascimento et al., 2003).

For the titratable acidity variable (% citric acid), there were significant ($p \leq 0.05$) correlations with the factors peel color, storage time and storage temperature (Table 5), but there was no interaction between these factors. In general, the samples from light purple fruits had the highest pulp acidity (6.31), while the lowest acidity was found for the pulp of dark purple fruits (5.26), although this latter value was not significantly different from that for the yellow fruits (5.38). The results also indicated that the acidity tended to increase with storage time, from 5.14 before storage to 5.74 after 30 days (Table 5).

With respect to storage time and storage temperature, the acidity was lower in the pulp stored at ambient temperature. A similar result was reported by Arruda et al. (2011), who also observed lower acidity at room temperature (25 °C). According to them, this result is a reflection of the higher metabolic activity associated with higher temperature. In contrast, in the present study the pulp samples kept under refrigeration had lower acidity. These results corroborate those of Pongener et al. (2014) and Schotsmans et al. (2008) both research groups noted alterations in passion fruit pulp quality with storage time and temperature.

Table 5. Evatuation of the titratable acidity (TA) of passion fruit pulp with different peel colors in function of storage time and different storage temperatures.

Peel color	TA (%)
Light purple	6.31 a
Yellow	5.38 b
Dark purple	5.26 b
Storage time (days)[1]	**TA (%)**
0	5.14 b
10	5.79 a
20	5.56 ab
30	5.74 a
Storage conditions	**TA (%)**
Ambient	5.14 b
Refrigerator	5.85 a
Freezer	5.64 a
Liquid nitrogen + Freezer	5.66 a
Ultrafreezer	5.62 a
CV (%) = 11.06	

[1]Means followed by the same letter in the column do not differ by the Tukey test ($p \leq 0.05$).

Acidity is a very important chemical attribute for conservation of fresh produce and food products by consumers as well as for the food industry, because it makes the food more resistant to deterioration by microorganisms and allows more flexibility in the addition of sugar, which is of particular importance in preparing ready-to-drink beverages (Dell'Ort Morgado et al., 2010).

For the ratio (ratio between soluble solids and titratable acidity), there were interactions ($p \leq 0.05$) involving storage conditions x peel color and also peel color x storage time (Table 6).

Considering the effect of storage time and peel color, the pulp extracted from the dark purple fruits presented the highest SS/TA ratio (2.88), followed by the light purple fruits, with 2.63 (Table 6). The table also shows that with the exception of the pulp from the yellow fruits, the SS/TA ratio of the pulp declined with longer storage time.

According to Table 6, the SS/TA ratios of the pulp before processing and storage varied from 2.47 to 2.88, while in the pulp samples submitted to refrigeration, the variation was from 1.63 to 2.48, indicating that with the exception of the pulp from the yellow fruits, there was slight tendency for the SS/TA ratio to decline with longer storage time under refrigeration (Table 6). These results are lower than those found by Gomes et al. (2006), who observed a variation in the SS/TA ratio in fresh passion fruit pulp from 3.13 to 3.18 and from 3.07 to 4.40 for pulp samples after frozen storage. We found that the pulp samples stored under refrigeration presented the lowest SS/TA ratios for the three fruit colors. The SS/TA ratio is considered one of the best ways to assess the palatability of fruits, with acidity being decisive in this respect, since higher acidity reduces the ratio (Kolayli et al., 2010; Tietel et al., 2010).

Table 6. Evatuation of the ratio (SS/TA) of passion fruit pulp with different peel colors in function of storage time and different storage temperatures.

Peel color	Storage time (days)[1]				
	0	10	20	30	
Yellow	2.47 bA	2.28 abA	2.32 aA	2.20 aA	
Light purple	2.63 abA	2.09 bB	2.10 bB	2.01 bB	
Dark purple	2.88 aA	2.41 aB	2.06 bC	2.26 aBC	
Peel color	**Storage conditions**				
	Ambient	Freezer	Liquid nitrogen + Freezer	Refrigerator	Ultrafreezer
Yellow	2.47 bA	2.45 aA	2.47 aA	1.68 aB	2.47 aA
Light purple	2.63 abA	2.18 bB	2.18 bB	1.72 aC	2.20 bB
Dark purple	2.88 aA	2.44 aB	2.48 aB	1.63 aC	2.45 aB
CV (%) = 8.58					

[1]Means followed by the same lower-case letters in the column and upper-case letters in the row do not differ by the Tukey test ($p \leq 0.05$).

The results obtained indicate that from the physico-chemical standpoint, all the passion fruit pulp samples, both from the fresh fruit and those kept in cold storage, presented pH, soluble solids and titratable acidity values within the technical regulations for standards of identity and quality for passion fruit pulp issued by the Brazilian Ministry of Agriculture, which establishes pH between 2.70-3.80, soluble solids greater than 11 °Brix and titratable acidity above 2.50%.

4 Conclusions

1) The peel color has an influence on the preservation of the pulp color during the conservation period under the storage conditions analyzed, with the pulp from the purple fruits maintaining the same color after storage as when fresh.

2) The peel color also influences the organoleptic traits of passion fruit pulp associated with SS/TA ratio, such as pulp flavor. In general, the fruits with purple peel were sweeter and less acidic than the yellow fruits.

3) The physico-chemical variables pH, TA, SS and SS/TA ratio underwent changes in function of storage time and refrigeration conditions, but without damaging the pulp quality, since the values found were compliant with the quality standards established by Brazilian regulations.

4) The pulp quality declined substantially when stored under refrigeration at 10 °C. On the other hand, the physico-chemical characteristics of the samples stored under freezing and ultra-freezing did not deteriorate with storage time.

5) Passion fruit pulp can be stored for up to 30 days while preserving physical and physico-chemical characteristics near those of pulp *in natura*.

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