Improving mulberry shelf-life using PEAKfresh package in cold environment

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Abstract
Mulberries (Morus species) were packed in regular paper bag, PEAKfresh plastic bag and perforated plastic bag and stored for 3, 6 and 10 days at 3°C. The effect of different packages on its respiration rate, physiological loss of mass (PLM), color, total soluble solids (TSS) and sensory quality was studied. PEAKfresh package is a Modified Atmosphere Packaging (MAP) film specifically developed for the packaging of fresh fruits, vegetables, plants and cut flowers. It can retard the natural ageing process by removing harmful gasses besides ensuring that the produce does not dehydrate. Respiration rates (RR CO₂) in PEAKfresh packaged mulberries ranged between 43.4 and 50.0 mL kg⁻¹ h⁻¹ after 3 days storage at 3°C and increased between 48.8 and 61.9 mL kg⁻¹ h⁻¹ by the end of 6 days, but decreased between 49.6 and 64.4 mL kg⁻¹ h⁻¹ by the end of 10 days. Mulberries packed in PEAKfresh showed significantly lower respiration rates than the mulberries in the other two packages. This particular factor indicates the potential of modified atmosphere package for improving shelf-life. The PLM of PEAKfresh packaged mulberry was 0.1-0.15% after 3 days of storage at 3°C, and after 6 days and 10 days the PLM of mulberries increased to 0.3% and 0.33%, respectively. There was no significant difference between the packages and no significant difference in TSS for different durations.

Keywords: Mulberry; shelf-life; cold storage; PEAKfresh package; respiration.

Introduction
Mulberry (Morus species) is grown wild or cultivated in many countries for its foliage, which is a primary source of food for silkworms (Bombbyx mori). In general, there are three types of mulberry, including white (Morus alba), black (M. nigra) and red (M. rubra). Mulberry fruit is an aggregate fruit that is composed of many smaller fruits called drupes. The skin is smooth and fragile. The color depends on the cultivar. For Morus alba L., some cultivars have white fruits, others have black fruits; for Morus nigra L., the fruit is black; for Morus rubra L. and Morus multicaulis Loud, some cultivars have black fruits while others have deep red fruits when ripe; for Morus kagayamae Koidz, the fruit is black. Mulberries have a stem that persists on the fruit when it is picked from the tree, distinguishing it from blackberries and raspberries.

Mulberry fruit is rich in carotene, vitamins B1, B2 and C, glucose, sucrose, morin, tartaric acid and succinic acid. Mulberry fruit has a long history of use in Chinese medicine, and almost all parts of the plant are used for different purposes. Mulberry fruit is used for liver-kidney deficiency, tinnitus, dizziness, insomnia, rheumatic pain, premature gray hair,
Materials and Methods

Materials: Wild Mulberries (Morus species) were harvested from a local tree at ripening stage. Two kilograms of mulberries were harvested and the stem on the fruit was cut to obtain uniform samples. Three different materials, namely, regular paper bags, PEAKfresh plastic bags and perforated plastic bags were used to pack 100 gm of mulberry in each pack the fresh mulberries. The initial moisture content of the mulberries was 87%, density 950 kgm⁻³ and TSS 7.75 °Brix. The packed fruits were stored at 3 °C for 3, 6 and 10 days to observe the change in mass loss, surface color, TSS, moisture and visual quality.

Measurement of total soluble solids (TSS): The total soluble solids of the packaged mulberries were determined after 3, 6 and 10 days of storage, using a handheld refractometer (Reichert, Inc., Japan; Model – r mini Handheld). The juice of the mulberries extracted through cheesecloth was used to measure the TSS in triplicates. The means are reported here.

Measurement of fruit respiration rate (RR): Fruit respiration rate was monitored at 3, 6 and 10 days after storage by a static method. The mulberries were allowed to respire for about 3 hours inside air-tight glass bottles having a silicone septum on the lid (Palanimuthu et al., 2009; Song et al., 1992). The bottles were placed at 3 °C for 3 hours to allow the fruits to respire. The head space gas composition inside the bottles was analyzed using a gas chromatograph (SRI Instruments Inc., California, USA; Model-8610A) equipped with a thermal conductivity detector. The respiration of mulberries in terms of CO₂ evolution (RR_CO₂), O₂ consumption (RR_O₂) and respiratory quotient (RQ) were calculated as follows

\[
\text{Respiration Rate (RR_CO₂)} = \frac{\text{Change in CO₂ concentration in head space (%)} \times \text{Free volume (mL)}}{\text{Fruit mass (g)} \times \text{Duration of respiration (h)}}
\]

\[
\text{Respiration Rate (RR_O₂)} = \frac{\text{Change in O₂ concentration in head space (%)} \times \text{Free volume (mL)}}{\text{Fruit mass (g)} \times \text{Duration of respiration (h)}}
\]

\[
\text{Respiration Quotient (RQ)} = \frac{\text{Respiration Rate (RR_CO₂)}}{\text{Respiration Rate (RR_O₂)}}
\]

\[
\text{Free volume, mL = Container volume (mL) - \frac{\text{Fruit mass (g)}}{\text{Fruit density (g/mL)}}}
\]

Measurement of visual quality: The sensory analysis was performed to determine the visual quality of the mulberries after 3, 6 and 10 days of storage. Visual quality was evaluated by a six-member expert group, trained to score the quality attributes of mulberries prior to the test. Samples were scored for overall visual quality by using numbers as follows: “1” is the worst and “5” is the best. From “1” to “5” the visual quality changes from worst to best were analyzed. The average was taken after 6 members of the group scored the samples. The presence of mold was observed during 3, 6 and 10 days of storage in different packages. Similar analysis was performed by Correa et al. (2011).

Measurement of color: The color of different packages of mulberries was measured after 3, 6 and 10 days of storage in terms of L*, a* and b* values under CIELAB Color System using a Spectra QC Spectrophotometer (Minolta Corp., Japan; Model-CR 300). The color difference ∆E_ab of different packaged mulberries against the initial color of fresh

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mulberries before storage was determined as
\[ \Delta E'_{ab} = \sqrt{\left( E' - E'_{control} \right)^2 + \left( a' - a'_{control} \right)^2 + \left( b' - b'_{control} \right)^2} \]  
(6)

For each replication (of a treatment), color measurement was made on 3 mulberries at 3 different locations and the mean value of 9 readings was noted.

Statistical analysis: Statistical analysis of the data obtained by a full factorial design with three replicates was carried out using JMP 8 for Windows (SAS Inc., Chicago, IL, USA).

Results and Discussion

Effect of packaging on PLM of the mulberries: The cumulative physiological loss of mass of mulberries in regular paper bag ranged between 15.7 and 16.5% after 3 days of storage at 3°C and increased to a range of 25.7 to 33% at the end of 6 days of storage and increased to an extent of 43.5 to 49.06% at the end of 10 days of storage (Fig. 1). But for mulberries packed in perforated plastic bag, after 3, 6 and 10 days of storage the PLM ranged between 2.4 - 3.72%, 5.72-7.02% and 9.01-11.9% respectively. In PEAKfresh plastic bag the PLM of the mulberries was 0.1-0.15% after 3 days; after 6 days and 10 days the PLM increased to 0.31 and 0.62% respectively.

There are very significant differences in PLM between different packaged mulberries as observed at any given time of storage. And the interaction between packaging and duration also had significant effect on PLM of mulberries.

Effect of packaging on the total soluble solids (TSS): The total soluble solids of mulberries in various packages varied between 9.37 °Brix and 10.13 °Brix (Fig. 2) after 3 days of storage. After 6 and 10 days, the TTS was increased to 9.53-12.07 °Brix and 9.23-15.00 °Brix respectively. Statistically, there were significant differences (p≤0.01) between the packages but no significant differences between the duration as far as the TSS was concerned.

Effect of packaging on respiration rate and respiratory quotient: Respiration rate of mulberries expressed in terms of CO₂ production (RRCO₂) after 3, 6 and 10 days of storage at 3°C is shown in Fig. 3. In regular paper package, respiration rates ranged between 6133 and 6168 mLkg⁻¹h⁻¹ after 3 days, and increased to 6308 and 6878 mLkg⁻¹h⁻¹ by the end of 6 days, but decreased to 4667 and 6846 mLkg⁻¹h⁻¹ by the end of 10 days of storage. For mulberries in PEAKfresh pack, RRCO₂ ranged between 5247 and 5565 mLkg⁻¹h⁻¹ after 3 days storage, and increased to 6107 and 6115 mLkg⁻¹h⁻¹ by the end of 6 days of storage, and increased to 10030 and 11361 mLkg⁻¹h⁻¹ by the end of 10 days of storage. After the initial 3 days and 6 days, there were significant differences (p=0.01) in the respiration rates between paper and PEAKfresh packaged samples. But the differences between paper and perforated plastic bags were not significant at p=0.05. The difference between perforated and PEAKfresh was not significant at p=0.05 also. But after 10 days of storage, the respiration rates of PEAKfresh packed mulberries were significantly lower (p≤0.001) when compared to the perforated plastic packaged mulberries. The reduction in respiration rate (RRCO₂) of PEAKfresh packed mulberries could be attributed to the modified atmosphere that could have retarded the respiration rate due to some physiological changes that might have occurred in the mulberries. This reduction indicates that there is a potential for extending the shelf-life of mulberries with PEAKfresh packaging. The mulberries in the paper bags had same respiration rate as that in the PEAKfresh bags, the possible reason could be that the fruits in the paper bags were dry and deteriorated. The PEAKfresh package is a Modified Atmosphere Packaging (MAP) method specifically developed for the packaging of fresh fruits, vegetables, plants and cut flowers. It can slow down the natural ageing process by removing harmful gases while ensuring that product does not dehydrate.

The respiratory quotient (Fig. 4) was in the range of 1.03–1.17 for various packaged mulberries after 3 days of storage and significantly increased to the range of 1.14-1.51 by the end of 10 days storage. The higher respiratory quotient for the mulberries might be due to its greater organic acid content. There was no significant difference between different packages with respect to respiratory quotient for 3 days. But after 6 days of storage, there was significant difference between PEAKfresh and the other two packages (p=0.01), but there was no significant difference between perforated plastic and PEAKfresh packaged mulberries. After 10 days of storage, there was no significant difference between paper and PEAKfresh packaged mulberries, but the RQ of perforated plastic packaged mulberries was higher than the others. Mulberry is a non-climacteric fruit (Darias-Martin et al., 2003) and its respiration rate is generally expected to decline (for matured fruit) with the time of storage until the onset of physiological breakdown and
Figure 1. Cumulative physiological loss of mass of different packaged mulberries at 3°C.
Values within a same duration denoted by the same letters (a-c) were not significantly different (p<0.05).
Values within a same duration denoted by the same letters (A-C) were not significantly different (p<0.01).

Figure 2. Total soluble solids content of mulberries in different packages at 3 °C
Values within a same duration denoted by the same letters (a-c) were not significantly different (p<0.05).
Values within a same duration denoted by the same letters (A-C) were not significantly different (p<0.01).
Figure 3. Respiration rate (CO₂) of mulberries in different packages during storage at 3 °C. Values within a same duration denoted by the same letters (a-c) were not significantly different (p<0.05). Values within a same duration denoted by the same letters (A-C) were not significantly different (p<0.01).

Figure 4. Respiratory quotient of mulberries in different packages during storage at 3 °C. Values within a same duration denoted by the same letters (a-c) were not significantly different (p<0.05). Values within a same duration denoted by the same letters (A-C) were not significantly different (p<0.01).
decay by microorganisms. But the increase in respiration rate of CO$_2$ and respiratory quotient with storage duration in all the treatments in the present study indicated that a few mulberries in each lot might be the site of anaerobic respiration due to fungal decay.

Effect of packaging on color: The color of different packaged mulberries measured in terms of L*, a* and b* values under CIELAB color system on storage is given in Table 1. There was no significant difference between mulberries in different packages in terms of absolute color values L*, a*, b* and $\Delta E^{*\text{ab}}$ after 3, 6 and 10 days of storage respectively. However, the color difference value, $\Delta E^{*\text{ab}}$ of packed mulberries calculated against the initial color before packaging showed a significant difference (p≤0.05) throughout the storage period.

Effect of package on visual quality: The visual quality of all mulberry samples decreased during storage with a similar trend in all the treatments (Fig. 5). The type of package and storage time had statistically significant effects on visual quality (p≤0.001). After 10 days of storage, this reduction in quality became more noticeable. Moreover, there was no significant difference in mold formation in different packaging during storage.

<p>| Table 1 CIELAB color values (L*, a*, b*) and color difference $\Delta E^{*\text{ab}}$ of mulberries in different packages after 3, 6 and 10 days of storage at 3 °C |
|----------------------------------|------------|--------|--------|--------------|</p>
<table>
<thead>
<tr>
<th>Duration</th>
<th>Package type</th>
<th>L</th>
<th>a</th>
<th>b</th>
<th>$\Delta E^{*\text{ab}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 days</td>
<td>paper</td>
<td>17.46$^\text{ab}$</td>
<td>1.76$^\text{ab}$</td>
<td>0.94$^\text{ab}$</td>
<td>1.55$^\text{a}$</td>
</tr>
<tr>
<td></td>
<td>PEAK</td>
<td>16.49$^\text{ab}$</td>
<td>2.07$^\text{ab}$</td>
<td>0.94$^\text{ab}$</td>
<td>0.51$^\text{a,b}$</td>
</tr>
<tr>
<td></td>
<td>Perforated</td>
<td>17.62$^\text{ab}$</td>
<td>2.54$^\text{ab}$</td>
<td>0.94$^\text{ab}$</td>
<td>2.03$^\text{b}$</td>
</tr>
<tr>
<td>6 days</td>
<td>paper</td>
<td>17.49$^\text{ab}$</td>
<td>3.77$^\text{ab}$</td>
<td>1.32$^\text{ab}$</td>
<td>2.44$^\text{a}$</td>
</tr>
<tr>
<td></td>
<td>PEAK</td>
<td>17.34$^\text{ab}$</td>
<td>2.36$^\text{ab}$</td>
<td>0.82$^\text{ab}$</td>
<td>2.08$^\text{a}$</td>
</tr>
<tr>
<td></td>
<td>Perforated</td>
<td>18.01$^\text{ab}$</td>
<td>2.07$^\text{ab}$</td>
<td>1.31$^\text{ab}$</td>
<td>1.86$^\text{b}$</td>
</tr>
<tr>
<td>10 days</td>
<td>paper</td>
<td>15.93$^\text{ab}$</td>
<td>2.17$^\text{ab}$</td>
<td>1.16$^\text{ab}$</td>
<td>1.06$^\text{a}$</td>
</tr>
<tr>
<td></td>
<td>PEAK</td>
<td>17.50$^\text{ab}$</td>
<td>4.19$^\text{ab}$</td>
<td>1.38$^\text{ab}$</td>
<td>2.40$^\text{a,b}$</td>
</tr>
<tr>
<td></td>
<td>Perforated</td>
<td>16.18$^\text{ab}$</td>
<td>3.88$^\text{ab}$</td>
<td>1.66$^\text{ab}$</td>
<td>2.79$^\text{b}$</td>
</tr>
</tbody>
</table>

Means with the same letter are not significantly different.

Figure 5. Visual quality of mulberries in different packages during storage at 3 °C
Values within a same duration denoted by the same letters (a-c) were not significantly different (p≤0.05).
Values within a same duration denoted by the same letters (A-C) were not significantly different (p≤0.01).
Conclusion
In the present study, the potential of reducing the respiration rate of mulberries with PEAKfresh packaging has been observed. The PLM in PEAKfresh package was less than that in the case of the other two packages. The visual quality was better with PEAKfresh packed fruits. Thus, this can be exploited to enhance the shelf-life of mulberries without affecting fruit quality. Hence it can be concluded that mulberries stored at 3 °C in PEAKfresh has the best quality and the longest shelf life.

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References