PROCESSING AND PRODUCTS

Effect of Dietary Vitamin E on the Oxidative Stability, Flavor, Color, and Volatile Profiles of Refrigerated and Frozen Turkey Breast Meat

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ABSTRACT In this study, the effect of varying dietary vitamin E levels on the oxidative stability, flavor, color, and volatile profiles of refrigerated and frozen turkey breast meat was examined. Nicholas turkey toms were reared on diets containing vitamin E levels as dl-α-tocopheryl acetate equivalent to the NRC recommendations (12 and 10 IU/kg from 0 to 8 and 9 to 18 wk, respectively) and 5x, 10x, and 25x the NRC diet. Two other diets were evaluated and included feeding the NRC diet until 15 and 16 wk followed by a diet containing 20x the NRC vitamin E level. All turkeys were processed in a commercial turkey processing plant and breast meat scored for color. Breast meat was excised from four carcasses per treatment and evaluated after refrigeration (1 and 7 d) or frozen storage (30, 90, 150 d) for oxidative stability and sensory quality by TBA analysis, descriptive flavor profiling, and headspace gas chromatography. The TBA values were inversely related to the dietary vitamin E levels. Refrigerated samples had TBA values 78 to 88% lower for the 10x and 25x vitamin E treatments, respectively, than for the NRC control treatment. No differences in TBA values (refrigerated samples) were detected for the 10x, 25x, and 20x (3 wk feeding duration) or across all treatments for samples frozen for 5 mo. The 10x and 25x NRC diets produced the most typical and acceptable turkey meat flavors with the fewest oxidized off-flavor notes for both fresh and frozen samples as opposed to the more oxidized flavor notes detected in the control samples. Mean color scores increased, indicative of less pale meat, as the level and duration of feeding dietary vitamin E increased. These findings showed that varying dietary vitamin E levels significantly influenced the oxidative stability and functionality of turkey breast meat.

(Key words: vitamin E, oxidation, turkey breast meat, sensory characteristics, stability)

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INTRODUCTION

The control of lipid oxidation in fresh and further processed meat products continues to be a goal of food scientists and food processors. These efforts are driven by the fact that lipid oxidation in fresh, processed, and cooked muscle food systems is often associated with product quality deterioration in the form of generating off-odors and flavors that are often described as “stale”, “rancid”, or “warmed-over” in the case of precooked and reheated meat products (Einerson and Reineccius, 1977; Bailey et al., 1980).

Previous studies have shown that poultry diets supplemented with vitamin E produce birds that have greater carcass lipid stability and better quality characteristics (Webb et al., 1972; Marusich et al., 1975; Bartov and Bornstein, 1977). Variations in vitamin E deposition in fatty tissues have been found between different poultry species (Mecchi et al., 1953). For example, Marusich et al. (1975) found that concentrations of tocopherol in turkey liver and breast muscle were only one-fifth to one-third, respectively, those of broilers fed similar dietary levels. In a more recent study in which female turkey poults were fed elevated dl-α-tocopheryl acetate levels over the last 3 wk prior to slaughter, tocopherol levels were 100 to 600% higher in thigh meat than in breast or skin and subcutaneous fat (Sheldon, 1984). When expressed on a per unit of fat basis, breast tissues had higher concentrations of tocopherol than thigh tissues, yet both tissue types had similar oxidative stabilities. These variations in oxidative stability and vitamin E levels among tissues were thought to be related to differences in the vascular network among tissues, lipid concentration and fatty acid profile, and degree of physical activity exerted by the different muscle groups (Sheldon, 1984).

Poultry diets are often supplemented with rendered poultry fat that contains highly unsaturated fatty acids. An increase in the degree of unsaturation of carcass fat of broilers and turkeys due to dietary unsaturated fat...
supplements decreases the carcass lipid stability. Under such conditions, vitamin E supplementation, even at elevated levels, is not always effective in stabilizing these tissues from oxidation reactions (Bartov and Bornstein, 1981).

One of the rising concerns of the industry regarding turkey breast meat functionality is a condition similar to pale, soft, exudative (PSE) pork meat. This condition causes problems with the texture, cohesiveness, color, and juiciness of processed turkey breast meat. This PSE-like condition, which has been observed to affect as much as 40% of a market tom flock, is thought to be related to anaerobic muscle metabolism and growth alterations in the musculoskeletal system (i.e., focal myopathy) (Sosnicki et al., 1991, 1992; Cherel et al., 1988a,b; 1989, 1991a,b; Sosnicki and Wilson, 1991, 1992; Cherel et al., 1992). Histopathological observations by M. D. Ficken (1996, College of Veterinary Medicine, North Carolina State University, Box 8401, Raleigh, NC 27695-8401, personal communication) indicate that PSE-like breast meat has muscle fibrils rupturing out of the muscle fiber bundles, which is unlike PSE in pork meat. In turkeys, PSE seems to be related to poor cell membrane or collagen connective tissue integrity. Like pork PSE, this PSE-like problem in turkey breast meat is likely from stress-susceptible turkeys.

Poor membrane integrity (PSE-like meat) in stress-susceptible turkeys could be ameliorated by a surfeit of dietary vitamin E. Schanus et al. (1981) observed a deficiency of the antioxidant enzyme, glutathione (GSH)-peroxidase in stress-susceptible pigs. He postulated that PSE was consistent with an antioxidant disorder leading to oxidative damage of cell membranes. Both stress-susceptible pigs and vitamin E-deficient animals have elevated activities of pyruvate kinase and creatine kinase in plasma and increased erythrocyte lysis due to free radical mediated damage to cell membranes (Duthrie et al., 1987). With this in mind, the intent of this study was to determine whether dietary vitamin E supplementation had an effect on the incidence and severity of PSE-like breast meat in turkeys.

The objective of this present study was to evaluate the effects of feeding supplemental vitamin E at concentrations significantly above the NRC requirements on the oxidative stability, quality, and color (PSE-like condition) of turkey breast tissues. The findings presented in this manuscript represent part of a more comprehensive study (Ferket, unpublished data) that sought to determine the effect of increased dietary levels of vitamin E on the performance, immune function, and carcass yield of commercial market turkey toms. Breast meat was chosen for analysis due to its higher economic value relative to dark meat tissues, lower overall vitamin E deposition rates than dark meat, and its greater susceptibility to oxidation than dark meat tissues, which is attributed to its higher ratio of unsaturated phospholipids.

### MATERIALS AND METHODS

Nicholas turkey toms were reared on a commercial feeding program in which the diets contained vitamin E levels as dl-α-tocopheryl acetate that corresponded to NRC (1984) recommendations, and 5×, 10×, and 25× the NRC vitamin E recommendations (Table 1). Two other treatment groups were raised on diets containing the NRC recommended level of vitamin E until 15 and 16 wk of age, respectively, and then fed supplemental vitamin E at a level of 20× the NRC through 18 wk of age. This feeding of elevated vitamin E concentrations (200 IU/kg) during the last 2 and 3 wk before processing was done to evaluate the effect of feeding excess vitamin E concentrations for shorter durations on breast meat quality and changes in flavor characteristics during storage.

The feeding program and basal diet formulations used were formulated by P. R. Ferket. All toms were raised according to standard commercial practices in a 48-pen curtain-sided facility. Each pen contained a tube feeder and Placon water fount to provide feed and water for ad libitum consumption. Each treatment was assigned to six replicate pens containing 18 birds with a stocking density of 0.372 m² per bird. At 1 d of age, the birds were placed in the pens containing used litter without new shavings placed on top. The used litter was from a previous flock that was challenged with *Eimeria adenoides*, *Eimeria gallapavonis*, and *Eimeria meleagritamitis*. Therefore, the poults received a natural challenge of coccidia and other microbes upon placement. A coccidiostat was not included in the prestarter feed to accentuate the coccidia challenge. All turkeys were slaughtered in a commercial turkey processing plant using standard processing procedures.

### Refrigerated Turkey Meat Study

Breast meat (*Pectoralis major* and *Pectoralis minor* muscles) was excised from four carcasses per dietary treatment, vacuum-sealed in commercial bags, and evaluated after 1 or 7 d of refrigeration (4 C) (one carcass per replicate per treatment was randomly selected from among the six treatment replicates). Half of the breast tissue from each carcass was used for sensory evaluation.

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### TABLE 1. Experimental vitamin E dietary treatments and design

<table>
<thead>
<tr>
<th>Treatment</th>
<th>0 to 8 wk</th>
<th>9 to 18 wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 NRC</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>2 5x NRC</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>3 10x NRC</td>
<td>120</td>
<td>100</td>
</tr>
<tr>
<td>4 25x NRC</td>
<td>300</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Age period</td>
<td>Vitamin E level</td>
</tr>
<tr>
<td>5 20x NRC</td>
<td>16 to 18 wk</td>
<td>200</td>
</tr>
<tr>
<td>6 20x NRC</td>
<td>15 to 18 wk</td>
<td>200</td>
</tr>
</tbody>
</table>

1Turkey strain: Nicholas males, completely randomized block design with 2 blocks, 6 replicate pens per treatment, and starting with 18 poults per pen.
and the other half for 2-thiobarbituric acid (TBA) analysis and headspace gas chromatography. The tissues were analyzed in duplicate for oxidative stability by the TBA distillation assay as outlined by Yu and Sinnhuber (1967) and headspace volatiles by gas chromatography (Sheldon, 1984; Wu and Sheldon, 1988).

Duplicate 2-g samples of ground turkey breast meat were weighed into a 5-mL Perkin Elmer3 headspace vial and sealed using a teflon-lined silicon septum. The vial was heated at 90 C for an equilibration time of 30 min. A 30- and 15-s vial pressurization and injection time, respectively, were employed. The volatiles were injected and separated on a Perkin Elmer Model HS-6 Headspace Sampler3 interfaced to a Varian Model 3700 dual-flame gas chromatograph.4 A 30-M × 0.319-mm i.d. bonded phase fused silica capillary column coated with DB-5 to a film thickness of 1-µ was used for separation. The column inlet pressure was 138 kPa helium with an injection split ratio of 10:1 and a flow rate of 9.1 mL/min at ±20 C. The column was temperature-programmed from ±20 to 250 C at 10 C/min with a final 5-min hold time. Injector and detector temperatures were 250 and 300 C, respectively. Detector signals were integrated with a Waters6 820 chromatography data station. Volatile peak areas were normalized to a dry meat weight basis.

Sensory evaluation of turkey breast meat (four carcasses per treatment per sampling time) was accomplished using a descriptive analytical flavor profiling method described by Cairncross and Sjostrom (1950). An eight-member professional flavor profile panel evaluated the flavor (aroma and taste) of cooked ground turkey meat for all treatments. The panelists are able to detect, describe, define, and quantify aroma and taste descriptors relative to a reference standard (cooked, fresh turkey breast meat) that was available at all times in addition to universal reference standards. The panelists underwent two orientation training sessions to familiarize themselves with the product and develop a ballot of cooked aroma and taste descriptors (typical fresh turkey meat aroma and taste, oxidized aroma and taste, and cooked and oxidized aftertaste flavors. Sensory characteristics were individually scored with 14-point scales (1, not detectable to 14, strongly detectable) that measured the intensity of each character note.

Turkey samples were ground on the afternoon prior to the day of evaluation using a Model FG-A Kitchen Aid processor7 with grinder attachment and stored in vacuum-sealed Whirlpak® bags8 at 4 C. On the following day, 30-g samples per panelist were placed in individual glass baby food jars and covered with foil. The reference (fresh, unfrozen and unbasted turkey breast meat was purchased within 1 d of processing from a retail store) and six randomly selected samples (one per treatment) per panelist were cooked in a preheated convection oven9 at 175 C for 12 min. Covered jars were then placed in preheated pans of sand (to retain heat) and taken to the evaluation room. Samples were allowed to cool to 65 C before beginning evaluation. Once panelists had completed the first set of samples, the remaining three sets of samples were each cooked separately and evaluated.

Frozen Turkey Meat Study

Frozen turkey breast samples (four carcasses per treatment per sampling time) were thawed after 30, 90, and 150 d of frozen storage and analyzed for lipid oxidation using the sensory evaluation, TBA, and headspace volatile procedures as described previously.

Breast Muscle Color Scores

The incidence and severity of PSE-like breast meat from turkeys fed all the vitamin E treatments were evaluated by comparing the turkey meat to a color score scale developed to qualitatively evaluate PSE in pork. The scores used ranged from 1 (very pale: like PSE-like meat) to 4 (dark: like dark, firm, and dry meat). Color scores of 1 or 4 were associated with poorer meat processing functionality as previously established by Quality Control plant personnel than color scores of 2 and 3. A three-member panel of plant quality control and laboratory technician personnel and one of the authors evaluated and scored the color of freshly excised breast tissues (n = 12 to 35 carcasses per treatment) using a sodium vapor lighting background.

Statistical Analysis

Where applicable, significant differences between treatments, days, and treatment by day interactions were determined by analysis of variance (P ≤ 0.05) and the treatment means separated for each pair using the Student’s t test at P ≤ 0.05 (SAS Institute, 1990). Data were pooled across days when nonsignificant treatment by day interactions were observed. The residual mean square was used for testing main effects and the treatment by day interaction.

RESULTS AND DISCUSSION

The TBA values obtained from previously refrigerated and frozen breast meat samples were significantly influenced by the concentration of tocopherol in the diet (Table 2). The TBA values for refrigerated samples were not influenced by days of refrigeration (P > 0.05), and thus were pooled across days. An inverse relationship was observed between TBA values and dietary tocopherol concentrations. Birds fed the 25× NRC diet (Treatment 4) had significantly lower breast (refrigerated) tissue TBA values and thus greater oxidative
The six treatments (Table 2). Although not statistically different at the $P < 0.05$ level, a similar treatment pattern, as observed for refrigerated samples, was also evident in the frozen samples analyzed at 30 d. As previously observed in past studies (Sheldon, 1984), TBA numbers decreased across most treatments after 90 and 150 d of storage in comparison to the 30-d samples. This observation points to the problem of using the TBA assay on samples that have been frozen for long periods of time. It is interesting to note that a similar reduction as detected in TBA numbers was also observed in the concentration of eight volatile aldehydes following 30 d of frozen storage. This result is not unexpected as many compounds that are generated during lipid oxidation, such as aldehydes, undergo further reactions that produce other secondary end products which may not be detectable with the TBA assay.

The mean sensory scores for refrigerator and frozen turkey breast samples were summarized in Tables 3 and 4.

### Table 2. Effect of dietary vitamin E on the mean thiobarbituric acid (TBA) values for refrigerated and frozen turkey breast meat

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Refrigerated</th>
<th>Frozen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>30 d</td>
<td>1.47 ± 0.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.94 ± 0.6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>90 d</td>
<td>1.22 ± 0.0&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.16 ± 0.3&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>150 d</td>
<td>0.72 ± 0.1&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>0.71 ± 0.2&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup><sup>b</sup><sup>c</sup>Means ± SD within refrigeration and frozen storage categories with no common superscript differ significantly ($P < 0.05$).

<sup>1</sup>Treatment 1: NRC dietary vitamin E recommendations; Treatment 2: 5× NRC recommendation; Treatment 3: 10× NRC recommendation; Treatment 4: 25× NRC recommendation; Treatment 5: NRC recommendation over last 2 wk; Treatment 6: 20× NRC recommendation over last 3 wk.

<sup>2</sup>Day 1 and Day 7 refrigerated sample means were pooled; n = 4.

#### Table 3. Mean sensory scores for turkey breast meat refrigerated for 1 or 8 d

<table>
<thead>
<tr>
<th>Treatments</th>
<th>ATM</th>
<th>AOX</th>
<th>FTM</th>
<th>FOX</th>
<th>TTM</th>
<th>TOX</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Day 1</td>
<td>3.1 ± 0.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.1 ± 1.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.9 ± 0.9&lt;sup&gt;f&lt;/sup&gt;</td>
<td>4.5 ± 1.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.3 ± 0.9&lt;sup&gt;g&lt;/sup&gt;</td>
<td>3.3 ± 1.1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>1 Day 8</td>
<td>4.7 ± 1.0&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>3.4 ± 1.2&lt;sup&gt;abcd&lt;/sup&gt;</td>
<td>4.6 ± 0.6&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>4.0 ± 1.0&lt;sup&gt;pb&lt;/sup&gt;</td>
<td>3.4 ± 0.5&lt;sup&gt;f&lt;/sup&gt;</td>
<td>3.0 ± 1.4&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>2 Day 1</td>
<td>4.1 ± 1.0&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>3.6 ± 2.1&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>4.2 ± 1.2&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>3.6 ± 1.6&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>3.6 ± 0.7&lt;sup&gt;efg&lt;/sup&gt;</td>
<td>3.0 ± 1.2&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>2 Day 8</td>
<td>4.9 ± 0.9&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>3.9 ± 1.2&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>4.9 ± 1.6&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>4.4 ± 1.1&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>4.1 ± 0.8&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>3.1 ± 1.2&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>3 Day 1</td>
<td>4.2 ± 1.1&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>3.4 ± 1.5&lt;sup&gt;abcd&lt;/sup&gt;</td>
<td>4.5 ± 1.2&lt;sup&gt;def&lt;/sup&gt;</td>
<td>3.7 ± 1.5&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>3.9 ± 1.0&lt;sup&gt;f&lt;/sup&gt;</td>
<td>2.8 ± 1.3&lt;sup&gt;bcd&lt;/sup&gt;</td>
</tr>
<tr>
<td>3 Day 8</td>
<td>5.1 ± 1.2&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>2.8 ± 1.3&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>5.1 ± 1.1&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>2.4 ± 1.4&lt;sup&gt;de&lt;/sup&gt;</td>
<td>4.7 ± 0.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.9 ± 1.1&lt;sup&gt;def&lt;/sup&gt;</td>
</tr>
<tr>
<td>4 Day 1</td>
<td>5.1 ± 0.8&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.6 ± 0.8&lt;sup&gt;e&lt;/sup&gt;</td>
<td>3.9 ± 0.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.7 ± 1.1&lt;sup&gt;e&lt;/sup&gt;</td>
<td>4.3 ± 1.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.6 ± 0.7&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>4 Day 8</td>
<td>5.1 ± 1.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.6 ± 0.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.6 ± 0.9&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.9 ± 1.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.6 ± 0.4&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.6 ± 0.5&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>5 Day 1</td>
<td>3.8 ± 0.8&lt;sup&gt;de&lt;/sup&gt;</td>
<td>3.7 ± 1.2&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>4.3 ± 0.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.1 ± 1.2&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.5 ± 0.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.0 ± 1.2&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>5 Day 8</td>
<td>4.8 ± 0.9&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>2.6 ± 1.2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4.9 ± 1.2&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>2.7 ± 1.8&lt;sup&gt;cde&lt;/sup&gt;</td>
<td>4.2 ± 1.0&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>2.4 ± 1.6&lt;sup&gt;bcd&lt;/sup&gt;</td>
</tr>
<tr>
<td>6 Day 1</td>
<td>4.7 ± 1.3&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>2.9 ± 1.2&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>5.3 ± 1.3&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>2.5 ± 1.0&lt;sup&gt;de&lt;/sup&gt;</td>
<td>4.4 ± 1.2&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>2.2 ± 1.0&lt;sup&gt;bcd&lt;/sup&gt;</td>
</tr>
<tr>
<td>6 Day 8</td>
<td>4.4 ± 1.3&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>3.4 ± 1.3&lt;sup&gt;abcd&lt;/sup&gt;</td>
<td>4.9 ± 0.7&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>3.4 ± 1.7&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>4.1 ± 0.8&lt;sup&gt;bcd&lt;/sup&gt;</td>
<td>2.6 ± 1.4&lt;sup&gt;bcd&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup><sup>b</sup><sup>c</sup>Means within a flavor category with no common superscript differ significantly ($P < 0.05$).

<sup>1</sup>Treatment 1: NRC dietary vitamin E recommendations; Treatment 2: 5× NRC recommendation; Treatment 3: 10× NRC recommendation; Treatment 4: 25× NRC recommendation; Treatment 5: NRC recommendation over last 2 wk; Treatment 6: 20× NRC recommendation over last 3 wk.

<sup>2</sup>Mean ± SD; ATM, turkey meat aroma; AOX, oxidized meat aroma; FTM, turkey meat flavor; FOX, oxidized meat flavor; TTM, turkey meat aftertaste; TOX, oxidized meat aftertaste; 14-point sensory scale where 1 = not detectable and 14 = strongly detectable; n = 4.
and 4, respectively. The higher the score, the more intense the aromatic or taste note. In agreement with the TBA values, the panelists perceived more typical and acceptable roasted turkey aromatic notes in samples from Treatments 4 and 6, which were significantly higher than Treatments 2, 3, 5, and 1. The NRC samples had the lowest acceptable turkey meat aromas; these were not different from aromas of Treatment 5. After 8 d of refrigerated storage, Treatments 4 and 6 were significantly different, although no aroma differences were detected between Treatments 1, 2, 3, and 5. Panelists were able to detect some oxidized aromatic notes after 1 d of refrigerated storage, with no differences detected between Treatments 1, 2, 3, and 5. Treatment 4 consistently produced the most stable refrigerated product in terms of perceived oxidation aromas. No significant day differences (Day 1 vs 8) in oxidized aroma notes were perceived in samples from Treatment 4.

A similar treatment pattern, as sensed in the aroma and aftertaste sensory categories, was perceived by the panelists for the typical turkey meat flavor and oxidized flavor categories. Treatments 4 and 6 again produced the most acceptable and typical turkey meat tastes with the fewest oxidized off-notes. This effect was especially evident on Day 1. The NRC diet produced the least acceptable turkey meat flavors and more intense oxidized flavors, which were not different from the oxidized sensory scores for Treatments 2, 3, and 5 on Day 1 and Treatments 2 and 6 on Day 8.

After 30 d of frozen storage, samples from turkeys receiving the highest tocopherol levels had significantly more typical turkey meat aromas and less oxidized aromatics than the NRC Treatment (Table 4). Treatments 3 and 4 had the least detectable oxidized aromas in comparison to the other four treatments. To some degree, oxidized aromas were detected in all samples. This same general pattern was also observed in the flavor and aftertaste sensory categories. These findings agree with past studies in that increases in dietary vitamin E levels help to prolong the flavor shelf life of turkey meat products by reducing the degree of lipid oxidation (Sheldon, 1984). The higher the dietary vitamin E concentration and longer the duration of feeding this vitamin, the greater the oxidative lipid stability.

The results of varying dietary vitamin E concentrations on individual and total volatile aldehyde concentrations are summarized for refrigerated and frozen breast meat samples in Tables 5 and 6, respectively. Of the eight aldehydes detected, hexanal was present in the highest concentration followed by pentanal. No treatment differences were detected in the individual or total volatile aldehyde concentrations after 1 d of refrigeration. As an indicator of lipid oxidation, 7-d refrigerated samples from Treatments 1 and 2 had significantly higher total aldehyde concentrations in comparison to samples refrigerated for 1 d. Furthermore, 7-d refrigerated samples representing Treatments 3, 4, 5, and 6 had significantly lower total aldehyde concentrations in comparison to samples from Treatments 1 and 2. These findings agree in part with the TBA results and oxidized aroma, flavor, and aftertaste sensory panel scores such that higher aldehyde concentrations directly correlated

### Table 4. Mean sensory scores for turkey breast meat frozen for 30, 90, or 150 d

<table>
<thead>
<tr>
<th>Treatments</th>
<th>ATM</th>
<th>AOX</th>
<th>FTM</th>
<th>FOX</th>
<th>TTM</th>
<th>TOX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 Day 30</strong></td>
<td>3.9 ± 0.8def</td>
<td>3.4 ± 1.5ab</td>
<td>4.6 ± 1.1bcd</td>
<td>3.2 ± 1.47bc</td>
<td>3.6 ± 1.0def</td>
<td>2.6 ± 1.3abc</td>
</tr>
<tr>
<td>Day 90</td>
<td>4.3 ± 1.0cde</td>
<td>2.3 ± 0.9def</td>
<td>4.6 ± 1.2bc</td>
<td>2.6 ± 1.2bc</td>
<td>3.9 ± 1.8cde</td>
<td>2.3 ± 1.0cdef</td>
</tr>
<tr>
<td>Day 150</td>
<td>4.1 ± 0.8def</td>
<td>2.5 ± 0.6cde</td>
<td>4.4 ± 0.8cde</td>
<td>2.1 ± 0.7cde</td>
<td>3.8 ± 0.4de</td>
<td>2.0 ± 0.7cdef</td>
</tr>
<tr>
<td><strong>2 Day 30</strong></td>
<td>4.1 ± 1.1def</td>
<td>2.8 ± 1.3abcd</td>
<td>4.7 ± 1.1bc</td>
<td>2.8 ± 1.2abc</td>
<td>4.1 ± 0.8bc</td>
<td>2.1 ± 0.8bcdef</td>
</tr>
<tr>
<td>Day 90</td>
<td>4.9 ± 0.8abc</td>
<td>2.2 ± 0.9defg</td>
<td>4.7 ± 1.1bc</td>
<td>2.8 ± 0.7abc</td>
<td>3.8 ± 0.8de</td>
<td>2.3 ± 1.0bcdef</td>
</tr>
<tr>
<td>Day 150</td>
<td>3.5 ± 0.6f</td>
<td>2.5 ± 0.8abcd</td>
<td>4.2 ± 0.7def</td>
<td>2.3 ± 1.1cde</td>
<td>3.4 ± 0.8de</td>
<td>1.8 ± 0.9def</td>
</tr>
<tr>
<td><strong>3 Day 30</strong></td>
<td>4.2 ± 1.0cde</td>
<td>2.4 ± 1.3cdef</td>
<td>4.9 ± 1.0abc</td>
<td>2.1 ± 1.3cde</td>
<td>4.0 ± 0.9cdef</td>
<td>1.9 ± 0.8def</td>
</tr>
<tr>
<td>Day 90</td>
<td>5.0 ± 0.9a</td>
<td>1.8 ± 0.7fg</td>
<td>4.8 ± 1.3bc</td>
<td>1.9 ± 1.0cde</td>
<td>4.1 ± 1.1bc</td>
<td>1.7 ± 0.9def</td>
</tr>
<tr>
<td>Day 150</td>
<td>4.0 ± 0.5abcd</td>
<td>2.6 ± 1.2bcde</td>
<td>4.0 ± 0.8def</td>
<td>2.6 ± 1.0cde</td>
<td>3.8 ± 0.8def</td>
<td>2.1 ± 0.9bcdef</td>
</tr>
<tr>
<td><strong>4 Day 30</strong></td>
<td>4.5 ± 1.1abc</td>
<td>1.9 ± 1.1efg</td>
<td>5.6 ± 1.2f</td>
<td>1.7 ± 1.0f</td>
<td>4.9 ± 1.0a</td>
<td>1.6 ± 0.8ef</td>
</tr>
<tr>
<td>Day 90</td>
<td>4.6 ± 1.1abc</td>
<td>1.6 ± 0.8e</td>
<td>5.3 ± 1.2fg</td>
<td>1.8 ± 0.9c</td>
<td>4.5 ± 1.1abc</td>
<td>1.5 ± 0.8ef</td>
</tr>
<tr>
<td>Day 150</td>
<td>4.2 ± 0.9cdef</td>
<td>2.2 ± 0.9defg</td>
<td>4.6 ± 0.8cde</td>
<td>2.4 ± 0.8cde</td>
<td>3.8 ± 0.5ef</td>
<td>2.1 ± 0.9cdef</td>
</tr>
<tr>
<td><strong>5 Day 30</strong></td>
<td>4.3 ± 0.7bcd</td>
<td>2.8 ± 0.9abc</td>
<td>4.6 ± 0.7cde</td>
<td>2.8 ± 1.0abc</td>
<td>3.8 ± 0.4def</td>
<td>2.3 ± 0.8bcd</td>
</tr>
<tr>
<td>Day 90</td>
<td>4.4 ± 1.0abcd</td>
<td>2.2 ± 1.0def</td>
<td>4.7 ± 1.1cde</td>
<td>2.7 ± 1.2abc</td>
<td>4.0 ± 0.9abc</td>
<td>2.2 ± 1.2abcd</td>
</tr>
<tr>
<td>Day 150</td>
<td>3.6 ± 1.0abc</td>
<td>3.5 ± 0.8a</td>
<td>3.6 ± 0.8f</td>
<td>3.5 ± 1.1a</td>
<td>3.2 ± 0.8f</td>
<td>2.8 ± 0.8a</td>
</tr>
<tr>
<td><strong>6 Day 30</strong></td>
<td>4.2 ± 0.9cdef</td>
<td>3.1 ± 1.1abc</td>
<td>4.5 ± 1.2cde</td>
<td>2.8 ± 1.2abc</td>
<td>4.1 ± 0.9bc</td>
<td>2.6 ± 1.1ab</td>
</tr>
<tr>
<td>Day 90</td>
<td>4.9 ± 1.0a</td>
<td>1.8 ± 0.7fg</td>
<td>4.7 ± 1.2bc</td>
<td>2.8 ± 0.8abc</td>
<td>4.1 ± 1.1bc</td>
<td>2.3 ± 0.8bcd</td>
</tr>
<tr>
<td>Day 150</td>
<td>3.5 ± 0.5f</td>
<td>2.8 ± 0.9abcd</td>
<td>3.9 ± 0.5ef</td>
<td>2.8 ± 1.0abc</td>
<td>3.4 ± 0.6d</td>
<td>2.1 ± 0.9abcd</td>
</tr>
</tbody>
</table>

*Means within a flavor category with no common superscript differ significantly (P ≤ 0.05).

1Treatment 1: NRC dietary vitamin E recommendations; Treatment 2: 5× NRC recommendation; Treatment 3: 10× NRC recommendation; Treatment 4: 25× NRC recommendation; Treatment 5: 20× NRC recommendation over last 2 wk; Treatment 6: 20× NRC recommendation over last 3 wk.

2Mean ± SD, n = 4.
### TABLE 5. Effect of varying dietary vitamin E on the concentration of individual and total aldehydes in turkey breast meat (refrigerated samples)

<table>
<thead>
<tr>
<th>Aldehyde peak area</th>
<th>1 Day</th>
<th>7 Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Day 1</td>
<td>6,040b</td>
<td>13,842a</td>
</tr>
<tr>
<td>2 Day 1</td>
<td>3,563b</td>
<td>13,960a</td>
</tr>
<tr>
<td>3 Day 1</td>
<td>2,722b</td>
<td>7,480ab</td>
</tr>
<tr>
<td>4 Day 1</td>
<td>3,671b</td>
<td>5,606b</td>
</tr>
<tr>
<td>5 Day 1</td>
<td>6,066b</td>
<td>8,632ab</td>
</tr>
<tr>
<td>6 Day 1</td>
<td>3,414b</td>
<td>6,137ab</td>
</tr>
</tbody>
</table>

Means within columns with no common superscript differ significantly (P ≤ 0.05); n = 4.

1 Treatment 1: NRC dietary vitamin E recommendations; Treatment 2: 5 × NRC recommendation; Treatment 3: 10 × NRC recommendation; Treatment 4: 25 × NRC recommendation; Treatment 5: 20 × NRC recommendation over last 2 wk; Treatment 6: 20 × NRC recommendation over last 3 wk.

VITAMIN E EFFECTS ON TURKEY BREAST MEAT QUALITY

TABLE 6. Effect of varying dietary vitamin E on the concentration of individual and total aldehydes in turkey breast meat (frozen samples)

<table>
<thead>
<tr>
<th>Aldehyde peak area</th>
<th>30 Day</th>
<th>90 Day</th>
<th>150 Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Day 1</td>
<td>3,892abcd</td>
<td>19,600abcd</td>
<td>158</td>
</tr>
<tr>
<td>2 Day 1</td>
<td>4,811abcd</td>
<td>22,402abcd</td>
<td>0</td>
</tr>
<tr>
<td>3 Day 1</td>
<td>3,012abcd</td>
<td>14,358abcd</td>
<td>0</td>
</tr>
<tr>
<td>4 Day 1</td>
<td>2,115abcd</td>
<td>11,012abcd</td>
<td>0</td>
</tr>
<tr>
<td>5 Day 1</td>
<td>3,968abcd</td>
<td>18,615abcd</td>
<td>0</td>
</tr>
<tr>
<td>6 Day 1</td>
<td>1,694cd</td>
<td>8,654d</td>
<td>0</td>
</tr>
<tr>
<td>7 Day 1</td>
<td>816d</td>
<td>4,940d</td>
<td>0</td>
</tr>
<tr>
<td>8 Day 1</td>
<td>3,975abcd</td>
<td>19,222abcd</td>
<td>0</td>
</tr>
<tr>
<td>9 Day 1</td>
<td>2,196abcd</td>
<td>11,610abcd</td>
<td>0</td>
</tr>
<tr>
<td>10 Day 1</td>
<td>6,608a</td>
<td>27,470a</td>
<td>73</td>
</tr>
<tr>
<td>11 Day 1</td>
<td>2,734abcd</td>
<td>13,102abcd</td>
<td>0</td>
</tr>
<tr>
<td>12 Day 1</td>
<td>1,736cd</td>
<td>8,409abcd</td>
<td>0</td>
</tr>
<tr>
<td>13 Day 1</td>
<td>6,261ab</td>
<td>26,198abcd</td>
<td>110</td>
</tr>
</tbody>
</table>

Means within columns with no common superscript differ significantly (P ≤ 0.05); n = 4.

1 Treatment 1: NRC dietary vitamin E recommendations; Treatment 2: 5 × NRC recommendation; Treatment 3: 10 × NRC recommendation; Treatment 4: 25 × NRC recommendation; Treatment 5: 20 × NRC recommendation over last 2 wk; Treatment 6: 20 × NRC recommendation over last 3 wk.

with higher TBA numbers and more perceivable oxidized off-flavors and aromas. Although oxidized flavors among treatments were detected by the panelists after only 1 d of refrigeration, these treatment differences were not reflected in the individual or total aldehyde concentrations. This finding is not unexpected because it has been firmly established that meat aromas and flavors are not composed of just aldehydes but complex mixtures of many different classes of volatile and nonvolatile compounds (Ramaswamy and Richards, 1982). Few treatment differences were observed within and across sampling days for individual or total aldehydes detected in frozen breast meat samples.

The effect of level of dietary vitamin E supplementation in breast meat color score and score distribution is summarized in Table 7. Mean color score significantly increased as the level of dietary vitamin E increased. Moreover, a greater proportion of meat with a low color score was observed from birds fed the NRC (Treatment 1) and 5× NRC (Treatment 2) levels of vitamin E than
TABLE 7. Effect of dietary vitamin E supplementation on breast muscle color score of 18-wk-old turkey toms

<table>
<thead>
<tr>
<th>Dietary vitamin E level</th>
<th>Mean color score ± SE</th>
<th>Color score distribution1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>n</td>
</tr>
<tr>
<td>NRC</td>
<td>2.12 ± 0.11c</td>
<td>33</td>
</tr>
<tr>
<td>5x NRC</td>
<td>2.36 ± 0.20bc</td>
<td>11</td>
</tr>
<tr>
<td>10x NRC</td>
<td>2.33 ± 0.19bc</td>
<td>12</td>
</tr>
<tr>
<td>25x NRC</td>
<td>2.78 ± 0.12a</td>
<td>32</td>
</tr>
<tr>
<td>20x NRC, 16 to 18 wk</td>
<td>2.67 ± 0.19ab</td>
<td>12</td>
</tr>
<tr>
<td>20x NRC, 15 to 18 wk</td>
<td>2.54 ± 0.11ab</td>
<td>35</td>
</tr>
</tbody>
</table>

1 Color score distribution is expressed as a percentage of the number of sampled birds (n). Subjective scores: 1 = very pale; 2 = pale; 3 = dark; 4 = very dark. Color scores of 1 or 4 are associated with poor meat processing functionality.

from birds fed higher levels of vitamin E. The incidence of pale meat decreased even when 200 IU vitamin E/kg was fed during the last 2 to 3 wk before slaughter (Treatments 5 and 6); the longer high dietary vitamin E was fed, the lower the incidence of very pale meat. These results suggest that a surfeit of dietary vitamin E may reduce the incidence of PSE-like breast meat in turkeys, even if high vitamin E (200 IU/kg) was fed 3 wk before slaughter. Further study is warranted in relating vitamin E supplementation level and PSE-like breast meat in turkeys.

The findings from these analyses demonstrate that varying dietary vitamin E concentrations can influence the oxidative stability and muscle functionality of turkey breast tissues. It is apparent that the NRC recommended dietary vitamin E levels produce turkey breast meat tissues that are more prone to oxidation than breast meat tissues taken from turkeys that received elevated dietary tocopherol levels. However, it must further be noted that the economics of implementing one or more of these experimental diets into the nutritional program of turkey producers must be considered in light of any potential benefits. It is hypothesized that feeding high level vitamin E supplements throughout the production cycle is not cost-effective (about $2.00/ton). The cost-benefit relationship of feeding high vitamin E (200 to 300 IU/kg) for the last three weeks before slaughter requires more evaluation before it can be recommended for practice. However, the associated benefits in meat processing functionality (reduced PSE-like incidence) and improved flavor stability may make this alternative cost-effective.

REFERENCES


