Effect of Oregano Essential Oil on the Storage Stability and Quality Parameters of Ground Chicken Breast Meat

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Summary and Implications

A study was conducted to investigate the effect of oregano essential oil on the oxidative stability and color of raw and cooked chicken breast meat. Five treatments, including 1) control (none added), 2) 100 ppm oregano essential oil, 3) 300 ppm oregano essential oil, 4) 400 ppm oregano essential oil, and 5) 5 ppm butylated hydroxyanisole (BHA), were prepared with ground boneless, skinless chicken breast meat and used for both raw and cooked meat studies. For the raw meat study, samples were individually packaged in oxygen-permeable bags and stored in a cold room (4 ℃) for 7 days. For the cooked meat study, the raw meat samples were vacuum-packaged in oxygen-impermeable vacuum bags and then cooked in-bag to an internal temperature of 75 °C. After cooling to room temperature, the cooked meats were repackaged in new oxygen-permeable bags and then stored at 4 ºC for 7 days. Both raw and cooked meats were analyzed for lipid and protein oxidation, volatiles, and color at 0, 3, and 7 days of storage. Oregano essential oil significantly reduced ($p < 0.05$) lipid and protein oxidation, and improved color stability of raw and cooked meat. However, oregano oil at 400 ppm showed the strongest effect for all these parameters. Hexanal was the major aldehyde detected, which was decreased significantly ($P < 0.05$) by oregano oil treatment, in cooked meat. Overall, oregano essential oil at 100-400 ppm levels could be a potential replacement for the synthetic antioxidants in chicken meat.

Introduction

Poultry meat is among the most popular meats in the world because of its low price, short production time, and ease of preparation. Chicken meat contains high levels of polyunsaturated fatty acids, which make it susceptible to oxidative deterioration during storage. Both raw and cooked poultry meats can be oxidized, but cooked meat is more susceptible to oxidative changes than raw meat. Lipid oxidation produces many volatile compounds responsible for off-flavor and rancidity in meat. Several synthetic antioxidants have been used widely in the food industry to prevent the deteriorative changes. However, the use of synthetic antioxidants is discouraged due to consumer concerns about their negative effects on human health. Therefore, the food industry is interested in finding new natural antioxidant sources to replace the synthetic ones. Herbs, spices and many plant extracts have been widely used in foods to improve their flavor and quality, and to extend their shelf-life. Oregano essential oil is one of the many plant extracts that have strong antioxidant effects when added to meat. The antioxidant effect of oregano essential oil is due to its high polyphenol contents; Carvacrol, thymol, *p*-cymene and γ-terpenene are the major components responsible for the antioxidant activity of oregano essential oil. Even though oregano essential oil has a great potential as a natural antioxidant, little is known about the optimal level to prevent oxidative changes of meat products while maintaining other quality parameters such as flavor. The objective of this study was to investigate the effect of different levels of oregano essential oil on major meat quality parameters, including oxidative stability and color of raw and cooked ground chicken breast meat.

Materials and Methods

One hundred and twenty, 6-wk-old broilers raised on a corn-soybean meal diet were slaughtered using the USDA guidelines. The chicken carcasses were chilled in ice water for 2 h, drained in a cold room, and the breast muscles were separated from the carcasses 24 h after slaughter. The breast muscles were ground twice through a 10-mm and a 3-mm plates after removing the skin. Five different treatments, including 1) control (none added), 2) 100 ppm oregano essential oil, 3) 300 ppm oregano essential oil, 4) 400 ppm oregano essential oil, and 5) 5 ppm butylated hydroxyanisole (BHA), were prepared. For the raw-meat study, prepared meat samples were individually packaged in oxygen-permeable bags (polyethylene, 4 x 6.2 mil), stored in a cold room at 4 °C for 7 days, and analyzed for lipid and protein oxidation, and color at 0, 3, and 7 days of storage. For the cooked-meat study, raw meat samples were vacuum-packaged in oxygen-impermeable vacuum bags (O_2 permeability, 9.3 mL $O_2/m^2/24$ h at 0 °C) first, and then the meats were cooked in-bag in a 90 °C water bath until the internal temperature of the meat reached to 75 °C. Lipid and protein oxidation, color, and volatiles were analyzed. Lipid oxidation was determined using the 2-barbituric acid reactive substances (TBARS) method. Volatiles of samples were analyzed using a Solatek-72 Multimatrix-

Vial Autosampler/ Sample Concentrator 3100 connected to a GC/MS. Protein oxidation was determined by carbonyl method.

Statistical Analysis

Data were analyzed using the procedures of the generalized linear model (Proc. GLM, SAS program). Mean values and standard error of the means (SEM) were reported. The significance was defined at $P < 0.05$ and Tukey test or Tukey's Multiple Range test were used to determine whether there are significant differences between the mean values.

Result and Discussion

Measurement of the antioxidant activity of oregano essential oil indicated that there were no significant differences among treatments at day 0 in raw meat. TBARS values increased more in the cooked meat compared to the raw meat during storage. In general, adding oregano essential oil to both raw and cooked ground chicken meat reduced the TBARS values (Table 1). The use of higher levels of oregano oil than 400 ppm might further improve its antioxidant effect, but may negatively affect the sensory characteristics of meat. Cooked meat was more sensitive to oxidative changes than the raw meat because the antioxidant enzymes in meat are denatured during cooking, iron ions are released from the intracellular to extracellular compartment, and membrane bi-layers become damaged resulting in phospholipids exposure to catalysts and oxygen during cooking and storage. However, the TBA values for the ground raw chicken meat showed little change during storage regardless of the oregano essential oil treatments. All the oregano essential oil levels (100, 300, and 400 ppm) showed significantly lower TBARS values compared with the control for both raw and cooked meat after 7 days of storage. The oregano essential oil at 400 ppm, however, showed a stronger effect than BHA (5 ppm), especially on the cooked meat at Day 7 (Table 1). The oregano essential oil at 100 ppm and 200 ppm were the minimum levels that could be used to slow down the oxidative changes in ground chicken meat.

The functional properties of proteins such as protein solubility, gelation, and emulsification capacity in the foods are dependent on their amino acid composition and structure. Ground meat is more susceptible to oxidation than the whole meat cuts due to particle size and surface area that is in contact with oxygen. Several other factors that may increase protein carbonyl formation in the meat system include metal catalysts (iron, copper, heme and non-heme iron, and myoglobin), pH, temperature, and presence of other inhibitors (antioxidant phenolic compounds. Oregano essential oil significantly ($P < 0.05$) reduced the total carbonyl formation (nmol/mg of protein), especially in the cooked meat (Table 2). There was no significant difference ($P > 0.05$) in the total carbonyl content between the treatments for raw meat during the first 3 days of storage. The changes of total carbonyl content in the raw meat compared to the cooked meat during storage were very small because the oxidative processes in the cooked meat were faster than in the raw meat. Also, the total antioxidant capacity of the fresh chicken meat is usually higher than that of the cooked meat. The reduction of antioxidant capacity in cooked meat is mainly due to the denaturation of antioxidant enzymes and the loss of endogenous antioxidants by heat. Generally, the formation of total carbonyls agrees with the TBARS values in raw meat during storage. Oregano essential oil at 400 ppm showed the strongest effect in reducing the total carbonyl values (Table 2). The total estimated carbonyl contents fall in the range of 1-3 nmol/mg protein for raw meat and up to 5 nmol/mg protein for cooked meat products. The total carbonyl values in this study agreed well with the TBARS results, and meats with the highest level of oregano oil produced the lowest total carbonyls. There were no significant differences between oregano oil treatments at 100 and 300 ppm, and BHA for both raw and cooked meat at day 7 (Table 2). The antioxidant effect of oregano essential oil was more prominent in the cooked meat than in the raw meat.

Adding oregano essential oil reduced the amounts of off-odor volatiles in cooked chicken meat (Table 3). The volatiles produced by the raw meat were very low and no sulfur or aldehyde compounds were detected after 7 days of storage. In the cooked meat, oregano essential oil at 100 ppm and 300 ppm significantly ($P < 0.05$) reduced the amounts of lipid oxidation-dependent volatiles, such as aldehydes (e.g., propanal, hexanal, pentanal and heptanal) and hydrocarbons (cyclohexane, hexane, heptane and octane), compared to the control. Oregano oil at 400 ppm showed the strongest effect in suppressing the aldehydes formation. Hexanal and pentanal have been reported as major indicators of lipid oxidation. Hexanal formation in the cooked meat increased rapidly during storage (Tables 3), which reflected the relationship between total aldehydes and lipid oxidation status of cooked chicken meat. The volatile content of aerobically-packaged meat increased more rapidly than the vacuum-packaged ones during storage, indicating the role of oxygen in the formation of volatiles.

Sulfur volatiles escaped or disappeared after 7 days of storage due to their high volatility. Samples from oregano essential oil treatments showed presence of some terpenoids such as sabinene, *p*-cymene, limonene, camphene, β–myrcene, and γ-terpenene in varying amounts. These compounds have a significant impact to the odor and flavor of meat products. No carvacrol and thymol were detected in oregano treatments due to their low volatilities.

Conclusion

Oregano essential oil, at 300 and 400 ppm levels, showed the highest antioxidant effect on ground chicken meat. Adding >100 ppm of oregano essential oil improved the color stability of raw meat and decreased off-odor volatiles in cooked meat. However, the effects of oregano essential oil on the lipid and protein oxidation, and the volatiles of cooked meat were more significant than in raw meat. Overall, oregano essential oil can be used in place of synthetic antioxidant (e.g., BHA) to prevent quality deterioration in raw and cooked meat during storage.

Table 1. TBARS values of raw and cooked chicken breast meat with different levels of oregano essential oil during storage

Time	Control without	100 ppm oregano	300 ppm oregano	400 ppm oregano	5 ppm BHA
Raw Meat	---------------------- TBARS (mg MDA/kg meat) --------------------				
Day 0	0.13^{az}	0.12^{ay}	0.11^{ay}	0.11^{ax}	0.13^{ax}
Day 3	0.16^{ay}	0.14^{by}	0.12^{bcxy}	0.12^{cx}	0.13^{bcx}
Day 7	0.23^{ax}	0.15^{bx}	0.13^{bx}	0.12^{bx}	0.14^{bx}
Cooked Meat	---------------------- TBARS (mg MDA/kg meat) --------------------				
Day 0	0.26^{ay}	0.14^{by}	0.09^{by}	0.08^{bz}	0.11^{bz}
Day 3	2.44^{ax}	2.35^{ax}	0.72^{cx}	0.27^{dy}	1.87^{by}
Day 7	2.55^{ax}	2.43^{bx}	0.74^{dx}	0.35^{ex}	2.02^{cx}

$^{a\text{-}c}$Values with different letters within a row are significantly different ($P < 0.05$). n = 4. $^{x\text{-}z}$Values with different letters within a column are significantly different ($P < 0.05$). Abbreviation: SEM, standard error of the mean; BHA, butylated hydroxyanisole; TBARS, 2-thiobabituric acid reactive substances; MDA, malondialdehyde.

Table 2. Protein oxidation of raw and cooked chicken breast meat with different levels of oregano essential oil during storage

Time	Control without	100 ppm oregano	300 ppm oregano	400 ppm oregano	5 ppm BHA
Raw Meat	--------------- carbonyl content (nmole/mg protein) ---------------				
Day 0	0.70^{ay}	0.69^{ax}	0.69^{ax}	0.65^{ax}	0.69^{ax}
Day 3	0.77^{axy}	0.75^{ax}	0.74^{ax}	0.65^{ax}	0.75^{ax}
Day 7	0.94^{ax}	0.79^{abx}	0.77^{bx}	0.69^{bx}	0.80^{abx}
Cooked Meat	--------------- Carbonyl (nmol/mg of protein) -------------------				
Day 0	0.69^{ay}	0.44^{by}	0.43^{bx}	0.40^{bx}	0.47^{by}
Day 3	1.25^{ay}	0.50^{by}	0.45^{bx}	0.42^{bx}	0.48^{by}
Day 7	1.90^{ax}	0.95^{bcx}	0.56^{bcx}	0.44^{cx}	1.00^{bx}

$^{a\text{-}c}$Values with different letters within a row are significantly different ($P < 0.05$). n = 4.; $^{x\text{-}z}$Values with different letters within a column are significantly different ($P < 0.05$). Abbreviation: SEM, standard error of the mean; BHA, butylated hydroxyanisole.

Table 3. Profile of volatiles from cooked chicken breast meat with different levels of oregano essential oil at day 7.

Compounds	Control (None)	100 ppm Oregano	300 ppm Oregano	400 ppm Oregano	5 ppm BHA
	------------------------------- Total ion x 10^4 ------------------------------				
2-Propanone	2307[a]	2031[a]	1966[a]	2065[a]	1224[a]
2-Propanol	991[a]	909[a]	1008[a]	452[a]	951[a]
Hexane	47[ab]	172[ab]	0[b]	0[b]	209[a]
Heptane	160[a]	0[b]	0[b]	0[b]	132[a]
Acetaldehyde	90[a]	0[b]	0[b]	0[b]	0[b]
Propanal	297[a]	0[b]	0[b]	0[b]	0[b]
Pentanal	1153[a]	563[b]	305[bc]	297[bc]	254[c]
Heptanal	72[a]	0[b]	0[b]	0[b]	0[b]
Octane	322[ab]	137[b]	397[ab]	309[ab]	822[a]
Cyclohexane	127[a]	45[b]	45[b]	26[b]	184[a]
Hexanal	41262[a]	7887[b]	1252[c]	1215[c]	2095[bc]
α-Pinene	0[c]	325[bc]	762[a]	378[b]	0[c]
Camphene	0[b]	258[b]	866[a]	503[ab]	0[b]
Limonene	0[c]	114[bc]	349[ab]	465[a]	0[c]
β-Myrcene	0[b]	335[ab]	640[a]	412[a]	0[b]
γ-Terpenene	0[b]	491[ab]	1326[a]	1020[a]	0[b]
Sabinene	0[c]	73[bc]	133[b]	355[a]	0[c]

[a-d]Different letters within a row are significantly different ($P<0.05$), n = 4.
Abbreviation: SEM, standard error of the mean; BHA, butylated hydroxyanisole.