Packaging and Pork Quality
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Packaging effects on quality

Pork quality is affected by many different things, beginning with genetics and including nearly every step in production, processing and delivery to consumers. Quality levels achieved during production require careful protection during processing and merchandising. One of the last lines of defense for preservation of pork quality is a good packaging system. Packaging is expected to provide the necessary protection for pork products from physical, chemical and/or microbiological contamination. However, packaging should also provide the internal package environment that will maximize quality retention during storage. While meat scientists have long recognized the conditions needed for high quality packaging systems, the recent movement toward “case-ready” packaging has refocused attention on the use packaging environments to maintain quality (Higgins, 2000; Eilert and Rathje, 2001). Very recently, Hormel Foods Corp. and Excel Corp. announced a joint venture to market case-ready beef and pork. The joint venture, named Percept Foods LLC, will market products under the Hormel always tender brand name.

The development many years ago of the barrier bag and vacuum packaging of primal cuts was a major step forward in shelf-life extension for fresh meat. The effectiveness of oxygen removal, and the subsequent accumulation of carbon dioxide from meat respiration, have been demonstrated many times. The discovery that carbon dioxide is the active component for extending shelf life in vacuum packages has resulted in a variety of gas-flush systems. Flushing with carbon dioxide, up to about 25%, provides excellent microbial control and reduces some of the purge which occurs with vacuum packages. Despite the advantages of vacuum or gas-flush packages for shelf-life, most fresh products have been displayed at retail with oxygen-permeable packaging in order to maximize red color for consumer appeal. The case-ready packaging systems now being offered have utilized a variety of approaches to barriers, atmospheres, oxygen scavengers and individual vs. master packs to maintain meat quality. Shelf-life of up to 28 days can be achieved for fresh pork with some of these systems. However, the fact remains that exposure of meat surfaces to oxygen for color development reduces the product shelf life. Further, many different packaging options are being investigated and proposed as part of case-ready systems for improved microbiological safety and reduction of pathogens. This is a very different requirement than that for shelf life extension and none of the developing technologies seem to be clearly more effective than others. However, the emphasis of food safety has also resulted in “…misinformation, disinformation and ignorance being communicated…of the march into case-ready red meat…and…too much of the field appears to belong to hucksters and opportunists…”, according to some professionals in the packaging industry (Brody, 2002).

One of the packaging alternatives that offers attractive color for fresh meat without oxygen exposure is use of carbon monoxide (CO). Carbon monoxide exposure to meat surfaces result in bright red color, visually identical to red meat bloom achieved by oxygen. Carbon monoxide effects on meat color has been known for many years (Wolfe, 1980) but commercial applications did not develop due to concerns over human exposure to carbon monoxide.
However, gas mixing technology has permitted suppliers to provide gas mixtures with very low (less than 1%) carbon monoxide levels. These concentrations of carbon monoxide will produce bright red meat color and the risks to workers or to consumers is negligible (Sorheim, et al., 1997).

Recent research in Europe has suggested that use of carbon monoxide at 0.5% or less in modified atmosphere packages has potential to both maximize attractive meat color and extend product shelf life (Sorheim, et al., 1999, Sorheim et al., 2001). The use of carbon monoxide may also offer the opportunity to increase carbon dioxide well above the 20-30% level where it is currently used. Carbon dioxide is well-recognized as inhibitory for microbial growth (Blickstad and Molin, 1983) but high concentrations (over about 40%) result in fresh meat discoloration (Silliker et al., 1977, Sebranek, 1985). Combining carbon monoxide with high levels of carbon dioxide may have potential to maximize both shelf life and attractive fresh pork color.

A study of packaging systems

To investigate the potential for carbon monoxide in combination with high carbon dioxide concentrations for fresh pork, a study was designed to compare this concept with different packaging systems. Both moisture-enhanced (injected) and regular (uninjected) fresh pork were studied. To do this comparison, boneless pork loins were selected for normal quality and purchased from a local supplier. A total of 48 loins were used for each of two replications of this experiment. Twenty-four loins in each replication were injected with 12% of the green weight with a brine composed of 9.3% potassium lactate, 3.7% sodium phosphate and 2.8% sodium chloride to result in 1% lactate, 0.4% phosphate and 0.3% salt in the injected products. The other 24 loins in each replication were not injected. All loins, injected and uninjected, were then cut into 1¼ inch thick chops prior to packaging. Four packaging environments were compared in this study. These included traditional overwrap (aerobic – high oxygen-permeable film), vacuum (high-barrier film), gas flush/modified atmosphere of 20% carbon dioxide/80% nitrogen, and gas flush/modified atmosphere of 0.5% carbon monoxide, 70% carbon dioxide and 29.5% nitrogen. Each of the modified atmospheres were enclosed in high-barrier bags.

Products were stored at 1º C to 3º C in lighted display and evaluated at 3-day intervals until quality deterioration occurred. The quality evaluations included instrumental color by Hunter L* a*b* reflectance, sensory panel assessment of color, odor and appearance, package purge, thiobarbituric acid values for rancidity and microbial counts (total plate counts and lactic acid organisms).

Results

Instrumental color. All measurements (n=16) on the pork chops were taken first on day 1 after packaging and subsequently on days 4, 6, 8, 11, 13, 15, 18, 20, 22, 25, 27, 29, 32, 34, and 36. Surface color of the pork chops was measured with the Hunter Lab instrument. L* (lightness), a* (redness), and b* (yellowness) measurements were taken on two random locations for each chop. The results shown in Table 1, indicate that MAP-packaged chops resulted in the lowest L* values for both the control and injected chops, while the MAP-CO chops showed the highest L* values (p<0.001). The L* values for MAP packages tended to be the lowest over the entire storage period for both the control and the injected treatments. The L* values generally remained steady over the entire storage period and neither the control (uninjected) nor the injected treatment significantly (p>0.001) affected the L* values (Figures 1 and 2). The L*
values, however, remained higher at the end of the storage period for the injected chops relative to the other packaging treatments (Figure 2).

Table 1. The effect of packaging atmosphere on the Least Square Means of L* (lightness), a* (redness), and b* (yellowness) values of pork chop measurements.

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>Injected</th>
<th>S.E. a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OW</td>
<td>Vacuum</td>
<td>MAP</td>
</tr>
<tr>
<td>L*</td>
<td>49.52d</td>
<td>51.32bc</td>
<td>48.65c</td>
</tr>
<tr>
<td>a*</td>
<td>6.94c</td>
<td>2.74e</td>
<td>3.80d</td>
</tr>
<tr>
<td>b*</td>
<td>12.43b</td>
<td>10.20c</td>
<td>9.51d</td>
</tr>
</tbody>
</table>

aStandard error of means.
b-cMeans within same row with different letters are significantly different at P<0.001

Figure 1. Least square means for L* values of control pork chops as related to storage time for OW, Vacuum, MAP and MAP-CO (S.E. = 1.32).
The a* values were greatly affected by each packaging atmosphere. After day 4, the MAP-CO treatments produced significantly (p<0.001) higher redness (a*) values than all other treatments for the entire storage period (Figure 3 and 4). Color development (redness) in the MAP-CO treatments typically occurred within 24 hours. However, this is not reflected in figures 3 and 4 because of an equipment breakdown for the first replication in this experiment. Chops were repackaged on day 4, after which the a* (redness) clearly developed. The delayed color development in figures 3 and 4 does not reflect the actual rate of color development for carbon monoxide packaging. In the second replication, measurements taken on day 1 showed that a* values were at 10.07 and 10.32 for the control and injected groups, respectively. This confirms that even a low level of carbon monoxide will result in a bright red color for pork chops overnight. The overwrap (OW) treatments were also significantly (p<0.001) higher in a* values than either the vacuum or the MAP, but at the same time were still significantly (p<0.001) lower than the MAP-CO treatments throughout the entire storage period (Table 1). The overwrap packages clearly declined in redness with time as the color losses typical of spoilage occurred (Figures 3 and 4). In both the control and injected treatments, the MAP-CO packaged chops maintained their high a* values for the complete storage period. Color remained highly attractive even after 36 days.
The b* (yellowness) values between each packaging treatment did not change as greatly as the L* or a* differences. The overwrap packages in both treatments were significantly (p<0.001) higher than all other treatments and the MAP treatments are significantly (p<0.001) lower than all other treatments (Table 1). Figures 5 and 6 also show that overwrap treatments were greater throughout the entire storage period. Vacuum and MAP-CO in the control group showed no significant (p>0.001) difference as evidenced by Figures 5 and 6. The b* values are not as clearly related to visual color of fresh meat as the L* and a* values.
5. Least square means for $b^*$ values of control pork chops as related to storage time for OW, Vacuum, MAP and MAP-CO (S.E. = 0.54).

6. Least square means for $b^*$ values of injected pork chops as related to storage time for OW, Vacuum, MAP and MAP-CO (S.E. = 0.54).

Purge. Purge loss was measured and calculated for each treatment. The results, in Table 2, showed that injection, as expected, had a significant (p<0.001) effect on the purge loss from the vacuum, MAP and MAP-CO treatments. Although the overwrap treatments were not significantly (p>0.001) different for purge, the injected chops still had a slightly lower purge percentage. The uninjected (control) MAP-CO was significantly (p<0.001) higher for purge than the other three control treatments. The results show nearly a 2% increase in purge by the MAP-CO treatment compared to vacuum. However, in the injected chops, the percentage purge loss was much less than the uninjected control. In this case, the MAP-CO treatment was not significantly (p<0.001) higher than the overwrap or the vacuum packaged samples.
Table 2. The effect of packaging atmosphere on the Least Square Means of purge values of pork chops.

<table>
<thead>
<tr>
<th>Packaging Atmosphere</th>
<th>Control</th>
<th>Injected</th>
<th>S.E.</th>
<th>a</th>
</tr>
</thead>
<tbody>
<tr>
<td>OW</td>
<td>Vacuum</td>
<td>MAP</td>
<td>MAP-CO</td>
<td></td>
</tr>
<tr>
<td>Purge (%)</td>
<td>1.25&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.63&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>3.53&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>4.53&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Standard error of means.
<sup>b-c</sup>Means within same row with different letters are significantly different at P<0.001

The reasons for increased purge with the MAP systems is not clear. Other researchers have reported a decreased surface pH for meat products packaged in carbon dioxide atmosphere, and attributed color changes to surface pH alterations. We conducted separate experiments with additional MAP-carbon monoxide packages and measured surface pH values as well as purge. The increased purge in MAP-CO was repeatable but there was no difference in surface pH. Other researchers have also reported increased cooking losses for products packaged in MAP-CO which also implies a decreased retention of moisture. It will be important to determine the cause of these purge observations for MAP-CO packaging. It should be noted that the increased purge occurred only with uninjected chops. Injected chops showed slightly larger purge values for the MAP-CO packages compared with the overwrapped chops but the difference was not statistically significant.

**TBA values.** The TBA (2-thiobarbituric acid) measurements, shown in Table 3, resulted in a significant (p<0.001) differences for the overwrapped (OW) samples. The control overwrap treatment was the highest for TBA values. This was expected due to the oxygen exposure of the overwrapped product and the more rapid development of rancidity. The injected product in the overwrap package is lower probably due to the antioxidant contributions of lactate and phosphate. The overwrap treatments were eliminated from the study on day 25 due to their very obvious spoilage, indicated by color and sensory observations. The injected MAP samples resulted in higher than expected TBA values, relative to the others. The reason is not clear. There were no major differences in TBA values between the other treatments; all were equally effective for suppressing rancid flavor development.

**Microbial counts.** Microbial counts were conducted at each sample time. Samples were measured for total aerobic plate counts and for lactic acid bacteria (anaerobic). The results indicated no significant (p>0.001) difference for any of the treatments.
Table 3. The effect of packaging atmosphere on the Least Square Means of TBA values of pork chops.

<table>
<thead>
<tr>
<th>Packaging Atmosphere</th>
<th>Control</th>
<th>Injected</th>
<th>S.E.(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OW</td>
<td>Vacuum</td>
<td>MAP</td>
</tr>
<tr>
<td>TBA Values</td>
<td>.365(^b)</td>
<td>.096(^c)</td>
<td>.111(^c)</td>
</tr>
</tbody>
</table>

\(^a\)Standard error of means.
\(^b\)-\(^c\)Means within same row with different letters are significantly different at P<0.001

Because of high variability for the microbial measurements, statistical differences could not be determined. Variability was increased due to loins of the second replication which started with relatively high microbial numbers. The high initial numbers probably masked treatment differences in the second replication. Review of the data from the first replication suggests differential effects on microbial counts by the packaging treatments. In figure 7, for example, the number of days required to reach a 10\(^6\) count is 7 days for overwrapped packages, 23-28 days for vacuum and MAP, and 36+ days for MAP-CO. This suggests greater effectiveness by the MAP-CO system if microbial counts are low in initially.

Figures 7-14 show the logarithmic growth for the microbial counts and are separated into replication 1 and replication 2 to distinguish the differences in the two replications. Samples with microbial counts of less than log\(_{10}\) CFU/g of 1.0 are not plotted because small values below 1.0 are automatically deleted from the statistical analysis for microbial counts. The microbial data were also expressed in graph form to measure the slopes and utilize a regression model. The data was transformed to logs to account for the exponential growth rates of bacteria. The least square means of the regressions are presented in Table 4.

Table 4. The effect of packaging atmosphere on the Least Square Means of microbial growth (CFU/g) regression values of pork chops.

<table>
<thead>
<tr>
<th>Packaging Atmosphere</th>
<th>Control</th>
<th>Injected</th>
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<tbody>
<tr>
<td></td>
<td>OW</td>
<td>Vacuum</td>
</tr>
<tr>
<td>Item</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerobic</td>
<td>.281</td>
<td>.093</td>
</tr>
<tr>
<td>Anaerobic</td>
<td>.321</td>
<td>.184</td>
</tr>
</tbody>
</table>

The more rapid growth rate in the overwrapped packages is obvious in Table 4. There is no difference among the other package treatments in this comparison. The days where microbial values (Log\(_{10}\) CFU/g) were less than 1.0 are not plotted in the figures to account for censoring (small values below 1) in the statistical analysis.
Figure 7. Aerobic plate count values ($\log_{10}$ CFU/g) on control pork chops from OW, Vacuum, MAP and MAP-CO packages during rep #1.

Figure 8. Aerobic plate count values ($\log_{10}$ CFU/g) on injected pork chops from OW, Vacuum, MAP and MAP-CO packages during rep #1.
Figure 9. Aerobic plate count values $\log_{10}$ CFU/g on control pork chops from OW, Vacuum, MAP and MAP-CO packages during rep #2.

Figure 10. Aerobic plate count values $\log_{10}$ CFU/g on injected pork chops from OW, Vacuum, MAP and MAP-CO packages during rep #2.
Figure 11. Lactic Acid Bacteria values (Log$_{10}$ CFU/g) on control pork chops from OW, Vacuum, MAP and MAP-CO packages during rep #1.

Figure 12. Lactic Acid Bacteria values (Log$_{10}$ CFU/g) on injected pork chops from OW, Vacuum, MAP and MAP-CO packages during rep #1.
Sensory Evaluation. Sensory characteristics were measured using a 12-member trained panel. Samples were evaluated on all 16 sampling days. The characteristics measured included color (desirable-undesirable), appearance (desirable-undesirable) and odor (no off odor-extreme off odor) each utilizing a 100 point scale. The sensory data is shown in Table 5.
Table 5. The effect of packaging atmosphere on the Least Square Means of sensory characteristic values (100-point scale) of pork chops.

<table>
<thead>
<tr>
<th>Item</th>
<th>Packaging Atmosphere</th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th>S.E.</th>
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<tbody>
<tr>
<td></td>
<td>Control</td>
<td>OW</td>
<td>Vacuum</td>
<td>MAP</td>
<td>MAP-CO</td>
<td>OW</td>
<td>Vacuum</td>
<td>MAP</td>
</tr>
<tr>
<td>Color</td>
<td></td>
<td>62.47c</td>
<td>44.52d</td>
<td>42.42d</td>
<td>85.91b</td>
<td>57.70c</td>
<td>50.49c,d</td>
<td>44.64d</td>
</tr>
<tr>
<td>Appearance</td>
<td></td>
<td>62.73b</td>
<td>50.17bc</td>
<td>46.47c</td>
<td>60.12b</td>
<td>58.21b</td>
<td>55.78b</td>
<td>47.21c</td>
</tr>
<tr>
<td>Odor</td>
<td></td>
<td>35.37b</td>
<td>34.19b</td>
<td>30.28b</td>
<td>32.20b</td>
<td>42.94b</td>
<td>36.68b</td>
<td>36.70b</td>
</tr>
</tbody>
</table>

*aStandard error of means.
*b-c Means within same row with different letters are significantly different at P<0.001

Results during the first sample evaluations indicated that in both the control and injected groups, the MAP-CO treatments received very significantly (p<0.001) higher scores for color. The high sensory color score also is supported by the high a* values discussed earlier for the MAP-CO treatments. The results also indicated that the panel scored the appearance of the MAP-CO chops and the overwrap chops higher in both the control and injected groups. The odor scores showed no significant (p<0.001) differences over the entire storage period. Samples were removed from the study when color deterioration was obvious thus avoiding the exposure of panelists to extreme off-odors generated by spoilage.

The color scores for each test day over the entire storage period are shown in Figure 15 and 16. As evidenced by the figures, MAP-CO received the highest scores from the panel in both the control and injected chops. The overwrap treatment decreased rapidly in color score compared to the other treatments and was not tested after day 25 due to obvious spoilage. MAP and vacuum treatments were recognized as the least desirable in terms of color, but the scores remained relatively steady for the entire storage period.
Appearance scores were more similar between the treatments than color scores, according to sensory data. This probably reflects a more generalized evaluation of “appearance” by the panel as opposed to a more specific “color” characteristic. The overwrap treatment generally received higher scores for appearance than the other treatments during the first two weeks. The relatively high appearance score for overwrapped chops may reflect the panelists assessment of a traditional expected appearance (overwrapped tray similar to current retail packages) as opposed to the other packaging systems. The MAP chops earned significantly (p<0.001) lower scores, in both the control and injected groups, than any other treatments. Figures 17 and 18 show the relative similarity of all appearance values over the entire storage period. The deterioration over time for the overwrapped chops is obvious and clearly results from the change in color noted previously.
Figure 17. Least square means for appearance values of control pork chops as related to storage time for OW, Vacuum, MAP and MAP-CO (S.E. = 7.99).

Figure 18. Least square means for appearance values of injected pork chops as related to storage time for OW, Vacuum, MAP and MAP-CO (S.E. = 7.99).

Conclusions

The results of this study showed that low levels of carbon monoxide (0.5%) in a modified atmosphere package achieved a dramatically stable, bright-red color over an extended storage period. The carbon monoxide treatment also suppressed lipid oxidation when compared to overwrap-package treatments. Microbial counts were suppressed by the carbon monoxide treatment at least as affectivity as for vacuum. Therefore, the overall shelf life of fresh pork can be increased with the carbon monoxide packaging system. The results also, however, indicated that modified atmosphere packages containing low carbon monoxide and high carbon dioxide increased purge loss of uninjected pork chops. On the other hand, injected/marinated pork chops demonstrated less purge loss than non-injected chops, and the MAP-CO did not result in
significant changes in purge for injected chops. It appears that the injection treatment prevented the purge effects observed for carbon monoxide packaging on uninjected chops.

Therefore, carbon monoxide packaging showed significant overall advantages as a packaging system for injected pork products. For uninjected pork products, the carbon monoxide packaging system has shelf life advantages but the effects on purge need further investigation to determine means for controlling and minimizing the changes in purge losses.

References


Photos of chops sampled after 6 days of storage.
Photos of chops sampled after 6 days of storage. Vacuum packaged samples are not included due to rapid bloom after opening package.
Photos of chops sampled after 11 days of storage.
11 days
Photos of chops after 18 days of storage.
Photos of chops after 18 days of storage.
Photos of chops after 27 days of storage.
Photos of chops after 36 days of storage.
**Dr. Joe Sebranek**  
Dr. Joe Sebranek is currently University Professor of Animal Science and of Food Science and Human at Iowa State University. He received his B.S., M.S. and Ph.D. degrees from the University of Wisconsin in 1970, 1971 and 1974 respectively. He joined the faculty at Iowa State University as an Assistant Professor in 1975 after a 1-year post-Doctoral fellowship. He was promoted to Associate Professor in 1979 and Professor in 1984. He was named University Professor in 1997.

At Iowa State University, Dr. Sebranek’s responsibilities include teaching (60%) and research (40%) in Meat Science with emphasis on meat processing. Dr. Sebranek’s research has included safety and quality effects of non meat ingredients (nitrite, phosphates, carrageenans, salt, antioxidants, reductants, and antimicrobials), meat ingredients (mechanically-separated meat, PSE pork, surimi), processes (fermentation, co-extrusion, grinding, high pressure processing, irradiation) and packaging (vacuum levels, oxygen absorbers, film permeability). He has published over 200 manuscripts, and abstracts several book chapters and has two patents. He is currently a contributing editor for Meat Processing magazine and is on the editorial board of AOAC International and the Journal of Muscle Foods. He is also currently Director of Graduate Education for the Department of Animal Science.

Dr. Sebranek has received 23 awards from university, local and national organizations in recognition of his accomplishments in teaching, research and service.