CONSUMER ACCEPTABILITY AND SHELF LIFE OF “FLOR DE INVIERNO” PEARS (*Pyrus communis* L.) UNDER DIFFERENT STORAGE CONDITIONS

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ABSTRACT

Two groups of “Flor de Invierno” pears (*Pyrus communis* L.), one recently harvested and another stored in a refrigerated controlled atmosphere for 7 months, were studied after storage at 20°C in a normal atmosphere. Survival analysis was used to estimate sensory shelf life, which was 29 and 15 days for a 50% rejection probability, or 13 and 7 days for a 25% rejection probability for recently harvested and stored pears, respectively. A consumer panel evaluated the overall acceptability of the pears on a 9-point hedonic scale. Recently harvested pears obtained higher acceptability scores throughout the 20°C storage time. Instrumental firmness measurements were performed with a texture analyzer through a compression test. The results obtained showed that prolonged storage in a controlled atmosphere causes changes in the fruit that lead to lower firmness, lower acceptance scores and, consequently, a shorter sensory shelf life.

PRACTICAL APPLICATIONS

The use of survival analysis to study the shelf life of foods is quite a novel technique in which the key concept is to focus the shelf life estimation on consumer rejection. In this study, survival analysis was applied to pears, but can be applied to other fruits or foods. This approach is useful to know the adequate storage time of food without detrimental sensory quality changes that would conduct to the consumer rejection. Normally, loss in sensory quality appears before microbiological spoilage in many food, so this methodology could be used to predict sensory shelf life.

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INTRODUCTION

Fruit ripening processes are very important because they influence the changes that occur during fruit storage, transport and sale, such as softening, becoming sweeter and changes in aroma and color, as well as affecting nutritional value. The state of maturity has a great influence on consumer acceptance of a fruit. Not only is the eating quality affected by the state of maturity, but the shelf life of the product can also be seriously limited by physiological stresses as a result of processing operations (Soliva-Fortuny et al. 2004). In most fruits, maturity is responsible for significant variations in the fruit’s oxidative/antioxidative balance. In pears, moreover, the phenolic composition, which together with the polyphenol oxidase content, determines the browning potential of a fruit, can vary greatly with the cultivar, stage of maturity and postharvest storage conditions (Amiot et al. 1995).

Pears are usually harvested between August and mid-September in Spain, so appropriate postharvest storage conditions are required to preserve fruit quality over a period of up to 9 months. Pears are usually chilled at temperatures of −1 to 1°C after harvesting (Gerasopoulos and Richardson 1996; Elgar et al. 1997) for three reasons. First, this fruit can be stored for a long time at low temperatures. Second, most winter pears do not ripen at warm temperatures until they have been exposed to a critical period of cold storage that is specific to each cultivar (Chen et al. 1982), and third, chilling makes it possible to synchronize the ripening of individual fruits. Maintenance of pear attributes is likely if storage under controlled atmosphere conditions is provided (Drake et al. 2001; Galvis-Sánchez et al. 2006). A reduced O2 concentration (1.5–2.5%) and a slightly raised CO2 concentration (0.7–1%), in combination with a low temperature, are believed to be the optimal controlled atmosphere conditions to prolong the storage life of pears by reducing the respiration and other metabolic reactions and by preventing microbial growth (Franck et al. 2003). However, a decrease in firmness in different pear varieties throughout storage under different conditions has been observed by several authors (López et al. 2001; Galvis-Sánchez et al. 2003, 2004a,b). This decrease in firmness is caused by solubilization of pectin via the action of various hydrolyases (Bartley et al. 1982). Research into the changes in the firmness and color of pears after an extended storage time and the global acceptability of this fruit from a sensory point of view has been limited. Furthermore, fruit is kept at ambient temperature by small-scale distributors and retailers and for daily home consumption, so the question arises of how long the pears will remain fit to eat after having undergone a prolonged period of storage (Varela et al. 2005). Galvis-Sánchez et al. (2003, 2004b) confirmed, using a sensory panel, that the firmness and color of “Rocha” pears were strongly affected by storage time and by time in the open air at room temperature after harvest. Sensory
data revealed that the fruits stored in air were yellowier (high susceptibility to browning) and less sweet than those stored in a controlled atmosphere, whereas firmness and juiciness were influenced to a lesser extent. However, they did not compare the results with recently harvested pears in order to determine whether a long storage period might have affected their physical and sensory properties.

“Flor de invierno” pears grow in the area of Lérida (Spain); it is a variety appreciated by local growers as it has a good yield (approximately 80,000–120,000 kg/ha), and if it has the right ripening process, its quality is excellent. “Flor de invierno” pears are usually stored refrigerated during 6 or 7 months (Recasens et al. 1989). As it is a local pear variety, it is not well known outside Spain, and there are almost no studies about its ripening and storage (Recasens and Roig 1996).

The aims of this work were (1) to estimate the sensory shelf life at ambient storage of “Flor de invierno” pears (Pyrus communis L.) by survival analysis; (2) to compare pears previously stored in a refrigerated controlled atmosphere for 7 months, with recently harvested pears; and (3) to relate the acceptability to consumers and firmness of both types of pears to the sensory failure.

**MATERIALS AND METHODS**

**Plant Material and Storage Conditions**

Fifty kilograms of “Flor de invierno” pear fruits (Pyrus communis L.) (250 units) were harvested at commercial maturity (11°Brix, firmness ranged from 5.5 to 6.5 kg measured with a 8-mm diameter probe) from the same Spanish orchard (Lérida, Spain) in October 2003 and October 2004. Immediately after harvest the fruits were selected for uniformity and absence of defects. Pears of the first group, harvested in October 2003 (pears 2003), were placed in a refrigerated controlled atmosphere (1C, 2% O2 and 2% CO2) for 7 months. Pears of the second group, harvested in October 2004 (pears 2004), were refrigerated for 1 month to ensure correct ripening (Chen et al. 1982). Sub-batches of both groups of pears were subsequently transferred to storage at 20°C without atmosphere control, as they would be treated by small-scale distributors and retailers and for daily home consumption. They remained at 20°C for 0, 6, 11, 17, 21 and 27 days (pears 2003) and for 0, 12, 22, 34 and 43 days (pears 2004) to attain samples with different storage times. The storage times were determined through previous tests. Before storage at 20°C, the pears were sanitized with a 200 ppm chlorine solution for 10 min, rinsed and individually dried.
Sensory Evaluation

Testing was carried out in a sensory laboratory equipped with individual booths (ISO 1988). The samples were peeled and cut into 1.5-cm sided cubes for evaluation. Cutting took place at 8°C, 1 h at most before the evaluation, to ensure browning did not occur before the evaluation.

Consumers were recruited among nonscientific personnel of the Instituto de Agroquímica y Tecnología de Alimentos and the Universidad de Valencia, Valencia, Spain. Thirty persons, 22–60 years old, approximately 50% female and 50% male, who consumed pears frequently, were recruited for the preliminary study performed in a laboratory-scale consumer acceptability test. These consumers performed the sensory analysis in two different sessions on two different days. In the first one, they received six cubes of pears 2003 and in the second one, five cubes of pears 2004, one cube from each different storage time, following a balanced complete block experimental design. The cubes were presented in random order. For each sample, consumers had to evaluate the visual aspects, taste them and score the product using a 9-box scale labeled on the left with “dislike very much,” in the middle with “indifferent” and on the right with “like very much.” They also answered the question “Would you normally consume this product?” with a yes or a no (Hough et al. 2003; Gámbaro et al. 2004a,b). This answer is used to calculate the shelf life of pears by survival analysis methodology.

Instrumental Texture Evaluation

A TA-XTplus Texture Analyser (Stable Micro Systems, Godalming, U.K.) was used to evaluate the texture of the pear samples. Immediately before measurement, the samples were peeled and cut into 1.5-cm sided cubes with a sharp cutter, avoiding vascular tissue. All tests were performed on the cubes with the same orientation because of the fibrous nonisotropic properties of pear flesh. Four replicates were carried out for each sample. A compression test was performed with a 75-mm aluminum compression plate (P/75) to an 80% strain, with a test speed of 1 mm/s, a trigger force of 5 g and force in compression mode.

Statistical Analyses

Survival analysis methodology, developed by Hough et al. (2003), was used to estimate the shelf life of “Flor de invierno” pears using the answers obtained from consumers to the question of whether they would normally consume the samples with different storage times. The key concept of survival analysis methodology is to focus the shelf-life hazard on the consumer rejecting the product rather than on the product deteriorating. The SPLIDA software
package for S-PLUS (Insightful Corporation, Seattle, WA) was used to calculate the survival curves. Rejection probabilities of 25 and 50% were used to estimate the shelf life (Gacula and Singh 1984; Cardelli and Labuza 2001; Gámbaro et al. 2004b; Varela et al. 2005).

Analysis of variance (ANOVA) was performed on consumers’ acceptability scores and the texture data. In order to study the differences among samples, least significant differences were calculated by Fisher’s test. These analyses were performed using the Statgraphics Plus 2.1 package (Bitstream, Cambridge, MA).

RESULTS AND DISCUSSION

Acceptability Test (Laboratory Scale Consumer): Preliminary Study

The results of the consumer acceptability test are shown in Figs. 1 and 2. The overall acceptability of pears 2003 decreased significantly from 6 days’ storage at 20°C onward, while the overall acceptability of pears 2004 decreased after 12 days’ storage but then remained constant until the end of the study. However, it should be noted that the acceptability of the pears 2003 on day 0 was 6.1 and 6.2 for pears 2004 on day 0. In a hedonic scale of 9 points, a score of 6 is considered a commercial or quality limit (Muñoz et al. 1992). Nevertheless, fresh fruit acceptability scores are generally not very high, particularly in comparison with the ratings given to elaborated dessert (Varela et al. 2005). Indeed, although little research on fruit consumer preferences has been

![FIG. 1. MEAN VALUES OF CONSUMER ACCEPTABILITY SCORES (30 CONSUMERS) OBTAINED FOR PEARS STORED IN A CONTROLLED ATMOSPHERE FOR 7 MONTHS, OVER STORAGE TIME AT 20°C IN A NORMAL ATMOSPHERE](image)

Different letters indicate significant differences at $P \leq 0.05$. 
published, Jaeger et al. (1998) found fresh-apple acceptability values between 4.7 and 6.8 for the “Jonagold,” “Cox” and “Boskoop” apple varieties, and Abbot et al. (2004) reported values between 4.5 and 6.8 for “Golden Delicious,” “Granny Smith” and “Goldrush” apples.

Significantly, pears 2004 retained greater acceptability over the 20°C storage period. Therefore, it may be concluded that prolonged controlled atmosphere storage may induce changes in the structure of the product, such as the development of undesirable color and texture and abnormal taste and flavor, as found by Drake et al. (2001).

Working in sensory analysis with fresh-cut fruits is a difficult task, and sometimes choosing a small number of consumers is preferable to sacrificing sample homogeneity and conditions of presentation. The results obtained with only 30 consumers are regarded as preliminary; nevertheless, they are marked and clear in tendency, which would be corroborated with a representative consumer test.

**Shelf-life Studies**

Table 1 shows the maximum likelihood estimates of the parameters using the Weibull distribution for both groups of pears studied. The shelf-life times and confidence intervals for 25 and 50% rejection probabilities were estimated by solving the equation $F(t; \mu, \sigma) = 0.25$ and 0.50, respectively. For instance, the estimated values for $\mu$ and $\sigma$ in the Weibull model are 3.7 and 0.9 for recently harvested pears and 3.0 and 0.8 for stored pears. Hence, solving...
These parameters can be used to graph percentage rejection versus storage time (Fig. 3). It can be observed that the shapes of the curves are different for the two groups of pears.

The shelf lives corresponding to 25 or 50% consumer rejection (ordinate axis) can be read on the abscissa axis. The survival estimates of the shelf life of the pears, with their 95% confidence band values, are summarized in Table 1.

![Graph showing percentage rejection over time for stored versus fresh pears.](image)

**FIG. 3. ESTIMATION OF THE PERCENTAGE OF CONSUMERS REJECTING PEARS OVER TIME OF STORAGE AT 20°C**

\[ F(t; \mu = 3.7, \sigma = 0.61) = 0.5 \text{ and } F(t; \mu = 3.0, \sigma = 0.8) = 0.5 \text{ implies } t = 29 \text{ and } t = 15, \text{ respectively, which indicates that the estimated shelf life for pears for a 50% rejection probability is 29 days for recently harvested pears and 15 days for stored pears.} \]

**TABLE 1.**

VALUES OF THE MAXIMUM LIKELIHOOD ESTIMATES OF \( \mu \) (LOCATION PARAMETER) AND \( \sigma \) (SHAPE PARAMETER) AND CONFIDENCE INTERVALS (CI) FOR THE FAILURE FUNCTION MODEL USING THE WEIBULL DISTRIBUTION

<table>
<thead>
<tr>
<th>Pears</th>
<th>( \mu \pm CI )</th>
<th>( \sigma \pm CI )</th>
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<tbody>
<tr>
<td>Recently harvested pears</td>
<td>3.7 ± 0.3</td>
<td>0.9 ± 0.4</td>
</tr>
<tr>
<td>Pears stored in a controlled</td>
<td>3.0 ± 0.2</td>
<td>0.8 ± 0.2</td>
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<tr>
<td>atmosphere for 7 months</td>
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\[ F(t; \mu = 3.7, \sigma = 0.61) = 0.5 \text{ and } F(t; \mu = 3.0, \sigma = 0.8) = 0.5 \text{ implies } t = 29 \text{ and } t = 15, \text{ respectively, which indicates that the estimated shelf life for pears for a 50% rejection probability is 29 days for recently harvested pears and 15 days for stored pears.} \]
Table 2. At this point a question could arise: would working with more consumers improve the estimation? Not necessarily, although it would give more precise values for the estimators – $\mu$ and $\sigma$ – and narrower confidence bands (Salvador et al. 2006). Nevertheless, the cost and time of interviewing more consumers would have to be taken into account. Another way of improving the estimation would be storing the samples for longer times, but it was not possible as 27 or 43 days, respectively, is a limit in this case: preliminary studies detected spoilage appearance in some pears stored at 20°C for longer. As it can be seen, the shelf life of pears 2004 was higher than for pears 2003. These results are in accordance with the acceptability data obtained: it was found that the acceptability of pears 2003 decreased more quickly during the storage time at 20°C than that of pears 2004. Acceptability of pears 2003 decreased from 6.06 to a significant lower value (4.06) on day 11 and pears 2004 decreased from 6.2 to a significant lower value (4.3) on day 22; both days (11 and 22, respectively) were near the 50% rejection estimate.

### Texture Evaluation

The complete profiles of the compression curves were studied, as they were useful in illustrating the evolution of the textural characteristics over the shelf life period (Varela et al. 2005). Figure 4 shows the evolution of the compression profiles over the storage period for the pears 2003 (days 0, 6, 11, 21 as examples). The sample of day 0 is far more brittle than the more aged pears (it has a more definite breakage peak, indicating a net collapse of the structure); it is also more rigid (steeper slope at the beginning of the curve) and firmer (greater maximum force). With storage at 20°C the pears became softer, maintaining some brittleness on day 6, but losing their compact structure completely from day 11 of storage. The evolution of the compression profiles for the pears 2004 is plotted on Fig. 5. It can be observed that the profile of the sample of day 0 is very different from the rest of the samples measured; it is a typical plot of a crispy product, with a net breakage and a number of sudden subsequent failures. The rest of the profiles had a flatter shape comparable to

<table>
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<th>Table 2. SHELF-LIFE ESTIMATES AND CONFIDENCE INTERVALS FOR 25 AND 50% REJECTION BY CONSUMERS</th>
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<tr>
<td>Shelf life (days) ± 95% confidence bands</td>
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<tr>
<td>25% rejection</td>
</tr>
<tr>
<td>Recently harvested pears</td>
</tr>
<tr>
<td>Stored pears</td>
</tr>
</tbody>
</table>

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FIG. 4. COMPARISON OF THE COMPRESSION PROFILES OF “FLOR DE INVIERNO” PEARS
Curves corresponding to 0, 6, 11 and 21 days at 20°C (previously stored in controlled atmosphere for 7 months).

FIG. 5. COMPARISON OF THE COMPRESSION PROFILES OF RECENTLY HARVESTED “FLOR DE INVIERNO” PEARS
Curves corresponding to pears stored 0, 12 and 43 days at 20°C.
that described for pears 2003 on day 0 (with a force peak near 70–80 N), and they then maintained the magnitude of the resistance to compression until day 34 and the shape during the storage even on day 43, indicating the loss in the structure of the fruits was not so dramatic.

To statistically analyze the data, a firmness index was taken as the peak force value at breakage or maximum value after initial slope in the force-versus-time compression curve (Table 3). During the storage period, both groups suffered a regular firmness decrease. Other studies also found that softening took place during ripening, associating it to the solubilization of pectins by hydrolases (Murayama et al. 2002; Galvis-Sánchez et al. 2003). However, Shang Ma and Chen (2003) studied “Doyenne du Comice” pears and found that fruit stored in air for 4 months or longer did not soften properly during ripening and remained firmer – even on day 7 at 20°C – than those stored for 3 months or less. That is why is important to study the ripening behavior for each variety and storage conditions in particular and not to generalize data obtained in different conditions or for different varieties.

Apart from the softening during storage at 20°C for each group of pears, when the plots of both groups are compared, it can be noticed that firmness values for pears 2004 were much higher for most of the dates of analysis than the stored ones. Our data are in agreement with previous studies on other pear varieties; Murayama et al. (2002) worked with the varieties “Marguerite Marillat” and “La France” and found that flesh firmness in fruit after long-term storage was significantly lower than in fruit after short-term storage for both cultivars. Galvis-Sánchez et al. (2003) also found that firmness was influenced by storage time in controlled atmosphere, as well as by the time of exposure to the open air at room temperature, and that firmness of “Rocha” pears decreased sharply after 7 months of storage in controlled atmosphere.

In future studies, it would be interesting to correlate the difference in sensory acceptability found in pears subjected to prolonged storage in

<table>
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<th>TABLE 3. INSTRUMENTAL FIRMNESS (N) THROUGH TIME OF STORAGE AT 20°C</th>
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<tr>
<td>Storage at 20°C (days)</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td>17</td>
</tr>
<tr>
<td>21</td>
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<td>27</td>
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Different letters in the same column indicate that there is significant difference at $P \leq 0.05$. 
controlled atmospheres with the changes that may occur in the cell walls of the fruit, which might affect physical properties and the sensory quality of the product.

**CONCLUSIONS**

Survival analysis methodology was useful to estimate the sensory shelf life of pears stored under different conditions. Weibull model allowed comparing the rejection time distributions of the different samples. Controlled atmosphere-stored pears had lower sensory shelf life, lower acceptability and were less firm than recently harvested pears, indicating that some softening process or change in ripening capacity took place during prolonged controlled atmosphere storage caused by the solubilization of pectin via the action of various adventitious hydrolases.

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