ADDITION OF ANTIOXIDANTS TO PACKAGING FILMS TO EXTEND THE SHELF LIFE OF FRESH BEEF

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Background:

Beef pigment is naturally purple in the absence of oxygen but rapidly becomes red when exposed to oxygen. This color change is due to the conversion of the purple pigment deoxymyoglobin to the red pigment oxymyoglobin. During refrigerated storage, beef surfaces will begin to turn brown as oxygen at the surface causes an undesirable oxidation reaction converting the red pigment oxymyoglobin to the brown pigment metmyoglobin. Consumers perceive a brown color as highly undesirable, even though the brown color often does not indicate a food safety threat (Klis, 1993). Surface color can be objectively measured using a colorimeter. There are five components that a colorimeter can measure to describe the color of a sample: L-value (lightness), a-value (redness), b-value (yellowness), chroma (intensity), and hue (an angle within the color scale ranging through the visible range) (AATCC, 1993).

By maintaining the oxymyoglobin red pigment for a longer time, the usable shelf life of fresh beef could be extended, benefiting both producers and consumers. Natural antioxidants are used to stabilize the color of ground turkey meat. Because the shift from the desirable red pigment to the undesirable brown pigment is caused by an oxidation reaction, antioxidants applied to the surface of fresh beef should inhibit the formation of metmyoglobin. Developing a system that can deliver the antioxidant to the meat surface may maintain the non-oxidated pigment at the fresh meat surface.

Objective:

The objective of this research was to examine the effect of selected natural and synthetic antioxidants added to polyethylene packaging material on the shelf life of fresh beef.

Materials and Methods:

Two experiments were performed measuring the effect of antioxidant packaging on beef surface color. In the first experiment, steaks were sliced from an eye of round roast and the antioxidant packaging was immediately applied to the meat before the meat color changed from deep purple to bright red. In the second experiment steaks were again sliced from an eye of round roast but the steaks were then allowed to bloom, or oxygenate until they turned red. After steaks were red at the surface the antioxidant packaging materials were applied to the meat. The two experiments were identical other than this distinction. Antioxidant and control disks of polyethylene film were produced on a heat press. For each of the four antioxidant film types the antioxidant was added at 0.1% by weight. The experimental antioxidant films were applied to steaks and the steaks were then over-wrapped with a high oxygen transfer rate plastic film drawn in a partial vacuum. This ensured that the experimental packaging materials would be in direct contact with the meat for the duration of the experiment. The steaks were stored in refrigeration and color of the steaks was then read once a day every day with a colorimeter through eight or nine days. The eight or nine day limit was chosen since the control samples had discolored to a brown pigment. The experimental disks were placed on steaks in a balanced incomplete block experimental design. Ten steaks were cut from one complete eye of round roast. For each experiment three roasts were used as replicates, making a total of thirty steaks used for each experiment. Results were analyzed using ANOVA for a balanced incomplete block experiment.

Another companion study was conducted on the migration of the synthetic antioxidants, BHA and BHT into the beef. Two solvents were used to simulate the migration of the antioxidants into beef in two separate trials. The first used water as a solvent and the second used a 95% ethanol solution. Samples of the film containing BHA or BHT were placed on the bottom of a small vial and then covered with 1.5mL of the appropriate solvent. The solvent was then drawn off the film at day 0, 3, 6 and 9 and analyzed using an HPLC to determine what levels of antioxidant had migrated from the film. Triplicates of each day for each treatment were performed and the concentration of antioxidant that had migrated from the film was determined.

Results and Discussion:

The results for Experiment 1 and 2 were very similar. For both tests the a-value (redness) was statistically higher for the BHA treatment for the last two days of the study than for either of the control treatments (Tables 1 and 3). A hue of 0° would indicate a perfectly red color while a hue of 90° would indicate a perfectly yellow color. In both experiments the BHA treatment had a statistically lower hue (more red) than either of the control packages for the last two days of the study (Tables 2 and 4). This again indicates that the BHA packaging keeps the steaks redder for a longer period of time than the packaging with no antioxidant present. Additionally, on the final day of experiment 2, all the antioxidant treatments had a statistically lower hue than either of the control groups. This indicates that antioxidant addition was able to maintain a redder color in the fresh beef over a long storage period. For all treatments, chroma declined during storage time while hue increased. This combination of color intensity decreasing while the angle of the color increases indicates that the steaks were turning brown, which was expected. The control treatments had the lowest chroma and highest hue for the last two days of the experiments, indicating that they had turned brown by the end of the experiment.

The BHA migrated from the films at a higher rate than the BHT in films exposed to water (Table 5). No significant BHT migrated from the films that were exposed to water. The greater migration of BHA is theorized to be the reason for its' greater color stabilizing effect on meat compared to BHT. BHA and BHT are more soluble in ethanol than water, and both migrated from the films at approximately the same rate (Table 6). In either solvent the levels of antioxidant found were below FDA allowable levels.

Conclusions:

The BHA impregnated packaging material developed in this experiment was the most effective at extending the shelf life of fresh steaks compared to other treatments. In the BHA film, a-value readings were higher for the last 2 days (day 7-8 or 8-9) as compared to a control packaging in experiments in which the meat was or was not allowed to oxygenate before packaging. Hue values were also lower for meat exposed to the BHA film for the last 2-3 days of storage compared to either of the control packages. Thus, the BHA treatment was effective at maintaining a red color in steaks for about an extra two days as compared with control packaging.

Table 1: Experiment 1 a-value Results

Day	Control, no film	Control, with film	BHA	BHT	Rosemary	δ-tocopherol
1	19.0208^{a}	11.6556^{c}	14.9967^{b}	14.5683^{b}	13.5930^{b,c}	13.2722^{b,c}
2	19.2042^{a}	10.3654^{c}	14.7076^{b}	14.5270^{b}	12.4070^{b,c}	11.5760^{c}
3	18.2053^{a}	9.6976^{d}	14.3623^{b}	12.8723^{b,c}	11.5284^{c,d}	11.2835^{c,d}
4	16.1548^{a}	8.9931^{d}	13.9343^{a,b}	13.2666^{b,c}	11.0144^{c,d}	11.0233^{c,d}
5	11.7155^{a,b}	7.2389^{d}	13.6210^{a}	11.6621^{a,b,c}	9.2104^{c,d}	9.6153^{b,c,d}
6	9.6232^{a,b}	6.7149^{c}	11.8670^{a}	9.0997^{b,c}	8.6964^{b,c}	8.3371^{b,c}
7	8.7844^{b}	5.8220^{c}	12.4732^{a}	9.0469^{b}	9.5567^{b}	9.9426^{a,b}
8	4.9644^{c}	5.5613^{c}	9.9915^{a}	8.2289^{a,b}	7.5114^{b}	8.7651^{a,b}

Table 2: Experiment 1 Hue Results

Day	Control, no film	Control, with film	BHA	BHT	Rosemary	δ-tocopherol
1	31.7874^{b}	36.4319^{a}	33.6865^{a,b}	33.1471^{a,b}	36.0153^{a}	35.9168^{a}
2	32.6356^{b}	39.6194^{a}	35.0799^{b}	34.7544^{b}	38.9152^{a}	39.1891^{a}
3	32.1313^{c}	40.3907^{a}	33.7239^{c}	35.4852^{b,c}	38.3535^{a,b}	39.1346^{a}
4	33.9994^{b}	43.5085^{a}	34.9224^{b}	36.6406^{b}	40.1813^{a}	41.2354^{a}
5	39.7568^{b}	46.0341^{a}	35.6864^{c}	38.7643^{b,c}	43.8386^{a}	43.9251^{a}
6	48.6378^{a}	48.9032^{a}	40.9691^{b}	46.1571^{a}	47.2276^{a}	47.8199^{a}
7	51.3130^{a,b}	54.1866^{a}	39.5369^{c}	48.0048^{b}	48.6728^{b}	43.6249^{c}
8	62.1991^{a}	53.6591^{b}	43.8793^{c}	49.6532^{b}	52.4952^{b}	49.6456^{b}

Treatment means with a different superscript within the same day are significantly different (p-value<0.05).

Table 5. Migration of antioxidants exposed to water and 95% ethanol.

	Water (ppm, w/v)				95% ethanol (ppm, w.v)			
Antioxidant	Day 0	Day 3	Day 6	Day 9	Day 0	Day 3	Day 6	Day 9
BHA	0.0008	0.0040	0.0096	0.0184	0.0012	0.0195	0.0261	0.0253
BHT	0.0	0.0	0.0	0.0	0.0	0.0213	0.0250	0.0262

Table 3: Experiment 2 a-value Results

Day	Control, no film	Control, with film	BHA	BHT	Rosemary	δ-tocopherol
0	18.4538^{a}	14.3032^{b}	15.8127^{a,b}	14.9451^{b}	15.3779^{b}	15.1128^{b}
1	18.1014^{a}	13.2303^{b}	14.4978^{b}	14.0447^{b}	13.9161^{b}	13.9775^{b}
2	17.5872^{a}	13.1003^{b}	13.9381^{b}	13.6498^{b}	13.3221^{b}	13.6899^{b}
3	19.9392^{a}	13.2619^{b}	13.9805^{b}	12.9627^{b}	13.6439^{b}	13.4988^{b}
4	17.3127^{a}	12.4279^{b}	14.5932^{b}	13.1391^{b}	13.3734^{b}	13.5750^{b}
5	16.7836^{a}	11.6203^{c}	14.3334^{a,b}	12.7473^{b,c}	12.4454^{b,c}	12.8501^{b,c}
6	16.2770^{a}	10.5205^{c}	14.1778^{a,b}	12.2042^{b,c}	12.5432^{b,c}	11.7375^{b,c}
7	13.1876^{a}	8.5259^{c}	13.1087^{a}	11.1989^{a,b}	10.7134^{a,b,c}	10.1031^{b,c}
8	8.6567^{b,c}	6.8378^{c}	12.1570^{a}	9.8042^{a,b}	9.3310^{b,c}	8.3726^{b,c}
9	6.2570^{c}	6.5043^{c}	11.1518^{a}	9.4116^{a,b}	9.3039^{a,b}	7.8199^{b,c}

Table 4: Experiment 2 Hue Results

Day	Control, no film	Control, with film	BHA	BHT	Rosemary	δ-tocopherol
0	30.7763^{a}	31.8734^{a}	30.4911^{a}	30.1189^{a}	31.4236^{a}	30.2186^{a}
1	30.7964^{b}	34.3157^{a}	31.8734^{a,b}	32.0254^{a,b}	33.2452^{a,b}	31.9413^{a,b}
2	31.2865^{b}	35.0387^{a}	32.4230^{a,b}	33.2870^{a,b}	34.1020^{a,b}	33.0455^{a,b}
3	31.6624^{b}	35.8452^{a}	33.4455^{a,b}	34.1596^{a,b}	35.4309^{a}	33.0947^{a,b}
4	32.3706^{b}	36.8806^{a}	33.1868^{b}	34.9898^{a,b}	35.2109^{a,b}	33.6932^{b}
5	32.8005^{c}	38.8442^{a}	33.3210^{c}	35.8101^{a,b,c}	37.7227^{a,b}	34.9794^{b}
6	33.5214^{c}	41.3339^{a}	33.3638^{c}	36.3133^{b,c}	37.7869^{b}	37.8791^{b}
7	36.3907^{d,e}	45.5873^{a}	34.6828^{e}	38.1500^{c,d}	41.8389^{b}	40.0435^{b,c}
8	47.8647^{b}	51.2931^{a}	36.1693^{e}	41.0495^{d}	46.4039^{b,c}	43.7868^{c,d}
9	54.9716^{a}	52.1380^{a}	36.3978^{d}	42.3501^{c}	45.8636^{b}	44.8600^{b,c}

Treatment means with a different superscript within the same day are significantly different (p-value<0.05).

References:

AATCC. "Color Measurement Principles". *AATCC Workshop Summary*. October 1993.

Klis, John. "Vitamin E Could Improve Color Stability of Beef". *Food Technology*, June 1993.