PROVEMENT OF PIGMENT AND LIPID STABILITY IN BEEF WITH VITAMIN C MIX, SPREAD AND DIP TREATMENTS

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SUMMARY

The effects of vitamin C mix, spread and dip treatments on pigment and lipid stability in beef longissimus lumborum were studied g 7 or 16 days of illuminated display at 4°C. 1) Vitamin C mix treatment showed low pigment and lipid oxidation in raw ground beef pared to the control, and it retarded metmyoglobin formation and lipid oxidation for 5 days compared with the control. 2) Spreading a vitamin C solution in the ratio of 0.1 ml solution to 20 g meat resulted in less metmyoglobin than for the control after 4 days of display. min C spread treatment delayed metmyoglobin formation for 3 days compared to the control. 3) Dip treatment with a 1 % vitamin C ion was effective in maintaining stability of beef pigment and lipid.

INTRODUCTION

Metmyoglobin formation and lipid oxidation in beef are the most important problems in maintaining a stable display of retail meat. undesirable brown metmyoglobin results from oxidation of the red oxymyoglobin and purple deoxymyoglobin, and metmyoglobin acts initiator of lipid oxidation (Kanner and Harel, 1985; Rhee et al., 1987). Ground meat tends to become brown and rancid more rapidly whole muscle retail cuts of meat. Grinding not only exposes more surface to air and microbial contamination, but also accelerates the of intracellular reductants, such as reduced nicotinamide-adenine dinucleotide which minimizes metmyoglobin formation (Ledward and arlane, 1971).

There are some reports in which the color of ground meat or a meat cut was stabilized by application of vitamin C which is a gical antioxidant. Addition of vitamin C increased pigment and lipid stability in ground pork (Watts and Lehmann, 1952a) and ground (Caldwell et al., 1960; Greene et al., 1971; Shivas et al., 1984). Costilow et al. (1955) reported that spraying beef with a 1% vitamin lution using an atomizer delayed the discoloration of the surface of beef for about one day. Harbers et al. (1981) reported that dip ment of beef psoas major steaks in a 5% vitamin C solution retarded pigment oxidation and protected muscle color more than untreated cles or muscles treated in 0, 0.5 or 1.0% vitamin C solutions. Okayama et al. (1987) reported that dip treatment of beef short loin steaks 3% vitamin C solution showed a higher surface metmyoglobin percentage than the control at day 3 after treatment, but vitamin treatment ne better than the control after day 9.

On the other hand, vitamin C acts as a prooxidant in the model solutions at high concentrations (over 0.5%; Watts and Lehmann, 5b) and low concentrations (under 0.0176%; Kanner et al., 1977) with trace metal ions. Therefore, appropriate concentrations of vitamin ust be determined that will be effective in retarding pigment and lipid oxidation of beef.

The purpose of our work was to investigate the effects of mix, spread and dip treatments of vitamin C solution on pigment and lipid ility in beef.

MATERIALS AND METHODS

Longissimus lumborum (LL) from six crossbred beef steers, eleven Holstein steers and nine (4 crossbred beef plus 5 Holstein) steers used in experiments 1 (Mitsumoto et al., 1991a), 2 (Mitsumoto et al., 1991b) and 3 (Mitsumoto et al., 1991c), respectively. Animals were a basal diet of 90% high-moisture corn plus supplement, and 10% corn silage. The steers were slaughtered at Packerland Pkg. Co., Green , WI, and the left strip loin from each steer was removed at 24 hr post-mortem. These sub-primal cuts were then vacuum-packaged and ported to the University of Wisconsin-Madison meat lab and stored for an additional 6 days at 4°C. The α-tocopherol contents in LL cles were measured by the method of Cort et al. (1983).

min C mix (Exp. 1)

Chlortetracycline (CTC, Sigma Chemical Co.) was dissolved in distilled water (3 mg/ml). Vitamin C solution was freshly prepared dissolving L-ascorbic acid sodium salt (Sigma Chemical Co.) in CTC solution (50 mg/ml). Vitamin C was added at a concentration of mg/kg tissue into ground meat. CTC was blended into ground meat at 30 mg/kg tissue for prevention of microbial growth in all treatments to make clear the effect of vitamin C addition. Hutchins et al. (1967) determined that CTC did not affect either metmyoglobin reducing ity or oxygen utilization in raw ground beef.

The caudal 15 cm of each LL muscle was ground three times through a 0.45 cm plate of a laboratory meat grinder at 4°C after all rnal fat and connective tissue were removed. Two 200 g aliquots of the ground meat were allotted to the following treatments: 2 ml CTC

solution (control) and 2 ml vitamin C solution (vitamin C mix treatment). Immediately after these solutions were added, each ground m sample was thoroughly hand-mixed. Samples of 20 g of the treated meat were then shaped into miniature beef patties using the bottom of a tissue culture dish (15 x 60 mm). Molding of the samples in this way allowed for a consistent surface area : volume ratio betwe samples. These patties were placed into 100 ml disposable weigh boats, over-wrapped with PVC film (MW 4, O_2 transmission is 1000-1 ml/645 cm^2/24 hr at 23°C, Filmco Ind. Inc., Aurora, OH) and displayed under cool white fluorescent lights (2475 lux) at 4°C for 7 days

Vitamin C spread (Exp. 2)

LL muscles were sliced into 1 cm thick steaks, and 50 mm diameter pieces were cut from these sliced steaks using a template cu Samples were randomly allotted to control or vitamin C spread treatment. After the weight of each sample was determined, the volume control or vitamin C solution were spread according to the ratio of 0.1 ml solution to 20 g meat. The control solution was sterile distilled w and vitamin C solution was 10% L-ascorbic acid sodium salt (Sigma Chemical Co.) in sterile distilled water. Immediately after the solu was dropped on the surface of the sample, it was spread with a sterile glass rod bent at a 70° angle. The sample was then placed into a ml disposable weigh boat, over-wrapped with PVC film and displayed under cool white fluorescent lights at 4°C for 16 days.

Vitamin C dip (Exp. 3)

LL muscles were sliced into 1 cm thick steaks, and 50 mm diameter pieces were cut from these sliced steaks with a template cu Samples were randomly allotted to undipped control or dip treatments with vitamin C solution. The latter samples were dipped for 20 sec a solution of 1% L-ascorbic acid sodium salt (Sigma Chemical Co.), prepared with sterile distilled water, and drained for 10 sec. All samp were individually placed on styrofoam, over-wrapped with PVC film and displayed under cool white fluorescent lights at 4°C for 16 da

Pigment analyses

Surface metmyoglobin, oxymyoglobin and deoxymyoglobin percentages were determined at day 1, 3, 5 and 7 (Exp. 1) and day 1, 7, 10, 13 and 16 (Exp. 2 and 3) by reflectance spectrophotometry (Krzywicki, 1979) using a Shimadzu UV-265 FW spectrophotomet Extract metmyoglobin percentage of the patty (Exp. 1) was determined at day 1, 3, 5 and 7 by the method of Krzywicki (1982). A Beckm DU-65 spectrophotometer was used for spectrophotometric analysis of extracts.

Lipid oxidation analysis

2-Thiobarbituric acid (TBA) values were measured by the method of Witte et al. (1970) in Exp. 1 and 3. Trichloroacetic acid solut (20% w/v) was used for the extraction blending. A Beckman DU-65 spectrophotometer was used for spectrophotometric analysis. Valu of absorbance at 530 nm were multiplied by 5.2 and expressed as mg malonaldehyde equivalent per kg meat.

Statistical analyses

Data were analyzed by the General Linear Models procedure of SAS (1985). Pairwise comparisons of means were analyzed b Scheffe's test (Snedecor and Cochran, 1980).

RESULTS AND DISCUSSION

Exp. 1

Vitamin C mix treatment showed much better pigment and lipid stability compared to the control. The control showed large increase of surface (from 24.2% to 57.6%; Fig. 1) and extract (from 38.3% to 73.4%; Fig. 2) metmyoglobin percentages and TBA values (from 1.1 to 4.34; Fig. 3) during 7 days of display. Vitamin C mix treatment showed small increases of surface (from 23.9% to 26.7%; Fig. 1) and extract (from 9.9% to 24.3%; Fig. 2) metmyoglobin percentages and TBA values (from 0.23 to 1.52; Fig. 3) during the same period of display. Vitamin C mix treatment retarded metmyoglobin formation and lipid oxidation at least for 5 days compared with the control. Other workers also observed that the addition of vitamin C maintained a good color in ground pork (Watts and Lehmann, 1952a) and ground beef (Caldwell et al., 1960; Greene et al., 1971; Shivas et al., 1984), and that the addition of vitamin C retarded rancidity in ground beef (Greene et al., 1971; Shivas et al., 1984).

Shivas et al. (1984) reported that vitamin C added in ground beef to achieve final concentrations of 500 ppm and 1000 ppm prolonged display life as determined by visual color scores, spectrophotometric color analyses and TBA values when compared to controls and the 100 ppm level after 5 days of display. Benedict et al. (1975) reported that 50 ppm vitamin C addition to ground beef showed greater TBA values than for the control treatment. Vitamin C at concentrations over 5000 ppm in a hemoglobin solution can act as a prooxidant (Watts and Lehmann, 1952b) and vitamin C under 176 ppm in an aqueous carotene-linoleate solution will also act as a prooxidant with metal ions (Kanner et al., 1977). Therefore, when vitamin C is used at low concentrations (under 176 ppm), the addition of metal chelators will be needed to suppress the prooxidant reactions (Mahoney and Graf, 1986; Cheng and Cocoma, 1989). Since meats contain about 0.7 ppm Cu^{2+} and 21.9 ppm Fe^{3+} (Anderson et al., 1985), a range of 200 - 1000 ppm vitamin C should be sufficient to act as an antioxidant without use of chelators. In our study 500 ppm vitamin C concentration in ground beef was adequate to retard discoloration and rancidity.

The 30 ppm CTC suppressed microbial growth (Messer et al., 1984) in samples (from 280 to 2190 colony-forming units) compared

on-CTC samples (from 1980 to 253330 units) during 7 days of display.

2

Meat spread with vitamin C solution showed lower metmyoglobin percentages than control, and higher oxymyoglobin percentages control after day 4 (Fig. 4). Vitamin C spread treatment delayed metmyoglobin increase of the meat at least for 3 days compared to the ol. The data indicated that spreading of vitamin C solution on beef steak was a very useful treatment to retard metmyoglobin formation. deoxymyoglobin percentage in control became smaller than that of vitamin C-treated meat after day 10. The difference between yoglobin percentages of the vitamin C and control treatments was equal to the difference between oxymyoglobin percentages plus the rence between deoxymyoglobin percentages.

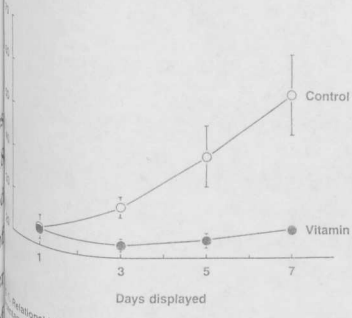
Costilow et al. (1955) reported that spraying with 1% vitamin C solution delayed the discoloration of the surface of beef for about day. In our study, the spreading of 10% vitamin C solution with the ratio of 0.1 ml solution to 20 g beef retarded the metmyoglobin ation for three days. Therefore, a 10% vitamin C solution may be more effective than a 1% solution for this purpose.

3

Dip treatment in vitamin C solution was effective in retarding oxidation of beef color and lipid in comparison with undipped control. min C dip treatment showed lower metmyoglobin percentages (Fig. 5) from day 7 and TBA values (Fig. 6) from day 1 than the undipped ol.

Harbers et al. (1981) reported that dip treatment of beef psoas major steaks in a 5% vitamin C solution showed an initial discoloration g the first 30 min then slowly increased in brightness in the presence of radiant energy. Okayama et al. (1987) reported that dip treatment eef short loin steaks in a 3% vitamin C solution showed a higher surface metmyoglobin percentage than controls at day 3 after treatment. ur study, a 1% vitamin C dip treatment showed greater pigment and lipid stability than undipped control during 16 days of display.

Vitamin C functions as an antioxidant with some substrates by scavenging oxygen and inhibiting radical formation at double bonds t, 1982). Tappel et al. (1961) indicated that vitamin C could act synergistically with vitamin E to inhibit lipid oxidation. The natural min C content of fresh meat is usually considered to be negligible (0 ppm in meat; Anderson et al., 1985). On the other hand, there were at 4.3, 2.8 and 3.4 mg α-tocopherol/kg tissue in the LL muscles from steers in experiment 1, 2 and 3, respectively. We considered that min C mix treatment had the antioxidant activity of 4,3 ppm vitamin E in muscle plus 500 ppm of added vitamin C. Also, vitamin C tion in the spread and dip treatments probably penetrated into the meat to some extent where it acted as an antioxidant with vitamin E



Relationship between days displayed and surface metmyoglobin ages. Standard error bars are indicated.

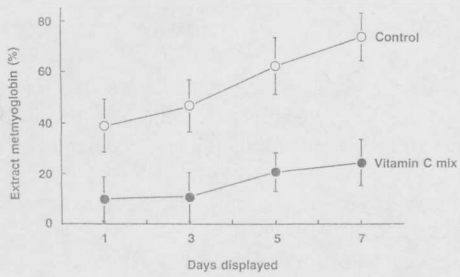


Fig. 2. Relationship between days displayed and extract metmyoglobin percentages. Standard error bars are indicated.

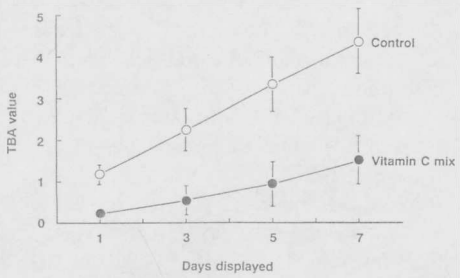
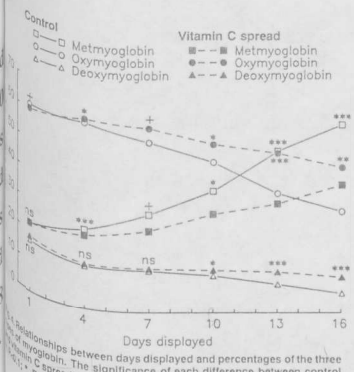


Fig. 3. Relationship between days displayed and TBA values. Standard error bars are indicated.



Relationships between days displayed and percentages of the three of myoglobin. The significance of each difference between control C spread treatment is shown within a day. ns, not significant; *, P<0.05; **, P<0.01; ***, P<0.001.

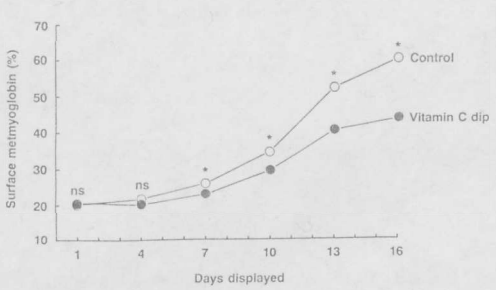


Fig. 5. Relationship of vitamin C dip treatment x days displayed on surface metmyoglobin percentages. The significance of difference between control and vitamin C dip treatment is shown within a day. ns, not significant; *, P<0.05.

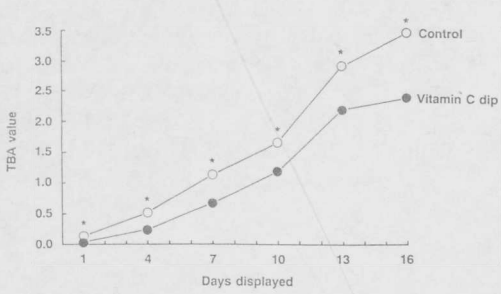


Fig. 6. Relationship of vitamin C dip treatment x days displayed on TBA values. The significance of difference between control and vitamin C dip treatment is shown within a day. *, P<0.05.

in the meat surface layer and improved stability of pigments and lipid.

CONCLUSION

Vitamin C mix treatment (500 ppm) improved pigment and lipid stability in raw ground beef compared to the control. Vitamin spread and dip treatments retarded pigment and lipid oxidation in beef cuts in comparison with controls.

REFERENCES

Anderson, B.A., Lauderdale, J.L., Hoke, I.M., 1985. Composition of Food: Beef Products. Agric. Handbook No. 8–13, U.S. Dept. Agriculture, Washington, DC.

Benedict, R.C., Strange, E.D., Swift, C.E., 1975. Effect of lipid antioxidants on the stability of meat during storage. J. Agric. Food Che 23, 167–173.

Caldwell, H.M., Glidden, M.A., Kelley, G.G., Mangel, M., 1960. Effect of addition of antioxidants to frozen ground beef. Food Res., 25, 13 144.

Cheng, C.S., Cocoma, G.J., 1989. Ascorbic acid use in fresh meat. Meat Industry Research Conference, Chicago, IL, September 20–21.

Cort, W.M., 1982. Antioxidant properties of ascorbic acid in foods. In "Ascorbic Acid: Chemistry, Metabolism, and Uses," P.A. Seib and B. Tolbert (Ed.), p. 533. American Chemical Society, Washington D.C.

Cort, W.M., Vicente, T.S., Waysek, E.H., Williams, B.D., 1983. Vitamin E content of feedstuffs determined by high–performance liq chromatographic fluorescence. J Agric. Food Chem., 31, 1330–1333.

Costilow, R.N., Batshon, B.A., Bratzler, L.J., Robach, D.A., 1955. Interactions between ascorbic acid and psychrophilic bacteria associat with the discoloration of prepackaged beef. Food Technol., 9, 560–563.

Greene, B.E., Hsin, I., Zipser, M.W., 1971. Retardation of oxidative color changes in raw ground beef. J. Food. Sci., 36, 940–942.

Harbers, C.A.Z., Harrison, D.L., Kropf, D.H., 1981. Ascorbic acid effects on bovine muscle pigments in the presence of radiant energy. Food Sci., 46, 7–12.

Hutchins, B.K., Liu, T.H.P., Watts, B.M., 1967. Effect of additives and refrigeration on reducing activity, metmyoglobin and malonaldehy of raw ground beef. J. Food Sci., 32, 214–217.

Kanner, J., Harel, S., 1985. Initiation of membranal lipid peroxidation by activated metmyoglobin and methemoglobin. Arch. Bioche Biophys., 273, 314–321.

Kanner, J., Mendel, H., Budowski, P., 1977. Prooxidant and antioxidant effects of ascorbic acid and metal salts in a ß–carotene–linolea model system. J. Food Sci., 42, 60–64.

Krzywicki, K., 1979. Assessment of relative content of myoglobin, oxymyoglobin and metmyoglobin at the surface of beef. Meat Sci., 3, 1–1

Krzywicki, K., 1982. The determination of haem pigments in meat. Meat Sci., 7, 29–36.

Ledward, D.A. and MacFarlane, J.J., 1971. Some observations on myoglobin and lipid oxidation in frozen beef. J. Food Sci., 36, 987–99

Mahoney, J.R. Jr., Graf, E., 1986. Role of alpha–tocopherol, ascorbic acid, citric acid and EDTA as oxidants in model systems. J. Food Sci 51, 1293–1296.

Messer, J.W., Peeler, J.T., Gilchrist, J.E., 1984. Aerobic plate count. Ch. 4. In "Bacteriological Analytical Manual, U.S. F.D.A." 6th ed Association of Official Analytical Chemists, Arlington, VA.

Mitsumoto, M., Faustman, C., Cassens, R.G., Arnold, R.N., Schaefer, D.M., Scheller, K.K., 1991a. Vitamins E and C improve pigment and lipid stability in ground beef. J. Food Sci., 56, 194–197.

Mitsumoto, M., Cassens, R.G., Schaefer, D.M., Scheller, K.K., 1991b. Pigment stability improvement in beef steak by ascorbic acid application. J. Food Sci., 56, 857–858.

Mitsumoto, M., Cassens, R.G., Schaefer, D.M., Arnold, R.N., Scheller, K.K., 1991c. Improvement of color and lipid stability in beef longissimus with dietary vitamin E and vitamin C dip treatment. J. Food Sci., 56, 1489–1492.

Okayama, T., Imai, T., Yamanoue, M., 1987. Effect of ascorbic acid and alpha–tocopherol on storage stability of beef steaks. Meat Sci., 21 267–273.

Rhee, K.S., Ziprin, Y.A., Ordonez, G., 1987. Catalysis of lipid oxidation in raw and cooked beef by metmyoglobin–H_2O_2, nonhem iron, and enzyme systems. J. Agric. Food Chem., 35, 1013–1017.

SAS Institute, Inc., 1985. "SAS User's Guide: Statistics," Version 5 Ed. SAS Institute, Cary, NC.

Shivas, S.D., Kropf, D.H., Hunt, M.C., Kastner, C.L., Kendall, J.L.A., Dayton, A.D., 1984. Effects of ascorbic acid on display life of ground beef. J. Food Protect., 47, 11–15, 19.

Snedecor, G.W. and Cochran, W.G., 1980. "Statistical methods," 7th ed. Iowa State University Press, Ames, IA.

Tappel, A.L. Duane Brown, W., Zalkin, H., Maier, V.P., 1961. Unsaturated lipid peroxidation catalyzed by hematin compounds and its inhibition by vitamin E. J. Am. Oil Chem. Soc., 38, 5–9.

Watts, B.M. and Lehmann, B.T., 1952a. Ascorbic acid and meat color. Food Technol., 6, 194–196.

Watts, B.M. and Lehmann, B.T., 1952b. The effect of ascorbic acid on the oxidation of hemoglobin and the formation of nitric oxide hemoglobin. Food Res., 17, 100–108.

Witte, V.C., Krause, G.F., Bailey, M.E., 1970. A new extraction method for determining 2–thiobarbituric acid values of pork and beef during storage. J. Food Sci., 35, 582–585.

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