Studies on Vitamin E and Meat Quality. 1. Effect of Feeding High Vitamin E Levels on Time-Related Pork Quality

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The objective of this work was to study the influence of vitamin E (as *all-rac*-α-tocopheryl acetate) supplementation on the sensory quality of pork as a function of cold storage at 4 °C. Two dietary treatments were compared: (1) 60 mg of vitamin E/kg of feed from 20 to 100 kg live weight; and (2) 60 mg of vitamin E/kg of feed from 20 to 45 kg live weight and 200 mg of vitamin E/kg of feed from 45 to 100 kg live weight (10 and 11 weeks preslaughter). Meat quality was evaluated by sensory analysis and by instrumental techniques such as loin area determination, drip loss measurement, color determinations, and induced thiobarbituric acid reactive substance (TBARS) values. Vitamin E supplementation has a beneficial effect on the sensory data (freshness, tenderness, and juiciness and on the oxidative stability of pork as measured by induced TBARS values.

Keywords: *Meat; sensory quality; vitamin E*

INTRODUCTION

Sensory properties of meat have an important influence on the purchasing behavior of consumers. The greatest challenge to the raw meat industry is to offer well-colored, tender, juicy, and flavorsome products. Besides production of meat with positive quality attributes, prevention of off-flavor and off-odor development and loss of color during storage is also a major objective. Because of the increasing amount of meat sold commercially through supermarkets, conservation of meat freshness during shelf life is of growing importance.

The role of vitamin E in preventing lipid oxidation in muscle systems has been studied by several authors (Machlin, 1984; Diplock, 1985). It is now generally recognized that vitamin E as a lipid-soluble antioxidant is incorporated into the cell membranes and prevents formation of hydroperoxides from the unsaturated fatty acids of the triacylglycerols and of the oxidation-sensitive phospholipids.

Recent studies have demonstrated that in relation to consumer perception of beef, the dominant effect of vitamin E supplementation consists of preventing discoloration and extending color display life (Faustman et al., 1989a,b; Arnold et al., 1992).

Poultry meat contains relatively high amounts of unsaturated fatty acids, so prevention of oxidation and off-flavor formation during refrigerated and frozen storage is a major quality concern. Several studies have revealed a positive effect [lower thiobarbituric acid (TBA) values] of high α-tocopherol levels on TBA and induced TBA values (Sheehy et al., 1990; Frigg et al., 1991) and flavor scores (Blum et al., 1992). The TBA method is an index of rancidity development. The method measures a red-colored complex formed by reaction of malondialdehyde, a secondary degradation product of lipid peroxydation, and TBA.

Different aspects of the effect of feeding high vitamin E levels to pigs on pork quality have been studied, for example, pork chop color (Asghar et al., 1991), oxidative stability of raw and cooked muscle (Monahan et al., 1990), and the influence of dietary fat composition and dietary fat quality on meat oxidation (Monahan et al., 1992; Buckley et al., 1989).

The aim of this study was to evaluate the influence of two dietary supplementation levels on the oxidative stability and the sensory quality of pork.

MATERIALS AND METHODS

Quality evaluations were performed by sensory analysis (taste panel) and by instrumental techniques such as loin area determinations, color measurements according the CIE *L*a*b** system, drip loss, and induced TBA values.

Reagents. All chemicals used for induced TBA measurements were p.a. grade. Sodium chloride was obtained from UCB, Leuven, Belgium. Tris(hydroxymethyl)aminomethane, ascorbic acid, maleic acid, 2-thiobarbituric acid, trichloroacetic acid, and malondialdehyde bis(dimethylacetal) were obtained from Merck, Darmstadt, Germany. The α-tocopheryl acetate used in the pig diets was ROVIMIX-E-50 SD.

Animals and Dietary Treatments. To prevent interference with boar taint in the sensory analysis, only female pigs were used in the trial. Forty-eight female pigs (Danis) were divided into two groups. 24 animals were fed a control diet containing 60 mg of α-tocopheryl acetate/kg feed from 20 to 100 kg of live weight; and another 24 animals were fed the same diet from 20 to 45 kg live weight, but received a diet containing 200 mg of α-tocopheryl acetate/kg of feed at 10 or 11 weeks preslaughter from 45 to 100 kg live weight. To allow a large number of panel evaluations, duplicate slaughterings (2 × 24 animals) were performed in a commercial slaughterhouse on two consecutive Thursdays.

Experimental Procedure. After slaughter on Thursday (day 0), all 24 carcasses were deboned, and the longissimus dorsi were stored at 4 °C in a refrigerator. At day 1, the longissimus dorsi was divided in two parts of about equal size, and loin area was determined on both center parts. From one part, three loin chops were used for color measurements, one loin chop was frozen for determination of induced TBA values, and drip loss measurements were started on three loin chops. The other part was stored as a whole at 4 °C in a refrigerator for sensory analyses. Color measurements were also performed at days 2, 4, 5, 6, 7, and 8. Sensory analyses were performed at days 4 and 5. For statistical analysis of the sensory data, the evaluations of days 4 and 5 of both repeti-

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tions were treated together to have a judgment on all 48 animals (2 × 24) after 4.5 days.

Loin Area Measurement. After cutting the longissimus dorsi in two pieces, loin area was measured on both middle parts with transparant plastic films and a planimeter.

Drip Loss. A standardized method was used for measuring how much exudate a muscle will lose during cold storage. A 2.5-cm thick slice of longissimus dorsi with freshly cut surfaces was weighed, suspended with a thread inside a plastic pouch, and sealed under atmospheric pressure. The samples in the pouches were hung in such a way that the exudate dripping from the meat was not in contact with the meat. After 72 h of storage at 4 °C, the muscle was taken from the pouch, dried gently with an absorbing tissue, and reweighed. Drip loss was expressed as percentage of original weight of meat.

Color Measurements. Color measurements were performed with a Hunterlab Miniscan reflectance instrument using the CIE *L*a*b** System and two illuminants; that is, D65 (daylight) and TL84 (fluorescent light). Different procedures were used for both slaughter dates. The meat from the first slaughtering was cut on day 1, placed on plastic foam packaging, covered with plastic foil, and stored in a commercial refrigerator at 4 °C for imitation of retailer practice. Because of problems with the stability and uniformity of temperature in the open refrigerator, the loins from the second slaughtering were stored in a closed refrigerator at 4 °C. Measurements were performed on three slices after 1, 2, 4, 5, 6, 7, and 8 days of storage at 4 °C in the refrigerator.

Sensory Analysis. Sensory analysis was performed in a panel room with separate booths, air conditioning, and red light for color masking. Standardized meat sample preparation consisted of roasting slices of 1 cm in thickness for 2 min in a commercial grill (SEB, France), turning the samples and roasting 2 min more. The samples were coded, and presentation order was randomized.

The panel consisted of laboratory staff members. They were not preselected, but most of them were familiar with taste testing. A paired comparison test was used and the panel had to select the sample with the least fresh odor, the freshest taste, and the highest juiciness and tenderness (scores: 1 = least intensity of characteristic; 2 = most intensity). Twelve replications per comparison were performed.

Induced TBA Values. Oxidative stability of muscle tissue was determined by a modification of the method described by Monahan et al. (1992), which is a combination of the methods of Kornbrust and Mavis (1980) for induction of lipid peroxidation and of the method of Beuge and Aust (1978) for determination of TBA-reactive substances (TBARS). In contrast to Kornbrust and Monahan, who used 4 and 1 mM $FeSO_4$, respectively, $FeSO_4$ had to be omitted in our experiments because lipid oxidation proceeded too fast and could not be measured as a function of forced oxidation time in the presence of $FeSO_4$. Induced TBARS were expressed as mg malonaldehyde/kg meat.

Statistical Analysis. The sensory and instrumental data were evaluated by analysis of variance (Statgraphics).

RESULTS AND DISCUSSION

Loin area determination, drip loss, and color measurement are related to the visual appearance characteristics that play a major role in consumer appreciation of meat. The mean loin area of supplemented and control samples were, respectively, 66.8 and 63.3 cm^2. As presented in Figure 1, analysis of variance did not demonstrate a significant difference at the 95% level between control and supplemented samples. Also, drip loss measurements were not significantly different. Triplicate determinations on all 48 animals, according to the procedure described, resulted in high values for both types of animals; that is, 8.3 and 8.1% for control and supplemented samples, respectively.

For the time-related color measurements, the meat from the first slaughtering (24 animals), packed in trays

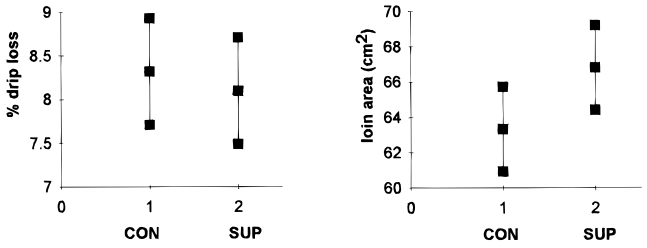

Figure 1. Means and 95% confidence limits for drip loss and loin area determinations of control and vitamin E-supplemented samples.

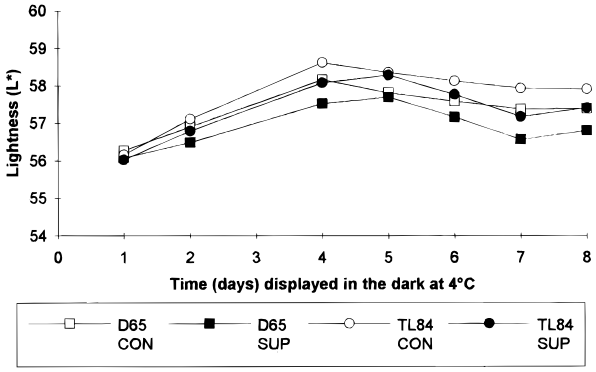

Figure 2. Mean lightness values (*L**) as a function of storage in the dark at 4 °C for control and vitamin E-supplemented pork samples (24 animals, three repetitions).

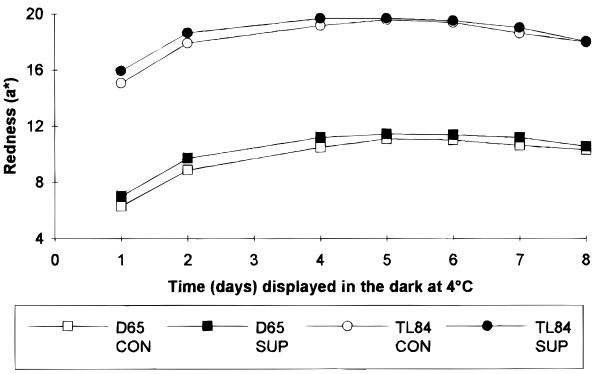

Figure 3. Mean redness values (*a**) as a function of storage in the dark at 4 °C for control and vitamin E-supplemented samples (24 animals, three repetitions).

that were covered with plastic foil, was stored in an open refrigerator to imitate practical shelf-life conditions. However, temperature and humidity standardization in the open refrigerator was insufficient, which resulted in drying out of several samples depending on their position in the open refrigerator. For color measurements of the meat from the second slaughtering (24 animals), the experimental procedure of using a classical closed refrigerator for storage of the meat in the dark at 4 °C proved more successful. Triplicate color measurements with a Hunterlab Miniscan were performed on days 1, 2, 4, 5, 6, 7, and 8.

The mean values for lightness (*L**) and for redness (*a**) as a function of storage time are presented in Figures 2 and 3, respectively. Although statistical analysis did not show a significant difference at the 95% level, vitamin E-supplemented samples had lower mean *L** values than the control samples, indicating darker meat. The redness values give more important information with respect to the sensory perception of meat color. Consumers perceive a bright red color as indicative of freshness and discriminate against meat

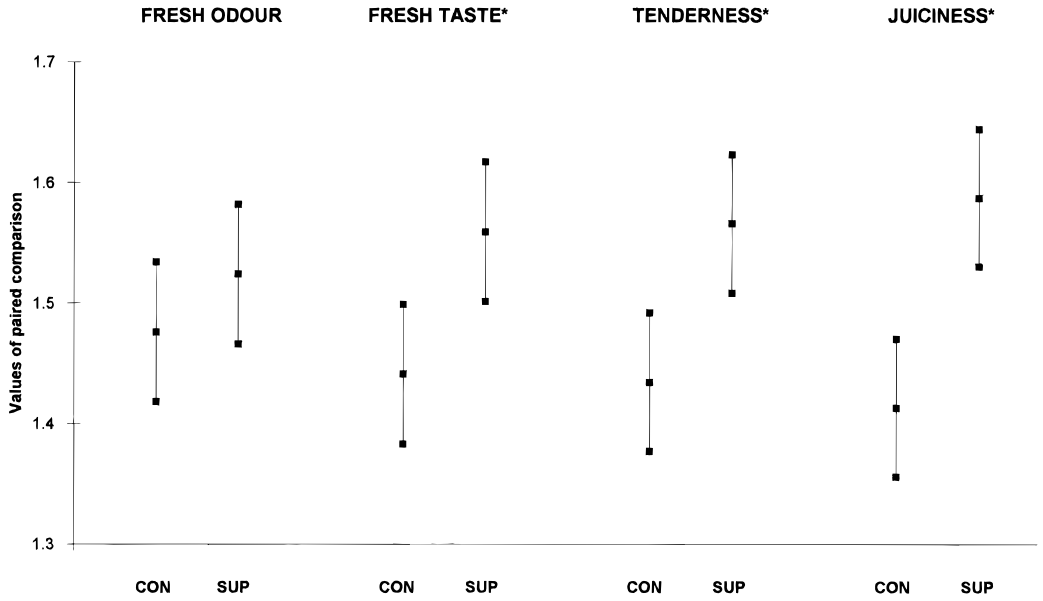

Figure 4. Means and 95% confidence limits for fresh odor, fresh taste, tenderness, and juiciness of control versus vitamin E-supplemented samples. $n = 2 \times 288$ replications. Asterisks indicate significant difference at the 95% level.

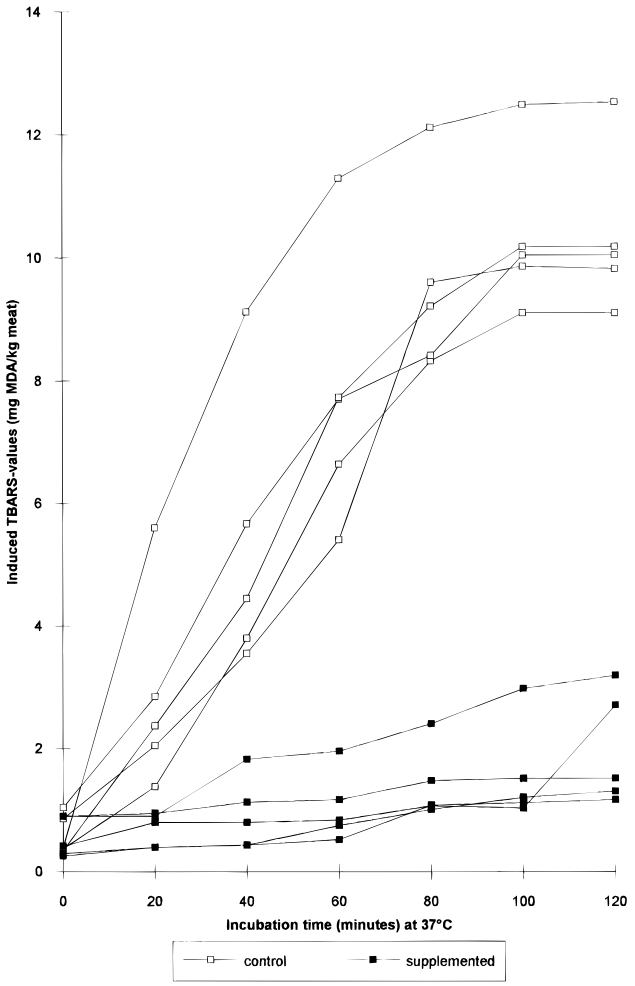

Figure 5. Induced TBA values (TBARS) for five supplemented and five control samples as a function of incubation time.

that has turned brown in color. Despite storage in the dark, supplemented samples had higher redness values than the control samples for both light sources (D65 and TL84). The difference in redness values were more important after short storage times (2−4 days at 4 °C), but the difference was not significant at the 95% level.

The mean values ($n = 2 \times 288$ replications) and the 95% confidence limits of the sensory evaluations for fresh odor, fresh taste, tenderness, and juiciness after 4.5 days of storage at 4 °C for the control samples and the supplemented samples are shown in Figure 4. The overall results of both slaughterings indicated a significant difference between supplemented and control samples after 4.5 days of storage at 4 °C. The vitamin E-supplemented samples had a fresher taste and were more tender and juicy compared with the control samples. Prevention of autoxidation and the protective action of vitamin E on the cell membranes could also benefit positive sensory attributes, such as flavor, freshness, and texture.

In addition to the sensory approach, the use of objective tests for measuring organoleptic deterioration as a function of storage time is highly desirable. A frequently used method for measurement of lipid oxidation is the TBA test. In a first attempt, we tried to determine TBA values in muscle tissue according to the steam distillation procedure of Tarladgis (1960). Unfortunately, although successful for cooked meat and certain processed meat products, the distillation method was not sensitive enough for measuring flavor deterioration in raw meat. Very low absorbance values were obtained, probably also because of the low intramuscular fat content of Belgian breeds.

In a second approach, lipid oxidation was induced according to a method adapted from Monahan (1992). As shown in Figure 5, induced TBARS values increased significantly faster as a function of time after disruption of the cells for control samples compared with vitamin E-supplemented samples. From these results one can objectively conclude that feeding high vitamin E levels has a beneficial effect on the oxidative stability of raw muscle.

Evidence of the effect of vitamin E in delaying formation of a whole range of volatile off-flavor components was also obtained in this study. The use of GC−MS for evaluation of the influence of vitamin E supplementation on the formation of volatile off-flavor compounds will be the topic of a separate publication.

CONCLUSIONS

Dietary supplementation of α-tocopheryl acetate has a beneficial effect on the sensory properties of pork as a function of storage time. Sensory analysis has shown that supplementation prolongs flavor freshness and positively influences tenderness and juiciness. These sensory results correlate well with objective determinations of TBARS as a function of forced oxidation. Induced TBARS measurements have shown that vitamin E has a beneficial effect on the oxidative stability of muscle tissue and delays off-flavor formation from the unsaturated fatty acids of the phospholipids and triacylglycerols.

LITERATURE CITED

Arnold, R. N.; Scheller K. K.; Arp, S. C.; Williams, S. N.; Beuge, D. R.; Schaefer, D. M. Effect of long- or short-term feeding of α-tocopherol acetate to holstein and crossbred beef steers upon performance, carcass characteristics and beef color display life. *J. Anim. Sci.* **1992**, *70*, 3055−3065.

Asghar, A.; Gray, J. I.; Booren, A. M.; Gommaa, E. A.; Abouzied, M. M.; Miller, E. R. Effects of supranutritional dietary vitamin E levels on subcellular deposition of α-tocopherol in the muscle and on pork quality. *J. Sci. Food Agric.* **1991**, *57*, 31−41.

Beuge, J. A.; Aust, S. D. Microsomal lipid peroxidation. *Methods Enzymol.* **1978**, *52*, 302−310.

Blum, J. C.; Touraille, C.; Salichon, M. R.; Richard, F. H.; Frigg, M. Effect of dietary vitamin E supplies in broilers. 2. Male and female growth rate, viability, immune response, fat content and meat flavour variations during storage. *Arch. Gefluegelk.* **1992**, *56*, 37−42.

Buckley, D. J.; Gray, J. I.; Asghar, A; Price, J. F.; Crackel, R. L.; Booren, R. L.; Pearson, A. M.; Miller, E. R. Effects of dietary antioxidants and oxidised oil on membranal lipid stability and pork product quality. *J. Food Sci.* **1989**, *54*, 1193−1197.

Diplock, A. T. In *Fat Soluble Vitamins: Their Biochemistry and Applications*; Diplock, A. T., Ed.; Heinemann: London, 1985; p 194.

Faustman, C.; Cassens, R. G.; Schaefer, D. M.; Beuge, D. R.; Scheller, K. K. Vitamin E supplementation of holstein steers diet improves sirloin steak color. *J. Food Sci.* **1989a**, *54*, 485−486.

Faustman, C.; Cassens, R. G.; Schaefer, D. M.; Beuge, D. R.; Williams, S. N.; Scheller, K. K. Improvement of pigment and lipid stability in holstein steer beef by dietary supplementation of vitamin E. *J. Food Sci.* **1989b**, *54*, 858−862.

Frigg, M.; Prabucki, A. L.; Banken, L.; Schwere, B.; Häuser, A.; Blum, J. C. Effect of dietary vitamin E supplies in broilers. 1. Report: evaluation of parameters related to oxidative stability of broiler meat. *Arch. Gefluegelk.* **1991**, *55* (5), 201−207.

Kornbrust, D. J.; Mavis, R. D. Relative Susceptibility of Microsomes from Lung, Heart, Liver, Kidney, Brain, and Testes to Lipid Peroxidation. Correlation with Vitamin E Content. *Lipids* **1980**, *15*, 315−322.

Machlin, L. J. In *Handbook of Vitamins. Nutritional, Biochemical and Clinical Aspects*; Machlin, L. J., Ed.; Dekker: New York, 1984; p 99.

Monahan, F. J.; Buckley, D. J.; Gray, J. I.; Morrissey, P. A.; Asghar, A.; Hanrahan, T. J.; Lynch, P. B. Effect of dietary vitamin E on the stability of raw and cooked pork. *Meat Sci.* **1990**, *27*, 99−108.

Monahan, F. J.; Buckley, D. J.; Morissey, P. A.; Lynch, P. B.; Gray, J. I. Influence of dietary fat and α-tocopherol supplementation on lipid oxidation in pork. *Meat Sci.* **1992**, *31*, 229−241.

Sheehy, P. J. A.; Morrissey, P. A.; Flynn, A. Effect of dietary α-tocopherol level on susceptibility of chicken tissues to lipid peroxidation. *Proc. Nutr. Soc.* **1990**, *49*, 28.

Tarladgis, B. G.; Watts, B. M.; Younathan, M. T; Dugan, L., Jr. A distillation method for the quantitative determination of malonaldehyde in rancid foods. *J. Am. Oil Chem. Soc.* **1960**, *37*, 44−48.

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