ANTIOXIDANT SUPPLEMENTATION MINIMIZES THE NEGATIVE IMPACT OF DIETARY OXIDIZED OIL ON CHICKEN BROILER BREAST AND THIGH MEAT QUALITY

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Abstract – Studies have shown that animal nutrition can have a major impact on tissue gene expression, and, intuitively, may affect the quality of meat and meat products. This study investigated the influence of dietary antioxidants and quality of oil on the oxidative and physiochemical properties of chicken broiler breast and thigh meat stored in either an oxygen-enriched (MAP: 80% O_2/20% CO_2) or an air-permeable polyvinylchloride (PVC) packaging system during retail display at 2-4 °C for up to 14 days. Broilers were fed 42 days either a diet with a low-oxidation (23.0 meq peroxide) or high-oxidation (121.3 meq peroxide) oil, supplemented with or without tocopherol/selenium-based antioxidants. Lipid and protein oxidation and purge loss were analyzed. In both packaging systems, lipid oxidation (TBARS) was inhibited by up to 65 and 57% in chicken breast and thigh, respectively with an antioxidant-supplemented diet, when compared with diets without antioxidants. In both breast and thigh samples, protein sulfhydryls and water-holding capacity (purge loss) were better protected by the antioxidant dietary treatment, regardless of oil quality. The results suggest that dietary antioxidants can minimize the negative impact of oxidized oil on broiler meat quality, and the protection may be linked to reduced lipid and protein oxidation.

Key Words – Protein oxidation, Selenium, Vitamin E

- INTRODUCTION

The consumption of poultry meat has continued to increase over the past two decades due to consumers' preference for low-fat or less-saturated fat meat and meat products [1]. The higher market demand for poultry meat has driven breeders, nutritionists and growers to increase the growth rate of birds, feed efficiency and size of the breast muscle, which has placed added stress on the growing birds [2]. Oxidative damage that occurs in the live animal can result in reduced meat quality, therefore, negatively influencing consumer acceptability. Furthermore, poultry meat is more susceptible to lipid oxidation than beef and pork due to the relatively high proportion of polyunsaturated fatty acids (PUFA). One approach in overcoming oxidation and its related problems is to enhance the diets with antioxidants. The use of dietary antioxidants has a distinct advantage over direct incorporation of antioxidants into meat through processing because dietary antioxidants absorbed by the bird can be effectively distributed in muscle (meat) both inside the cell and at the membrane [3]. Enhancing diets with antioxidants such as vitamin E and selenium and optimizing nutrient regimen could not only reduce lipid oxidation but also may improve water-holding capacity and textural traits of meat. The objective of this study was to test the hypothesis that dietary antioxidants absorbed by the bird may be effectively distributed throughout the muscle tissue, thereby minimizing oxidative impact on poultry meat quality during storage.

- MATERIALS AND METHODS

Broiler chicks were randomly placed in floor pens, each randomly assigned one of four dietary treatments: (1) basal diet–low oxidized oil (LO); (2) basal diet–low oxidized, supplemented with antioxidants (ALO); (3) basal diet–high oxidized oil (HO); (4) basal diet–

high oxidized oil, supplemented with antioxidants (AHO). Soybean oil was acquired from a local retailer, and the initial peroxide value (PV), 23.0 meq/mg, was determined according to the AOAC method [4], with slight modifications. To oxidize, the oil mixture was poured into aluminum pans and heated in a convection oven at 95°C ± 5°C for up to 7 d. This treatment raised the concentrations of lipid peroxidation products in the oil, until the final PV (oxidized) was 121.3 meq/mg. Birds consumed feed in mash form and water on an ad libitum basis.

After 42 d on the specific diets, one broiler from each pen was randomly selected, harvested and the carcass was chilled in an ice bath for approximately 1.5 h, then deboned (n = 48 per trial). *Psoais major* (breast) and thigh muscles were removed and packaged with a vacuum seal (99% vacuum) and stored in a –30 °C freezer until use. Breast and thighs were thawed at 2 °C for 40 h, and then randomly allotted to packaging treatments, where one randomly selected broiler breast or thigh was individually place in a tray and packaged with either a gas mixture of 80% O_2/ 20% CO_2 for MAP packaging or overwrapped with an air-permeable polyvinylchloride film for PVC. The impact of dietary treatment on lipid and protein oxidation under simulated retail display conditions (14 d for MAP; 7 d for PVC) at 2-4 °C was measured using the 2-thiobarbituric acid-reactive substances (TBARS), 2,4-dinitrophenylhydrazine (DNPH), and 5,5'-dithiobis(2-nitrobenzoic acid) (DTNB) methods [5]. Purge loss (%) was calculated from the weight difference of thawed meat samples before and after respective storage days. Data were analyzed statistically using the ANOVA, and significances between means ($P < 0.05$) were identified with LSD.

- RESULTS AND DISCUSSION

Lipid oxidation increased throughout the first 7 d of storage for all dietary treatments, packaging conditions, and muscle types (Table 1). Compared to breast, thigh samples had significantly higher TBARS contents ($P < 0.05$), due to the larger amount of lipids and high concentrations of heme proteins and inorganic iron, both of which are catalysts for lipid and protein oxidation. Compared with basal dietary regimes, regardless of oil quality, the dietary antioxidant treatment groups (ALO, AHO) had lower TBARS values under all packaging conditions. Previous studies have shown that feeding broilers high levels of selenium [6] or tocopherols [7] delayed the onset of off-flavor formation and reduced lipid oxidation. TBARS values of HO thigh meat were significantly higher than all other dietary treatments throughout storage, most likely due to dietary oxidized oil increasing the susceptibility of PUFAs to oxidation [8]. Furthermore, samples packaged under MAP showed a higher degree of lipid oxidation compared to PVC.

Table 1 Formation of TBARS (mg/kg MDA) in thawed chicken breast and thigh meat stored in MAP and PVC at 2°C for various time periods

Storage Time (Day)	Diet	Breast		Thigh	
		MAP	PVC	MAP	PVC
0	LO	0.050	0.050	0.405	0.405
	ALO	0.054	0.054	0.413	0.413
	HO	0.095	0.095	0.551	0.551
	AHO	0.065	0.065	0.337	0.337
4	LO	0.232	0.174	0.965	0.633
	ALO	0.191	0.138	0.994	0.412
	HO	0.274	0.264	1.270	0.754
	AHO	0.186	0.197	0.954	0.638
7	LO	0.660	0.340	1.335	0.686
	ALO	0.463	0.330	0.877	0.441
	HO	0.547	0.535	2.008	0.766
	AHO	0.512	0.476	0.858	0.635
14	LO	0.979		2.368	
	ALO	0.342		2.474	

HO	0.787	2.800	
AHO	0.505	2.088	

Oxidative conditions commonly exist in muscle foods due to manufacturing and storage processes which can deteriorate the quality of proteins in meat. Previous studies have assessed that protein oxidation results in several chemical modifications, including loss of tryptophan and sulfhydryl groups, formation of intra- and inter-molecular crosslinks, and formation of carbonyls, which detrimentally affects meat quality [9]. As shown in Table 2, protein carbonyl content was significantly ($P < 0.05$) higher in thigh samples compared to breast. HO samples, regardless of muscle type and packaging condition, exhibited the greatest sensitivity to protein oxidation compared to other dietary treatments. For example, on 7 d, HO thigh samples packaged in MAP and PVC had a 34.7% and 18.7% lower carbonyl content compared to AHO, respectively. The greater oxidative stability in the antioxidant supplemented dietary group may be attributed to the neutralization of free radicals by vitamin E and selenium, thereby slowing the propagation of lipid and protein oxidation. Furthermore, a promoting effect of MAP on the formation of protein carbonyls in both breast and thigh samples was observed.

Table 2 Protein carbonyls (nmol/mg protein) formation in myofibrillar protein isolated from thawed chicken breast and thigh meat stored in MAP and PVC at 2°C for various time periods

Storage Time (Day)	Diet	Breast		Thigh	
		MAP	PVC	MAP	PVC
0	LO	0.374	0.374	1.717	1.717
	ALO	0.333	0.333	1.267	1.267
	HO	0.550	0.550	1.896	1.896
	AHO	0.253	0.253	1.862	1.862
4	LO	0.528	0.742	2.332	3.118
	ALO	0.521	0.545	3.556	3.196
	HO	0.755	0.566	5.125	2.907
	AHO	0.612	0.748	3.349	2.364
7	LO	0.518	0.600	3.772	3.493
	ALO	0.624	0.335	3.319	3.460
	HO	0.668	0.632	4.634	3.849
	AHO	0.515	0.754	3.815	4.271
14	LO	0.831		8.206	
	ALO	0.904		4.491	
	HO	1.390		4.727	
	AHO	0.920		4.755	

Sulfhydryls from cysteine residues are highly susceptible to oxidation and provide an additional assessment of protein oxidation. As shown in Table 3, there were significant losses in sulfhydryl content within the first 7 d of storage for all samples. Thigh meat showed greater losses in sulfhydryl content compared to breast meat, which is in agreement with the TBARS (Table 1) and carbonyl (Table 2) data. Furthermore, antioxidant dietary supplementation, regardless of oil quality, packaging type, or muscle sample (ALO, AHO), showed greater protein sulfhydryl maintenance compared with the basal dietary treatment. Samples from broilers fed high dietary oxidized oil (HO, AHO) showed greater sulfhydryl destruction compared to the low oxidized oil regimen. The loss in sulfhydryls may be attributed to the formation of disulfide bonds due to oxidatively induced cross-linking.

Antioxidants, such as vitamin E and selenium, may minimize the negative effects of dietary and environmental stresses placed on the birds throughout rearing. Specifically, the aforementioned antioxidants can accumulate in various tissues and either delocalize radicals or reduce peroxides, thereby slowing the propagation of lipid oxidation of the highly unsaturated fatty acids in the cellular and subcellular membranes, and concertedly reducing protein oxidation.

Table 3 Free sulfhydryls (nmol/mg protein) in myofibrillar protein isolated from thawed chicken breast and thigh meat stored in MAP and PVC at 2°C for various time periods

Storage Time (Day)	Diet	Breast		Thigh	
		MAP	PVC	MAP	PVC
0	LO	58.97	58.97	57.87	57.87
	ALO	62.68	62.68	60.96	60.96
	HO	52.74	52.74	40.59	40.59
	AHO	57.21	57.21	44.19	44.19
4	LO	52.77	52.84	42.97	34.88
	ALO	57.18	54.00	45.69	44.83
	HO	46.08	46.64	41.99	34.02
	AHO	49.61	49.19	38.60	39.39
7	LO	43.06	27.94	36.25	31.03
	ALO	44.02	35.25	36.03	32.79
	HO	31.23	34.51	23.31	30.59
	AHO	39.29	37.48	27.65	32.13
14	LO	24.09		14.04	
	ALO	26.86		17.94	
	HO	18.80		21.25	
	AHO	19.24		17.08	

The amount of exudate (purge loss) from breast meat was larger than that from thigh meat (Table 4). The difference was most likely due to the larger breast sample size (238.7 ± 34.5 g) compared to thigh meat sample size (81.4 ± 11.1 g). In general, the amount of purge loss increased throughout storage for most samples and packaging conditions. However, variations in sample sizes may have influenced the results. In both MAP and PVC, thigh samples from antioxidant supplemented diets, regardless of oil quality (ALO, AHO), had lower amounts of purge compared to LO and HO, respectively. A similar effect was only noted in chicken breast samples packaged under PVC. The higher amount of percent purge loss from the basal dietary group (LO, HO) may be attributed to a higher degree of protein oxidation. Oxidatively induced formation of disulfide bonds within myosin and between myosin molecules has been shown to decrease water-holding capacity of myofibrils [10].

Table 4 Purge Loss (%) from thawed chicken breast and thigh meat stored in MAP and PVC at 2°C for various time periods

Storage Time (Day)	Diet	Breast		Thigh	
		MAP	PVC	MAP	PVC
4	LO	9.73	12.12	3.80	3.42
	ALO	9.15	11.55	1.74	3.26
	HO	8.23	12.34	3.13	5.91
	AHO	8.62	10.70	2.42	3.75
7	LO	9.05	14.91	6.06	7.06
	ALO	9.12	13.47	3.89	4.37
	HO	12.08	14.88	7.48	5.50
	AHO	10.42	14.47	5.94	8.84
14	LO	10.54		9.56	

	HO	18.38	11.06
	AHO	12.96	9.04

- CONCLUSION

The results indicate that dietary antioxidant supplementation imparts a protective barrier against oxidation of broiler breast and thigh meat under both MAP and PVC packaging conditions throughout retail storage, thereby minimizing the negative impact of oxidized oil on broiler meat quality. The improved water-holding capacity of meat, the most notable benefit, can be attributed to the reduced protein oxidation. Chicken thigh meat showed more extensive oxidative damage due to the higher amount of lipids, heme proteins, and inorganic iron, compared to chicken breast meat.

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