Influence of maturity and storage period on physical and biochemical characteristics of pear during post cold storage at ambient conditions

Kirandeep Kaur · W. S. Dhillon

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Abstract The fruits of semi-soft pear (*Pyrus communis*) cv. Punjab Beauty harvested at three different harvest dates were stored at 0–1⁰ C temperature with 90–95 % Relative Humidity for 30, 45, 60 and 75 days to assess the physical and chemical changes during storage. After every storage interval, the fruits were removed and kept at room temperature for 3 and 6 days to study the shelf life of fruits. Immature fruits always had the highest values of flesh firmness; optimum-mature fruits had the next and over-mature fruits the lowest at each corresponding sampling period during storage. The fruits harvested at optimum stage of maturity exhibited significantly ($p < 0.05$) lower incidence of fruit softening and physiological loss in weight. These fruits retained excellent quality up to 60 days of storage in cool chamber with 3 days shelf life at ambient temperature. The fruits of first harvest date were incapable of developing acceptable flavor and quality upon ripening throughout the storage period. However, the fruits harvested at post-optimum stage recorded maximum physiological loss in weight and lesser firmness thus making them suitable for immediate consumption with no shelf life at ambient temperature storage.

Keywords Cold storage · Harvesting dates · Pear · Quality · Shelf life · Storage life

Introduction

The degree of maturity at harvest has a direct effect on the period for which fruit can be stored without losing quality (Kader 1999). Several maturity indices (firmness, total soluble

solids, titratable acidity, ground colour and total sugars) have been evaluated to judge the best harvest time. These maturity indices are greatly influenced by prevailing climatic conditions and vary from season to season (Lotze and Bergh 2005). The weight of pear fruit decreased during storage and the fruits harvested late had higher organoleptic rating and it increased during storage (Bhat et al. 2012). Storability of pears is strictly dependent on the cultivar, fruit maturity during harvest and storage conditions (Elgar et al. 1997). Fruit maturity during harvest is a main factor influencing the quality of stored pears (Sugar and Powers 1994). Pears that were harvested too early never reached an acceptable quality for consumption. On the other hand, when pears were picked late, the rates of firmness degradation and weight loss increased (De Belie et al. 2000). Hence, it is of absolute importance that optimum harvest maturity is well defined to reduce postharvest losses and attain ‘acceptable’ eating quality after storage (Hansen and Mellenthin 1979). Kvikliene et al. (2011) reported that the effect of the harvest date on fruit quality and storability was significant up to 150 days of storage. After this date a fast decline of apple quality parameters was observed. Proper prediction for harvest maturity will also allow producers to plan for harvesting and marketing well in advance and capitalize on labour productivity. Thus, the aim of the study was to determine the influence of harvest date and storage intervals on quality and shelf life of ‘Punjab Beauty’ pears after 3 and 6 days post cold storage at ambient temperature.

Materials and methods

The studies were carried out in the Department of Horticulture and Punjab Horticultural Post-harvest Technology Centre PAU, Ludhiana for two consecutive years and the data represents the average of 2 years. Pear fruits cv. ‘Punjab Beauty’

K. Kaur (✉) · W. S. Dhillon
Department of Horticulture, Punjab Agricultural University,
Ludhiana 141 004, Punjab, India
e-mail: drkirankang@gmail.com

were harvested at 3 different stages i.e. pre-optimum (125 days after full bloom), optimum (140 days after full bloom) and post-optimum (155 days after full bloom) were air dried and packed in Corrugated Fibre Board boxes and stored at 0–1 °C and 90–95 % RH in walk-in-cool chambers. The observations for physical and biochemical parameters which include physiological loss in weight (PLW), firmness, total soluble solids (TSS), Organoleptic score, titratable acidity and total sugars evaluation were recorded at 30, 45, 60 and 75 days storage interval. After every storage interval, the fruits were removed and kept at room temperature (30.5 ± 2.5 °C and 80 ± 2.5 % Relative Humidity) for 3 and 6 days to study the post cold storage life of fruits. The physiological loss in weight (PLW) was calculated on initial weight basis. The firmness of the fruit was measured with hand held penetrometer (Model FT-327) having plunger diameter of 8 mm, and expressed in terms of kg/cm^2 . The total soluble solids (TSS) were determined from fresh strained thoroughly stirred juice of fruits on each sampling date with the help of a hand refractometer. The readings were corrected at 20 °C and expressed as percentage soluble solids. Organoleptic evaluation of the fruits was done by five panels of judges with each panel having five judges on the basis of Hedonic scale (1 to 9 points), on the basis of general appearance, taste and texture (Amerine et al. 1965). Each panelist scores were reflected on a hedonic scale of 1 to 9 where 1=dislike extremely and 9=like extremely. The titratable acidity in juice as malic acid was determined by titrating a known volume of juice with 0.1 N NaOH using phenolphthalein as an indicator. The total sugars were determined by the method of Lane and Eynon (AOAC 2000).

Statistical analysis The experiment was laid out in completely randomized block design with factorial arrangement having three replications. Total samples analyzed were 36 for each set of experiment and each replication comprised of 2 kg fruits. The data of two seasons was pooled and subjected to analysis of variance (ANOVA) using SAS 9.3 (2011) to find out the significance of different treatments. The treatment combinations significant at $p < 0.05$ were subjected to mean comparison using Tukey's HSD.

Results and discussion

The rate of weight loss in storage for each stage of maturity was determined on the basis of water loss from the fruit after 30, 45, 60 and 75 days of cold storage followed by storage at ambient temperature for 3 and 6 days (Table 1). With increasing storage periods, a notable increase in weight loss was found in all treatments. The third harvest had the highest total weight loss at all times during storage, while pears harvested at early maturity (first harvest) had the lowest weight loss (less

than 10 %) compared with the last harvest that lost more than 10 % of their weight after post cold storage of 75 days and became unmarketable. The results revealed that there was significantly less loss in weight in the fruits harvested earlier than those harvested later. This could be due to higher respiration and transpiration losses as the maturity advances. Physiological loss in weight decreased significantly after 3 and 6 days at ambient temperature with the advancement in storage period but the decrease was more pronounced at 6 days of shelf life. The PLW of fruits beyond certain limits leads to shriveling of fruits, ultimately resulting in loss of freshness, appearance and quality of the fruit. The physiological loss in weight (PLW) of fruits, in general, increased with the advancement of storage period rather slowly in the beginning but at a faster pace as the storage period advanced (Mahajan et al. 2013).

After storage and a simulated shelf-life period, the 'Punjab Beauty' pears, harvested at the earliest date, and stored in cold chamber, were usually the firmest ones (Table 1). The least firm pears could be observed in those from the last harvest, which had showed sharp decline in firmness after post cold storage at ambient temperature for 3 and 6 days. Eccher Zerbini et al. (2002) also reported that after storage the pears harvested at the later date had lesser firmness. Thus, the fruits harvested at pre-optimum and optimum stage recorded acceptable firmness (5.78 and 5.32 kg/cm^2) till 60 days of storage with shelf-life of 3 days whereas the fruits harvested at post-optimum stage recorded acceptable firmness only up to 45 days of cold storage with 6 days shelf life at ambient temperature. The change in firmness of fruits is gradual and significant after 6 days of shelf life. After 3 days of shelf life significant change was observed only in a few cases. The softening of flesh during cold storage could be due to the degradation of soluble pectin by high activity of endopolygalacturonase in fruits. Pears harvested earliest had the highest firmness both before and after storage and lost less percentage of their firmness during storage (Li et al. 2011).

The organoleptic rating during the ambient storage of cold stored fruits decreased progressively with the advancement of storage period due to physiological loss in weight and shriveling of fruits (Table 1). However the organoleptic score increased in fruits kept for 3 days at ambient temperature as compared to fruits taken immediately for analysis after 30 days of cold storage. The fruits harvested at optimum stage retained excellent appearance, taste and quality compared to fruits harvested post optimum stage which turned bland in taste and showed less acceptability. However, the fruits harvested pre-optimum stage did not attain the same level of sensory quality as compared to threshold mature fruit. The fruits loosed their quality traits at a faster rate after 75 days of storage. The decrease in organoleptic rating with the advancement of storage period might be associated with over ripening, loss of texture, increase in some biochemical changes and

Table 1 Effect of harvesting times and storage interval on physical characteristics of pear cv. Punjab Beauty during post cold storage at ambient temperature for 3 and 6 days.($n=6$)

Storage period	Harvesting Times	Shelf life (Days)	PLW (%)	Firmness (Kg/cm ²)	Organoleptic score
30 Days	H1	3	2.60 ⁿ	7.79 ^a	7.79 ^b
		6	3.24 ^l	6.37 ^c	7.15 ^{de}
	H2	3	4.23 ^j	6.88 ^b	8.11 ^a
		6	6.13 ^h	5.86 ^{de}	7.66 ^{bc}
	H3	3	6.17 ^h	6.04 ^d	7.85 ^{ab}
		6	7.93 ^e	5.52 ^{fg}	6.43 ^f
45 Days	H1	3	2.69 ^{mn}	6.85 ^b	7.41 ^{cd}
		6	3.63 ^k	5.68 ^{ef}	7.12 ^{de}
	H2	3	4.28 ^j	6.37 ^c	7.83 ^{ab}
		6	6.21 ^h	5.22 ^g	7.63 ^{bc}
	H3	3	7.69 ^e	5.87 ^{de}	5.82 ^g
		6	8.52 ^d	4.68 ^h	4.93 ^h
60 Days	H1	3	2.94 ^{lm}	5.78 ^{def}	6.91 ^c
		6	3.79 ^k	5.35 ^g	5.09 ^h
	H2	3	4.48 ^j	5.32 ^g	7.72 ^{bc}
		6	6.59 ^g	4.58 ^h	6.19 ^f
	H3	3	9.12 ^c	4.82 ^h	5.66 ^g
		6	9.82 ^b	2.81 ^k	4.06 ⁱ
75 Days	H1	3	3.87 ^k	5.87 ^{de}	5.14 ^h
		6	4.98 ⁱ	5.21 ^g	4.26 ⁱ
	H2	3	4.97 ⁱ	4.75 ^h	6.22 ^f
		6	7.00 ^f	4.23 ⁱ	5.18 ^h
	H3	3	9.53 ^b	3.27 ^j	4.21 ⁱ
		6	10.70 ^a	2.46 ^l	3.24 ^j
F value					
Harvest time X Storage Period			195.11*	86.69*	102.09*
Harvest time X Shelf life			204.95*	12.47*	28.04*
Storage Period X Shelf life			6.52**	21.36*	111.01*
Harvest time X Storage Period X Shelf life			17.11*	42.13*	12.37*

H1=pre-optimum, H2=optimum, H3=post-optimum, Means followed by different superscript letters in the same column are significantly different by Tukey's test ($P<0.05$). Level of significance, NS – Non Significant, *Significant at $P<0.05$, ** Significant at $P<0.01$

decrease in biochemical attributes like TSS and total sugars. The organoleptic score is the balance between sugars and acids. The juicy and buttery texture of ripened pear fruits also indicates the involvement of cell substances and then degradation by enzymes (pectinesterase and polygalacturonase) in ripening process during storage (Chen and Mellenthin 1981). Moreover with delay in harvesting dates an increase in sugars due to hydrolysis of polysaccharides (Wills et al. 1980) and concentration of juice as a result of dehydration, decrease in astringency and acidity might have increased the organoleptic score. Guerra et al. (2009) also reported that both harvest date and storage time played a significant role in quality and sensory characteristics.

TSS content increased gradually with the increase in storage period up to 60 days may be due to the hydrolysis of polysaccharides to monosaccharides and concentration of

juice as a result of moisture loss through transpiration but showed a tendency to decrease towards the later part of storage period (Table 2). The TSS content of pear fruits varied significantly with the harvesting maturity. The fruits harvested at pre-optimum stage recorded the least TSS content. However, fruits harvested at post-optimum stage showed maximum increase in TSS content after 45 days of storage with 3 days shelf life at ambient temperature whereas this increase in TSS content was extended to 60 days with 3 days shelf life in case of fruits harvested at optimum stage of maturity. The increase in total soluble solids during storage up to 60 days may be attributed to numerous metabolic processes taking place in the fruits, preparing it for senescence. The hydrolysis of starch and pectins, yielding mono and disaccharides could be the reason for increase in TSS. However, on complete hydrolysis of starch, no further increase in TSS occurs and consequently

a decline in TSS is predictable as they are the primary substrates for respiration and are used by fruits in various metabolic activities (Wills et al. 1980). Li et al. (2011) reported that the latest picked pears showed higher total soluble solids value and serious internal browning and skin blackening due to their over ripeness.

Storage period and shelf life intervals did not significantly influenced the acid content in juice of pear fruits (Table 2). There was no significant decrease in the acid content of fruits with the delay in harvesting time. The change in acid content from the first to the last storage period ranged from 0.303 to 0.150 %. Harvesting dates also had a nonsignificant influence on the acidity when the fruits were kept at ambient temperature. Among the metabolic reactions, respiration is an important process, which may utilize organic acids as a substrate during the peak energy requirement of fruits, which usually

coincides with ripening leading to a decrease in acidity with prolonged storage (Sonkar and Ladaniya 1999).

The total sugars increased with increase in storage period (Table 2). The total sugars increased with delay in harvesting dates, but in fruits harvested at post-optimum stage, the total sugars decreased after 45 days of cold storage when kept 6 days at ambient temperature whereas the fruits harvested at optimum stage showed increase in total sugars up to 60 days of cold storage with 3 days shelf life at ambient temperature. However, after 75 days of post cold storage at room temperature, the total sugars declined and this decline was more pronounced in fruits harvested at post-optimum stage which might be due to fermentation in overripe fruits which converted sugars into alcohols. The increase in total sugars with the delay in harvesting dates was also noted by Yamaki et al. (1993) who reported that the increase in sugar concentrations

Table 2 Effect of harvesting times (and storage interval on biochemical characteristics of pear cv. Punjab Beauty during post cold storage at ambient temperature for 3 and 6 days. ($n=6$)

Storage period	Harvesting Times	Shelf Life (Days)	TSS (%)	Acidity (%)	Total Sugars (%)
30 Days	H1	3	12.74 ^l	0.303 ^a	8.72 ^{hi}
		6	13.22 ^k	0.300 ^a	8.95 ^{gh}
	H2	3	13.17 ^k	0.251 ^a	9.39 ^{abcdef}
		6	13.66 ^{ij}	0.241 ^a	9.47 ^{abcd}
	H3	3	13.26 ^k	0.207 ^a	9.53 ^{ab}
		6	13.86 ^{ghi}	0.198 ^a	9.61 ^a
45 Days	H1	3	13.99 ^{fgh}	0.291 ^a	9.01 ^{gh}
		6	14.25 ^{abcdef}	0.281 ^a	9.18 ^{defg}
	H2	3	14.1 ^{cdefgh}	0.242 ^a	9.58 ^a
		6	14.4 ^{abcd}	0.234 ^a	9.53 ^{ab}
	H3	3	14.45 ^{ab}	0.201 ^a	9.44 ^{abcde}
		6	14.05 ^{efgh}	0.186 ^a	9.25 ^{bcdefg}
60 Days	H1	3	14.14 ^{bcdefg}	0.278 ^a	9.24 ^{bcdefg}
		6	14.02 ^{fgh}	0.272 ^a	9.2 ^{cdefg}
	H2	3	14.52 ^a	0.231 ^a	9.63 ^a
		6	14.35 ^{abdec}	0.221 ^a	9.5 ^{abc}
	H3	3	14.41 ^{abc}	0.185 ^a	8.97 ^{gh}
		6	13.47 ^{jk}	0.173 ^a	8.71 ^{hi}
75 Days	H1	3	14.09 ^{defgh}	0.263 ^a	9.14 ^{efg}
		6	13.23 ^k	0.245 ^a	9.08 ^{fg}
	H2	3	14.4 ^{abcd}	0.212 ^a	9.44 ^{abcde}
		6	13.81 ^{hi}	0.195 ^a	9.21 ^{cdefg}
	H3	3	13.65 ^{ij}	0.165 ^a	8.6 ^{ij}
		6	12.44 ^l	0.150 ^a	8.29 ^j
F value					
Harvest time X Storage Period			56.92*	0.21 ^{NS}	64.32*
Harvest time X Shelf life			43.23*	0.10 ^{NS}	9.25**
Storage Period X Shelf life			165.21*	0.01 ^{NS}	9.60*
Harvest time X Storage Period X Shelf life			8.93*	0.22 ^{NS}	0.37 ^{NS}

H1=pre-optimum, H2=optimum, H3=post-optimum, Means followed by different superscript letters in the same column are significantly different by Tukey's test ($P<0.05$). Level of significance, NS – Non Significant, *Significant at $P<0.05$, ** Significant at $P<0.01$

during maturity of pear in the free space of cell may be to the enhancement of permeability of sugars across the tonoplast, thus giving the fruits a sweet and juicy taste.

Conclusion

Pear fruits harvested at optimum stage (140 days after full bloom) can be stored for 60 days in cold storage (0–1 °C, 90–95 % Relative Humidity) with post-storage shelf life of 3 days at ambient temperature (30.5±2.5 °C and 80±2.5 % Relative Humidity) with acceptable edible quality of fruits.

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