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Effect of Dietary Dried Tomato Pulp on Oxidative Stability of Japanese Quail Meat

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Ninety, 21-day-old, Japanese quail (*Coturnix coturnix japonica*) divided into three groups with five subgroups each were fed a basal diet that served as control or a basal diet containing 5 or 10% of dried tomato pulp (DTP), a byproduct of the tomato-processing industry. The DTP contained lycopene and β-carotene at 281 and 24.3 mg kg^{-1} of dry weight, respectively. On day 42 of age, birds were slaughtered, and carcasses were trimmed for breast meat. To assess the effect of dietary treatment on the oxidative stability of raw and cooked meat, raw meat was subjected to iron-induced lipid oxidation, whereas both raw and cooked meats were subjected to refrigerated storage at 4 °C. The extent of lipid oxidation was determined on the basis of the malondialdehyde (MDA) formed through the use of third-order derivative spectrophotometry. Results showed that after 6 and 9 days of refrigerated storage, MDA values in raw meat were increased. The increase was higher ($P < 0.05$) for the 10% DTP group and lower ($P < 0.05$) for the 5% DTP group, compared to control. An analogous oxidation profile was observed for cooked meat at 3, 6, and 9 days of storage. Iron-induced lipid oxidation of raw meat showed that the 10% DTP group as well as the control group exhibited MDA values that did not differ ($P > 0.05$) from each other at all time points, whereas the 5% DTP group presented MDA values that, although not differing from those of the other groups at 0 and 50 min, were significantly ($P < 0.05$) lower than those of the other groups at 100 and 150 min of iron-induced lipid oxidation. These results suggested that inclusion of dried tomato pulp in feed at a level of 5% exerted an antioxidant effect, whereas addition at level of 10% exerted a prooxidant effect. Mean α-tocopherol levels in the control, 5% DTP, and 10% DTP groups were 2.2, 2.1, and 1.4 mg kg^{-1} of meat, respectively. Fatty acid analysis showed that the 10% DTP group had a higher ($P < 0.05$) content of total polyunsaturated fatty acids and a greater ($P < 0.05$) unsaturated/saturated fatty acid ratio compared to control. There might be an interaction between DTP and α-tocopherol that is of importance for the balance between pro- and antioxidative activities. Future experiments should be designed to explore the interaction between individual carotenoids and tocopherols in order to better elucidate their role in oxidative changes.

KEYWORDS: Dried tomato pulp; fatty acids; α-tocopherol; oxidative stability; quail meat; refrigerated storage

INTRODUCTION

Dried tomato pulp (DTP) is the waste obtained during tomato processing in the form of seeds and skin residues. Tomato seeds constitute a rich source of edible oil, whereas the seed flakes are a good protein source (*1*). Because of its nutritive value, DTP could be used in animal feeding. In countries around the Mediterranean Sea, the United States and The Netherlands, where there is large-scale production and processing of tomatoes, use of DTP as a feed ingredient would be economically advantageous (*2*).

Published information on the use of dried tomato pulp as a feedstuff for poultry suggests that it could be included in the diet of broiler chickens at 5% without adverse effects on bird performance (*3*). Several authors (*4*, *5*) reported that incorporation of DTP in the diet of laying hens up to the levels of 12 and 15% did not affect laying but improved significantly yolk color. Feeding trials with quail showed that addition of DTP in

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the diet up to the level of 6% did not adversely affect growing and laying performance (*6*), whereas dietary incorporation up to the level of 10% improved significantly carcass color without any adverse effect on growth (*7*).

Tomatoes (*Lycopersicon esculentum*) and tomato products are currently of renewed interest in both animal and human nutrition because they are excellent sources of natural antioxidants largely in the form of carotenoids, phenolic compounds, tocopherols, and ascorbic acid (*8*, *9*). Among the carotenoids, lycopene predominates, with lesser amounts of β-carotene (*10*), as it constitutes 60−74% of the carotenoids present in tomatoes and tomato products (*11*). This compound has at least twice the antioxidant capacity of β-carotene and 10 times that of α-tocopherol, which makes its presence in foods of considerable interest (*12*−*14*). Tomato skin is a rich source of lycopene (*15*), as it contains ∼5 times more lycopene (53.9 mg 100 g^{-1}) than the whole tomato pulp (11 mg 100 g^{-1}). Therefore, a large quantity of lycopene would be normally discarded as tomato processing waste.

A major trend in the food industry, driven by consumer concerns, has been a shift from synthetic to natural antioxidants for inhibiting the development of oxidative rancidity in muscle foods (*16*, *17*). Poultry meat is particularly prone to oxidative deterioration due to its high concentration of polyunsaturated fatty acids that can be further increased by specific dietary treatments (*18*). Thus, there have been many studies showing an improvement in the oxidative stability of tissues by feeding poultry with natural antioxidants (*19*−*24*). Dietary supplementation may be a simple and convenient strategy to introduce lipid soluble antioxidants into the phospholipid membranes of tissues, where they can effectively inhibit the oxidative reactions at their localized sites (*25*, *26*). However, no research on the effects of feeding DTP to poultry on lipid oxidation of the produced meat has been yet published. There have been only a few pertinent studies showing that the antioxidants lycopene and lutein, which are abundant in tomatoes, may be of high beneficial effect on health (*27*−*29*). Incorporation of natural antioxidants in poultry meat through tomato pulp feeding might be of particular interest to both the meat industry and the consumers.

In a previous study (*7*), we investigated the effect of dried tomato pulp on the performance and carcass characteristics of growing Japanese quail. In the present study, the objective was to determine the effect of DTP incorporated in feed at levels of 5 and 10% on the oxidative stability of raw and cooked quail breast meat during refrigerated storage.

MATERIALS AND METHODS

Animals and Diets. Ninety, 21-day-old, Japanese quail (*Coturnix coturnix japonica*), half male and female, were used in this study. The birds were assigned, according to their initial body weights, to three treatment groups with five subgroups of three males and three females each. All 15 subgroups were housed in separate wire suspended cages.

To meet the nutrient requirements of growing quail, a complete basal control diet based on corn, soybean meal, and barley was formulated. **Table 1** presents the ingredients and the composition of the basal diet that was in mash form. The basal diet was given to one of the groups that served as control. The diets given to the other two groups were also based on the basal diet but contained an additional 5% of DTP replacing 40 g kg^{-1} soybean meal and 20 g kg^{-1} barley and an additional 10% of DTP replacing 50 g kg^{-1}soybean meal and 70 g kg^{-1} barley. Due to this addition, the incorporation levels of corn and fish meal in these diets increased to 48.8 and 1.2 g kg^{-1} and to 49.6 and 1.4 g kg^{-1} for the 5 and 10% supplementation levels, respectively, to allow all three diets to be isonitrogenous and isocaloric according to the nutrient composition values listed by the NRC (*30*). Feed and drinking water were offered to birds ad libitum, whereas conventional breeding and management procedures were applied throughout the feeding period that lasted 42 days. All birds were handled according to the principles for the care of animals in experimentation.

Table 1. Composition of Experimental Diets

	composition (g kg^{-1})		
ingredient	control diet	diet with 5% dried tomato pulp	diet with 10% dried tomato pulp
maize, grains	480.0	488.0	496.0
soybean meal	300.0	260.0	250.0
barley grains	150.0	130.0	80.0
herring meal	10.0	12.0	14.0
dried tomato pulp	0.0	50.0	100.0
soybean oil	19.0	19.0	17.0
limestone	7.0	7.0	7.0
dicalcium phosphate	18.0	18.0	18.0
lysine	1.5	1.5	3.0
methionine	1.0	1.0	1.5
vitamin premix[a]	5.0	5.0	5.0
mineral premix[b]	5.0	5.0	5.0
salt	3.5	3.5	3.5
chemical analysis[c]			
dry matter, %	90.5	90.6	90.8
crude protein, %	18.1	18.5	18.3
crude fat, %	3.5	5.0	5.1
crude fiber, %	5.0	7.0	8.0
calculated analysis			
calcium, %	0.9	0.9	0.9
phosphorus, %	0.6	0.6	0.6
metabolizable energy, kcal kg^{-1}	3100	3100	3100

[a] Supplying, per kg of feed: 10000 IU of vitamin A, 2500 IU of vitamin D_3, 20 mg of vitamin E, 7 mg of vitamin K, 5 mg of thiamin, 6 mg of riboflavin, 6 mg of pyridoxine, 0.02 mg of vitamin B_{12}, 60 mg of niacin, 15 mg of pantothenic acid, 1.5 mg of folic acid, 0.25 mg of biotin, 10 mg of vitamin C, and 500 mg of choline chloride. [b] Supplying, per kg feed: 100 mg of Zn, 120 mg of Mn, 20 mg of Fe, 15 mg of Cu, 0.2 mg of Co, 1 mg of I, and 0.3 mg of Se. [3] According to AOAC (*37*).

On day 42 of age, birds were slaughtered under commercial conditions, and carcasses were trimmed for breast meat by removing skin, bones, and connective tissue. Following trimming, breast samples within each subgroup were pooled, sliced, vacuum packaged, and stored at −70 °C pending further experimentation and analysis. All analyses were completed within 2 months.

Refrigerated Storage-Induced Lipid Oxidation. To assess the effect of dietary treatment on lipid oxidation of raw meat during refrigerated storage, samples were thawed, wrapped in transparent oxygen-permeable poly(vinyl chloride) film (6000−8000 cm^3 m^{-2} 24 h^{-1}), placed in a nonilluminated refrigerated cabinet at 4 °C for a total of 9 days, and submitted to determination of lipid oxidation at 0, 3, 6, and 9 days of storage.

To assess the effect of dietary treatment on lipid oxidation of cooked meat during refrigerated storage, thawed samples were put in Zip-Lok plastic bags to be heated in a water bath at 85 °C for 30 min, cooled under tap water, placed in a nonilluminated refrigerated cabinet at 4 °C, and submitted to determination of lipid oxidation at 0, 3, 6, and 9 days of storage.

Iron-Induced Lipid Oxidation. To assess the effect of dietary treatment on iron-induced lipid oxidation, a modification of the method of Kornbrust and Mavis (*31*) was employed. In brief, meat samples were homogenized (Polytron homogenizer, PCU) for 15 s in 9 volumes of 10 mM, pH 7.4, ice-cold phosphate buffer containing 1.15% potassium chloride. Three portions from each homogenate were treated to reach a final concentration of 1 M ferrous sulfate and immediately submitted to iron-induced lipid oxidation by incubation at 37 °C for 50, 100, and 150 min. Following incubation, all three incubated portions along with a fourth nonincubated portion from each homogenate were immediately analyzed for their malondialdehyde (MDA) content.

Measurement of Lipid Oxidation in Meat. Lipid oxidation was assessed on the basis of the malondialdehyde formed during refrigerated

storage. MDA, the compound used as an index of lipid peroxidation, was determined by a selective third-order derivative spectrophotometric method (*32*). In brief, 1-g samples were homogenized (Polytron homogenizer, PCU) in the presence of 8 mL of 5% aqueous trichloroacetic acid and 5 mL of 0.8% butylated hydroxytoluene in hexane, and the mixture was centrifuged. The top layer was discarded, and a 2.5-mL aliquot from the bottom layer was mixed with 1.5 mL of 0.8% aqueous 2-thiobarbituric acid to be further incubated at 70 °C for 30 min. Following incubation, the mixture was cooled under tap water and submitted to conventional spectrophotometry (Shimadzu, model UV-160A, Tokyo, Japan) in the range of 400−650 nm. Third-order derivative spectra were produced by digital differentiation of the normal spectra using a derivative wavelength difference setting of 21 nm. The concentration of MDA (nanograms per gram of wet tissue) in analyzed samples was calculated on the basis of the height of the third-order derivative peak at 521.5 nm by referring to slope and intercept data of the computed least-squares fit of a standard calibration curve prepared using 1,1,3,3-tetraethoxypropane.

Fatty Acid Analysis in Meat. Fatty acid analysis of breast meat was carried out according to the one-step extraction−transesterification procedure described by Sukhija and Palmquist (*33*). Separation and quantification of the methyl esters of fatty acids was carried out with a gas chromatographic system (model GC-17A, Shimadzu Corp., Kyoto, Japan) equipped with a flame ionization detector, a model Class-VP chromatography data system, and a fused silica capillary column, 30 m × 0.25 mm i.d., coated with cyanopropyl polysiloxane (phase type SP-2340) with a film thickness of 0.25 μm (Supelco, Bellefonte, PA). Chromatographic conditions were as described by Botsoglou et al. (*34*).

Determination of α-Tocopherol in Meat. Extraction of α-tocopherol from breast meat was carried out according to the method of Botsoglou et al. (*35*). In brief, 0.5-g samples were homogenized (Polytron homogenizer, PCU) with 100 μL of pyrocatechol solution and 5 mL of a saturated methanolic solution of KOH to be then saponified in a bath at 80 °C for 15 min. Following saponification, 5 mL of hexane and 1 mL of water were added, the mixture was vortex-mixed and centrifuged at 2000*g*, and an aliquot of the upper phase was evaporated to dryness to be further reconstituted in methanol and injected into the liquid chromatograph (Shimadzu, model 6AV, Tokyo, Japan). Liquid chromatography was carried out as described by Sheehy et al. (*36*). The chromatographic column used was a Nucleosil C_{18}, 5 mm, 250 × 4.6 mm, column, whereas the mobile phase was methanol/water (97:3, v/v) and delivered in the system at a flow rate of 2 mL min^{-1}. A fluorometric detector set at an excitation wavelength of 290 nm and an emission wavelength of 330 nm monitored the column effluents. Detector signals were quantified using peak heights and a standard calibration curve.

Determination of β-Carotene and Lycopene in Dried Tomato Pulp. Extraction of the total amount of β-carotene and lycopene in DTP was performed according to an AOAC method (*37*). The carotenoids were extracted from 2 g of sample using a hexane/acetone/alcohol/toluene mixture as solvent. The obtained extract was filtered through a 0.22-μm filter paper and diluted with hexane so that its concentration fell inside the range of the calibration curve, before direct injection onto the column. Liquid chromatography was carried out according to the procedure of Sadler et al. (*38*). The chromatographic column used was a Nucleosil C_{18}, 5 mm, 250 × 4.6 mm, column, whereas the mobile phase was methanol/tetrahydrofuran/water (67:27:6, v/v) and delivered in the system at a flow rate of 1.5 mL min^{-1}. Detector signals were quantified using peak heights and a standard calibration curve of 2.5, 5.0, 7.5, and 10 ppm of pure β-carotene and lycopene (Sigma Chemical Co., St. Louis, MO).

Statistical Analysis. Data on malondialdehyde levels in meat were subjected to two-way analysis of variance including main effects of dietary treatment (three levels) and time of storage (four levels), as well as interaction between the two factors. Data on α-tocopherol and fatty acid levels in meat were subjected to one-way analysis of variance. Before statistical analysis, Bartlett's test was applied to test the homogeneity of variances correlated with the mean (*39*). When the effect of factors was significant, Tukey's test was applied to determine statistical differences between least-squares means. A probability level of $P < 0.05$ was used in testing the statistical significance of data that were computerized using the SPSS 10.05 statistical package (SPSS Ltd., Woking, Surrey, U.K.).

RESULTS AND DISCUSSION

The dried tomato pulp used in the present study was obtained from a factory in northern Greece as a byproduct of tomato processing. Proximate analysis (*37*) showed that this processing waste contained 184 ± 4 g of crude protein, 92 ± 2 g of ether extract, 355 ± 31 g of crude fiber, and 31 ± 2 g of ash kg^{-1} of dry weight (wt). It also contained 281.0 ± 10.4 mg of lycopene and 24.3 ± 2.6 mg of β-carotene kg^{-1} of dry wt. Therefore, DTP could be an important source of natural antioxidants for the food industry.

The concentration of β-carotene in the DTP used in the present study was quite close to the value of 29.6 ± 3 μg g^{-1} of dry wt reported by other authors (*40*). On the other hand, the concentration of lycopene in the DTP, although high, was still much lower than that determined by other authors. Cadoni et al. (*41*) reported that tomato skin and seeds acquired as a byproduct from a tomato processing facility contained 778 μg of lycopene g^{-1} of dry wt. In other experiments, Rozzi et al. (*42*) found that tomato skin and seeds contained 24.5 μg of lycopene g^{-1} of dry wt, whereas Baysal et al. (*40*) found 310 μg of lycopene g^{-1} of dry wt, a value quite close to that found in the present study. The reasons for these discrepancies, although unknown, might be attributed to a high variability in lycopene content of the tomato fruits used for processing. Normally, tomatoes contain ∼3−5 mg of lycopene 100 g^{-1} of raw material (*43*). However, some deep-red varieties contain >15 mg 100 g^{-1} of raw fruits, whereas the yellow varieties contain only ∼0.5 mg 100 g^{-1} of tomatoes (*43*). Many factors including maturity, cultivar, and heat can affect the lycopene content of tomato fruits (*15*, *44*).

Carotenoids have been shown in a number of studies to be able to act as radical scavenging antioxidants. The antioxidant activity of carotenoids is highlighted by their singlet oxygen quenching properties and their ability to trap peroxyl radicals. β-Carotene scavenges peroxyl radicals by forming an adduct between β-carotene and the peroxyl radical, yielding a resonance-stabilized carotenoid radical, and not by donating a hydrogen atom as phenolic antioxidants do (*45*). On the other hand, the quenching constant of lycopene was found to be twice as great as that of β-carotene and 10 times greater than that of α-tocopherol, which makes its presence in foods of considerable interest (*12*, *13*, *46*).

Following quail feeding with carotenoids through diet supplementation with dried tomato pulp at levels of 5 or 10%, the susceptibility of breast meat to lipid oxidation was investigated during refrigerated storage at 4 °C. The extent of lipid oxidation, as measured by MDA formation, differed ($P < 0.05$) between the dietary treatments, even at zero time of storage (**Figure 1**). The 5% DTP group presented a mean MDA value of 44 ng g^{-1} in breast meat, which was lower ($P < 0.05$) than that in the control group (55 ng g^{-1}) but not different ($P > 0.05$) from the 10% DTP (48 ng g^{-1}) group. Because neither mincing nor any other oxidation-inducing procedure had been applied to the fresh tissue, the MDA values found should be due to either consumption and subsequent deposition by quail of MDA that was already present in the diets or in vivo production of MDA by quail during digestion. If the former possibility was valid, the levels of MDA should have been equal among treatments. Therefore, in vivo production of different levels of MDA by quail as a function of inclusion of the tomato pulp carotenoids in their diet seems more reasonable. The oxidation profile seen

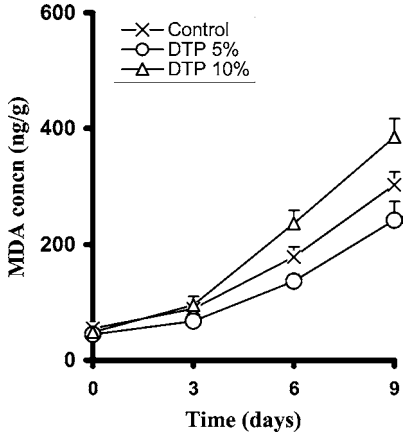

Figure 1. Effect of refrigerated storage at 4 °C on lipid oxidation of raw breast meat ($n = 5$) of quail as a function of dietary supplementation with dried tomato pulp at levels of 50 and 100 g kg^{-1} of diet.

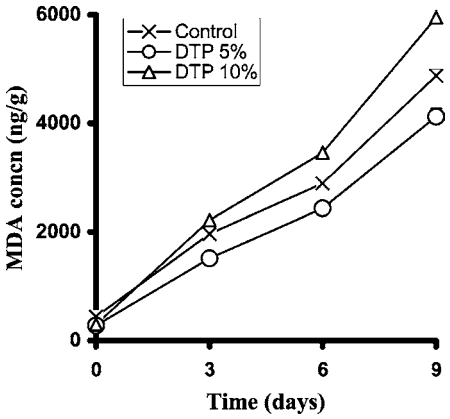

Figure 2. Effect of refrigerated storage at 4 °C on lipid oxidation of cooked breast meat ($n = 5$) of quail as a function of dietary supplementation with dried tomato pulp at levels of 50 and 100 g kg^{-1} of diet.

on day 0 could be also observed on day 3 of storage; however, MDA values, although higher and numerically different, did not present any significant ($P > 0.05$) difference. On days 6 and 9 of refrigerated storage, all groups exhibited progressively higher MDA values compared to days 0 and 3. However, the 5% DTP group presented lower ($P < 0.05$) MDA values, whereas the 10% DTP group presented higher ($P < 0.05$), MDA values compared to the control group.

An analogous lipid oxidation profile could be observed when breast meat was cooked at 85 °C prior to storage at 4 °C for 9 days (**Figure 2**). However, cooked samples showed higher MDA values and, therefore, greater susceptibility to oxidation than raw meat. Cooking causes membrane disruption that accelerates oxidative processes due to exposure of the unsaturated phospholipids to oxygen action and to release of prooxidant substances, such as non-heme iron (*47*). On day 0, the 5% DTP group presented a mean MDA value of 275 ng g^{-1} of meat, which was significantly ($P < 0.05$) lower than that in the control group (442 ng g^{-1}) but not different ($P > 0.05$) from the 10% DTP (298 ng g^{-1}) group. After 3, 6, and 9 days of storage, MDA values increased greatly, the 5% DTP group presenting lower ($P < 0.05$) MDA values and the 10% DTP group higher ($P < 0.05$) MDA values compared to the control.

To further study the effect of DTP on quail meat stability under accelerated conditions, an iron-induced lipid oxidation procedure was applied. Application of this procedure generated large amounts of MDA in all groups even at zero time (**Figure 3**). At all time points, the 10% DTP group as well as the control group exhibited MDA values that did not differ ($P > 0.05$) from each other, a finding suggesting that the DTP at its higher inclusion level did not exert any antioxidative effect. This is in contrast to what was found when the samples were submitted to refrigerated storage-induced lipid oxidation, when the 10% DTP group presented higher ($P < 0.05$) MDA values compared to the control group. However, it comes to agreement with reports of other authors (*48*) who stated that the antioxidative behavior of carotene differs between refrigerated storage-induced and iron-induced lipid oxidation. This might be attributed to the fact that carotenoids act against lipid peroxidation by mainly quenching singlet oxygen to prevent the formation of peroxides and not by binding iron ions in forms that will not generate reactive species. Nevertheless, the 5% DTP group presented MDA values that, although they did not differ from those of the other groups at 0 and 50 min, were lower ($P < 0.05$) at 100 and 150 min of iron-induced lipid oxidation.

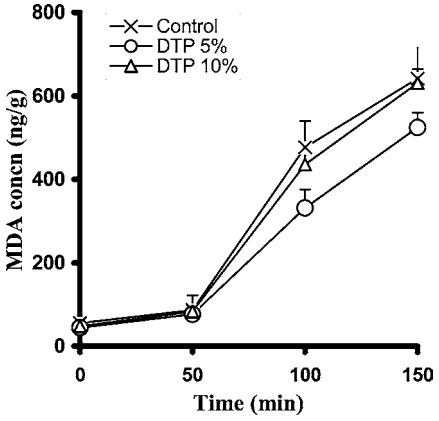

Figure 3. Iron-induced lipid oxidation of raw quail meat ($n = 5$) as a function of dietary supplementation with dried tomato pulp at levels of 50 and 100 g kg^{-1} of diet.

The effect of the dietary treatments on the fatty acid composition of breast meat is shown in **Table 2**. The dominant saturated fatty acids were palmitic acid ($C_{16:0}$) and stearic acid ($C_{18:0}$). Among the monounsaturated fatty acids, the dominant fatty acid was oleic acid ($C_{18:1}$), with lesser amounts of palmitoleic acid ($C_{16:1}$) and *cis*-11-eicosenoic acid ($C_{20:1}$). With regard to polyunsaturated fatty acids, linoleic acid ($C_{18:2}$ $n-6$) was dominant, ranging from 19.52% in the control group to 20.35% in the 5% DTP group and to 21.15% in the 10% DTP group. Arachidonic acid ($C_{20:4}$ $n-6$) contributed to 2.84−3.08%. The dominant $n-3$ fatty acid was α-linolenic acid ($C_{18:3}$) with a range 1.21% in the control group to 1.37% in the 10% DTP group. Among $n-3$ fatty acids, least abundant were eicosapentenoic ($C_{20:5}$) and docosapentenoic ($C_{22:5}$) acids, comprising 0.35−0.45 and 0.02−0.04%, respectively. The content of docosahexenoic acid ($C_{22:6}$) varied from 0.9 to 1.24%. Fatty acids were aggregated to give values for total saturated (SFA), monounsaturated (MUFA), and polyunsaturated (PUFA) fatty acids to allow calculation of total UFA/SFA ratios. The SFA content ranged from 40.10 to 41.58%, the MUFA content from 28.62 to 29.06%, and the PUFA content from 26.26 to 27.86%. Analysis of the data showed that the only statistically significant difference in the fatty acid profile of breast meat among the dietary treatments was the content in linoleic acid, which was linearly increased with the level of dried tomato pulp in the diet. Analysis of the experimental diets for their fatty acid composition was not made. Nevertheless, the increase in linoleic acid might be explained on the basis of the fatty acid composi-

Table 2. Effect of Dietary Treatments on Fatty Acid Profile of Breast Meat of Quail[a]

	fatty acid composition of quail carcass (% of total fatty acids)		
fatty acid	control diet	diet with 5% dried tomato pulp	diet with 10% dried tomato pulp
$C_{10:0}$	2.32 ± 0.08	2.34 ± 0.12	2.42 ± 0.14
$C_{12:0}$	2.40 ± 0.24	2.62 ± 0.36	2.50 ± 0.18
$C_{14:0}$	1.44 ± 0.32	1.35 ± 0.12	1.38 ± 0.08
$C_{16:0}$	22.08 ± 0.23	22.16 ± 0.56	22.28 ± 0.61
$C_{16:1}$	3.32 ± 0.21	3.18 ± 0.30	3.34 ± 0.24
$C_{18:0}$	12.28 ± 0.42	11.46 ± 0.62	11.34 ± 0.47
$C_{18:1}$	24.76 ± 0.58	25.13 ± 0.69	25.22 ± 0.45
$C_{18:2}$	19.52 ± 0.14[a]	20.35 ± 0.28[b]	21.15 ± 0.22[c]
$C_{18:3}$	1.21 ± 0.14	1.32 ± 0.35	1.17 ± 0.42
$C_{20:0}$	1.06 ± 0.44	1.12 ± 0.56	0.98 ± 0.32
$C_{20:1}$	0.54 ± 0.17	0.49 ± 0.09	0.50 ± 0.18
$C_{20:3}$	0.24 ± 0.10	0.25 ± 0.09	0.24 ± 0.06
$C_{20:4}$	3.08 ± 0.51	2.84 ± 0.35	2.95 ± 0.61
$C_{20:5}$	0.44 ± 0.13	0.35 ± 0.12	0.45 ± 0.21
$C_{22:4}$	0.50 ± 0.24	0.42 ± 0.36	0.53 ± 0.26
$C_{22:5}$	0.03 ± 0.04	0.04 ± 0.04	0.02 ± 0.02
$C_{22:6}$	1.24 ± 0.31	0.90 ± 0.22	1.05 ± 0.24
$total_{SFA}$	41.58	41.05	40.90
$total_{MUFA}$	28.62	28.80	29.06
$total_{PUFA}$	26.26[a]	26.47[a]	27.56[b]
$total_{UFA}/total_{SFA}$	1.32[a]	1.35[a]	1.38[b]

[a] Values in the same line with a superscript in common do not differ significantly ($P > 0.05$).

tion of the seeds and skins of tomatoes, which have been found to contain as high as 57.18% of linoleic acid (*42*). As a result of this increase, the 10% DTP group exhibited a higher ($P < 0.05$) content of total PUFAs and a greater UFA/SFA ratio compared to the control group.

Collectively, **Figures 1−3** indicated that the antioxidative effect of DTP was governed mainly by its incorporation level in the diet. Inclusion of dried tomato pulp in feed at the level of 5% exerted an antioxidant effect on quail breast meat, whereas inclusion at the level of 10%, a prooxidant effect. Because pertinent studies with DTP are missing in the literature, these results could be compared only with reports on the antioxidative effectiveness of dietary single carotenoids. Carotenoids, although capable of trapping peroxyl radicals acting as antioxidants, can also form peroxyl radicals acting as prooxidants (*49*). Although in some studies on raw and cooked chicken meat stability no antioxidative effect of adding carotenoids to diets has been seen (*50*), a prooxidant action has been found in studies when diets were supplemented with 25 mg of β-carotene kg^{-1} (*51*). It has been reported that carotenoids may work as prooxidants at high supplementation levels and as antioxidants at low levels, the balance between prooxidant and antioxidant behavior being very delicate and most pronounced at low oxygen partial pressure (*52*).

The effectiveness of β-carotene as antioxidant during meat storage is not as conclusive as for α-tocopherol (*50*, *51*, *53*). Higher concentrations of α-tocopherol in tissues would afford better protection against oxidative attack, so the quail meat samples were analyzed for α-tocopherol content. The control breast meat was found to contain 2.2 ± 0.3 mg of α-tocopherol kg^{-1} of tissue, whereas the 5 and 10% DTP groups contained 2.1 ± 0.4 and 1.4 ± 0.2 mg of α-tocopherol kg^{-1} of tissue, respectively. Therefore, when DTP was supplemented at the level of 5%, no effect on tissue α-tocopherol concentrations occurred compared to control, but at the supplementation level of 10%, the concentrations of α-tocopherol in tissue were reduced ($P < 0.05$).

Previous studies with chicken thigh muscle stored under fluorescent light showed that β-carotene acted as a prooxidant when the tissue level of α-tocopherol was low and as an antioxidant at higher tissue concentrations of tocopherol (*54*). A decrease of 68% in the levels of α-tocopherol in liver has been also observed in chickens supplemented with 100 mg of β-carotene kg^{-1} in the diet (*55*). The interaction between α-tocopherol and β-carotene has been further confirmed by studies showing that β-carotene at the level of 200 mg kg^{-1} in feed acted as a prooxidant in chicken thigh meat, whereas at the level of 15 mg kg^{-1} as an antioxidant (*48*). Two different mechanisms might account for this important interaction, one in which β-carotene and α-tocopherol are competing for the same receptors during absorption and one in which α-tocopherol is being consumed in regenerating carotene being oxidized (*56*). α-Tocopherol could regenerate carotenoids as has been shown in vitro (*57*, *58*), with a rapid decrease of α-tocopherol levels (*59*, *60*). Therefore, when levels of α-tocopherol in tissues decreased under a certain threshold level, β-carotene alone could not delay lipid oxidation. Further experiments are needed to distinguish between these two and possibly other mechanisms.

Considering the above, one could say that the decreased α-tocopherol level in meat of the 10% DTP group was not due to its interaction with the increased levels of carotenoids in the 10% DTP diet but to a lower α-tocopherol content in this diet compared to the other diets. The higher supplementation level of dried tomato pulp in the 10% DTP diet might lead to a substantial decrease of α-tocopherol in this diet because of the increased level of linoleic acid. Analysis of the experimental diets for their total α-tocopherol content was not made because the same amount of α-tocopheryl acetate (20 mg kg^{-1}) was added to all diets. However, the oxidative study showed that meat samples from both DTP groups presented lower MDA values than the control group at zero time of storage (44 and 48 vs 55 ng g^{-1} of meat, respectively). Assuming that the MDA content in meat at zero time of storage should be due to consumption and subsequent deposition by quail of the MDA already present in the diets, it might be deduced that both DTP diets contained lower MDA than the control diet and, therefore, the possibility for oxidative degradation of α-tocopherol in the 10% DTP diet by the unsaturated fatty acids could hardly occur. Consequently, the prooxidant effect observed in the 10% DTP group might be due to the reduction of α-tocopherol levels in meat because of its interaction with diet carotenoids. However, the elevated levels of PUFAs found in 10% DTP meat could also be responsible for this prooxidant action.

In conclusion, the results of the present study indicated that dried tomato pulp showed antioxidative properties when incorporated in quail diet at the level of 5%. Incorporation of DTP at the level of 10% caused higher MDA values than the control, exerting a prooxidant effect, which was accompanied by a significant reduction in α-tocopherol content of breast meat and a significant increase of total PUFAs that resulted in a greater UFA/SFA ratio compared to control group. There might be an interaction between DTP and α-tocopherol that is of importance for the balance between pro- and antioxidative activities. Future experiments should be designed to explore the interaction between individual carotenoids and tocopherol in order to better elucidate their role in oxidative changes.

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