INFLUENCE OF DURATION OF DIETARY VITAMIN E SUPPLEMENTATION ON FRESH AND CURED PORK COLOR STABILITY[1]

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Summary

Supplementing finishing pigs genetically predisposed to lipid deposition with α-tocopheryl acetate above 12 IU/lb of feed for as long as 70 d did not improve color stability of fresh and cured pork. Tissue α-tocopherol levels were similar across dietary treatments and higher than predicted. Muscle accumulation of α-tocopherol may be related to the rate and extent of lipid deposition in muscle. Also, chill temperature and carcass chill rate variability, under spray chill conditions, did not influence fresh pork color stability when carcasses with excessive amounts of external fat were utilized.

(Key Words: Pork, Vitamin E, Chill Rate.)

Introduction

Inadequate color is a major quality concern identified by all members of the pork marketing chain. The importance of visual appearance stems from its strong influence on consumer purchasing decisions at the retail case. Consumers discriminate against meat cuts that lack a fresh appearance and often misinterpret color blemishes as an indication of unwholesomeness. As a result, meat that becomes discolored is either marketed at a reduced price or is processed and merchandised in a reduced-value form at the expense of the industry.

Vitamin E is a potent antioxidant that has exhibited a dominant effect on preventing discoloration and extending color display life of beef, lamb, and pork. However, the ability of vitamin E to improve the color stability of fresh vacuum-packaged pork and cured pork products has not been determined. Therefore, the objectives of this research were to examine the effects of added dietary α-tocopherol and chill temperature on fresh loin chop color stability and to determine the influence of added dietary vitamin E on the cured color of inside ham muscles during retail display.

Procedures

Experimental Animals. Eighty medium-lean genotype crossbred barrows averaging 49.5 kg were allotted to one of four dietary treatments. Treatments were based on the duration of *d*-α-tocopheryl acetate administration. Pigs were fed either a control diet (corn-soybean meal, .7% lysine) containing 12.0 IU added *d*-α-tocopheryl acetate/lb of feed for 70 d or a diet supplemented with 91 IU *d*-α-tocopheryl acetate/lb of feed for 42, 56, or 70 d prior to slaughter. Pigs were housed in an environmentally controlled finishing facility with complete slatted flooring. There were two pigs per pen (5 ft × 5 ft) and 10 replications per treatment. Each pen contained a single-hole self-feeder and a nipple waterer to accommodate ab libitum access to feed and water. All carcasses were harvested humanely at the Kansas State University meat laboratory using standard industry procedures. Both sides of each carcass were sprayed with chilled water (2°C) for 10 s every 10 min during the first 10 h in the cooler; one side was chilled at

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0°C, and the other at 4.4°C. At 4 d postmortem, 10 carcasses within each dietary treatment were selected randomly, and both sides were fabricated to obtain the loin muscle from the 11th rib to the 4th lumbar vertebra. Six 1-in.-thick boneless loin chops were collected beginning at the 12th rib and proceeding posteriorly. The initial three chops collected were utilized, from anterior to posterior, to determine polyvinyl chloride (PVC) and vacuum-packaged fresh color stability and tissue α-tocopherol concentration, respectively. *Semimembranosus* and *adductor* muscles (inside ham muscles) from all sides chilled at 0°C within the control group and the group that received 91 IU/lb of feed for 70 d also were collected for cured color analysis. *Semimembranosus* samples were obtained at the time of fabrication for tissue α-tocopherol determination.

Tissue α-Tocopherol Concentration. α-Tocopherol was extracted from muscle tissue using iso-octane. Samples were saponified with KOH at 78°C prior to extraction. Normal-phase, isocratic liquid chromatography with a fluorescence detector (excitation 296 nm; emission 325 nm) was utilized to quantify α-tocopherol.

Fresh Color Evaluation. Chops were either placed on Styrofoam trays with absorbent pads and overwrapped with oxygen permeable PVC film or packaged in 4 in. × 10 in., 3 mil, standard, barrier nylon/PE vacuum pouches. All chops were displayed in an open-topped display case at 2 ± 2°C under 1614 lux (150 foot candles) of deluxe warm white fluorescent lighting. An experienced eight-member sensory panel evaluated both PVC- and vacuum-packaged chops. Chops packaged in PVC were evaluated at 0, 1, 3, 5, 7, and 10 d of retail display and assigned color scores on a scale of 1 to 5 (1 = very dark pink or brown; 2 = dark pink or brown; 3 = slightly dark pink; 4 = bright pink; and 5 = very bright pink). Vacuum-packaged chops were evaluated at 0, 1, 3, 7, and 14 d of retail display using a similar scale of 1 to 5 (1 = brown; 2 = brownish pink; 3 = slightly brownish pink; 4 = purplish pink; 5 = bright purplish pink). CIE $L^*a^*b^*$ values also were measured at these times using a Hunterlab LabScan 6000 Spectrocolorimeter. Three readings were averaged to determine the final L^*, a^*, and b^* values for each chop.

Cured Color Evaluation. Cured/cooked hams were produced by pickle injection (10 % of the weight) using a 5-needle, hand-stitch, brine pump injector at 50 p.s.i. The pickle composition (% w/w) was 15 % sodium chloride, 0.075 % nitrite, 3 % phosphate, and 81.9 % water. Ingredient concentrations and percentage pump were established to deliver a final product with a 2.0% salt concentration. Following a 2 d equilibration period, hams were stuffed into cellulose casings and cooked to an internal temperature of 70°C. A 1-in.-thick cross-sectional slice was removed from the center of each ham and vacuum packaged in 3 mil, standard, barrier nylon/PE vacuum pouches. Slices were displayed in an open-topped display case as described previously. The *semimembranosus* of each slice was evaluated for cured color by an experienced eight-member sensory panel at 0, 1, 3, 6, 9, 17, and 23 d using a scale of 1 to 6 (1 = tan or gray; 2 = grayish tan; 3 = very slightly pink; 4 = slightly pink; 5 moderately pink; 6 = pink). CIE L^* a^* b^* were collected at these times using a Hunterlab LabScan 6000 Spectrocolorimeter. Three readings per slice were averaged to determined final instrumental color values.

Statistical Analysis. This experiment was analyzed as a randomized complete block, using initial weight to establish blocks. All data were analyzed using the Mixed procedure of SAS. Diet, chill temperature, display time, and the corresponding two-way and three-way interactions were treated as fixed effects. For comparisons pertaining to measurements over time, either a split-split-plot or a split-plot analysis was conducted to account for repeated measures. Diet served as the whole-plot factor, chill temperature as the subplot factor, and display time as either the sub-subplot or subplot factor as determined by the presence or absence of a chill temperature variable. Satterthwaite adjusted degrees of freedom were used to test significance among main

effects and interactions. Main effect and interaction means were separated using least squares procedures when the respective F-tests were significant (P<.05).

Results and Discussion

Tissue α-Tocopherol Concentration. Feeding pigs a diet containing 91 IU added α-tocopheryl acetate/lb of feed for either 42, 56, or 70 d resulted in similar (P>.10) loin and *semimembranosus* α-tocopherol concentrations compared to control (12.0 IU/lb of feed) pigs. Supplementing pigs with 91 IU/lb of feed for 42, 56, and 70 d resulted in loin muscle α-tocopherol concentrations of 13.5, 12.5, and 13.8 μg/g of tissue, respectively, whereas control pigs had a mean loin muscle α-tocopherol level of 14.9 μg/g of tissue. Although differences were not detected, all dietary treatment groups had higher muscle α-tocopherol concentrations than expected. The highest levels of α-tocopherol in pork are detectable in adipose tissue, primarily because of the solubility of vitamin E in lipid. This suggests that muscle tissue lipid content may positively influence muscle α-tocopherol concentration. Therefore, the higher than expected muscle α-tocopherol concentrations across dietary treatments observed may have been influenced partially by the high muscle lipid content of the medium-lean genotype barrows utilized in this study. The population utilized had an average loin muscle lipid content of 4.71 ± .41 %. This is approximately 25% to 45% greater than expected for pigs of this genotype and 44% and 57% more than muscle tissue lipid of high-lean genotype barrows and gilts, respectively, often used in similar vitamin E studies. In addition to genetics, slaughter weight also may potentially influence tissue α-tocopherol levels because lipid deposition increases as pigs are fed to heavier weights. The barrows in this study were slaughtered at an average live weight of 261 ± 4 lb and had a mean 10th rib fat measurement of 1.4 ± .03 in. These results suggest that differences in slaughter weight, composition, and maturity may contribute to muscle α-tocopherol levels. Therefore, we speculate that when swine populations predisposed to lipid deposition are fed to heavier weights, muscle α-tocopherol accumulation may be accelerated. Also, supplementation of dietary vitamin E at levels greater than 12.0 IU/lb of feed does not appear to influence muscle α-tocopherol levels under these conditions.

Fresh Pork Color. Neither dietary α-tocopherol supplementation nor chill temperature main effects were detected (P>.10) for any visual sensory panel color scores and instrumental color measurements for PVC-packaged chops (Table 1). However, as expected, a display time main effect existed (P<.01) for visual sensory panel color scores, CIE $L^*a^*b^*$ values, saturation index, and hue angle (Table 2). Visual sensory panel color scores revealed a dramatic decline in fresh color over 10 d. Instrumental measures also indicated color deterioration over time. Lightness (L^*) values were higher (P<.05) at 0, 1, and 3 d of display than at 5, 7, and 10 d and were higher at 7 d than at 5 and 10 d. Overall, L^* values appeared to decline after 3 d of display. Redness (a^*) values of PVC-packaged chops declined at a more rapid rate than L^* and b^* values. Redness (a^*) values progressively decreased, with lower (P<.05) values obtained at 1, 3, 5, and 7 d of refrigerated display. Further decreases were not manifested; a^* values after 10 d were similar (P>.05) to those at 5 and 7 d. CIE b^* values also gradually declined; they were higher (P<.05) at 0 and 1 d than at 3, 5, 7, and 10 d. Values for b^* were similar (P>.05) at 3 and 5 d of display and at 5 and 7 d, whereas b^* values after 10 d were lower (P<.05) than all others. Color intensity (saturation index) values differed (P<.05), with lower values observed at 1, 3, and 5 d of display. Saturation index values were similar (P>.05) at 5 and 7 d and at 7 and 10 d. Hue angle exhibited a slow increasing trend; values differed (P<.05) at 1 and 5 d of display.

The lack of differences in color stability with vitamin E supplementation in fresh PVC-packaged pork chops may be a reflection of similar muscle tissue α-tocopherol concentrations. Improvements in pork color from supplementation with dietary vitamin E have been suggested to be related directly to the amount of α-tocopherol incorporated into

the muscle tissue. Our results indicate that elevated concentrations of vitamin E in muscle tissue do not guarantee an improvement in fresh color stability.

Results similar to those reported for chops packaged with PVC film were obtained for fresh pork chops displayed in vacuum pouches. All reported visual sensory panel color scores and instrumental color measures were similar (P>.10) across chill temperatures. A diet main effect was detected (P<.05) only for hue angle. The difference in hue angle means was difficult to attribute specifically to dietary vitamin E supplementation, because a relationship with loin muscle α-tocopherol concentration did not exist. Hue angle values were similar (P>.05) for chops from control pigs and pigs supplemented for 42, 56, and 70 d. However, hue angle values were lower (P<.05) for chops from pigs supplemented for 42 and 56 d compared to 70 d. Visual sensory panel color scores, L^* values, b^* values, and hue angle means for vacuum-packaged chops differed (P<.05) as a result of display time. Visual sensory panel color scores declined (P<.05) at each evaluation period. CIE L^* values were lower (P<.05) at 1 d of display than at 3 and 7 d and were lower at 3 and 7 d than at 14 d. Overall, gradual increase in L^* values occurred over 14 d of retail display. Both b^* and hue angle values decreased (P < .05) at 3 d and then remained unchanged during additional display. Both a^* and saturation index values remained constant (P>.10) over the 14 d of display.

Cured Pork Color. Means for visual sensory panel color scores and all instrumental color measures were similar (P>.10) for ham slices from both control pigs and pigs supplemented for 70 d. Visual sensory panel scores, $L^*a^*b^*$ values, and hue angle means differed (P<.05) with longer display time. Color scores were more intensely pink (P<.05) at 0 and 1 d of display, then declined (P<.05) at 3, 6, 9, 17, and 23 d. The measurable decrease in color stability observed visually was supported by instrumental measures. Values for L^* were similar (P<.05) at 0, 1, 3, 6, 9, and 23 d but were higher at 17 d (P<.05). Values for a^* were unchanged (P>.05) through 6 d of display. Values for a^* also were similar (P>.05) at 1, 3, 6, 9, and 23 d, and values at 17 d were less than those at 0 and 1 d. Values for b^* were higher (P<.05) at 1 d of display and again (P<.05) at 23 d. Although saturation index was not influenced by increases in display length, hue angle values increased. Hue angle values were lower (P<.05) at 0 d compared to all other times, and increased gradually up to 23 d. Improvements in the flavor attributes of cured hams from pigs supplemented with 91 mg α-tocopheryl acetate/lb of feed have been reported, but vitamin E was not effective in improving cured color stability in this study. However, the need to reduce the susceptibility of cured color to deterioration merits further research.

Table 1. Effects of Duration of Vitamin E Supplementation and Chill Temperature on Fresh Color of Pork Loin Chops Overwrapped in PVC and Displayed at 2°C[a]

		91 IU/Lb of Feed				Chill Temp.		
Item	Control	42 d	56 d	70 d	SE[b]	0°C	4.4°C	SE
Visual color score[c]	3.2	3.1	3.2	3.2	.09	3.2	3.2	.02
Instrumental color[d]								
L*	58.3	56.9	55.1	58.6	1.15	57.2	57.2	.77
a*	17.6	18.0	18.5	18.1	.39	18.0	18.0	.27
b*	16.3	16.3	15.0	16.4	.48	16.1	15.9	.33
Saturation index	24.1	24.4	23.9	24.4	.38	24.3	24.1	.28
Hue angle	43.1	42.1	39.3	42.4	1.23	41.9	41.6	.83

[a]No treatment differences (P>.05).
[b]Standard Error.
[c]Scores of 1 to 5: 2 = dark pink or brown; 3 = slightly dark pink; 4 = bright pink.
[d]Measure of dark to light (L*), redness (a*), yellowness (b*), vividness or intensity (saturation index), or red to orange (hue angle).

Table 2. Effects of Display Length at 2°C on Visual and Instrumental Color Measurements of Fresh Pork Loin Chops Overwrapped in PVC

	Display Length, d						
Item	0	1	3	5	7	10	SE[a]
Visual color score[b]	4.3[d]	4.1[e]	3.6[f]	2.9[g]	2.3[h]	1.9[i]	.05
Instrumental color[c]							
L*	57.9[d]	57.9[d]	57.9[d]	56.4[f]	57.2[e]	56.0[f]	.77
a*	21.9[d]	20.3[e]	18.9[f]	16.2[g]	15.4[h]	15.6[gh]	.34
b*	17.3[d]	17.4[d]	16.3[e]	15.6[ef]	15.1[f]	14.3[g]	.38
Saturation index	28.0[d]	26.8[e]	24.9[f]	22.6[g]	21.8[gh]	21.4[h]	.38
Hue angle	38.1[d]	40.5[e]	40.8[e]	43.8[f]	44.2[f]	43.1[f]	.89

[a]Standard Error.
[b]Scores of 1 to 5: 1 = very dark pink or brown; 2 = dark pink or brown; 3 = slightly dark pink; 4 = bright pink; 5 = very bright pink.
[c]Measure of dark to light (L*), redness (a*), yellowness (b*), vividness or intensity (saturation index), or red to orange (hue angle).
[d,e,f,g,h,i]Means in the same row with a different superscript letter differ (P<.05).