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Conditioning temperature for inducing uniform ripening of ‘Abate Fetel’ pears¹

Condicionamento por frio para indução e uniformização do amadurecimento de peras ‘Abate Fetel’

Moises Zucoloto², Lucimara Rogeria Antonioli^{3*}, Dalmo Lopes Siqueira⁴, Ana Beatriz Costa Czermainski³ and Luiz Carlos Chamhum Salomão⁴

ABSTRACT - The aim of this study was to determine the conditioning temperature period for inducing uniform ripening of ‘Abate Fetel’ pears as well as to determine the maximum storage period with no quality loss. Three harvests were carried out at weekly intervals and each harvest date was considered a factorial experiment (7x3), with seven storage periods at 0 ± 1 °C and $90 \pm 5\%$ relative humidity (0; 20; 40; 60; 80; 100 and 120 days) and three periods at room temperature (20 ± 1 °C) (zero, three and six days). The assessed quality attributes were flesh firmness, starch content, weight loss and soluble solids content. Acceptance and purchase intention sensory tests were carried out. Cold storage was efficient in inducing uniform ripening in ‘Abate Fetel’ pears after 20 days at low temperature followed by six days at room temperature for fruit from the three harvest dates. ‘Abate Fetel’ pears harvested at harvest maturity of 57 N can be stored for up to 120 days and commercialized within six days with no quality loss. However, fruit harvested at flesh firmness below 55 N can be stored for 80 days and commercialized within six days or stored for 100 days and commercialized within three days.

Key words: *Pyrus communis* L.. Cold storage. Acceptance. Shelf life.

RESUMO - O objetivo deste trabalho foi de definir o tempo necessário de condicionamento por frio para causar a uniformização do amadurecimento de peras ‘Abate Fetel’. Ainda, objetivou-se a determinação do período máximo de armazenamento sem que houvesse prejuízos à qualidade de frutos. Foram realizadas três colheitas em intervalos semanais e cada colheita constituiu um experimento fatorial (7x3), sendo sete períodos de manutenção sob baixa temperatura (0; 20; 40; 60; 80; 100 e 120 dias) e três períodos de manutenção em ambiente simulado a 20 ± 1 °C (zero, três e seis dias). Os atributos de qualidade avaliados foram firmeza de polpa, índice de degradação do amido, perda de massa fresca, teores de sólidos solúveis e aceitabilidade. O condicionamento por frio foi eficiente na indução e uniformização do amadurecimento de peras ‘Abate Fetel’, após 20 dias de manutenção em baixa temperatura seguidos de seis dias em ambiente simulado, para os frutos provenientes das três datas de colheita. Frutos da cultivar Abate Fetel com data de colheita DC1 podem ser armazenados por até 120 dias e comercializados em até seis dias sem que haja comprometimento da qualidade. Já frutos colhidos nas datas de colheita DC2 e DC3 podem ser armazenados por 80 dias e comercializados em até seis dias ou armazenados por 100 dias e comercializados no período de três dias.

Palavras-chave: *Pyrus communis* L.. Armazenamento refrigerado. Aceitabilidade.

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INTRODUCTION

Abate Fetel cultivar is well diffused in Europe, and Italy detains most of the cultivated area in the world (PREDIERI; GATTI, 2009). According to the same authors, the success of the cultivar can be attributed to the elongated fruit shape, characteristic that differs them from other cultivars, and to the quality storage during long cold storage periods. In Argentina, its cultivation has presented excellent fruits becoming a new option for the diversification of fruit growing (GARRIZ; ALVAREZ; COLAVITA, 2005). In Brazil, this cultivar has stood out among recently introduced cultivars (HAWERROTH *et al.*, 2010). However, due to the climate conditions of certain producing regions, the fruits present excess *russeting* which, despite developing a brown color to the epidermis and modifying the appearance, does not compromise the fruit organoleptic quality.

‘Abate Fetel’ pears like other European pears (*Pyrus communis* L.) are climacteric; however, they need post-harvest treatments for inducing uniform ripening (VILLALOBOS-ACUNÁ *et al.*, 2011a, b). In general, European pears must be picked in the physiological maturity stage, generally very firm and submitted to cold storage (-1 to 0 °C and 90% RH) or to exogenous application of ethylene, then kept at room temperature (15 to 21 °C and 80 to 85% RH) to ripen and reach optimal consumption quality (SUGAR; EINHORN, 2011; VILLALOBOS-ACUNÁ *et al.*, 2011a, b).

Uniform ripening of fruits varies according to cultivar (SUGAR; EINHORN, 2011; VILLALOBOS-ACUNÁ *et al.*, 2011a), temperature and exposure time during cold storage (PREDIERI; GATTI, 2009) and also with time and temperature used after the cold storage (VILLALOBOS-ACUNÁ *et al.*, 2011b).

Studies with ‘Abate Fetel’ were carried out by Predieri and Gatti (2009) in Italy. Pears were harvested with flesh firmness between 57 and 54N stored in normal atmosphere, with temperature from -1 to 0 °C and 95% RH for 13 and 23 weeks, being, then, maintained at temperature of 20 ± 2 °C. The reduction in acceptance of fruits stored by 23 weeks occurred, mainly, as a result of excessive flesh softening, fact that did not occur with fruits stored for 13 weeks. Despite affirming that the fruits were considered suitable for consumption when they reached flesh firmness inferior to 39.2N, the authors did not evaluate the time necessary for uniform ripening.

The purpose of this study was to determine the necessary time for cold storage of ‘Abate Fetel’ pears to obtain uniform ripening and flesh firmness recommended for consumption, when transferred to room temperature, as well as determine the maximum storage period without fruit quality loss.

MATERIAL AND METHODS

‘Abate Fetel’ pears were harvested from a commercial orchard located in Vacaria-RS, Brazil. Plants were grafted on ‘Adams’ quince tree and trees were trained on a central leader system, 0.8 m spacing between plants and 3.3 m between rows, totalizing 3788 plants/ha.

To initiate the harvesting process, monitoring of flesh firmness of 20 fruits harvested at random in the orchard was carried out for approximately one month. Three harvests were performed at weekly intervals, where fruits from the first harvest date (HD1) presented flesh firmness of 57.3N; those from the second date (HD2) presented firmness of 54.8N and those from the third harvest date (HD3), presented values of 51.2N.

In the lab, pear fruits were submitted to a selection in order to eliminate fruits with any type of defect and to homogenize the lot for size.

Each harvest date constituted an experiment in the randomized blocks delineation, 7 x 3 factorial scheme, with four replicates. The first variable was the fruit storage period: 0; 20; 40; 60; 80; 100 and 120 days; in cold room at temperature conditions of 0 ± 1 °C and relative humidity of 90 ± 5%. The second variable referred to the time kept at room temperature of 20 ± 1 °C, to simulate normal market conditions. This variable followed periods of zero (end of cold storage), three and six days. In evaluations carried out after removal fruits from the cool room, each experimental unit was constituted by six fruits and at room temperature evaluations, each repetition was constituted of three fruits. The evaluated quality attributes were flesh firmness, rate of starch degradation, weight loss, and soluble solids content. The sensory tests acceptance and purchase intention were carried out.

Flesh firmness was measured in both sides in the equatorial region of each fruit (observation unit), discarding a small area of the epidermis. An analog penetrometer model FT 327 (McCormick Fruit Tech, Yakima, EUA) with an 8 mm tip was used and data were presented as Newton (N).

For obtaining the rate of starch degradation, cross slices from the middle part of the fruits were partially immersed in 1.2% metal iodine solution and 2.4% potassium iodate, for two minutes. After this period, the slices were maintained for approximately ten minutes in forced air chamber and classified according to scale from 1 to 10 proposed, where 1 represents fruit with dark color and elevated starch content and 10 represents clear color and nearly null starch content.

To determine the weight loss at the end of each period, the following formula was used: Weight loss (%) = [(Initial weight – Final weight) / Initial weight] x 100.

To measure the soluble solid content of homogenized juice of all fruits of each replicate a digital refractometer model PR - 101 (Atago, Tokyo, Japan) was used.

The data of physical and chemical attributes, such as flesh firmness (N), soluble solid content (°Brix) and weight loss (%), of the three harvest dates were submitted to analysis of variance. According to the F-test results for main effects and interaction, polynomial regression analysis was performed for the storage period at low temperature and Tukey's test for comparison of the room temperature times.

The acceptance evaluation was performed by at least 30 untrained tasters, of both sexes and with age between 18 and 65 years. The pears were sliced at the moment of the test to avoid enzymatic browning and, consequently, any type of interference in the acceptance of the product. The labeled samples were randomly served to tasters. The analysis was carried using a 7-point hedonic scale, where = 1 dislike extremely, 2 = dislike very much, 3 = dislike, 4 = neither like, nor dislike, 5 = like, 6 = like very much, 7 = like extremely. Besides the scale, tasters were asked to report the marking characteristics noticed at the moment of sensory evaluation. From the frequency of scores attributed by tasters to samples of each treatment, an acceptance rate was calculated, according to method proposed by Czermainski (1999), expressed as percentage in a continuous scale, which amplitude is 0 for no acceptance and 100 for maximum acceptance. If all tasters attributed scores equal to 5 in the hedonic scale, in other words, "like", the acceptance rate value would correspond to 67%. This value was considered as minimum acceptance indicator or sensory satisfaction of tasted sample.

To verify acceptance regarding to the general aspect of fruits, potential consumers were questioned for intention in purchasing pears with identical quality to the samples, for the market value. When tasters did not opt for the market value purchase, they were asked if they would buy it at a 10; 30 or 50% discount or if they would not buy it, even at a discount price. This questionnaire was carried out 60 days after keeping fruits under low temperature, followed by six days at room temperature condition, considering that the period of 60 days of cold storage would induce ripening without causing dehydration that might compromise the appearance of fruits.

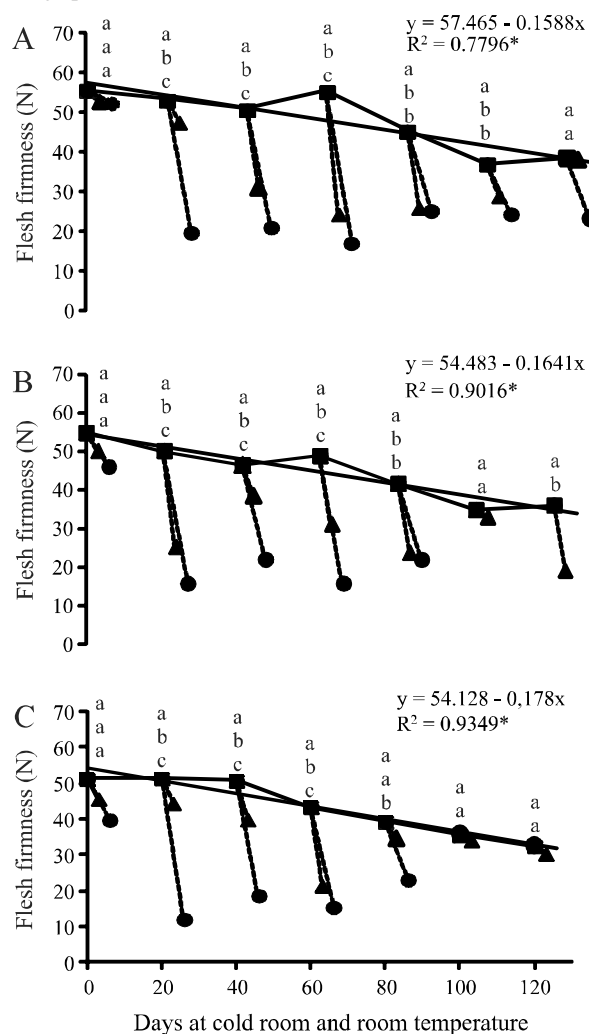
RESULTS AND DISCUSSION

Progressive reduction of flesh firmness was observed along the cold storage of fruits from the three harvest dates (Figure 1). The slope tool and its adjusted regression line increased as fruits were harvested later.

The necessary cold storage time for fruits to reach the recommended firmness for eating (39.2N) was 120 days for HD1, while HD2 fruits needed 93 cold storage days and those harvested later (HD3) reached the ideal firmness for consumption at 84 days at low temperature.

Pears from the three harvest dates evaluated at three and six days without cold storage did not present significant reduction in flesh firmness and, consequently, did not reach the recommended firmness for eating. That demonstrates the

Figure 1 - Flesh firmness of 'Abate Fetel' pears harvested in three dates (HD1=18/01/2010 (A), HD2=25/01/2010 (B) and HD3=01/02/2010 (C)) and kept for up to 120 days at $0 \pm 1^\circ\text{C}$ and $90 \pm 5\%$ RH followed by three (▲) and six days (●) at room temperature ($20 \pm 1^\circ\text{C}$). Sloping full line corresponds to simple linear regression adjusted to flesh firmness values observed at the end of each storage period (■). Same letters, in vertical, indicate that average firmness values at room temperature, for each cold storage period, do not differ ($P>0.05$). * $P>0.05$



necessity of cold storage or exogenous ethylene application to stimulate autocatalytic ethylene production and trigger ripening of pears (CHEN; VARGA; FACTEAU, 1997; GERASOPOULOS; RICHARDSON, 1997; SUGAR; EINHORN, 2011). Late-picked fruits (HD3) presented firmness close to those recommended for consumption after six days of storage at room temperature without prior cold storage. According to Coutinho *et al.* (2003), late-picked fruits can ripe without having been submitted to treatment for inducing ripening, however, the organoleptic quality of fruits can be damaged.

After 20 days of cold storage followed by six days at room temperature, fruits from the three harvest dates presented flesh firmness values inferior to those recommended for consumption, of 19.85; 15.75 and 12.15 N for HD1, HD2 and HD3, respectively. When the fruits were kept by a period equal or superior to 40 days in cold room, in any of the harvest conditions, only three days were enough at room temperature for flesh firmness to reach values inferior to 39.2 N (Figure 1).

Studying pears 'Abate Fetel', Predieri and Gatti (2009) not observed loss of ripening capacity after 161 days of cold storage, despite having their quality affected. In the present study, late-picked fruits (HD3) presented no reduction in firmness after 100 days of cold storage followed by six days of storage at appropriate temperature for ripening (Figure 1C). The results are in agreement with Murayama *et al.* (2002) who observed loss of ripening capacity of 'Marguerite Marillat' and 'La France' pears after four and five months of cold storage and seven days of storage at room temperature, respectively.

HD2 and HD3 fruits presented rot incidence superior to 50% after 100 and 120 days of cold storage followed by six days at room temperature, which led to discard of fruits.

The rate of starch degradation at harvest time for HD1 fruits was 2.50, that was smaller than the values obtained in the subsequent harvests (5.00 and 5.21 for HD2 and HD3, respectively). Fruits reached the maximum value in the starch degradation scale after twenty days of cold storage, followed by six days in room temperature, for the three harvest dates. Fruits kept in the cold room for 40 or more days also presented the maximum value in the starch degradation scale (not presented data).

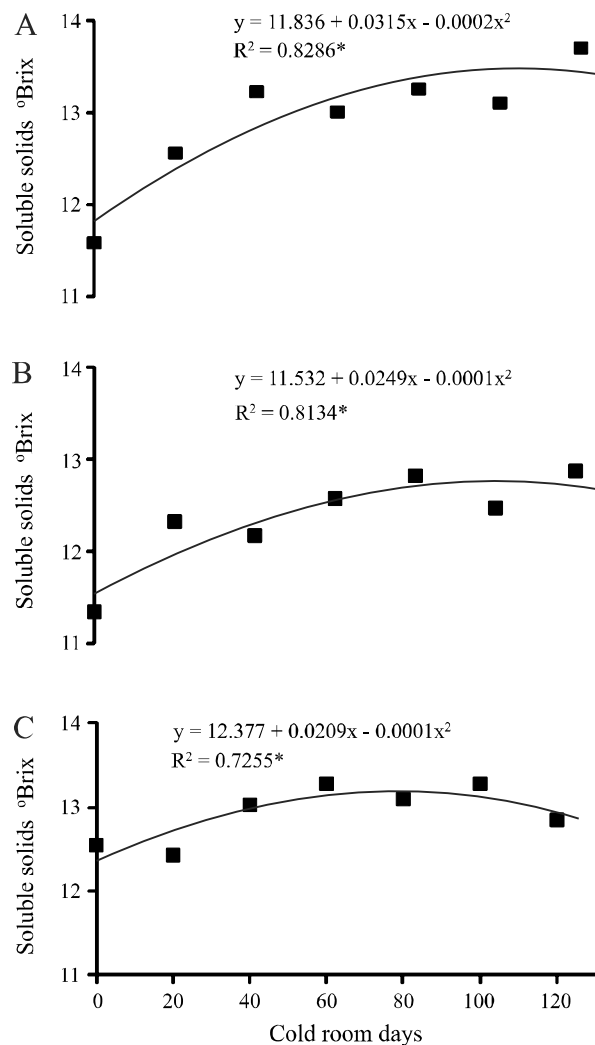
The soluble solids content increased in the course of the cold storage period, having its maximum values predicted by models adjusted in 104 days for HD1, 103 days for HD2 and 80 days for HD3 (Figure 2). The soluble solid content increase is due to polysaccharides degradation, favored by the action of amylase and phosphorylase, with consequent fruit ripening (CHITARRA; CHITARRA, 2005). Despite the increase in the soluble solids contents along

refrigeration, pears presented content reduction by the end of the cold storage period, for the three harvest dates. According to Coutinho *et al.* (2003), during senescence fruits have higher expenditure of reserves through respiration, which can explain the reduction observed in the soluble solids content at the end of the cold storage.

Regarding to the room temperature, there was difference ($p < 0.05$) for soluble solids contents only for HD1 fruits. After six days at 20 °C, soluble solids values were higher (13.6 °Brix) than those ones observed at three days (12.98 °Brix) and at the end of the cold storage period (12.92 °Brix).

Significant linear increase in fruit weight loss was observed along cold storage period, culminating at 120

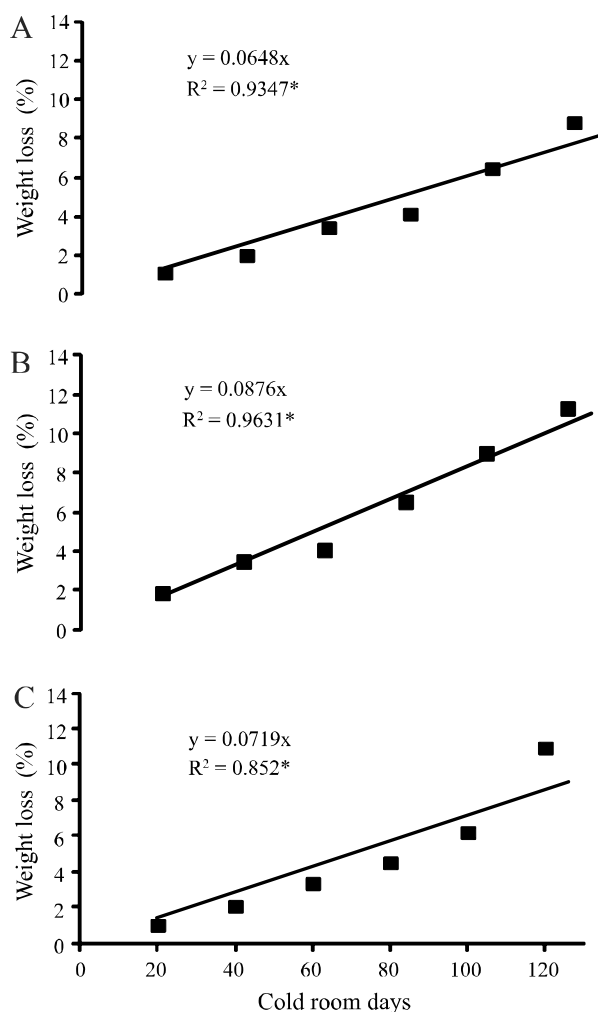
Figure 2 - Soluble solid contents of 'Abate Fetel' pears harvested in three dates (HD1=18/01/2010 (A), HD2=25/01/2010 (B) and HD3=01/02/2010 (C)) and kept for up to 120 days at 0 ± 1 °C and $90 \pm 5\%$ RH. * $P < 0.05$



days, in 8% for HD1 fruits, 11% for HD2 fruits and 9% for late-picked fruits (HD3) (Figure 3). Similar results were found by Mahajan, Singh and Dhillon (2010) with 'Patharnakh' pears stored for 90 days at 0 °C. According to the same authors, losses above 6% compromise fruit quality. In the present study, fruits reached the above-mentioned value after 68, 57 and 49 cold storage days for HD1, HD2 and HD3, respectively.

The weight loss may be caused by transpiration and respiration processes, damaging the global aspect of fruits, as consumers decide purchasing by judging, firstly, the appearance (KADER, 1999). Another negative factor that is directly associated with weight loss is the reduction of weight commercialized after storage, which can lead to profit reduction.

Figure 3 - Weight loss of 'Abate Fetel' pears harvested in three dates (HD1=18/01/2010 (A), HD2=25/01/2010 (B) and HD3=01/02/2010 (C)) and kept for up to 120 days at 0 ± 1 °C and $90 \pm 5\%$ RH. * $P < 0.05$

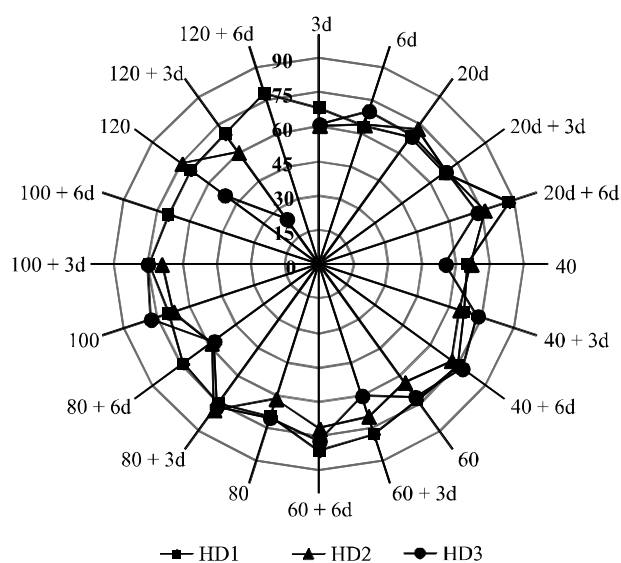


Fruits from the second and third harvests showed, respectively, elevated rot incidence and excessive dehydration after 100 cold storage days followed by six days at room temperature, which made them unsuitable for consumption. The results are in agreement with Benítez *et al.* (2005), who affirmed that early-picked fruits support longer cool storage compared with late-picked fruits.

The highest acceptance values (87%; 81% and 78%) were attributed to fruits of the first harvest date when kept for 20; 60 and 120 days in a cold room followed by six days at room temperature, respectively (Figure 4). Late harvested pears (HD3) kept for 120 days at 0 °C presented acceptance of 51%, whereas those maintained for the same period in a cold room followed by three days at 20 °C presented 24% acceptance. Values below 67% were attributed to fruits not submitted to cold storage and evaluated after three days at room temperature, for the three harvest dates. After 20 and 40 days of cold storage, tasters also attributed low values to fruits of the three harvest dates (Figure 4).

Regarding to the low acceptance values attributed to late-picked fruits (HD3) kept at 0 °C for 120 days; tasters reported that they were overripe, with no or bad taste, lack of juice and starchy pulp. This fact corroborates the studies of Benítez *et al.* (2005) who reported that late-picked fruits lose the organoleptic quality after long periods of cold storage.

Figure 4 - Acceptance rate (%) of 'Abate Fetel' pears harvested in three dates (HD1=18/01/2010, HD2=25/01/2010 and HD3=01/02/2010) and kept for up to 120 days at cold room (CR) 0 ± 1 °C and $90 \pm 5\%$ RH and up to six days in room temperature (RT) (20 ± 1 °C)



Tasters reported that fruits not submitted to cold storage were firm, with no taste, astringent and unripe. The low acceptance for this situation ratifies the necessity of cold storage for inducing ripening (PREDIERI; GATTI 2009; VILLALOBOS-ACUNÁ *et al.*, 2011a, b). Besides cold storage for inducing ripening, the storage of fruits at room temperature is necessary in order to acquire desirable quality for consumption, as tasters evaluated the fruits negatively after 20 and 40 days of cold storage for the three harvest dates.

The purchase intention showed that 52% of the potential interviewed consumers would not buy 'Abate Fetel' pears due to lack of attractiveness of the fruits. Only 15% of consumers would buy fruits with no discount, 18% opted for purchasing if 50% of discount was granted, 11% would buy if there was 30% discount and only 4% of consumers would buy at a 10% discount. The results indicated that presence of russetting interfered in the purchase intention, which can impair the commercialization of the fruits from this cultivar. Another factor reported by consumers that led to rejection of fruits was the elongated shape, since this cultivar is not much known in the Brazilian market. In the same period (60 days at 0 °C, followed by six days at 20 °C), the acceptance test showed that samples presented pleasant juiciness, softness and taste, with no reports of fruits with undesirable aspect. This indicates that marketing strategies must be used so that consumers know and start buying the fruits due to the presented taste and not to the outer appearance damaged by presence of russetting and different shape from other already known cultivars. The characteristics of 'Abate Fetel' pears at first sight damage the purchase intention, but in the future may be reverted into a positive aspect, given that consumers will be able to easily identify and differentiate them from other cultivars.

In accordance with the different evaluations performed along the experiment, it is possible to notice that fruit ripening, based on firmness values, rate of starch degradation and acceptance, occurred after twenty days in low temperature conditions followed by six days of storage at 20 °C for the three harvest dates. In this period, firmness values were inferior to 39.2N, which confers characteristics of suitable fruits for consumption in agreement with Predieri and Gatti (2009). Besides firmness, the rate of starch degradation reached the maximum value of the scale (10), where most of the starch present in fruits was converted into simple sugars, giving the fruits desirable characteristics for consumption. Regarding the sensory analysis, high acceptance was attributed to fruits in this period, which indicates that ripening induction by cold storage was able to stimulate the development of desirable characteristics for consumption.

Soluble solids content is one of the main factors that influence fruit quality pear (CRISOSTO; CRISOSTO, 2005). This attribute interfered in the acceptance only when fruits were still unripe, in other words, when sensory evaluation was performed without submit them to low temperature conditions and, therefore, presented high starch contents and low sugar contents. After detection of ripening, occurred at 20 days of cold storage followed by six days at room temperature, tasters indicated no difference for sweetness of fruits from the different harvest dates. These results are in agreement with Predieri and Gatti (2009) who despite finding differences between soluble solid contents of fruits from the three evaluated orchards, tasters were not able to distinguish such differences by sensory evaluation, indicating that the attribute causes little interference in the acceptance of 'Abate Fetel' pears.

For HD1 fruits, marketing can be initiated after 20 days of storage at 0 °C and extend to fruits maintained in this condition for up to 120 days, as pears did not lose the ripening capacity and maintained elevated quality along the whole period. Given the rot incident and excessive dehydration of HD2 and HD3 fruits observed after 100 days in cold room followed by six days at 20 °C, and also to the low acceptance of fruits after 120 storage days, it is suggested marketing of these fruits preferably occurs between 20 and 80 days, since fruits became unsuitable for consumption after that. If marketing is carried out within three days, cold storage of these fruits can be extended to up to 100 days.

CONCLUSIONS

1. 'Abate Fetel' pears harvested with flesh firmness between 57 and 51 N need 20 days of storage at 0 °C followed by six days at 20 °C for induction of uniform ripening;
2. The quality of 'Abate Fetel' pears is altered along cold storage;
3. Pears harvested with flesh firmness around 57 N can be stored for up to 120 days and marketed in up to six days without compromising quality. Fruits harvested with less than 55 N can be stored for 80 days and marketed in up to six days or stored for 100 days and marketed within three days.

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