Effects of Onion Quercetin on Oxidative Stability of Cook-chill Chicken in Vacuum-sealed Containers

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ABSTRACT

The effects of onion quercetin were evaluated in relation to the storage stability of cooked dark chicken meat in retarding post-cooking oxidative changes. Autoxidation was followed using the 2-thiobarbituric acid (TBA) test. Dried onion flesh at 1.6% (w/w), typical for common cooking, reduced (P < 0.001) the TBA value in cooked chicken during refrigerated storage, when mixed before processing. The NaCl did not act as a prooxidant. The antioxidant effect (by TBA) of onion mixed with chicken meat prior to processing was equivalent to that of its measured quercetin content, quantified by high-performance liquid chromatography.

Key Words: chicken, antioxidants, onions, quercetin, TBARS

INTRODUCTION

FLAVOR DETERIORATION IN COOKED MEATS LIMITS ACCEPTABILITY AFTER REFRIGERATION AND FROZEN STORAGE. THE TERM “WARMEOVER FLAVOR” (WOF) DESCRIBES OBSESSIONAL ODORS AND FLAVORS THAT BECOME PERCEPTIBLE WITHIN 48 H IN UNCURED COOKED MEAT STORED AT REFREGERATED TEMPERATURES. WOF IS PARTICULARLY NOTICEABLE AFTER REHEATING.

The rapid development of lipid oxidation is considered a primary contributor to WOF, and a decline in acceptability has been associated with a rise in 2-thiobarbituric acid (TBA) values. The TBA test is a colorimetric reaction between the TBA reagent and malondialdehyde (MDA), a secondary product of lipid oxidation (Melton, 1983; Hoyland and Taylor, 1991). 2-thiobarbituric acid reactive substances (TBARS) have been highly correlated with sensory properties, in studies of oxidative off-flavors, such as WOF (St. Angelo et al., 1987; Poste et al., 1986; Stapelfeldt et al., 1993). In addition, TBA values have been effectively used to indicate antioxidant effectiveness in food systems (Haldeman et al., 1987; Smith and Alfawaz, 1995).

The relatively high level of phospholipids in chicken tissues (Wilson et al., 1976), combined with the low levels of natural tocopherols (Dawson and Gartner, 1983), increase the susceptibility of chicken meat to oxidative changes. Cook-chill items based on chicken meat comprise a major sector of the convenience food market. However, the quality of cooked chicken stored at refrigeration temperatures is limited by changes, which mainly involve oxidative deterioration.

Synthetic antioxidants, such as butylated hydroxyanisole (BHA) and butylated hydroxytolune (BHT), prevent lipid oxidation in cooked meat products (Chen et al., 1984). Testing antioxidants from natural sources for controlling WOF in cooked meats has received considerable attention (Stoick et al., 1991). The application of plant origin extracts for prevention of meat flavor deterioration and oxidative rancidity has been studied (Osawa and Namiki, 1985; Haldeman et al., 1987). Processing of pre-cooked foods for improvement of quality has mainly involved packaging materials and techniques. Packaging is critical and usually follows cooking processes.

Our objective was to evaluate the effects of modifying product formulation in relation to storage stability of cooked dark chicken meat at refrigeration temperatures as a means of delaying or restricting post-cooking oxidative changes. Dark chicken meat was studied because it is more readily oxidizable than light meat. Dark meat has greater proportions of total lipids, especially phospholipids (Igene et al., 1980). In addition, its higher content of non-heme iron serves as a catalyst of lipid oxidation in cooked meats (Igene et al., 1984). Testing antioxidants from natural sources and plant origin extracts for prevention of meat flavor deterioration and oxidative rancidity has been studied (Osawa and Namiki, 1985; Haldeman et al., 1987). Processing of pre-cooked foods for improvement of quality has mainly involved packaging materials and techniques. Packaging is critical and usually follows cooking processes.

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Quantification was based on peak area. Each sample was injected 6 times in the column, and quantification was based on 6 chromatograms each time.

**Product preparation**

Thighs were randomly selected and defrosted at + 5 °C for 24 h, washed with tap water, and deboned manually. The skin, all visible external fat, and connective tissue were removed. The meat was ground in a food processor (Robot-Coupe Inc., Jackson, Miss., U.S.A.), equipped with a plastic work bowl and a stainless steel blade, for 1 min to provide a homogeneous product. An average TBA value of the prepared raw mince was 0.5 ± 0.1 mg MDA/kg meat.

**Recipe formulation**

Treatment formulations for cooking were prepared with onion and salt (NaCl) added separately and with mixtures of onion and salt. Individual formulations contained different onion levels, 1.6% or 3.0% (w/w) dried onion. Also, individual salt formulations contained two salt levels, 1.5% or 3.0% (w/w). The onion/salt mixture formulation contained 1.6% onion and 1.5% salt. The onion moisture content was 92.2%. Ingredients were mixed while grinding the meat. Grinding was interrupted at 0.5 min, the ingredients were added and grinding was continued another 0.5 min. The onion and salt levels were based on common cooking practice that suggested about 100 to 200 g of fresh onion (1 to 2 medium-size onions) per 500 g of meat and about 15 g of salt per kg cooked food.

Some formulations, instead of onion, contained quercetin dihydrate (3,3’,4’,5,7-pentahydroxyflavone), 99% purity by HPLC, purchased from FLUKA (Buchs, Switzerland) at a concentration of 200 ppm on total fat basis (5.5%) of raw chicken thigh meat. The fat content was determined in triplicate (AOAC, 1990). Control samples were chicken with no additives.

**Containers, cooking conditions, and process control equipment**

The ground meat (126 ± 1 g) was packed into lacquered cans with inner dimensions 65.4 mm × 50.5 mm and wall thickness 0.165 mm. The cans were vacuum-sealed and immersed in a water bath set at 80 ± 1 °C, equipped with a “Haake E8” water circulator. Vacuum sealing was applied to protect the sample from oxidation from the starting point of the cooking process due to any air in the headspace. Plastic insulating spheres were used as a floating lid for the water bath to minimize evaporation and heat losses.

The core region temperature of the food was monitored by insulated copper-constantan wire thermocouples of 0.19 mm, type T, positioned at the geometrical center of a can. The thermocouple was inserted into the can using a brass gland initially designed for use with pouches. For a perfect seal, a silicon rubber washer with a perforenation of the thermocouple diameter was fitted between the brass gland and the inner wall of the can. The thermocouple tip was carefully mounted in the geometrical center of the can during filling. Keeping the thermocouple in place was not troublesome because the food material was in the form of a thick paste. The thermocouples were connected to a “Comark 5335” scanning thermometer (Comark Instruments Inc., Beaverton, Oreg., U.S.A.) linked to a computer programmed to periodically monitor the temperature in the water bath and in the center of the cans. The cans were removed when the core region reached an end-point 70 °C and cooled under running tap water for approximately 30 min to internal temperature 15 to 20 °C. The applied heat treatment was tested with respect to protein coagulation and microbiological safety, in order to have a meaningful simulation of cooking. There were two criteria in selecting an end-point temperature of 70 °C. The first criterion was to induce denaturation of the myofibrillar and sarcoplasmic proteins as well as co-precipitation of myoglobin (60 °C) and collapse of the native structure of collagen (65 to 70 °C) (Lawrie, 1985). The second was to ensure the destruction of Salmonella senftenberg 775W (D0 = 0.21, z = 6.6 °C). The D-value was extrapolated from the thermal death time (TDT) curve for Salmonella senftenberg 775W, using z = 6.6 °C at 65.5 °C and a D-value of 1 min, which relates to the maximum heat resistance of Salmonella senftenberg 775W in pasteurized foods (Stumbo, 1973).

**Sampling**

Precautions were taken to prevent adventitious autoxidation during sampling. After cooling, the cooked contents of cans bearing the same composition were blended again in a food processor for 1 min. This was done to reduce sample variability from small differences due to water bath position. Subsamples (10 g) were weighed into resealable polythene sampling bags with dimensions 89 mm × 114 mm and material thickness 0.16 mm. Sampling was completed within 1.5 h after cooling.

**Chilled storage of cooked chicken**

Chilled storage was at + 5 °C for up to 6 d, including the day of cooking (day zero). The air in the cold room was circulating at an average velocity of 0.4 m/s as measured by a vane anemometer. Preweighed subsamples of the cooked and re-mixed paste-like chicken sealed in polythene bags were shaped into thin layers (slab-like), with an average pack thickness of 3 mm. The packs were labeled for composition and storage time and randomly distributed in a single layer on trays. Samples were frozen until tested for TBA value.

**Thiobarbituric acid reactive substances**

Lipid oxidation of cooked chicken was evaluated by following development of TBARS during 6 d refrigerated (5 °C) storage, using the well established modified distillation method. The storage time (6 d) was decided as related to conditions of the cook-chill foodservice system. The finely divided nature of the sample and the large surface area exposed to air during storage also provided the essential conditions for an accelerated storage test. We confirmed in a preliminary study that longer storage did not add any value to the results. The results were expressed as TBA value (mg malondialdehyde/kg sample). TBA values for three experimental replications (i.e., three cans) were computed. Each experimental replication was assayed twice (i.e., two distillations from each can); the TBA test was performed in duplicate for each distillate.

**Statistical analysis**

Two-way analysis of variance was conducted using the TBA values as the dependent variable and treatment (5 formulations and control) and storage time as independent variables. Due to the significant interactions between treatment and storage time that emerged, one-way analysis of variance was conducted for each storage day separately, using TBA values as the dependent variable and treatment as the independent variable. One-way analysis of variance was also computed for each of the 5 recipe formulations and the control, using TBA values as the dependent variable and storage day as the independent variable. Tukey’s tests were used to determine significance of means for multiple comparisons. Significance of differences was defined at P 0.05.

**RESULTS & DISCUSSION**

**Quercetin content in onion**

The reproducibility of the extraction method and analytical procedure was checked by determining the intra- and inter-assay variations of quercetin in onion samples with quercetin standard added. For the extraction, single day intra-assay reproducibility was obtained with a 2.1% average coefficient of variation (CV) and 3.7% for the inter-assay (n = 4).

Typical chromatograms from quercetin standard solutions (Fig. 1) and onion extracts (Fig. 2) were compared. No ultraviolet spectra of the onion flavonoids were recorded. Therefore, we could not eliminate the possibility that the peak did not also contain other compounds. Thus, the antioxidative effect of onion extracts might not be
Effects of Onion Quercetin on Cooked Chicken

The quercetin content of the edible part of the onions was 910 µg/kg (d.m. basis). This was equivalent to 65 mg/kg fresh weight, based on 92.8% onion flesh moisture. This quercetin content was comparable to quantities reported in the edible portion of onions in three cultivars (Bilyk et al., 1984), e.g., Sweet Spanish Hybrid, 62 mg/kg; Sweet Spanish Utah, 61 mg/kg; and Carmen Hybrid, 59 mg/kg. However, the quercetin content of the flesh of a nonreported cultivar by Hertog et al. (1992) was much higher at 5076 mg/kg of fresh weight.

Antioxidative effect of onions and quercetin standard

Chicken samples were cooked with onion or standard quercetin. As determined by HPLC analysis, the quercetin content of onions was 910 µg/g (freeze-dried). The quercetin content from the onion flesh was expressed on a total chicken thigh fat (5.5%) basis. The calculation was made based on 1.6% onion used in the formulation as:

\[
\text{Percent Inhibition} = \frac{\text{quercetin} \times \text{onion/fat}}{264.7 \text{ ppm quercetin}}
\]

where quercetin was 910 µg/g dry onion (as quantified by HPLC), dry onion was 1.6 g/100-g total chicken weight, and total chicken fat was 5.5 g/100-g raw thigh meat.

Therefore, the flesh of the Dutch onion contained 260 ppm quercetin on total fat of dark chicken meat. The amount of standard quercetin used in the cooking experiments was 200 ppm. Thus, the meat samples containing onion theoretically had 30% more quercetin than samples containing the standard. The storage stability of the cooked chicken increased considerably with both treatments, as measured by the TBA test. The antioxidant activity of the onion was expressed as the percentage inhibition of TBARS development relative to the control.

Effect of dried onion on TBA values

Differences between control and the two onion treatments were significant as early as on storage d 1 (Table 2). On d 1, the TBA value of the onion 1.6% treatment was slightly higher than that of the onion 3.0% treatment. This difference increased as storage time increased. Both onion treatments reduced development of oxidative rancidity (P < 0.001) in ground chicken thigh cooked to 70 °C in the core region of the pack, as measured by TBA.

The antioxidant effect of the onion was apparent on all 5 days of refrigerated storage, with the TBA values of the control higher than onion samples on all days. On d 0, differences between control and treatment samples were marginal. This was expected since the food system was freshly cooked and any deterioration including rancidity would be due to either poor quality of the meat source or poor handling during preparation. As expected TBA values increased from d 0 to d 5 (P < 0.001) for the control and the 1.6% (w/w) dry onion samples. The TBA values increased considerably from day to day in the control group (P < 0.001), while the day to day increase in TBA value was less notable in the 1.6% (w/w) dry onion sample, although the increase was statistically significant (P < 0.001).

Difference in antioxidant activity was also found between levels of 1.6% and 3% dried onion (Table 2) in the same food system (P < 0.001) from d 1 onwards. These results demonstrate that the effectiveness of onion in retarding the increase of TBA was directly related to its concentration.

Informal smell and taste tests indicated a detectable change in flavor was produced...
by both onion levels. Addition of 1.6% (w/w) dry onion induced a pleasant onion aroma while the samples containing 3% (w/w) dry onion had an offensive onion smell. The difference in TBA value between control and 3% onion was notable. However, the 3% level of dried onion would be excessive for practical use in cooking because of the objectionable flavor.

The beneficial effects of onion addition to chicken on its oxidative stability probably is due to its phenolic compound content (Pratt and Watts, 1964; Herrmann, 1976), which is mainly quercetin. Phenolic substances are potent antioxidants and function by interrupting the free radical chain in the propagation step of the oxidative process (Pratt and Hudson, 1990).

**Effects of sodium chloride (NaCl) on TBA values**

The TBA values of the two salt treatments and the control were comparable during storage (Table 2). Contrary to the majority of published reports (Andersen and Skibsted, 1991; Kanner et al., 1991), sodium chloride showed no accelerating effect on TBA value of the meat compared with controls.

Mechanical grinding and cooking would have caused disruption of the muscle membrane system, thus producing an emulsion-type product. Since the solubility of oxygen decreases with increasing salt, the amount of oxygen dissolved in the liquid phase would have decreased. Thus, the diffusion of oxygen to the sites of the unsaturated double bonds should have been retarded, reducing the rate of the oxidative reaction (Labuza, 1975). This effect might have obscured any proxidant effects of sodium chloride. Our results corroborate the concept that the state of the solvent system around the lipid has an important bearing on rancidity development in meats (Labuza, 1971).

### Table 2—Effect of dried onion alone, salt alone and onion/salt mixture on TBA values of chicken homogenate cooked to 70 °C and stored

<table>
<thead>
<tr>
<th>Storage time at 5°C (days)</th>
<th>Control</th>
<th>Onion 1.6%</th>
<th>Onion 3.0%</th>
<th>NaCl 1.5%</th>
<th>NaCl 3.0%</th>
<th>Onion 1.6%/NaCl 1.5% mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.54±0.04a</td>
<td>0.53±0.04</td>
<td>0.35±0.02</td>
<td>0.93±0.08</td>
<td>1.19±0.04</td>
<td>0.48±0.04</td>
</tr>
<tr>
<td>1</td>
<td>6.19±0.35</td>
<td>1.17±0.07</td>
<td>0.35±0.00</td>
<td>7.68±0.12</td>
<td>7.87±0.22</td>
<td>0.66±0.06</td>
</tr>
<tr>
<td>2</td>
<td>13.25±0.58</td>
<td>1.68±0.11</td>
<td>0.54±0.01</td>
<td>12.18±0.16</td>
<td>12.57±0.10</td>
<td>1.15±0.07</td>
</tr>
<tr>
<td>3</td>
<td>16.42±0.37</td>
<td>2.37±0.09</td>
<td>0.55±0.02</td>
<td>14.73±0.12</td>
<td>14.81±0.19</td>
<td>1.67±0.12</td>
</tr>
<tr>
<td>4</td>
<td>18.80±0.23</td>
<td>2.91±0.10</td>
<td>0.59±0.02</td>
<td>16.54±0.10</td>
<td>16.24±0.16</td>
<td>2.85±0.08</td>
</tr>
<tr>
<td>5</td>
<td>19.80±0.32</td>
<td>3.20±0.08</td>
<td>0.54±0.03</td>
<td>17.95±0.22</td>
<td>17.06±0.08</td>
<td>3.02±0.07</td>
</tr>
</tbody>
</table>

* TBA values for 3 experimental replications (i.e., 3 cans) were determined. Each experimental replication was assayed twice (i.e., 2 distillations from each can); the TBA test was performed in duplicate for each distillate.

b,c,x,y,z Means within the same row with different superscripts are significantly different (P<0.001).

**Effect of a mixture of dried onion and salt on TBA values**

The combined effects of onion and salt on the storage stability of cooked chicken was investigated, because such conditions would simulate a practical cooking situation. As refrigerated storage time increased from d 1, oxidative stability of samples containing the test mixture increased in comparison to controls (P < 0.001) (by TBA Table 2). However, there were no significant differences between the onion/salt mixture treatment and the onion 1.6% treatment after d 3.

### CONCLUSION

**USE OF ONION CULTIVARS RICH IN QUERCETIN AS NATURAL FOOD ANTIOXIDANTS**

The beneficial effects of onion addition to chicken on its oxidative stability probably is due to its phenolic compound content (Pratt and Watts, 1964; Herrmann, 1976), which is mainly quercetin. Phenolic substances are potent antioxidants and function by interrupting the free radical chain in the propagation step of the oxidative process (Pratt and Hudson, 1990).

**REFERENCES**


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