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Research Article

Synergistic Effects of Exogenous Grape Seed Extract and α-Tocopherol on Lipid Oxidation in Refrigerated and Frozen Rainbow Trout (*Oncorhynchus Mykiss*) and Pork Loin (*Longissimus Dorsi*) Muscle

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Abstract

The objective of this study was to assess the antioxidative effectiveness of Grape Seed Extract (GSE) with and without exogenous α-tocopherol in two raw meats that are particularly susceptible to lipid oxidation, rainbow trout (*Oncorhynchus mykiss*) and pork loin (*longissimus dorsi*). Thiobarbituric Acid Reactive Substances (TBARS) and lipid hydroperoxides were measured during 12 days of refrigerated storage and one year of frozen storage. α-Tocopherol levels were monitored during refrigerated storage in both species. GSE (0.1%) mitigated the formation of TBARS during refrigerated and frozen storage of raw rainbow trout and pork loin. Exogenous tocopherol (0.5%) enhanced the effect of GSE in both refrigerated meats. Results of this study add to the growing body of knowledge that GSE is an effective antioxidant in meat systems.

Keywords: Grape seed extract; Lipid Hydroperoxides; Lipid oxidation; TBARS; Tocopherol

Introduction

Shifts in consumer preference have changed the manner in which the worldwide meat industry delivers meat through the global supply chain, thermally processes meat (e.g. ultrarapid freezing, pressure-shift freezing, dielectric heating, ohmic heating, etc.), packages meat products, and utilizes preservatives to extend the shelf life of meat. The challenges affecting these factors have been extensively reviewed [1-7]. In industrialized societies, there is still considerable waste and loss, but this loss occurs much less at the industrial level and much more at the market and household level [8]. The shelf life of meat products at the market and household level is limited by alterations in flavor, odor, and color. One of the primary causes of loss is lipid oxidation because adversely affects sensory characteristics [1]. Although the efficacy of protective additives such as Ethylenediaminetetraacetic Acid (EDTA), Butylated Hydroxyl Anisole (BHA), Butylated Hydroxyl Toluene (BHT) and phosphates in meat is undisputed, consumer notions against artificial products have sparked a search for natural alternatives [9].

Natural antioxidants such as Grape Seed Extract (GSE) have been studied as potential replacements for artificial antioxidants [10]. The activity of GSE can be attributed to its phenolic content, namely the tannin proanthocyaninidin [11]. Proanthocyaninidins couple with gallic acid to form gallate esters and glycosides in the form of oligomers and polymers of polyhydroxy flavan-3-ols such as (+)-catechin and (-)-epicatechin [11]. Historically, tannins have been found to complex with proteins, decreasing the nutritional quality of dietary protein [12]. However, this anti-nutritional stigma has been overshadowed in light of recent evidence demonstrating the antioxidant capabilities of tannins, of which the proposed mechanisms of action include radical scavenging, nitrositive stress inhibition and nitric oxide generation [10]. GSE has been shown to inhibit or retard lipid oxidation in raw and cooked muscle of a variety of species, including chicken [13-15], turkey [16], duck [17], beef and pork [14] and fish [18,19].

Vitamin E is a lipid-soluble vitamin composed of eight analogous isomers,α,β,γ,δ−tocopherol and α,β,γ,δ-tocotrienol. Research has shown that endogenous ⟨-tocopherol functions as an antioxidant by neutralizing free radicals involved in the initiation and propagation of fatty acid peroxidation and can inhibit the formation of lipid hydroperoxides [20-22]. What is not known is whether synergy exists between GSE and Tocopherol in complex meat systems. The objective of this study was to assess the effectiveness of GSE with and without exogenous ⟨-tocopherol in two raw meats that are particularly susceptible to lipid oxidation, rainbow trout (*Oncorhynchus mykiss*) and pork loin (*longissimus dorsi*), that were stored refrigerated and frozen, by monitoring the formation of TBARS and lipid hydroperoxides.

Materials and Methods

Raw materials, sample preparation, and storage conditions

Grape seed extract (GSE, Gravinol-S→) was obtained from Kikkoman International. (San Francisco, CA). All other chemicals were obtained from Fisher Scientific Company (Pittsburgh, PA) except for α−tocopherol which was obtained from Sigma-Aldrich (St. Louis, MO). Fresh, boneless, pork loin was obtained from a

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local processor (Pleasant Meats, Athens, OH) about 72 hours after slaughter, the soonest that the pork loin was made commercially available by the processor. Pork loin was transported to the laboratory (approx. 15 minutes) on ice. Freshly slaughtered whole rainbow trout was obtained from a fish hatchery (Freshwater Farms of Ohio, Urbana, OH) and transported to the laboratory (approx. 2.5 hours) on ice.

Once in the laboratory, rainbow trout were filleted and then the tissue was cut into smaller pieces. Pork loin was cut by hand into small pieces with care taken to remove visible fat. Each meat was then minced for 1 min (Osterizer 12-speed blender with a dual blade food processor attachment, model 5900, Sunbeam Products, Boca Raton, FL) on the highest speed. At this point, the meat was divided into thirds and randomly assigned into treatment groups: a group to which nothing was added that served as the control, a group to which only GSE was added, and a group to which both GSE and α-tocopherol were added. An aqueous stock solution of GSE (33%), an ethanolic stock solution of α-tocopherol (1mg/ml), and/or equivalent volumes of water or ethanol were incorporated into the minced meat by hand at an appropriate volume/weight to standardize the systems to final reaction concentrations of 0.1% GSE and/or 0.5% α-tocopherol.

Pork loin and rainbow trout were stored either refrigerated (4°C) and sampled after 0, 3, 6, 9, and 12 days or frozen (-20°C) and sampled after 0, 3, 6, 9, and 12 months. Some samples were transferred to an ultralow freezer (-80°C) until analyzed.

Measurement of Lipid Hydroperoxides (LOOH)

LOOH were measured in refrigerated and frozen muscle using a standard assay [23]. Tissue was homogenized in chloroform-methanol (C-M, 2:1, v: v) at 20,000rpm for 30s using a Tissumizer (Tekmar, Cincinnati, OH). After the addition of ml 0.9% NaCl to aid in separation, the samples were centrifuged for 30 min at 2000g (IEC HN-SII Table Top Centrifuge, Intl. Equipment Co., Needham Heights, Mass., U.S.A.) and an aliquot of the lower chloroform layer was extracted using a glass syringe. The extractant was mixed with C-M (2:1), 3.94M thiocyanate solution, and 0.072M ferrous chloride and allowed to incubate for 20min at room temperature. LOOH were measured spectrophotometrically at 500nm. A cumene hydroperoxide standard curve was used to quantify LOOH.

Measurement of TBARS

Thiobarbituric Acid Reactive Substances (TBARS) were measured in refrigerated and frozen tissue using a spectrophotometric assay [24]. Muscle was homogenized using a Tissumizer (Tekmar, Cincinnati, OH) at 20,000rpm for 30s with 0.12 M KCL/200mM phosphate buffer (pH 7.2). Immediately after preparation, homogenates were mixed with 7.5% TCA/0.1% propyl gallate/100 M DTPA solution and then centrifuged at 2000g for 5min. Extracted supernatant was mixed with 0.02M TBA and incubated in boiling water for 20min. The mixture was centrifuged again at 2000g for 5min. Aliquots were collected and analyzed spectrophotometrically at 532nm. TBARS were quantified on the basis of a standard curve prepared from 1,1,3,3-tetramethoxypropane.

Measurement of tocopherol

Tocopherol isomers were separated from refrigerated minced muscle tissue by saponification for 45min with of 60% KOH in the presence of 7.5% ascorbic acid and ethanol. After saponification, tocopherol was isolated by two extractions with 5ml of 10% ethyl acetate in hexane containing 0.0025% BHT, which were pooled and evaporated to dryness under nitrogen, and reconstituted in methanol. Tocopherol isomers were separated with a mobile phase (methanol) using reverse-phase HPLC with a Hypersil 5mm C18 column (length: 250mm, I.D. 4.6 mm; Alltech, Deerfield, IL) and quantified at 286 nm by comparison with standard curves prepared from authentic standards.

Statistical analysis

Raw rainbow trout data was subject to factorial analysis using a 3 x 9 design including the main effects of treatment (Control, GSE, GSE+⟨-Tocopherol) and storage time refrigerated (0, 3, 6, 9, 12 d) or storage time frozen (0, 3, 6, 9, 12 m) using replication (1, 2, 3) means. A separate but similar 3 x 9 factorial design was implemented for raw pork loin data including the main effects of treatment (Control, GSE, GSE+⟨-Tocopherol) and storage time refrigerated (0, 3, 6, 9, 12 d) or storage time frozen (0, 3, 6, 9, 12 m) with replication (1, 2, 3) means.

All measurements were reported as means ± standard deviation and the level of significance for all tests was set at $p<0.05$. Main effects and two-way interactions were analyzed using the general linear model procedure of SPSS (Chicago, Ill.). Duncan's multiple range test was used to obtain mean separations. Significant correlations were determined at $p<0.05$.

Results and Discussion

Relationship between GSE and tocopherol in refrigerated rainbow trout and pork loin tissue

There was a strong, positive, linear correlation for LOOH (r=0.87) and TBARS (r=0.92) formation in the untreated (control) rainbow trout over the 12 days of refrigerated storage, as shown in table 1. The presence of GSE and tocopherol inhibited TBARS formation but not LOOH formation during the storage period. By three days of refrigerated storage, TBARS but not LOOH values were significantly inhibited in the samples that contained GSE compared to the untreated control. By nine days of storage, TBARS were inhibited by 20% in the tissue containing GSE and by 75% in the samples containing GSE and tocopherol. This suggests that exogenous tocopherol enhanced the ability of GSE to inhibit TBARS formation in refrigerated rainbow trout. It is interesting to note that endogenous tocopherols did not appear to be consumed during storage, as the level of endogenous tocopherols remained statistically unchanged throughout the storage period (Table 1) for the untreated control and the samples to which only GSE was added. However, 64% of the exogenous tocopherol was consumed during the 12-day storage period. Research has shown that lipid radicals attack α-tocopherol much faster than lipids and α-tocopherol can delay the breakdown of hydroperoxides into secondary oxidation products such as TBARS [1,25].

There was a strong, positive, linear correlation for LOOH (r=0.96) and TBARS (r=0.95) formation in the untreated (control) pork loin over the 12 days of refrigerated storage (Table 2). This is similar to what was observed in the rainbow trout, however, the magnitude of TBARS formation was much lower in the pork loin. LOOH values were significantly inhibited in the samples that contained GSE compared to the untreated control throughout the storage period.

The presence of tocopherol inhibited TBARS formation in the pork loin throughout storage, however, the pork loin that contained GSE alone exhibited an increase in TBARS after 3 d of refrigerated storage that was comparable to the increase observed in the untreated control, after which no further increase in TBARS was observed. Similar to the rainbow trout, endogenous tocopherols did not appear to be consumed during storage, as the level of endogenous tocopherols remained statistically unchanged throughout the storage period (Table 2) for the untreated control and the samples to which only GSE was added. However, almost all of the exogenous tocopherol (92%) was consumed during the 12-day storage period. Research shows that exogenous tocopherol can be an effective antioxidant in meat systems [26,27], however, dietary enhancement of tocopherol in tissues is a more common and effective antioxidant strategy in muscle [27].

	Day	Control	GSE	Both GSE and Toc
LOOH				
	0	0.636±0.047 EF	0.514±0.499 F	0.733±0.252 DEF
	3	0.910±0.070 BCDE	0.849±0.027 CDE	0.881±0.052 CDE
	6	1.070±0.119 ABC	1.107±0.030 ABC	1.053±0.013 ABC
	9	0.899±0.048 CDE	1.014±0.014 ABCD	0.912±0.035 BCDE
	12	1.203±0.018 AB	0.991±0.083 ABCD	1.212±0.029 A
TBARS				
	0	3.740±0.298 EF	2.858±0.019 FG	1.353±0.342 H
	3	8.430±0.373 BC	4.150±0.007 EF	2.372±0.635 GH
	6	7.500±0.438 CD	6.406±0.009 D	3.042±0.314 FG
	9	9.483±0.816 B	7.589±0.002 CD	2.372±0.563 GH
	12	12.273±2.018 A	4.526±0.004 E	2.885±0.709 FG
Tocopherol				
	0	3.4±0.6 D	4.3±0.3 D	20.7±0.8 A
	3	3.2±1.0 D	3.8±0.8 D	21.0±0.6 A
	6	3.3±0.9 D	4.3±0.5 D	19.4±0.7 A
	9	3.3±0.3 D	3.4±1.4 D	13.9±1.5 B
	12	3.7±0.2 D	3.3±0.1 D	7.5±0.2 C

Table 1: Level of Lipid Hydroperoxides (LOOH; mmol/kg tissue), Thiobarbituric Acid Reactive Substances (TBARS; mmol/kg tissue), and tocopherol (mmol/g tissue) during refrigerated storage of ground rainbow trout (*Oncorhynchus mykiss*) that was untreated (Control) or had added 0.1% Grape Seed Extract Alone (GSE) or with 0.5% α-tocopherol (Both GSE and Toc). (Note: Different letters within a measurement (LOOH, TBARS, Tocopherol) denote significant differences at $p<0.05$).

Relationship between GSE and tocopherol in frozen rainbow trout and pork loin tissue

In frozen untreated rainbow trout, LOOH significantly increased within 3 months of frozen storage and remained unchanged thereafter (Table 3) but TBARS continued to increase throughout the storage period. The addition of GSE with or without tocopherol did not mitigate this trend with respect to LOOH formation but significantly inhibited TBARS formation throughout the storage period. This suggests that GSE was able to prevent the breakdown of LOOH into secondary oxidation products. The addition of tocopherol did not enhance the efficacy of GSE (Table 4).

In frozen untreated pork loin, no significant accumulation of LOOH or TBARS occurred until in the untreated control until after 9 months of storage. This suggests that the lipids in the pork loin were not undergoing significant lipid oxidation during this period. However, the presence of GSE with and without tocopherol exhibited significantly reduced TBARS at 12 months of storage compared to the untreated control.

	Day	Control	GSE	Both GSE and Toc
LOOH				
	0	0.209±0.062 E	0.211±0.091 F	0.223±0.171 EF
	3	0.537±0.137 CD	0.253±0.149 EF	0.535±0.034 CD
	6	0.949±0.040 B	0.387±0.085 DEF	0.664±0.125 C
	9	1.018±0.014 AB	0.350±0.122 EFG	0.472±0.030 DE
	12	1.133±0.052 A	0.346±0.033 EFG	0.365±0.006 EFG
TBARS				
	0	0.250±0.043 D	0.270±0.017 D	0.243±0.041 D
	3	1.516±0.307 C	1.490±0.447 C	0.377±0.064 D
	6	2.106±0.116 BC	1.717±0.593 BC	0.867±0.810 D
	9	2.240±0.121 B	1.547±0.571 C	0.380±0.208 D
	12	2.860±0.295 A	1.516±0.304 C	0.550±0.069 D
Tocopherols				
	0	0.1±0.1 D	0.1±0.1 D	5.3±1.9 A
	3	0.2±0.1 D	0.2±0.1 D	6.2±2.2 A
	6	0.3±0.1 D	0.4±0.1 D	4.1±0.8 A
	9	0.2±0.1 D	0.1±0.1 D	1.2±0.4 B
	12	0.3±0.1 D	0.4±0.1 D	0.4±0.6 C

Table 2: Level of Lipid Hydroperoxides (LOOH; mmol/kg tissue), Thiobarbituric Acid Reactive Substances (TBARS; mmol/kg tissue), and tocopherol (mmol/g tissue) during refrigerated storage of ground pork loin (*longissimus dorsi*) that was untreated (Control) or had added 0.1% Grape Seed Extract Alone (GSE) or with 0.5% α-tocopherol (Both GSE and Toc). (Note: Different letters within a measurement (LOOH, TBARS, Tocopherol) denote significant differences at $p<0.05$).

	Month	Control	GSE	Both GSE and Toc
LOOH				
	0	5.43±3.80 D	6.06±0.86 D	7.07±10.79 D
	3	44.71±0.56 AB	25.36±1.41 C	44.43±3.72 AB
	6	52.16±1.90 AB	55.66±1.72 A	50.43±8.39 AB
	9	53.14±4.53 AB	52.65±2.83 AB	48.92±1.52 AB
	12	48.02±7.87 AB	52.16±2.30 AB	46.93±4.37 AB
TBARS				
	0	3.61±0.21 EFG	1.35±0.34 G	2.83±0.20 EFG
	3	5.90±0.01 DE	2.52±0.38 FG	4.09±0.45 DEFG
	6	7.07±0.87 CD	3.69±0.14 EFG	4.98±0.32 DEF
	9	13.01±4.88 A	4.84±2.31 DEF	5.13±1.12 DEF
	12	10.31±3.53 AB	3.32±1.01 EFG	8.86±0.98 BC

Table 3: Level of Lipid Hydroperoxides (LOOH; mmol/kg tissue) and Thiobarbituric Acid Reactive Substances (TBARS; mmol/kg tissue) during frozen storage of ground rainbow trout (*Oncorhynchus mykiss*) that was untreated (Control) or had added 0.1% Grape Seed Extract Alone (GSE) or with 0.5% α-tocopherol (Both GSE and Toc). (Note: Different letters within a measurement (LOOH, TBARS, Tocopherol) denote significant differences at $p<0.05$).

LOOH is a primary oxidation product for which an increase is usually observed during the early stages of oxidation, but LOOH are unstable and as lipid oxidation progressed, decomposition of hydroperoxides into secondary oxidation products such as TBARS is greater than that of formation [1]. In both meats, GSE appears to inhibit the breakdown of LOOH into secondary oxidation products and its efficacy is not enhanced by tocopherol.

	Month	Control	GSE	Both GSE and Toc
LOOH				
	0	5.43±3.81 DE	6.46±1.36 CDE	5.52±3.45 DE
	3	5.01±1.09 DE	4.58±0.72 E	8.82±0.88 BCDE
	6	5.08±2.87 DE	13.01±4.00 ABCD	11.10±4.55 BCDE
	9	6.25±0.68 CDE	10.82±4.11 BCDE	16.54±4.11 AB
	12	21.18±11.62 A	15.85±7.52 ABC	14.75±4.87 ABCD
TBARS				
	0	2.01±0.25 C	1.41±0.09 C	2.10±0.041 C
	3	1.74±0.72 C	0.60±0.02 C	0.86±0.064 C
	6	2.91±0.86 C	0.93±0.49 C	0.60±0.810 C
	9	3.47±1.67 C	0.56±0.17 C	0.54±0.208 D
	12	13.62±0.85 A	8.96±5.25 B	6.30±0.069 B

Table 4: Level of Lipid Hydroperoxides (LOOH; mmol/kg tissue) and Thiobarbituric Acid Reactive Substances (TBARS; mmol/kg tissue) during frozen storage of ground pork loin (*longissimus dorsi*) that was untreated (Control) or had added 0.1% Grape Seed Extract Alone (GSE) or with 0.5% α-tocopherol (Both GSE and Toc). (Note: Different letters within a measurement (LOOH, TBARS, Tocopherol) denote significant differences at $p<0.05$).

Summary and Conclusion

This study, the fourth in a series of papers from our laboratory exploring GSE in meat products [14,28,29], shows that 0.1% GSE mitigated the formation of TBARS during refrigerated and frozen storage of raw fish and pork loin. Exogenous tocopherol enhanced this effect in both refrigerated meats. This agrees with our previous work in which we determined that GSE at concentrations as low as 0.1% is a very effective inhibitor of primary and secondary oxidation products in muscle systems [14], that does not affect moisture content or pH during storage and may help to mitigate the prooxidative effects of NaCl [28]. Our past work also showed that GSE caused significantly darker meat products as measured by sensory analysis and objective color measurement [29]. This is particularly relevant to this study because the addition of GSE, a red powder made from grape skins, may cause undesirable color changes to light colored meat like rainbow trout and pork loin. This is important because research has shown that methods that inhibit lipid oxidation should not affect organoleptic quality and have good correlation with sensory scores [1].

In order for the meat industry to embrace a new natural antioxidant such as GSE, it must exceed the advantages offered by the use of other options. Manessis et al. [30], suggested that natural antioxidants such as GSE must overcome certain barriers to achieve wide acceptance which include regulatory considerations, the complex matrices used, the questionable usability and profitability of natural antioxidants, application that do not deteriorate the meat's organoleptic traits. Use of GSE can overcome all but one of these barriers because GSE is GRAS in powder or liquid form and is derived from readily available grape skins, a byproduct of the wine and juice industries. However, it may affect the color the product to which it is applied. Nonetheless, results of this study add to the growing body of knowledge that GSE is an effective antioxidant in meat systems.

References

1. Domínguez R, Pateiro M, Gagaoua M, Barba FJ, Zhang W, et al. (2019) A comprehensive review on lipid oxidation in meat and meat products. Antioxidants 8: 429.
2. Bohrer BM (2017) Review: Nutrient density and nutritional value of meat products and non-meat foods high in protein. Trends Food Sci Technol 65: 103-112.
3. Whitnall T, Pitts N (2019) Global trends in meat consumption. Agric Commod 2019: 96-99.
4. Dave D, Ghaly A (2011) Meat spoilage mechanisms and preservation techniques: A critical review. Am J Agric Biol Sci 6: 486-510.
5. Rahman U, Sahar A, Ishaq A, Aadil RM, Zahoor T, et al. (2018) Advanced meat preservation methods: A mini review. J Food Saf 38: 12467.
6. Pereira RN, Vicente AA (2010) Environmental impact of novel thermal and non-thermal technologies in food processing. Food Res Int 43: 1936-1943.
7. Zhou GH, Xu XL, Liu Y (2010) Preservation technologies for fresh meat-A review. Meat Sci 86: 119-128.
8. FAO (2019) The State of Food and Agriculture 2019. Moving Forward on Food Loss and Waste Reduction. Food and Agriculture Organization of the United Nations, Rome, Italy.
9. Kumar P, Verma AK, Umaraw P, Mehta N, Malav OM (2020) Plant Phenolics as Natural Preservatives in Food System. In: Plant Phenolics in Sustainable Agriculture. Springer 367-406.
10. Kwatra B (2020) A review on potential properties and therapeutic applications of grape seed extract. World J Pharm Res 9: 2519-2540.
11. Weber HA, Hodges AE, Guthrie JR, O'Brien BM, Robaugh D, et al. (2007) Comparison of proanthocyanidins in commercial antioxidants: Grape seed and pine bark extracts. J Agric Food Chem 55: 148-156.
12. Bravo L (1998) Polyphenols: Chemistry, dietary sources, metabolism, and nutritional significance. Nutr Rev 56: 317-333.
13. Sen AR, Reddy GV, Reddy KS, Reddy KK, Rao TM (2015) Antioxidative effect of grape (*Vitis vinifera*) seed extract on refrigerated stored chicken meat patties. Indian J Poult Sci 50: 180-185.
14. Brannan RG, Mah E (2007) Grape seed extract inhibits lipid oxidation in muscle from different species during refrigerated and frozen storage and oxidation catalyzed by peroxynitrite and iron/ascorbate in a pyrogallol red model system. Meat Sci 77: 540-546.
15. Lau DW, King AJ (2003) Pre- and post-mortem use of grape seed extract in dark poultry meat to inhibit development of thiobarbituric acid reactive substances. J Agric Food Chem 51: 1602-1607.
16. Mielnik MB, Olsen E, Vogt G, Adeline D, Skrede G (2006) Grape seed extract as antioxidant in cooked, cold stored Turkey meat. LWT-Food Sci Technol 39: 191-198.
17. Ao X, Kim IH (2020) Effects of grape seed extract on performance, immunity, antioxidant capacity, and meat quality in Pekin ducks. Poult Sci 99: 2078-2086.
18. Raeisi M, Tajik H, Aliakbarlu J, Valipour S (2014) Effect of carboxymethyl cellulose edible coating containing Zataria multiflora essential oil and grape seed extract on chemical attributes of rainbow trout meat. Vet Res Forum 5: 89-93.
19. Pazos M, Gallardo JM, Torres JL, Medina I (2005) Activity of grape polyphenols as inhibitors of the oxidation of fish lipids and frozen fish muscle. Food Chem 92: 547-557.
20. Machlin LJ (1991) Handbook of Vitamins. Marcel Dekker, New York, USA.
21. Shi HL, Noguchi N, Xu YX, Niki E (1999) Formation of phospholipid hydroperoxides and its inhibition by alpha-tocopherol in rat brain synaptosomes induced by peroxynitrite. Biochem Biophys Res Comm 257: 651-656.

22. Christen S, Woodall AA, Shigenaga MK, Southwell-Keely PT, Duncan MW, et al. (1997) Gamma-tocopherol traps mutagenic electrophiles such as NOx and complements alpha- tocopherol: physiological implications. Proc Natl Acad Sci USA 94: 3217-3222.

23. Shantha NC, Decker EA (1994) Rapid, sensitive, iron-based spectrophotometric methods for determination of peroxide values of food lipids. J AOAC Int 77: 421-424.

24. Srinivasan S, Xiong YL (1996) Sodium chloride-mediated lipid oxidation in beef heart surimi-like material. J Agric Food Chem 44: 1697-1703.

25. Yamauchi R, Kinoshita T, Hasegawa Y, Iwamoto S (2017) Hemin- and myoglobin-catalyzed reaction of 1-palmitoyl-2-linoleoyl-3-sn-phosphatidylcholine 13-hydroperoxide with γ-tocopherol in micelles and liposomes. Chem Phys Lipids 209: 37-44.

26. Ibrahim HM (2012) Lipid and color stability as affected by combination of sodium ascorbate and α-tocopherol acetate in minced buffalo meat during refrigerated storage. Food 6: 6-13.

27. Govaris A, Botsoglou N, Papageorgiou G, Botsoglou E, Ambrosiadis I (2004) Dietary versus post-mortem use of oregano oil and/or α-tocopherol in turkeys to inhibit development of lipid oxidation in meat during refrigerated storage. Int J Food Sci Nutr 55: 115-123.

28. Brannan R (2008) Effect of grape seed extract on physicochemical properties of ground, salted, chicken thigh meat during refrigerated storage at different relative humidity levels. J Food Sci 73: 36-40.

29. Brannan RG (2009) Effect of grape seed extract on descriptive sensory analysis of ground chicken during refrigerated storage. Meat Sci 81: 589-595.

30. Manessis G, Kalogianni AI, Lazou T, Moschovas M, Bossis I, et al. (2020) Plant-derived natural antioxidants in meat and meat products. Antioxidants 9: 1215.

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