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Effects of Ascorbic Acid on Display Life of Ground Beef

S. D. SHIVAS[1], D. H. KROPF[2*], M. C. HUNT[2], C. L. KASTNER[2], J. L. A. KENDALL[2] and A. D. DAYTON[3]

Departments of Animal Sciences and Industry and Statistics, Kansas State University, Manhattan, Kansas 66506

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ABSTRACT

Fresh ground beef containing 20 and 25% fat was either treated with 0.01, 0.05 or 0.10% crystalline ascorbic acid or remained as non-treated controls. Samples were displayed in polyvinyl chloride (PVC) film for up to 10 d (24 h/d) at 2 to 3°C under 1076 lux G. E. Natural light. Measures of display life included visual color scores, reflectance measurements, sensory panel scores, thiobarbituric acid (TBA) values and microbial standard plate counts (SPC). At days 1, 3 and 5 of display, average and worst point visual color scores were judged brighter for all ascorbic acid treatments compared to controls. Lower metmyoglobin percentages, higher %R630nm/%R580nm and higher CIE a* readings at days 3, 5 and 10 for the ascorbic acid-treated product supported visual color results. Higher fat (25%) and higher ascorbic acid levels (0.05 and 0.10%) gave brighter visual color responses at 5 d of display than the 20% fat product and that containing 0.01% ascorbic acid. More intense sensory panel beef flavor was associated with the 0.05 and 0.10% ascorbic acid treatments. More off-flavor was found in the higher fat product (25%). TBA values were not different for fat level comparisons, but were lower for the 0.05 and 0.10% ascorbic acid treatments. At day 5 of display, SPC were not affected by ascorbic acid treatment. The 25% fat product had lower SPC at day 5.

Consumers use meat color as an indicator of meat quality. Oxymyoglobin, the bright red pigment, is most preferred, but is quite unstable and deteriorates rapidly. Use of film which allows sufficient oxygen permeation for oxymyoglobin development eventually leads to oxidation to the less desirable brown pigment, metmyoglobin. Oxidative changes of heme pigment (metmyoglobin formation) may be of bacterial, enzymatic or lipolytic origin (*17*). Any process that leads to lower partial pressures of oxygen may accelerate metmyoglobin formation (*23,31*).

Grinding has detrimental effects on meat. Not only does it expose more surface to air and bacterial contamination, but it also increases loss of reductants, such as dihydronicotinamide adenine dinucleotide, which naturally decrease metmyoglobin formation (*19*). The evolution of the meat industry towards centralized packaging has brought a need to slow down formation of metmyoglobin, especially in ground meats, without masking quality deterioration.

In 1979, American production of ground beef was an estimated 6.92 billion pounds (*24*). Doordan et al. (*10*) reported 3.1 and 4.6% case pulls for all beef retail packages in two stores and cited the following disposition of all retail packages in three selected stores: converted (probably ground) and repacked 4.1%; trimmed and repacked, 2.9%; rewrapped, 2.9%; price reduced for quick sale, 0.6%; and discarded, 0.2%. Some of these categories do not apply to ground beef, but the discard percentage is probably higher for ground beef. Reducing agents, such as ascorbic acid, may be helpful in stabilizing oxymyoglobin in meat products and may delay lipid oxidation.

Several researchers have theorized the mode of action of ascorbic acid. Walters (*31*) suggested that ascorbic acid acts with naturally occurring tocopherols in restricting formation of fat peroxides. He also felt that it has an oxygen scavenging action. Another theory is that ascorbic acid reduces metmyoglobin as soon as it is formed or before the globin is denatured (*18*).

Several researchers have used ascorbic acid solutions to extend the shelf-life of intact meat cuts or ground meat (*12,13,16,22,33*). Results varied depending on concentrations of ascorbic acid used. The objective of this study was to determine the effect of adding low levels of dry ascorbic acid to ground beef of two fat levels and to monitor the display life by visual, reflectance, TBA, microbial and sensory panel analyses.

MATERIALS AND METHODS

Materials

Fresh beef chuck trim was ground through a 1.9-cm plate. This coarsely ground beef was mixed approx. 5 min, then sampled for fat content and analyzed using a Hobart model F-101 fat percentage indicator.

[1]*Present address: Oscar Mayer Foods Corporation, Madison, WI.*
[2]*Department of Animal Sciences and Industry.*
[3]*Department of Statistics.*

Sufficient ground fat was added to the coarse ground trim to make 20 and 25% fat ground beef, and mixed. Actual ether extract percentages were found to be 20.6 and 25.4, respectively, by the Soxhlet method (*2*).

Ascorbic acid treatments

Four 5.9-kg coarse ground batches of both fat levels were prepared. Dry ascorbic acid was added at either 0 (control), 0.01, 0.05 or 0.10% of the meat. Ascorbic acid was thoroughly hand mixed into the coarse ground beef. Finally, each batch was twice ground through a 0.32-cm plate, divided into approx. 454-g units, placed on styrofoam trays and overwrapped with 1 mil oxygen permeable moisture-proof polyvinyl chloride (PVC) film. Samples were displayed up to 10 d at 2 to 3°C under G. E. Natural light at 1076 lux light intensity for 24 h per d.

Visual color analysis

Before display (day 0) and at 1, 3, 5 or 10 d of display, a 7-member panel scored color to the nearest 0.5 point on each of three packages from each treatment using the Kansas State University Beef Color Scale: 1 = very bright red, 2 = bright red, 3 = slight dark red or brown, 4 = dark red or brown, and 5 = extremely dark red or brown. Panelists were asked to make an average score judgment of the total exposed top surface. An additional worst point score using the above Beef Color Scale was defined as a single area or cumulative area of at least 2 cm diameter deemed by the individual panelist as the "worst" area on the exposed surface. The worst point color score was an attempt to determine the maximum discoloration to a significant area. We felt this would be more indicative of consumer rejection or acceptance than would average color score or percentage discoloration. If no single worst point was observed, then average and worst point judgments were equal.

Instrumental color analysis

At the same time visual color was appraised, spectral reflectance of the same samples was measured using a Hunterlab model D54 P-5 spectrophotometer. The instrument was calibrated with both gray and white calibrated standards. Data were taken at light wavelengths 525, 572, 580 and 630 nm, also CIE a^* (*8*) was measured using light source illuminant C. Each sample from a treatment group was analyzed at the approximate geometric center of the exposed upper surface. Reflectance data were used to compute reflectance ratios %R630nm/%R580nm, and K/S572nm/K/S525nm. Percentage metmyoglobin (MetMb) of meat pigment was calculated from the above K/S ratio by the method of Stewart et al. (*26*).

Taste panel analyses

All sessions were conducted following American Meat Science Association guidelines (*1*). At days 3, 5 and 10 of display, duplicate samples for taste panel analysis were removed from display, rewrapped in freezer paper and frozen at -20°C until analyzed. At that time the ground beef was thawed for 36 h at 2°C. The upper 1.9 cm from the displayed surface were taken, thoroughly mixed and two 113-g samples were weighed. Each was formed into a round, 1.3-cm thick patty, and cooked on a Farberware Open Hearth electric broiler for 10 min on each side (medium degree of doneness). Duplicate patties were sliced into six pie-shaped wedges and kept warm for taste analysis using a double boiler filled with hot water.

Potential descriptive attribute panelists were trained, then screened using triangle tests. Test samples contained varying percentages of fresh and "off-flavored" ground beef and were cooked according to methods described previously. An 8-member panel was selected, and samples were rated for two attributes, i.e., beef flavor intensity and off-flavor. An 8-point beef flavor intensity scale: 1 = extremely bland, 2 = very bland, 3 = moderately bland, 4 = slightly bland, 5 = slightly intense, 6 = moderately intense, 7 = very intense and 8 = extremely intense was used. Off-flavor scores were: 1 = no off-flavor, 2 = slight off-flavor, 3 = moderate off-flavor, 4 = intense off-flavor and 5 = extreme off-flavor. Panelists were served eight samples per session in random order. These samples represented all eight treatments. Unsalted crackers and water were provided.

Oxidized lipid determination

2-Thiobarbituric acid (TBA) values were measured in samples displayed for 3, 5 or 10 d. The exposed top portion (0.64 cm thick) of the fresh product was removed and frozen in liquid nitrogen. Samples were placed in plastic zip-seal bags, excess air removed, sealed and stored at -80°C until analyzed. TBA values were determined according to Witte et al. (*34*). Mean values were reported as mg malonaldehyde/kg meat.

Microbial analysis

Samples for standard plate count (SPC) were removed from display at days 0, 3 and 5. The procedure outlined by Henrickson (*15*) was followed using standard methods agar (BBL). Samples were incubated 72 h at 20°C before counting. Numbers were reported as $\log_{10}$ colony-forming units (CFU)/g meat.

Statistical analysis

Data were analyzed using analysis of variance (*25*) following the procedure outlined in Statistical Analysis System (*3*).

RESULTS AND DISCUSSION

Average and worst point visual color scores for ascorbic acid and fat level treatments are reported in Table 1. All treatments were similar and acceptable in color at day 0. Costilow et al. (*9*) reported an immediate discoloration of longissimus dorsi steaks when dry ascorbic acid was sprinkled on the surface and these steaks remained dark throughout a refrigerated period of several days. Greening of hemoglobin solutions with 0.5% concentrations of ascorbic acid was noted by Watts and Lehmann (*32*); however, such discolorations were not observed in our study. Other researchers also failed to find greening or darkening with low concentrations of ascorbic acid (*7,12,33*).

Average visual color scores for each ascorbic acid treatment were brighter ($P<0.05$, Table 1) than controls at days 1, 3, 5 and 10 of display. Worst point color scores were also judged brighter ($P<0.05$) for ascorbic acid treatments versus control comparisons except at day 10. The 0.05 and 0.10% treatments at day 5 were similar ($P>0.05$) to control samples at day 1 and the 0.01% samples at day 3 for both average and worst point color scores. Costilow et al. (*9*) found steaks treated with a 1% dip or spray of ascorbic acid to discolor slower than controls. An 8-d display life was reported by Greene et al. (*12*) when 0.05% ascorbic acid was incorporated via aqueous solution into ground semitendenosus muscle. Watts and Lehmann (*33*) noted a color brightening of ascorbic acid-treated beef.

At 3, 5 and 10 d, the higher levels of ascorbic acid (0.05 and 0.10%, Table 1) had brighter ($P<0.05$) average color scores when compared to controls and 0.01% treatment at the same day (Table 1). Benedict et al. (*4*) used ascorbic acid at the 0.005% level in their study of ground beef display life. Samples were found unacceptable in 4 d. A dip treatment of beef psoas major into 5% ascorbic acid was judged more effective at preventing muscle discoloration than dipping into more dilute levels (0.1, 1.0 or 2.0%) (*13*).

Table 1 shows the effect of fat level treatments on color scores. The higher fat level (25%) had brighter ($P<0.05$) average and worst point color scores except at day 10, where no difference ($P>0.05$) in either color judgment was found. When both fat and ascorbic acid levels were considered, worst point color scores were brighter ($P<0.05$) for ascorbic acid treatments of 25% fat when compared to controls and all treatments of 20% fat level. Within the 20%

fat level treatment, the 0.05 and 0.10% ascorbic levels were brighter ($P<0.05$) than the other two treatments. Brighter worst point color scores for ascorbic acid treatments of the higher (25%) fat level were most likely due to the lightening effect of the white fat within the ground beef. However, Berry et al. (*5*) reported fat level (24 vs. 28%) did not affect color and surface discoloration scores.

Objective color measurement results followed trends similar to visual color scores (Table 2). At 3, 5 or 10 d of display, the three ascorbic acid treatments had higher ($P<0.05$) %R630nm/%R580nm (more oxymyoglobin) than controls. Day 3, 5 or 10 CIE a^* values indicated more ($P<0.05$) red color (higher values) when compared to controls. Similar %R630nm/%R580nm or CIE a^* values were found at day 10 for the 0.05% ascorbic acid treatment when compared to controls at day 3 and the 0.01% level at day 5. No differences ($P>0.05$) were found when comparing the 0.01 and 0.10% ascorbic acid levels at day 10 to controls at day 5. Strange et al. (*27*) suggested %R630nm/%R580nm as a reflectance ratio paralleling consumer acceptability. Leising et al. (*20*) found this measurement gave results similar to visual observations. Watts and Lehmann (*33*) reported

TABLE 1. *Mean average color score[a] and worst point color score[b] for different ascorbic acid and fat level treatments for ground beef.*

		Ascorbic acid (%)				Fat (%)	
Judgment	Days of display	0	0.01	0.05	0.1	20	25
Average color score	0	2.11^{c}	2.10^{c}	2.14^{cd}	2.19^{cde}	2.51^{r}	1.76^{p}
	1	2.65^{hi}	2.44^{fg}	2.30^{def}	2.37^{ef}	2.72^{s}	2.16^{q}
	3	3.60^{l}	2.81^{ij}	2.43^{f}	2.49^{fgh}	2.95^{t}	2.71^{s}
	5	3.55^{l}	2.94^{k}	2.70^{i}	2.63^{ghi}	3.13^{u}	2.78^{s}
	10	4.67^{o}	4.22^{n}	3.87^{m}	4.00^{m}	4.18^{v}	4.20^{v}
Worst point color score	0	2.67^{c}	2.48^{c}	2.58^{c}	2.62^{c}	3.00^{rs}	2.17^{p}
	1	3.00^{d}	2.63^{c}	2.52^{c}	2.67^{c}	3.05^{rst}	2.36^{q}
	3	3.90^{f}	3.15^{d}	2.58^{c}	2.61^{c}	3.20^{t}	2.92^{r}
	5	3.95^{f}	3.51^{e}	3.02^{d}	2.98^{d}	3.55^{u}	3.18^{st}
	10	4.83^{g}	4.62^{g}	4.39^{g}	4.54^{g}	4.61^{v}	4.58^{v}
	Fat (%)						
Worst point color score	20	3.80^{e}	3.64^{e}	3.23^{d}	3.26^{d}		
	25	3.55^{d}	2.91^{c}	2.81^{c}	2.90^{c}		

[a,b]Average color score and worst point color score scale 1 = very bright red, 3 = slightly dark red or brown, 5 = extremely dark red or brown.

[c,d,e,f,g,h,i,j,k,l,m,n,o]For either average or worst point color score, means with same superscript letter are not different ($P>0.05$).

[p,q,r,s,t,u,v]For either average or worst point color score, means with same superscript letter are not different ($P>0.05$).

TABLE 2. *Ratio %R630nm/%R580nm, CIE a^* and percentage of metmyoglobin[a] means for ascorbic acid treatments of displayed ground beef.*

			Ascorbic acid (%)			
Reflectance measurement		Days of display	0	0.01	0.05	0.1
Ratio	$\frac{\%R630nm}{\%R580nm}$	0	3.81^{b}	3.47^{cd}	3.67^{bc}	3.48^{cd}
		1	3.11^{ef}	3.18^{de}	3.30^{de}	3.19^{de}
		3	2.19^{j}	2.82^{fgh}	3.02^{efg}	3.10^{ef}
		5	1.67^{l}	2.29^{ij}	2.59^{hi}	2.77^{gh}
		10	1.23^{m}	1.62^{l}	2.00^{jk}	1.84^{kl}
CIE	a^*	0	24.00^{bc}	23.10^{bc}	24.29^{b}	23.22^{bc}
		1	20.71^{cd}	21.19^{cd}	22.16^{c}	21.61^{d}
		3	15.47^{e}	19.51^{de}	20.86^{cd}	21.19^{cd}
		5	11.55^{f}	15.82^{e}	17.49^{de}	18.99^{de}
		10	8.78^{g}	12.04^{f}	14.32^{ef}	12.32^{f}
Metmyoglobin (%)		0	3.13^{b}	9.05^{bc}	7.38^{bc}	12.10^{c}
		1	14.89^{c}	13.33^{c}	11.09^{bc}	13.10^{c}
		3	35.45^{e}	20.27^{cd}	15.10^{cd}	14.71^{c}
		5	54.13^{gh}	34.96^{e}	23.41^{d}	17.66^{cd}
		10	80.12^{i}	62.11^{h}	45.31^{f}	48.03^{fg}

[a]Percentage of metmyoglobin calculated by method of Stewart et al. (*26*).

[b,c,d,e,f,g,h,i,j,k,l,m]Either reflectance ratio %630nm/%580nm, CIE a^* or percentage of metmyoglobin means with same superscript letter are not different ($P<0.05$).

24-h transmission readings of hemoglobin solutions treated with 0.02 or 0.10% ascorbic acid were redder than controls and original solutions. Harbers et al. (*13*) observed intact muscle dipped into ascorbic acid concentrations of 1.0, 2.0 or 5.0% was brighter (lower K/S630nm/K/S580nm values) than nontreated muscle. However, in a study of the effect of 0.005% ascorbic acid on the storage stability of ground meat, Benedict et al. (*4*), found this level ineffective in maintaining red color as measured by the %R630-%R580 difference.

A method to calculate percentage metmyoglobin (MetMb) from K/S ratios was described by Stewart et al. (*26*). Their values for 100% oxymyoglobin (1.40) and 100% reduced myoglobin (0.56) were used in this study to calculate MetMb percentage (Table 2).

At days 3, 5 or 10, all treated ground beef gave lower ($P<0.05$) percentage MetMb than control samples, but were similar to day 1 controls. Lower percentages of MetMb were found for the 0.05 and 0.10% ascorbic acid treatments at days 5 and 10 when compared to the control and 0.01% level. Hood (*16*) injected ante-mortem 500 ml of a 50% wt/vol solution of sodium ascorbate into heifers and measured MetMb percentages in chilled psoas major and gluteus medius steaks. Color was found to deteriorate less rapidly and steak shelf-life was increased 2 and 5 d, respectively. A defatted ground round slurry taken at 4-d post-mortem and containing 8×10^{-5} moles of ascorbic acid possessed 0% MetMb vs. 15% MetMb for controls (*21*). Another study found more MetMb accumulation in non-treated muscles than in ascorbic acid-treated muscles (*13*).

Several authors have reported visually detectable percentages of MetMb or consumer rejection levels of MetMb. Brooks (*6*) found the visually detectable level of MetMb to be 60% oxidized pigment, whereas Van den Oord and Wesdorp (*30*) reported detection at 50% MetMb. Harrison (*14*) found MetMb was visually seen when it represented 30 to 40% of total heme pigment. Consumer rejection occurred at greater than 40% MetMb (*12*). In our study at day 5 (Table 2), only the control contained over 40% MetMb; however, by day 10, all samples had MetMb values over 40%.

No differences ($P>0.05$) among fat level treatments by days or ascorbic acid levels were found for objective color values. This indicates that the lightening effect of the higher fat content, detected by the visual color panel, did not affect reflectance measurements.

Table 3 lists taste panel scores and TBA values for ascorbic acid and fat level treatments. Higher levels of ascorbic acid (0.05 and 0.10%) resulted in more intense ($P<0.05$) beef flavor than other treatments. Off-flavor was not affected ($P>0.05$) by ascorbic acid level, but the fatter (25%) ground beef gave more ($P<0.05$) off-flavor than the leaner ground beef.

No treatment differences ($P>0.05$) in TBA values were found at day 0. At 3, 5 or 10 d of display, the 0.05 and the 0.10% ascorbic acid treatments gave lower ($P<0.05$) TBA values than controls and the 0.01% treatment (Table 3). No differences ($P>0.05$) were found by fat level treatments at day 3, 5 or 10. Several researchers have suggested maximum acceptable TBA values. Turner et al. (*29*) reported that ground pork having TBA values of greater than 0.46 are of "borderline" quality, whereas values above 1.20 are "unacceptable." Off-odors are detectable at MA (mg malonaldehyde 1000 g meat) values exceeding 1.0 (*20*). In a study to determine the relationship between TBA values and inexperienced taste panel assessments of oxidized lipid flavor, Greene and Cumuze (*11*) reported a TBA range of 0.6 to 2.0 as the minimum detectable level for ground beef. Trained taste panels detect oxidized flavor in a 0.5 to 1.0 TBA range (*28*).

By day 3, both the control and 0.01% ascorbic acid treatment had TBA values greater than 0.6 (Table 3). Greene et al. (*12*) observed retardation of lipid oxidation in ground beef, as measured by TBA values, by a 0.05% ascorbic acid treatment. A 0.025% ascorbic acid treatment of ground beef resulted in higher TBA values when compared to controls (*4*).

By day 5, the lower (20%) fat product had a 1.04 higher ($P<0.05$) $\log_{10}$ CFU/g meat than the 25% fat treatment (Table 4). Increased numbers of proteolytic bacteria may have been the causative agent. Berry et al. (*5*) suggested

TABLE 3. *Mean beef flavor intensity scores[a], off-flavor scores[b] and mean TBA values for different ascorbic acid and fat level treatments for ground beef.*

	Ascorbic acid (%)				Fat (%)	
	0	0.01	0.05	0.10	20	25
Beef flavor intensity score	5.49[c]	5.54[c]	5.94[d]	5.90[d]	5.78	5.66
Off-flavor score	2.27	2.02	1.98	2.21	1.97[e]	2.27[f]
Days of display	TBA values					
0					0.26	0.29
3	0.66[g]	0.74[g]	0.33[h]	0.28[h]	0.53	0.48
5	1.00[i]	0.78[i]	0.38[j]	0.34[j]	0.63	0.62
10	1.13[k]	1.05[k]	0.32[l]	0.26[l]	0.61	0.77

[a]Beef flavor intensity scale: 1 = extremely bland, 4 = slightly bland, 5 = slightly intense, 8 = extremely intense.

[b]Off-flavor scale: 1 = no off-flavor, 3 = moderate off-flavor, 5 = extreme off-flavor.

[c,d,e,f,g,h,i,j,k,l]Mean beef flavor intensity scores, off-flavor scores and TBA values within the same row with different superscripts are different ($P<0.05$).

TABLE 4. *Mean log_{10} viable counts per gram and percentage ether extract of ascorbic acid-treated ground beef.*

	Fat (%)	
	20	25
Days of display		
0	3.38	4.07
5	5.50[a]	4.54[b]
Ether extract	20.6	25.4

[a,b]Means with different superscript letter within same row are different ($P<0.05$).

lipolytic bacteria were responsible for their reported higher SPC for higher fat treatments.

No differences ($P>0.05$) in microbial numbers were found for the ascorbic acid treatments. Costilow et al. (*9*) also reported no measurable effect on microbial counts by dipping or spraying steaks in a 1% solution of ascorbic acid. They concluded initial low microbial contamination to be more important in maintaining desirable steak color than ascorbic acid treatments. Greene et al. (*12*) concluded spoiled ground beef would be brown or green whether or not it contained ascorbic acid.

CONCLUSIONS

Ascorbic acid levels of 0.05 and 0.10% prolonged display life as determined by both visual color scores and spectrophotometric analyses when compared to controls and the 0.01% level at 5 d of display. For fat level treatments, visual color scores favored the 25% level at every observation day and at all ascorbic acid levels. More off-flavor was found by the taste panel in the 25% fat level product. Beef flavor was scored as more intense for the higher (0.05 and 0.10%) ascorbic acid treatments. Also, these two higher ascorbic acid treatments had lower TBA values at 3, 5 or 10 d of display. Ascorbic acid had no effect on SPC, but after 5 d of display the lower fat ground beef had higher SPC.

Ground beef display life was extended to at least 5 d with ascorbic acid added. This could be very important, especially with centralized retail processing and packaging. Ascorbic acid could keep ground beef competitive in the marketplace. However, to assure that out of date product is removed from display, an adequate system of code dating for an ascorbic acid-treated product is needed.

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