INFLUENCE OF DIETARY VITAMIN E ON SWINE GROWTH AND MEAT QUALITY

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INTRODUCTION

It is believed that peroxidative changes in meat are initiated at the membrane level. The lipids associated with the subcellular organelles (e.g., mitochondria, sarcoplasmic reticulum) are particularly susceptible to oxidation by virture of their contents of phospholipids containing relatively large amounts of polyunsaturated fatty acids (Pearson et al., 1977). Various attempts have been made to reduce lipid oxidation in meats through the use of antioxidants. For example, Buckley & Connolly (1980) reduced the rate of rancidity development in frozen pork by including vitamin E in the feed (80 mg/kg/animal) for seven days before slaughter of the pigs.

There is ample experimental evidence pertaining to the protective role of α-tocopherol against peroxidative reactions in cellular (Ingold et al., 1987) and subcellular membranes (Asghar et al., 1989; Buckley et al., 1989). Thus, the present study is based on the hypothesis that undesirable levels of lipid peroxidation that possibly occur in the cellular membranes and other tissue components even during the normal growth and development of meat animals can be minimized by supplementation of the diet with supranutritional levels of vitamin E. This might help to exploit the full growth potential of meat animals and yield better quality meat. Previous studies in our laboratory (Asghar et al., 1989; Buckley et al., 1989) have demonstrated the beneficial effects of feeding vitamin E-supplemented diets to broilers and pigs, respectively, on the oxidative stability of membrane-bound lipids and meat products. This present report demonstrates further the advantages of feeding different levels of supplemental vitamin E on the growth performance of swine and on the quality of pork during refrigerated storage.

MATERIALS AND METHODS

Sixty pigs (barrows and gilts) averaging 29 kg in weight were randomly assigned from litters to 6 pens with approximate equalization on initial weight and sex. Pens were then randomly assigned to receive a grower diet containing 10, 100 or 200 mg/kg vitamin E. Thus, there were two pens of pigs fed each of the three diets. The pigs were housed in an environmentally controlled, complete confinement, slotted floor modern swine facility. Feed was available at all times as a meal in self-feeders. There was one three-hold feeder available in each pen and water was available ad libitum from one nipple waterer in each pen. Pen size was such that pen floor space was $0.56 M^2$ per pig which is somewhat less than optimum by design to provide conditions similar to commercial swine production.

Pigs were weighed individually every two weeks and pen feed consumption was determined also every two weeks. Blood was drawn at 4-week intervals from 4 pigs from each pen from the anterior vena cava and following centrifugation, plasma was obtained for determination of plasma enzyme activities including creatine kinase, lactic dehydrogenase and aspartic aminotransferase. Plasma α -tocopherol concentrations were

also determined.

At the termination of the feeding trial, the pigs were slaughtered at the University Meat Laboratory according to standard commercial procedures. Samples of tissue (liver, heart, kidney, lung, adipose tissue) from all pigs were collected and frozen. Hot and cold carcass weights were also recorded. The Longissimus dorsi muscle from each carcass was removed 24 hr postmortem and frozen for subsequent study. Pork chops (approximately 1.5 cm thickness) from 8 pigs per dietary treatment were placed on polystyrene trays (8 chops per tray), overwrapped with an oxygen-permeable PVC meat stretch-wrap and stored at 4°C under fluorescent light. Samples were taken at 0,3,6 and 10 days for various analyses.

Chemical and biological analyses

The α-tocopherol concentrations in the various tissues were determined by a HPLC method developed in our laboratory (Asghar, unpublished data). The activities of lactate dehydrogenase, creatine kinase and aspartate aminotransferase in blood plasma were assayed following the Sigma technical procedure (1986-87). The extent of oxidation in the pork chops was assessed by the TBA distillation procedure of Tarladgis et al. (1960), as modified by Crackel et al. (1988). The modified procedure involved the addition of 0.01% tertiarybutyl hydroquinone (TBHQ) to the pork samples (fat basis) before homogenization to minimize lipid oxidation during the TBA test. Objective color evaluation of the pork chops was performed by determining Hunter L, a, b values. Mitochondria and microsomes from the pork muscle were separated following the method described by Buckley et al. (1989). The peroxidative stability of the isolated membranes was determined by a modification of the metmyoglobin/hydrogen peroxide induced lipid peroxidation assay of Kanner & Harel (1985).

RESULTS AND DISCUSSION

Effect of vitamin E on swine performance

Pigs receiving a high dietary level of vitamin E (100 and 200 mg/kg) showed significant improvement in daily body gain in the early growth phase. The advantage in body weight gained (4% and 6%, respectively) during the first 4 weeks persisted throughout the subsequent growth phase as compared to that of the control group (group 1). Feed intake data (Table 1) indicated that the high vitamin E-supplemented pigs (groups 2 and 3) consumed approximately 5% more feed than the control group during the initial growth period. Similarly, the feed conversion efficiency of the pigs fed the high vitamin E supplements was significantly ($p<0.05$) better than that of the control group, especially during the early growth period. The advantages gained in growth rate by vitamin E supplementation were also reflected in the carcass weights (hot and cold), being greater by 2.4 to 4.8% than the control pigs. However, the dressing percentage and shrinkage losses were identical for all groups.

Enzyme activities in blood plasma

The activities of lactate dehydrogenase (LDH), creatine kinase (CK) and aspartate aminotransferase (AST) in the blood plasma of pigs varied respectively from 17 to 33, 22 to 78, and 1.2 to 2.7 units/dL. In general, the activity of these enzymes varied more with growth period than with the level of vitamin E in the diet. However, CK activity tended to be higher and LDH and AST activity lower in blood from pigs fed high levels of vitamin E (groups 2 and 3) compared to the control group during the initial

phase (4-8 weeks) of the feeding trial.

The activities of LDH, CK and AST have been used as indicators of cellular damage in living organisms (Reddy et al., 1987). A high activity of these enzymes in blood plasma means a high rate of cell damage. Administration of excess α-tocopherol is believed to protect mature red cell membranes which are not equipped with de novo lipid synthesis, and to aleviate oxidative stress (Elsas & McCormick, 1986). It also decreases TBA-reactive substances (TBARS) in blood serum (Tolonen et al., 1988). However, as vitamin E deficiency was not involved in the present study, it is not surprising that the activities of LDH, CK and AST in all three groups of pigs were within normal limits.

Concentration of α-tocopherol in tissues

The concentrations of α-tocopherol in different tissues significantly increased ($p<0.05$) with increasing levels of dietary vitamin E (Table 2). However, the response among the different organs varied and increased in the order: kidneys<lungs<heart<liver. The adipose tissue and muscle also showed a substantial increase in deposition of α-tocopherol with increasing dietary concentrations. Similar trends were also observed for α-tocopherol deposition in the microsomal and mitochondrial fractions.

The differences in the concentrations of α-tocopherol in the mitochondrial fractions isolated from the L. dorsi muscles of pigs fed the different levels of vitamin E was clearly reflected in the enhanced stability of the membrane-bound lipids when the mitochondria were subjected to the metmyoglobin/hydrogen peroxide peroxidation system (Figure 1). A similar trend was observed for the microsomal fractions (data not shown here).

Effect of α-tocopherol on meat quality

Data in Table 3 show the influence of different dietary levels of vitamin E on certain quality characteristics of pork chops when exposed to fluorescent light at 4°C for 10 days. TBARS numbers increased with storage time in all cases, although, as expected, the pork chops from group 3 exhibited the smallest increase in TBARS numbers. Another noticeable feature was that the "a" value (redness) of pork chops decreased markedly during storage under fluorescent light. Again, the rate of color fading was lowest in pork chops from group 3 (200 mg vitamin E/kg feed) followed by group 2 (100 mg/kg). Overall drip loss was also smallest in pork chops from group 3. Two factors may account for this phenomenon. First, the high concentration of α-tocopherol in pork chops may protect the integrity of the cell membrane from freeze injury, thus retaining the sarcoplasmic fluid within the muscle cells. Second, as a result of the presence of only very small quantities of TBARS, crosslinking of malonaldehyde with the functional amino groups of protein would be minimal and would not decrease to any extent protein binding of water molecules.

CONCLUSIONS

Results of this study reveal that the effects of vitamin E supplementation on the growth performance of pigs are only apparent at an early age. With advance in age, the growth curves of pigs fed the higher levels of vitamin E tended to become parallel to that of the control group, suggesting that the advantage gained in body weight in the early growth

period actually persisted in subsequent phases. Previous studies in this laboratory with broilers (Asghar et al., 1989) and swine (Buckley et al., 1989) have demonstrated the beneficial effect of vitamin E supplementation in the diet on the oxidative stability of membrane and meat lipids during storage. Apart from confirming those results, this study also demonstrated other positive effects of vitamin E supplementation in the diet on certain quality characteristics of meat. Increased color stability and decreased drip loss are of practical importance to the meat industry.

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Table 1. Carcass characteristics of pigs fed vitamin E -supplemented diets[a]

	Group 1	Group 2	Group 3
Slaughter wt (kg)	101.1±8.7	103.8±6.3	106.3±7.3
Hot carcass wt (kg)	75.5±6.9	77.3±4.7	79.1±6.5
Dressing percentage	74.7	74.4	74.4
Cold carcass wt (kg)	73.0±6.5	74.8±4.5	76.6±6.2
Shrinkage loss (%)	3.43	3.23	3.10

Group 1, 10 mg vitamin E/kg feed; Group 2, 100 mg/kg; Group 3, 200 mg/kg

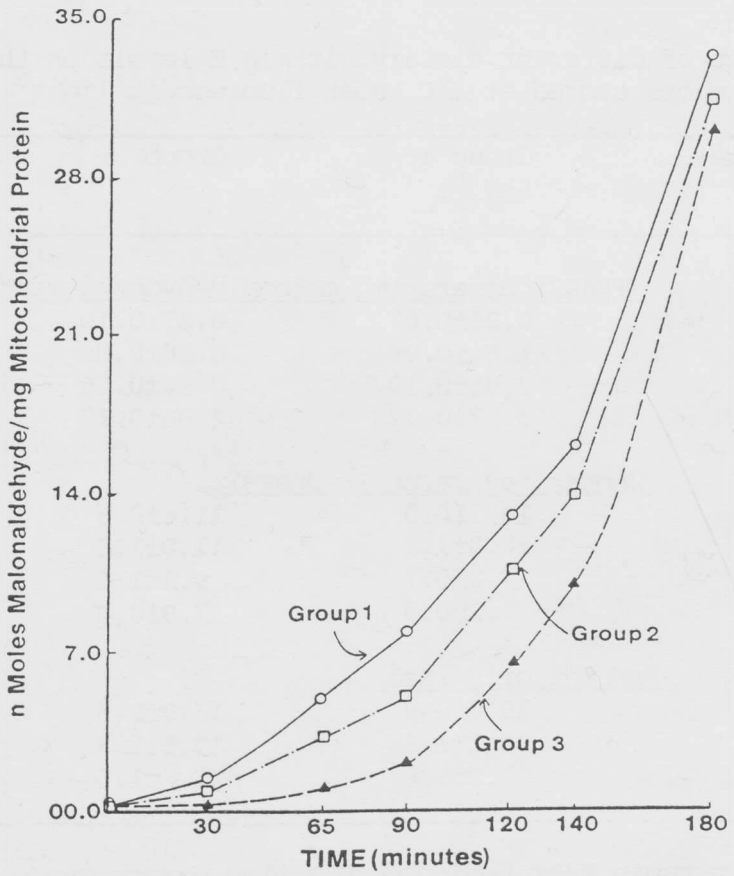

Figure 1. Metmyoglobin/hydrogen peroxide-initiated peroxidation in mitochondria isolated from the L. dorsi muscles of pigs fed vitamin E-supplemented diets. Group 1, 10 mg vitamin E/kg feed; group 2, 100 mg/kg feed; group 3, 200 mg/kg feed

Table 2. Concentrations of α-tocopherol in different organs and tissues from pigs fed vitamin E-supplemented diets[a]

Organs	α-Tocopherol (ug/g tissue, wet basis)		
	Group 1	Group 2	Group 3
Blood	0.58±0.18	2.48±0.55	4.07±0.74
Kidneys	0.50±0.16	3.38±0.36	4.02±0.49
Lungs	0.69±0.12	5.02±0.97	6.14±0.49
Heart	1.62±0.55	7.77±1.01	9.39±0.81
Liver	3.06±0.53	9.16±0.93	12.62±1.94
Back fat	0.21±0.03	1.79±0.34	2.89±0.27
Muscle	0.54±0.14	2.60±0.11	4.72±0.05
Mitochondria	1.76±0.04	14.51±0.83	20.93±0.79
Microsomes	1.17±0.02	2.86±0.69	5.16±0.12

Group 1, 10 mg vitamin E/kg feed; Group 2, 100 mg/kg; Group 3, 200 mg/kg

Table 3. Effect of different dietary vitamin E levels on the quality of pork chops stored at 4°C under fluorescent light[a]

Time of Storage (Days)	Group 1	Group 2	Group 3
	TBARS numbers (mg malonaldehyde/kg meat)		
0	0.28±0.03	0.27±0.10	0.27±0.05
3	1.54±0.09	0.56±0.06	0.35±0.04
6	2.96±0.19	0.94±0.05	0.58±0.04
10	5.17±0.37	2.96±0.17	1.93±0.08
	Hunter "a" value (redness)		
0	10.7±0.9	11.6±0.6	11.5±0.5
3	10.3±1.5	11.0±1.6	11.7±0.9
6	7.3±0.7	9.2±1.0	10.2±1.3
10	7.2±0.6	7.9±0.8	8.5±0.8
	Percent drip loss		
3	19.0±0.9	16.2±2.3	10.2±4.2
6	20.1±0.8	19.5±1.3	12.2±4.1
10	21.3±0.8	21.2±1.0	14.1±3.8

Group 1, 10 mg vitamin E/kg feed; Group 2, 100 mg/kg; Group 3, 200 mg/kg

[a]Pork loins were initially frozen at -20°C for three months before cutting into chops for the storage study