Effects of Dietary Oxidation on the Quality of Broiler Breast Meat

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Summary and Implications

One hundred and twenty 4-week-old broilers were randomly assigned to one of the three dietary treatments including control (none), oxidized oil (5% of diet) and antioxidants (500 IU vitamin E and 200 ppm BHT) and fed for 2 weeks. Blood samples were collected 1day before slaughter and breast muscles were sampled immediately after slaughter. Degree of lipids and protein oxidation in blood and breast muscle, and meat quality parameters were determined. Compared to control group, broilers fed diet with oxidized oil significantly increased lipid oxidation in both blood ($P < 0.05$). Dietary oxidized oil tended to increase carbonyl content in blood and muscle ($P < 0.05$). Addition of antioxidants significantly decreased lipid oxidation in both blood and muscle samples and arrested protein oxidation in muscle ($P < 0.05$). Meats from oxidized oil treatment showed higher drip loss at days 1 and 3 and lower water holding capacity at day 1 than control group ($P < 0.05$). No significant difference was found about drip loss and water holding capacity between control and antioxidant treatments. The rate of pH decline in breast meat from oxidized oil treatment was significantly higher than that of control between 0 and 1 hour after slaughter ($P < 0.05$). However, dietary treatments did not show significant effects on body weight gain, feed consumption and feed efficiency of live birds, and cooking loss and color of breast meat. This suggested that degree of oxidation in diet increased the oxidation in blood and muscle, and the oxidative stress in live birds were related to the variations in quality parameters including pH decline, drip loss, and protein and lipid oxidation of broiler breast meat.

Introduction

Lipid oxidation has been known to cause quality problems by forming off-odor and off-flavor compounds and decreasing nutritive values in meat. Dietary addition of unsaturated fatty acids may be related to increased level of lipid oxidation. However, limited research has been reported about the effects of dietary addition of oxidized oil on protein oxidation and meat quality. Protein oxidation can cause fragmentation and conformational changes of protein secondary and tertiary structures to modify their functions. Oxidation induced intermolecular bonds including disulfide, dityrosine and other intermolecular bridges can lead to protein aggregation and polymerization to change protein proteolytic properties. These alterations can influence the physical and chemical properties of proteins including solubility, hydrophobicity, water holding capacity, meat tenderness, gelation functions and even the nutritional value. In the current study, we hypothesized that addition of oxidized oil in diet may cause oxidation including lipid and protein and thus influence meat quality in chicken breast. The objective of this research was o determine the effects of dietary oxidation condition on oxidation stress in live chicken and breast meat quality.

Materials and Methods

Protein carbonyl content was determined by derivatization with 2,4- dinitrophenylhydrazine (DNPH) method. Lipid oxidation was determined by fluorometric thiobarbituric acid reactive substance method. Drip loss was measured under atmospheric conditions at 4 C.

Results and Discussion

Dietary treatments did not show significant effects on weight gain of broiler chickens between 4 and 6 weeks ($P > 0.05$). Feed consumption of birds between 4 to 6 weeks was not significantly different among three treatments ($P > 0.05$). No significant difference was found for feed efficiency (weigh gain/feed intake) during the experiment period ($P > 0.05$). No significant differences in growth performance and feed consumption of broiler chickens were detected between control and antioxidant supplemented group (Table 1).

Dietary supplementation with 5% oxidized oil resulted in higher levels of lipid oxidation in blood plasma than control group ($P < 0.05$). Addition of vitamin E and BHA in the diet showed significant effects in lowering the level of lipid oxidation compared to oxidized oil treatment ($P < 0.05$) in blood (Table 2). These results suggested that feeding broilers with oxidized oil increased the oxidative stress in *vivo*. The TBARS value of breast muscle from animals fed with a diet added with oxidized oil was significantly higher than those from control and vitamin E group ($P < 0.05$) (Table 2). The increased levels of lipid oxidation in breast samples from oxidized group may be due to the decreased accumulation of α-tocopherol, which could have been denatured by feeding oxidized oil. The blood of birds fed with oxidized oil tended to have higher levels of carbonyl content than control ($P = 0.08$) and antioxidant ($P = 0.10$) groups. Higher carbonyl content was detected in breast muscles from oxidized group than control and vitamin E group ($P < 0.05$). However, no significant

difference was found for protein oxidation between control and antioxidant group in both blood and breast samples (Table 2).

The breast meat of broiler chickens fed with a diet containing oxidized oil showed significantly higher drip loss than control group after 1 d of storage under atmospheric conditions at 4 °C ($P < 0.01$, Table 3). The drip loss of meat at d 1 from oxidized oil group was 63% and 44% higher than that of control and antioxidant-supplemented group, respectively. This tendency was also detected after 3 d of storage. The control and antioxidant-supplemented group had significantly lower drip loss than oxidized oil group ($P < 0.01$). The water holding capacity, measured by water loss during high speed centrifuge, of breast muscle from oxidized oil group was lower compared to control ($P < 0.05$) at d 1. However, no significant differences in drip loss were found between control and antioxidant-supplemented diet group after 1 and 3 d of storage ($P > 0.05$). Cooking loss was also not significantly different among three dietary treatments ($P > 0.05$) (Table 3).

The color L* (lightness), a* (yellowness) and b* (brownness) values of breast muscle from three diets did not differ significantly in current study ($P > 0.05$, Table 4). This result was consistent with the pH of breast muscle, which showed no significant differences among the three diet groups at 0, 1, 2.5 and 5 h postmortem.

The postmortem pH at 0, 2.5 and 5 h were not significantly different among three dietary treatments (Table 5). However, the pH of breast muscle from birds fed with a diet containing oxidized oil tended to be lower than those from control and antioxidant group ($P = 0.10$) at 1 h postmortem. The rate of pH decline between 0 and 1 h post-slaughter in breast muscle from birds fed oxidized diet was faster than that from other two groups ($P < 0.05$), but the rates of pH decline at 0-2.5 h and 0-5 h were not significantly ($P > 0.05$). The faster rate of pH decline early postmortem (0-1 h) in the breast muscles from oxidized diet may partly explain higher drip loss and lower water holding capacity in that group. This is due to the fact that a fast rate of pH decline or low pH plus high body temperature in early postmortem stage can lead to the denaturation of muscle proteins. The denaturation of myofibrillar proteins can result in the loss of their functionality which further decreases their water holding capacity. The higher drip loss or lower water holding capacity in broiler chickens from oxidized group also could be due to the higher levels of protein oxidation in that group. Protein oxidation could change the structure and biochemical function of proteins by fragmentation, aggregation and polymerization.

Addition of oxidized oil in diet lowered the specific SERCA activity measured in the calcium level 0.01 and 0.02 mM at pH 7 ($P < 0.05$). However, no significant difference in non- and specific SERCA activity between the control and antioxidant supplemented groups ($P < 0.05$) was detected (Table 6). The lower SERCA activity might be caused by the increased oxidative stress, which resulted in SERCA oxidation, in the birds fed with a diet containing oxidized oil. In addition, lower deposition of antioxidant in breast muscle of oxidized group could have decreased its ability to maintain the antioxidant system leading to increased accumulation of reactive nitrogen and oxygen species.

Table 1. Effects of dietary treatments on growth and feed consumption in broiler chickens.

	Control	Oxidized oil	Antioxidant
4 week weight (kg)	1.371±0.030	1.415±0.028	1.339±0.010
6 week weight (kg)	2.743±0.068	2.778±0.065	2.669±0.039
Weight gain (kg)	1.372±0.048	1.362±0.039	1.331±0.029
4-6 week feed intake (kg)	2.387±0.049	2.419±0.075	2.320±0.038
Gain/feed (kg/kg)	0.574±0.011	0.563±0.003	0.573±0.003

*Means within the same row with different superscripts are significantly different ($p < 0.05$).

Table 2. Effects of dietary treatments on carbonyl content (nmol/mg protein) and lipid oxidation (fluorometric reading) in blood and breast samples*

	Control	Oxidized oil	Antioxidant
Blood samples			
Protein oxidation	0.31±0.03	0.38±0.02	0.33±0.03
Lipid oxidation	15.38±0.42^{b}	18.75±0.45^{c}	14.14±0.34^{a}
Breast samples			
Protein oxidation	0.55±0.05^{a}	0.70±0.05^{b}	0.55±0.04^{a}
Lipid oxidation	19.60±3.08^{a}	27.40±3.40^{b}	13.00±0.62^{a}

*Means within the same row with different superscripts are significantly different ($P < 0.05$).

Table 3. Effects of dietary treatments on drip and cooking loss in broiler breast meat*

	Control	Oxidized oil	Antioxidant
Day 1 drip loss (%)	0.422±0.053^{a}	0.687±0.067^{b}	0.538±0.057^{a}
Day 3 drip loss (%)	0.794±0.085^{a}	1.372±0.164^{b}	0.934±0.091^{a}
Day 1 water holding capacity (%)	2.79±0.25^{a}	4.74±0.69^{b}	4.25±0.63^{ab}
Cooking loss (%)	21.20±0.81	21.50±0.97	20.23±1.18

*Means within the same row with different superscripts are significantly different ($p < 0.05$).

Table 4. Effects of dietary treatment on broiler breast meat color*

	Control	Oxidized oil	Antioxidant
L* value	63.6±2.3	63.0±3.1	63.7±3.1
a* value	9.3±1.1	9.6±1.9	9.5±1.3
b* value	12.6±2.3	12.2±1.9	12.2±2.1

*Means within the same row with different superscripts are significantly different ($P < 0.05$).

Table 5. Effects of dietary treatments on pH changes in broiler breast muscle*

	Control	Oxidized oil	Antioxidant
0 h	6.75±0.03	6.80±0.02	6.78±0.02
1 h	6.68±0.02	6.62±0.02	6.67±0.04
2.5 h	6.43±0.03	6.41±0.04	6.38±0.03
5.0 h	6.12±0.02	6.11±0.02	6.12±0.05
0-1 h decline (%)	1.38±0.34^{a}	2.65±0.14^{b}	1.62±0.30^{a}
0-2.5 h decline (%)	6.18±0.35	6.72±0.49	6.41±0.71
0-5 h decline (%)	9.99±0.91	10.53±0.20	9.53±1.10

*Means within the same row with different superscripts are significantly different ($p < 0.05$).

Table 6. Effects of dietary treatments on non-specific and specific SERCA activity (µmole Pi/mg protein/min) in broiler breast muscle*

	Control	Oxidized oil	Antioxidant
No-specific activity	298.03±60.62	222.20±25.68	313.75±56.49
Activity at 0.01 mM calcium	315.59±38.90[b]	229.59±26.87[a]	342.58±19.94[b]
Activity at 0.02 mM calcium	553.22±54.97[b]	378.63±33.62[a]	479.42±49.80[ab]

*Means within the same row with different superscripts are significantly different ($P < 0.05$).