Postmortem Addition of Vitamin E to Processed Meats: Improving Oxidative Stability of Cooked Products

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Story in Brief

The objective of this study was to determine how vitamin E, dissolved in an ethanol carrier, would partition itself between neutral (triacylglycerol) and membrane (phospholipid) lipid fractions of ground beef. Additionally, the effects of cooking on antioxidant partitioning and the oxidative stability of the resulting product were investigated. Ground beef was supplemented with 300ppm exogenous δ-tocopherol, formed into patties and cooked. Neutral lipid and membrane fractions of raw and cooked beef were separated and tocopherol contents measured. Following addition, 90-95% of supplemented tocopherol was recovered from lipid fractions. On an absolute weight basis, vitamin E partitioned almost equally between lipid fractions in raw meat; however, a considerable concentration effect occurred in membrane fractions. Cooking of beef patties resulted in a 25% loss of tocopherol. Cooking consequently resulted in a considerable redistribution of tocopherol between lipid fractions. As storage time progressed, tocopherol decreased linearly, signifying the antioxidant was being consumed in the oxidation process. Vitamin E treated samples inhibited the formation of oxidation products, suggesting an increased shelf life of the patties. The results from this study confirm the importance of choosing an appropriate antioxidant carrier for delivering the antioxidant to the site where oxidation is initiated and/or propagated.

Key Words: Processed Meat, Oxidation, Antioxidants, Shelf Life

Introduction

Processed meat items are commonly manufactured from muscle tissue high in total fat. The lipids of these products are more susceptible to oxidation than the lipids of whole muscle. Furthermore, the membrane phospholipids are more susceptible to oxidative changes than the neutral triacylglycerols (Dawson et al., 1990). As a consequence, antioxidants are added to muscle-based foods to improve the lipid and oxymyoglobin stability. However, the efficiency of an added antioxidant depends on whether or not it reaches the microenvironment that is most susceptible to oxidation. The determination of antioxidant partitioning between the different phases of a food product is an important parameter by which to select antioxidants (Huang et al., 1997). Direct addition of α-tocopherol to processed meat products has previously been reported to have no significant antioxidant effect (Kerry et al., 1998; Higgins et al., 1998). However, recent studies with chicken muscle have shown that tocopherol partitioning between membrane lipids and triacylglycerols is significantly affected by the carrier used to deliver the antioxidant into the system (Sigfusson and Hultin 2002a,b). Using ethanol, significant amounts of tocopherol were incorporated into membrane lipids, whereas virtually no incorporation was observed when corn oil was used as a carrier. The objective of this study was to determine the partitioning of exogenous ethanolic δ-tocopherol between the lipids of ground beef, and the effect of cooking and subsequent storage on oxidative stability.

Materials and Methods

Approximately 300ppm ethanolic δ-tocopherol on total lipid basis (13%) were sprayed onto ground beef while paddle mixing. The ground beef was formed into patties and cooked to core temperatures of 85˚C in an impingement oven. All patties were vacuumed-packaged and stored for 22 d at 2˚C. Partitioning of δ-tocopherol between the lipid fractions of raw and cooked beef was determined after physical separation of the lipids by ultracentrifugation techniques. Membrane lipids were obtained from a muscle buffer homogenate (pH 7.5) by differential ultracentrifugation. Triacylglycerols were collected after 40-min centrifugation of muscle at 130,000 g at ambient temperatures. Tocopherol contents of the separated lipid fractions were determined by HPLC after extraction with organic solvents. The progress of lipid oxidation was monitored by measuring TBARS. All experiments were performed in triplicate.

The Statistical Analysis System (SAS), version 8 was used for statistical analyses. An analysis of variance (ANOVA) was used to evaluate treatment and storage time as main effects. Interactions between treatment and storage time were included in the model. Mean separation was accomplished using Tukey's to determine significant differences among the treatments at $p<0.05$.

Results and Discussion

Partitioning of δ-tocopherol between the lipid fractions was estimated by comparison of tocopherol concentrations determined in each lipid fraction after separation. As some tocopherol (5-10%) is destroyed upon addition and mixing, partitioning calculations are based on tocopherols recovered from the ground beef immediately after its addition. Prior to cooking, the δ-tocopherol concentration in the beef triacylglycerols ranged from 85-230 ppm as compared to 2,600-3,500 ppm in the membrane lipids. On an absolute tocopherol weight basis for 100 g raw beef, approximately 52% (2,828 μg) of the added tocopherol was found associated with 0.8 g of membrane lipids, with the remaining 48% (2,700 μg) being associated with 16.2 g of triacylglycerols. These results demonstrate the efficiency of the ethanol carrier in delivering tocopherol into membranes.

Impingement cooking of patties resulted in approximately 25% overall loss of added δ-tocopherol, some of which may be accounted for by a mass loss upon cooking of approximately 40%. The membrane tocopherol concentration decreased by approximately 50%, whereas the tocopherol concentration in the triacylglycerols increased by approximately 30%. This may suggest a considerable redistribution of the added δ-tocopherol upon cooking. Contamination of the triacylglycerol fraction by phospholipids was not observed.

The tocopherol concentration of triacylglycerols isolated from cooked beef was approximately 250 ppm and did not change significantly ($p<0.05$) during 21 d of refrigerated storage (Figure 1). However, during this time the membrane tocopherol concentration decreased linearly, from approximately 3,300 ppm to 1,500 ppm. This underscores the importance of providing antioxidant protection to the less stable membrane lipids.

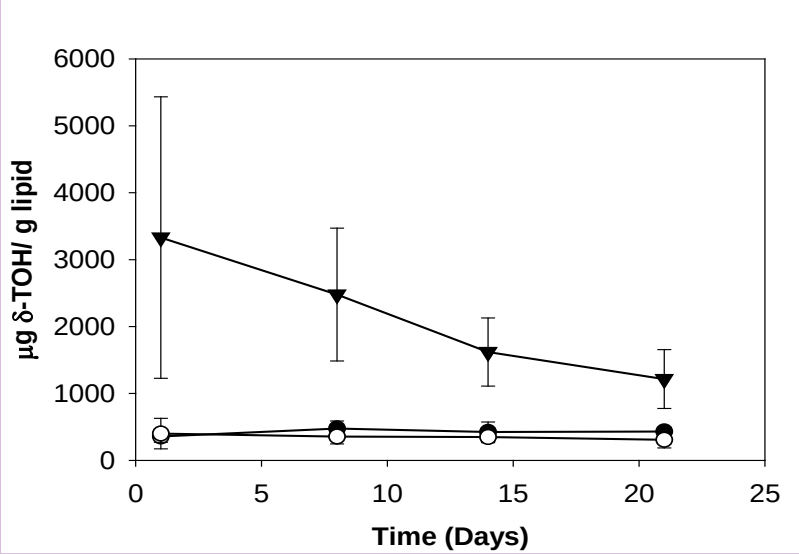

Figure 1. Changes in δ-tocopherol concentrations (ppm) of cooked patties, triacylglycerols and membrane lipids upon refrigerated storage. Results are means and standard errors of duplicate measurements from three replicate experiments. (●) Cooked patties; (○) Triacylglycerols; (▼) Membrane Lipids.

Trends for TBARS values of control and treated cooked patties followed a characteristic oxidation curve, increasing during the first days of storage followed by a decrease. The TBARS values of tocopherol-treated cooked patties were significantly lower ($p<0.05$) than that of control patties throughout the storage study; initial TBARS values of treated patties being approximately 5-times lower than control patties. These results demonstrate that addition of ethanolic exogenous δ-tocopherol improves the oxidative stability of cooked ground beef during refrigerated storage.

Although cooking of meat results in a significant reduction in membrane tocopherol levels, ethanol as an antioxidant carrier may raise the membrane tocopherol levels sufficiently to retard oxidative deterioration during refrigerated storage of cooked meats. Increasing the concentration of vitamin E in the membrane lipids may effectively extend the product shelf life and reduce the formation of off-flavors and odors associated with pre-cooked, refrigerated meat products. The results from this study confirm the importance of choosing an appropriate antioxidant carrier for delivering the antioxidant to the site where oxidation is initiated and/or propagated.

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