

Effects of Activated Ozone, on Lipid Peroxidation, When Applied to Carcasses And to Ground Beef During Blending

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SUMMARY

This study was conducted to evaluate the effect of ozone on lipid peroxidation of beef lean samples, beef fat samples, and ground beef. Excision samples of beef lean and fat tissue were either immersed in ozonated water or remained untreated (control). Ground beef samples were treated with ozone vapor during blending. Treatment with activated ozone had little effect on the TBARS levels of beef fat, however treatment of lean samples (rib lifter meat) did result in significantly higher TBARS values on Days 12, 36 and 48. Treatment of ground beef samples with ozone vapor resulted in significant increases in lipid peroxidation.

Key Words: ozone, lipid peroxidation, TBA test, TBARS

INTRODUCTION

Purizer Corporation recently received approval to test a proprietary system involving an activated chemical compound (the Deligen II system) for use in beef harvesting Multiple-Hurdles systems. The Deligen II system uses UV light to activate ozone, creating an extremely fast-reacting vapor that is a more effective decontaminant than either ozone or UV light alone. Deligen II offers extreme flexibility in the beef plant because of the options that exist for applying the compound (liquid or gas). However, there is concern that ozone would increase lipid peroxidation in tissue treated with ozone, causing the product to develop a rancid flavor.

Lipid peroxidation is one of the major causes of quality deterioration in raw and cooked meat products during refrigerated or frozen storage (Raharjo and Sofos, 1993). Because ozone is a prooxidant, this study endeavored to determine how treating samples with Deligen II affected natural oxidation of

the product during refrigerated storage. The thiobarbituric acid (TBA) test is often used to quantify lipid peroxidation and thus can be used as an assessment of rancidity. The TBA test measures the level of malondialdehyde (MDA) and other substances, jointly called TBA-reactive substances (TBARS), formed during lipid oxidation. Two molecules of TBA react with one molecule of malonaldehyde (or another aldehyde) to produce a red pigment. The amount of pigment produced is then measured spectrophotometrically (Raharjo and Sofos, 1993). TBARS values are expressed as mg malonaldehyde equivalents per kg of tissue.

According to Dr. Gary C. Smith, "In the trade, beef and pork are considered rancid if the TBARS value is 1.0 or greater" (Smith, 2000). However, some reports have indicated that oxidized flavors were detectable at TBA numbers of 0.3 to 1.0 in beef and pork (Raharjo and Sofos, 1993). See Table 1 for a more complete correlation of TBARS values to eating quality as described by Williams (2000). Care must be taken when comparing TBARS values between different studies because of the many variations that have been developed for performing the TBA test.

MATERIALS AND METHODS

To determine the effect of Deligen II treatment on the oxidative stability of beef, 150 samples each of fat (chilled) and lean were collected from carcasses in a commercial beef packing plant (sample surface area = 130cm²). Researchers used surgical scalpels and forceps to excise samples of fat (10 cm x 5 cm x 1 cm) from carcasses following chilling. For lean tissue, 10 cm x 5 cm x 1 cm samples were excised from rib lifter meat. Multiple samples were obtained from each piece of rib lifter meat. All tissue samples were placed individually in sterile Whirlpak® bags and transported to laboratories located in the Colorado State University Center for Red Meat Safety. Half (N = 75) of each tissue type was subjected to treatment with the deligenated ozone, while the remaining samples received no treatment (control). The lean and fat surface samples were treated with deligenated ozone via the liquid dipping method: approximately 200 ml of Deligen II liquid (activated ozone) was added to each sample bag, the bag was

gently stomached for 30 seconds, then the tissue was aseptically removed and placed in a new, sterile bag. The Deligen II liquid was produced using the "water test cart" prototype generation system provided to researchers at Colorado State University by the Purizer Corporation. The test cart was operated to produce a continuous flow of Deligen II (see Table 2 for ozone concentration and flow data).

Samples of 85% lean ground beef (N = 375) were collected during manufacturing in the Colorado State University Meat Laboratory (following coarse grinding and during the blending process) such that 75 samples were obtained from the blenders before application of the deligenated ozone (to serve as the negative control) and the remaining samples were collected from the blender following treatment with the Purizer Corporation formulation. Treatment of ground beef in the blender with Deligen II (four treatments with 75 samples per treatment) was accomplished by applying the compound as a vapor using the "water test cart" prototype generation system. Treatments (Table 3) differed in length of exposure (30 seconds or one minute) and ozone concentration (ppm).

Following treatment, samples of all tissue types were vacuum-packaged individually in vacuum package bags and assigned to a storage time group (either 2, 12, 24, 36, or 48 days of chilled storage); storage times for each packaged sample within a treatment group (treated or control) were assigned randomly, with 15 samples from each treatment group being assigned to each of the 5 storage periods. All samples were chilled, then shipped overnight to Food Safety Net Services, Inc. in Richardson, TX and stored under refrigerated conditions (40° F). Upon reaching the appropriate storage time, each package was opened and tested for thiobarbituric acid values to evaluate the extent of oxidation that occurred during storage for that treatment. The TBA tests were conducted using the methods described in Rhee (1978). This method modifies the methods developed by Tarladgis et al. (1960) by adding 5 ml of a 0.5% solution of propyl gallate (PG) and ethylenediaminetetraacetic acid (EDTA) for each 10 g sample during the blending process to minimize further lipid oxidation.

RESULTS

Results of the TBA tests indicated that immersing fat samples from the external surface of beef carcasses in ozonated water had little effect on the level of TBARS (Figure 1A). Initial TBARS values (Day 2) were statistically lower for treated samples compared to untreated control samples (0.34 vs. 0.44). This difference was not observed at Days 12 or 24. By Day 36 post-treatment, TBARS values for treated samples were statistically greater than for control samples, but mean values for both groups were still within the acceptable range. These results are not surprising, given that the positive effects of the ozone (reduction in bacteria counts due to the effects of oxidation) were not encountered either (see companion study also published in the Research Report, "Effects of Activated Ozone, as a Decontamination Intervention, When Applied to Hides, Carcasses, and to Ground Beef During Blending"). It is still unclear whether ozone concentrations great enough to have a bactericidal effect would significantly increase fat oxidation when applied to the external surface of a beef carcass because, in this study, such concentrations were not achieved.

Treatment of rib lifter meat samples with ozonated water resulted in significantly higher ($P < 0.05$) TBARS values on Days 12, 36 and 48 (Figure 1B). While TBARS values for treated samples did not reach the 1.0 threshold as described by Smith (2000), there appeared to be substantially more

oxidation occurring within treated samples. The increased onset of rancidity in these lean meat samples was a potential obstacle to applying the Deligen II technology to fresh meat cuts.

For ground beef, samples receiving Treatment 1 (treated with an ozone vapor, concentration of approximately 10%, for 1 minute) had TBARS values that were significantly higher ($P < 0.05$) at each storage time (Days 2, 12, 24, 36 and 48) compared to values for Control samples (Figure 1C). Reducing either the ozone concentration of the vapor, or the exposure time reduced the degree of oxidation as measured via the TBA analysis. TBARS values for Treatment 2 (ozone concentration of approximately 10%, for 30 seconds) and Treatment 3 (Two-thirds of original ozone concentration, approximately 6.5%, for 1 minute) tended to be higher than for control samples, but were statistically lower than for samples receiving Treatment 1. Treatment 4 (one-third of original ozone concentration, approximately 3.2%, for 1 minute) resulted in TBARS values that were not significantly different ($P > 0.05$) from control values at Days 2, 12, 24 and 36.

Mean TBARS values were above the 0.5 level (Table 1) for all treatment groups, including the control group, at Days 2 and 12, indicating that caution must be used in adding any processing step to ground beef production that significantly increases the rate of oxidation.

DISCUSSION

Activated ozone produced by use of the Deligen II system did significantly increase lipid peroxidation, as measured by the TBA test, in beef lean and ground beef samples. Thus, it can be assumed that strategies that may enhance the bactericidal effect of the ozone (greater concentrations of ozone or tissue exposure for a longer period of time) would likely result in an unacceptable degree of lipid peroxidation.

REFERENCES

- Raharjo, S., and J.N. Sofos. 1993. Methodology for measuring malonaldehyde as a product of lipid peroxidation in muscle tissues: A review. *Meat Science* 35: 145.
- Rhee, K.S. 1978. Minimization of further lipid peroxidation in the distillation of 2-thiobarbituric acid test of fish and meat. *J. Food Sci.* 43:1776.
- Smith, G.C. 2000. Colorado State University. Personal communication.
- Tarladgis, B.G., B.M. Watts, M.T. Younathan and L.R. Dugan. 1960. A distillation method for the quantitative determination of malonaldehyde in rancid foods. *J. Amer. Oil Chem. Soc.* 37:44.
- Williams, S.N. 2000. Roche Vitamins, Inc. Personal communication.

Table 1. Interpretations of Thiobarbituric Acid Reactive Substances (TBARS)^a values

| TBARS ^b | Interpretation |
|--------------------|--------------------|
| < 0.2 | Good quality |
| 0.2 to 0.5 | Limited, tolerable |
| 0.5 to 1.5 | Somewhat oxidized |
| 1.5 to 5.0 | Oxidized |
| > 5.0 | Rancid, non-edible |

^aAdapted from Williams, 2000.

^bTBARS values expressed as mg malonaldehyde/kg tissue.

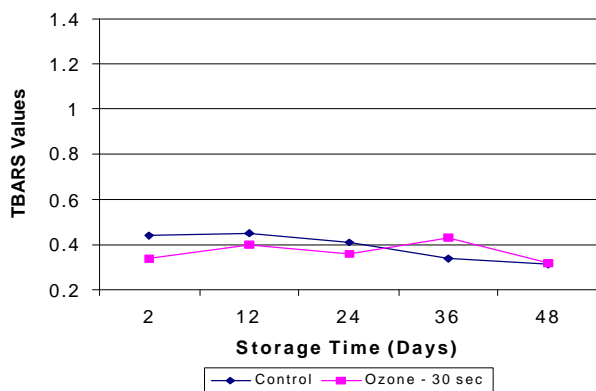
Table 2. Ozone concentration (ppm) and variable flow rate of ozonated water produced with the "water test cart" prototype generation system provided by the Purizer Corporation

| Sample | Ozone concentration (ppm) | Variable Flow Rate |
|----------------------|---------------------------|---------------------|
| Lean and Fat Samples | 9.46 | 9.6 L/min @ 10.5 Hz |

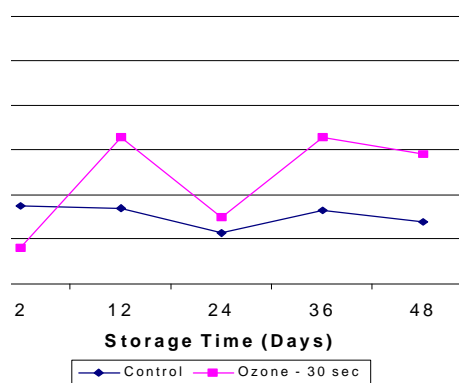
Table 3. Ozone concentration (in units of weight %) of the vapor produced with the “water test cart” prototype generation system provided by the Purizer Corporation for the treatment of ground beef

| Treatment | Ozone Concentration (%) |
|---|-------------------------|
| Control | 0 |
| Ozone: Full Strength for 1 minute | 10.05 |
| Ozone: Full Strength for 30 seconds | 10.45 |
| Ozone: Two-thirds Strength for 1 minute | 6.48 |
| Ozone: One-third Strength for 1 minute | 3.16 |

A. TBARS Values for Beef Fat



B. TBARS Values for Beef Rib Lifter Meat



C. TBARS Values for Ground Beef

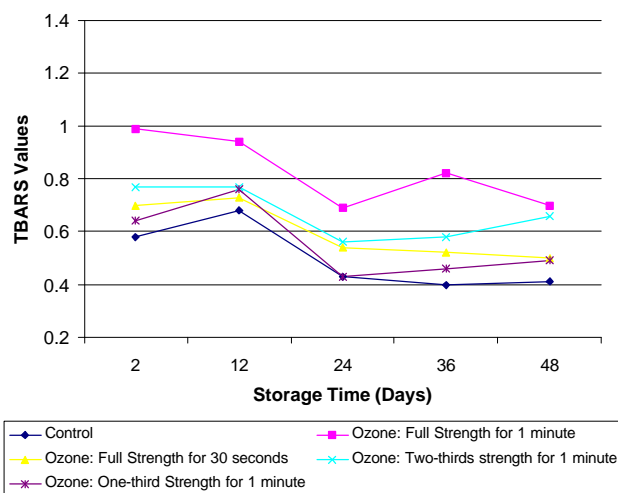


FIGURE 1. TBARS Values for samples treated with ozone; (A) Beef Fat, (B) Beef Rib Lifter Meat, and (C) Ground Beef.