Effect of Dry Honey on the Shelf Life of Packaged Turkey Slices

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ABSTRACT The development of off-flavors from oxidation reactions in cooked turkey products is a common problem and results in a less desirable, rancid flavor. Various strategies have been evaluated to minimize this off-flavor development, including vacuum and modified atmosphere packaging, feeding antioxidants to animals, and use of antioxidants in the final product. A natural protein-sugar reaction called the Maillard reaction produces a brown pigment, flavors, and antioxidants. This research tested the addition of honey to turkey breast meat before processing to retard production of oxidation products related to off-flavor. Three levels (0, 5, 15%) of dry honey were mixed with raw turkey breast meat pieces, then the mixture was stuffed into casing and cooked. The cooking process facilitated the Maillard reaction and the development of an antioxidative effect. The cooked chubs were then cooled, sliced, and vacuum-packaged as individual slices. The slices were refrigerated and tested for color, flavor, oxidative rancidity, and microbial growth over 11 wk. Sensory panelists detected increased sweetness and no negative flavor impact on acceptability for turkey with added honey. The addition of honey enhanced the oxidative stability of the meat, as indicated by lower TBA values, hexanal content, and oxidative stability index. Honey did impart a slightly darker color with lower lightness values but had no effect of redness and yellowness values.

Key words: antioxidant, flavor, honey, meat color, turkey meat

INTRODUCTION

Food processors are using honey in an ever-increasing array of food products. About 150 million pounds of honey per year are used as food ingredients, and small amounts are used in nonfood items such as drugs, cosmetics, or pet foods (Snowdon and Oliver, 1995). Sweetness, functional advantages, and nutritive value are a few of the reasons honey is a valuable food ingredient. Some of the functional characteristics contributed by honey include humectancy, viscosity, flavor enhancement, color, hygroscopicity, miscibility, and spreadability (LaBell, 1988; Veronique and Sanders, 1988). Although honey is a solution averaging 82.4% sugars, it is as sweet as sugar and contains fewer calories. Honey has 304 kcal/100 g, whereas sugar has 400 kcal/100 g (LaBell, 1988). Fructose and glucose in honey provide quickly digestible energy, and the vitamins and minerals present in honey make it attractive as a source of nutrition. The average pH of honey is 3.9, and water activity (aw) varies between 0.5 and 0.6. Honey has been used in many applications, including baking, confectionery, preserves and syrups, meat, tobacco manufacture, cosmetics, and other minor applications (Wilson and Crane, 1976; Tuley, 1989). The acidity of honey is such that it can be incorporated into many food products without disturbing the acidity level. The cereal and bakery industries are the 2 largest consumers of honey (Snowdon and Oliver, 1995). One growing area of honey use is in meats such as ham, bacon, and sausage. Honey enhances meat and spice flavor when mixed with the cure that is injected into ham or bacon. In sausage mixtures, honey helps in the binding of ingredients, improves texture, and enhances of flavor (LaBell, 1988). Honey has been used in salt-cured hams or bacons to mask the high saltiness of these products and in barbeque and meat sauces to add color and enhance caramelization (Wilson and Crane, 1976). The shelf life of ready-to-eat meats is limited primarily by changes in color, bacterial populations, and flavor due to oxidation.

Honey has been evaluated for use as an antimicrobial against food spoilage and pathogenic organisms (Garcia et al., 2001; Taormina et al., 2001; Mothersaw and Jaffer, 2004; Mundo et al., 2004). Honey has also been tested in vitro and vivo against pathogens exposed to intestinal environments (Shamala et al., 2000; Tumkur et al., 2002; Alnaqdy et al., 2005). The bactericidal activity of honey has been categorized as either peroxide-related or nonperoxide related. Snow and Manley-Harris (2004) reported that when excess catalase was added to New Zealand
Manuka honey, nonperoxide bactericidal activity (NPBA) remained. This NPBA was lost by raising the pH of the honey to 11 and was not recovered when the pH was returned to 7. Weston et al. (2000) had previously determined that phenols in general were not responsible for the NPBA of honey. Garcia et al. (2001) found that honey derived from the pollen of rosemary and labiatae plants inhibited *Staphylococcus aureus*, whereas honey from heather did not, suggesting that plant-specific compounds were, in part, responsible for the bactericidal properties of honey.

Warmed-over flavor in meat is 1 important problem facing the meat and food industry that limits quality and shelf life of the product. Restructured meat items (i.e., structuring individual muscles of lower value into formulated products of higher value) provide uniform, portion-controlled, and completely edible products for the food-service industry. Processes such as comminution and grinding enhance oxidative reactions in meat by introducing molecular O and mixing oxidation catalysts with lipids. The high content of unsaturated fatty acids and the close proximity of phospholipids to heme proteins and nonheme iron cause their rapid oxidation. Turkey is reported to be more susceptible than chicken, pork, beef, and mutton to warmed-over flavor (Cross et al., 1987). Several studies have examined the quality effects of honey on turkey meat (Antony et al., 2000, 2002; McKibben and Engeseth, 2002), chicken (Hashim et al., 1999a,b) and ground beef (Johnson et al., 2005). Honey (15% wt/wt) was reported to retard lipid oxidation in cooked beef patties compared with patties without honey; however, addition of 0.25% sodium tripolyphosphate was more effective than honey in slowing oxidation in the same study. The TBA values and oxidative stability index decreased with increasing levels of dry honey added to raw ground turkey, cooked ground turkey, and cooked meat refrigerated for 48 h (Antony et al., 2000). In previous studies, ground meat products were used without the addition of other ingredients and without using processes that are associated with commercial products. This study used a small-scale process and ingredients typical of commercial ready-to-eat meats. The objective of this study was to determine the effect of dry honey on the flavor, color, microbial status, and oxidative stability of sliced turkey rolls.

**MATERIALS AND METHODS**

**Processing**

Frozen turkey breast meat (Carolina Turkey, Mt. Olive, NC) was purchased and processed on different dates (replications). Meat was thawed at 4°C for 12 h before chopping into approximately 2.5-cm cubes, followed by mixing with ingredients. The ingredients (Table 1) were then added in the following order (with mixing time in parentheses): NaCl (2:20), sodium tripolyphosphate (0:40), cold water (0:30), dry honey (Groeb Farms, Onstead, MI; 3:30). The total mixing time used for all treatments was 7 min. The sodium tripolyphosphate was dissolved in 175 mL of water before addition to the meat batter. The 3 treatments evaluated were control (no added honey) and dry honey (5 and 15%). The dry honey was 70% roller-dried honey. The ingredients in roller-dried honey included wheat starch and Ca stearate (anticaking agents). The typical analysis was 2.3% moisture, 1.5% protein, 94.2% carbohydrate, 1.5% ash, and 0.2% fat. After mixing meat and ingredients, the batter was stuffed into a 62-mm diameter casings oven (Viskase Corp., Damien, IL) to form chubs. Chubs were placed on horizontal screen racks in a cook oven (Alkar Inc., Lodi, WI) then processed to a final temperature of 72°C using the following processing schedule: 57.2°C for 30 min, 65.5°C for 30 min, 68.3°C for 30 min, 73.9°C for 30 min, 82.2°C for 30 min, 90.5°C until a minimum internal temperature of 72.8°C was achieved. Chubs were exposed to a water shower for 5 min, held at room temperature for 30 to 60 min, then towed off and placed in a cooler at 4°C. The product was then sliced and vacuum-packaged in a high-O transmission rate film (Cryovac Division of Sealed Air Corp., Duncan, SC; 12,000 mL of O²/m² per 24 h) and heat-sealed using a vacuum heat sealer (Turbovac Inc., Columbia, MO). The packed samples (4 slices/package) were stored at 4°C for further evaluation.

**Proximate Analysis**

Moisture, fat, and protein were determined on the raw, precooked, and cooked samples using standard methods (Association of Official Analytical Chemists, 1984). Cook yield was determined by dividing postcook weight by precook weight and was expressed on a percentage basis by multiplying by 100. The moisture loss was determined by subtracting postcook weight from precook weight and dividing the result by precook weight and was expressed on a percentage basis.

**pH Measurement**

Ten grams of sample and 100 mL of deionized water were blended for 2 min, and pH of the mixture was measured using a pH meter (Orion Research Inc., Boston, MA).

**Total Plate Count**

Turkey breast meat slice samples were removed and aseptically weighed on tared sterile trays and placed into

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Control (%)</th>
<th>Dry honey (%)</th>
<th>Dry honey (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turkey breast meat</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>NaCl¹</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
</tr>
<tr>
<td>STPP¹</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Water¹</td>
<td>22.3</td>
<td>22.3</td>
<td>22.3</td>
</tr>
<tr>
<td>Dry honey¹</td>
<td>—</td>
<td>5</td>
<td>15</td>
</tr>
</tbody>
</table>

¹Added as a percentage of meat weight. STPP = sodium tripolyphosphate.
stomacher bags with 10 mL of 0.1% peptone rinse water. Samples were mixed in a stomacher (model 400 Lab Blender, Seward Ltd., London, UK) for 30 s. Appropriate decimal dilutions were made from the rinse solution, and aliquots were transferred into sterile, disposable petri dishes. Standard plate count agar (Difco Laboratory, Detroit, MI) tempered at 50°C in a water bath was poured into petri dishes containing the appropriate dilutions and rotated for uniform dispersion. Upon solidification, the dishes were incubated at 37°C for 48 h. The number of colony-forming units were counted and multiplied by dilution factor to determine colony-forming units per gram of sample.

**Color Evaluation**

Meat surface color was evaluated every week for 11 wk using the Spectroguard II Color System (BYK-Gardner Inc., Silver Spring, MD). Evaluation was performed on 2 packaged samples for each treatment (4 slices/package). The samples were stored in a refrigerator at 4°C, with each sample lying flat, exposed to 1,240 ± 200 lx of continuous fluorescent light. A total of 8 sample readings at the same location on slices per treatment per sampling time were taken through the package. Package reflectance was subtracted out instrumentally. Data were collected as International Commission on Illumination lightness (L*) redness (a*) and yellowness (b*) values. Total color difference (ΔE) was calculated using the following equation (Francis and Clydesdale, 1975)

\[
ΔE = [(L* - L*)^2 + (a* - a*)^2 + (b* - b*)^2]^{1/2}.
\]

**Sensory Evaluation**

Sensory analysis was conducted using a 14-member trained panel that developed the taste characteristics during 10 training sessions over a 3-mo period. Panelists were trained using sliced turkey meat prepared with and without added honey. The attributes tested were juiciness, tenderness, oxidation, sweetness, sweetness acceptability, and flavor acceptability (Figure 1). The samples were sliced and placed on a tray in coded containers. Celery, crackers, and water were provided to neutralize tastes in between samples. The samples were evaluated the day after production and after 2 wk of storage at 4°C.

**Headspace Analyses**

Volatile compounds from stored samples were analyzed using a headspace auto sampler (model 7000, Tekmar, Cincinnati, OH) interfaced to a capillary gas chromatograph (model 5890 series II, Hewlett-Packard, Wilmington, DE). A 1.5-g chopped sample was sealed in a headspace vial and heated at 100°C for 30 min, after which a sample of headspace volatiles was automatically injected onto the head of a capillary column (0.32 mm i.d., 30 m DB-5, J & W Scientific, Folsom, CA) maintained at −20°C. The gas chromatograph oven was programmed from −20 to 250°C at 10.0°C/min, with a 5 min final hold time. The flame ionization detector signals were stored and integrated using a Hewlett-Packard Chemstation. Peak identification was based on retention times of authentic reference standards.

**TBA Values**

The TBA values were determined on stored samples by the distillation method (Tarladgis et al., 1960). Ten grams of the sample were blended with 50 mL of distilled water for 2 min. The mixture was transferred into a Kjeldahl flask, and the jar was rinsed with an additional 47.5 mL of distilled water. The pH was brought to 1.5 by adding 2.5 mL of 4N HCl. A boiling chip and an antifoam agent were added to control foaming during distillation. Fifty milliliters of the distillate was collected, and then 5 mL of the distillate was mixed with 5 mL of 0.02 M of TBA reagent. The solution was mixed and placed in boiling water for 35 min and then cooled in ice. The amount of colored compound formed was evaluated at 538 nm on a UV-VIS spectrophotometer (Perkin-Elmer, Norwalk, CT). The TBA values were expressed as milligrams of malonaldehyde/kilogram of meat. The percentage of inhibition of oxidation was calculated as:

\[
\% \text{ inhibition} = 1 - \frac{\text{TBA value of treated sample}}{\text{TBA value of control}} \times 100
\]

**Oxidative Stability Index Profile**

Oxidative stability of the samples was evaluated with an oxidative stability instrument (OSI; Omnion, Rockland, MA) using the method of LeGall (1995). Samples were dispersed with equal amounts of mineral oil into OSI tubes. Sample tubes were held in a thermostatic block at 110°C, and a stream of purified air was bubbled through the sample. The air valve was opened to allow the air pressure to equilibrate at 5.5 lb/in2. Volatiles released from the sample passed through rubber tubing into a tube containing deionized water and a conductivity probe, which measured the change in the conductivity of deionized water. The time in hours before detectable (by change in conductivity) levels of volatile organic acids were trapped in deionized water was the measure of the induction period. The induction period length was determined by a change in slope in conductivity over time. A longer induction period indicated a better oxidative stability of the sample.

**Statistical Analysis**

A split-plot design was used to statistically analyze the proximate composition, hexanal content, TBA values, and OSI numbers, with the level of added honey as the whole-plot factor and the storage time as the subplot factor. Replication (meat batches) was the blocking variable.
Celery, crackers, and water are available in the booth for you to clear your palate before you begin tasting and between samples. You may go back and forth among the samples while making your decision. ENTER A NUMERICAL VALUE FROM THE APPROPRIATE SCALE FOR EACH ATTRIBUTE. IF you have any questions, press the assistance button in the booth, and help will be on the way!

**Figure 1.** Sensory panel sheet used for evaluation of sliced honey-added turkey rolls.

Control and 5% samples in trial 1 were discarded after 3 wk due to bacterial growth. Data were analyzed using the PROC MIXED procedure (SAS Institute, 2000) for treatment effects. Dunnett’s multiple comparison procedure was used to compare cook yield of the 2 treatments with respect to control. Repeated measures design was used to analyze color results, and treatment effects were analyzed by ANOVA using the GLM procedure. Tukey’s multiple comparison test was used to evaluate significant differences among means at $P \leq 0.05$ when there was no treatment $\times$ time interaction. Bonferroni’s multiple comparison procedure was used when interaction was observed.

**RESULTS AND DISCUSSION**

Cook yield for control, 5%, and 15% honey-added samples were 81.9, 83.44, and 83.90%, respectively, and did not differ ($P > 0.05$). Proximate analysis for raw meat, batter, and product containing 3 levels of added honey is given in Table 2. Level of honey added had an effect ($P \leq 0.05$) on moisture and protein content. Average moisture content of raw meat was 73.9%, and protein and fat contents were 23.3 and 1.3%, respectively. Moisture content of the batter and final product was different ($P$...
le 0.05) for control and 15% honey-containing samples. Moisture content for the product was 4.4% lower than the batter or the 5 and 15% honey-added meat. There was no interaction between moisture content and time of storage among samples. Moisture content was different (P ≤ 0.06) between control and 15% honey-added cooked samples. There was no difference in moisture content during storage, so moisture content was averaged over time and was 71.46 ± 2.23, 69.29 ± 2.23, and 65.07 ± 2.23 for control, 5%, and 15% honey-added samples, respectively. There was no treatment effect (P > 0.05) on fat content. There did not seem to be any specific trend in the pH values; with time, however, pH of the control, 5%, and 15% honey-added product descended from 6.20 ± 0.035, 6.10 ± 0.035, and 6.05 ± 0.035, respectively.

**Bacterial Growth**

All packaged samples were generally stable during the 11-wk storage period. The product with 15% honey showed little or no bacterial growth (<10^2 cfu/g) after 11 wk of storage at 4°C. Control samples and meat with 5% added honey showed 10^3 and 10^4 cfu/g at wk 8 and 10, respectively. Incipient aerobic spoilage is accompanied by a rise in pH. The higher concentration of carbohydrate would delay the onset of amino acid utilization (Jay, 1996) and explain (along with depressed growth) why pH does not increase as much during storage for the 5 and 15% honey-containing samples compared with controls. The breakdown of amino acids through deamination will produce a rise in meat pH. Many factors, including saprophytic microflora, pH, nitrite and salt concentration, and available and O2 partial pressure, influence survival and growth of pathogens (Jay, 1996). Precooking of turkey rolls to 71°C also effectively reduces total aerobes and coliforms (Kotula et al., 1987). Molan (1992) proposed that the antibacterial properties of honey were due to acidity, osmolarity, conversion of glucose to hydrogen peroxide by glucose oxidase, and some other less clearly defined factors such as pinocembrin, lysozyme, acids (phenolic and others), terpenes, and benzyl alcohol and volatile substances. Studies on gram-positive and gram-negative species have found gram-negative bacteria to be more sensitive to the inhibitory action of honey as compared with gram-positives. Certain factors present in honey have an effect on the bacterial cell wall, possibly leading to lyses of the bacteria (El-Sukhon et al., 1994). Einarsson (1990) reported that Maillard reaction products exerted antibacterial effects by the interaction between them and Fe, making them less available to bacteria.

**Sensory Panels**

Sensory panelists generally found little difference in the sensory attributes among the 3 treatments. As expected, sweetness was greater for both honey-added samples, and the 15% honey-added meat was judged as sweeter than the 5% honey-added meat. There was a replication difference among the 3 trials in various sensory panel attributes (Table 3). In the first trial, there was a difference (P ≤ 0.05) in juiciness and tenderness. The 15% honey-added samples ranked highest in juiciness and tenderness in trial 1 and trial 3. In trial 2, there was no difference (P ≥ 0.05) among the 3 samples for these 2 attributes. For oxidation, there was no difference among the 3 samples for trial 1. In trial 2, the oxidative ranking was higher for the control as compared with the 15% honey-added meat. In trial 3, there was an interaction between sample and week, with the control ranking higher in the first week and no difference among treatments in the second week. The 15% honey-added samples were rated higher (P ≤ 0.05) in sweetness as compared with control and 5% honey-added samples in all trials.

**Color Analysis**

There was an interaction (P ≤ 0.05) between treatment and storage time for lightness (L*) values. There was a difference (P ≤ 0.05) in L* values between the control and 5% honey-added meat in wk 1 and 2 and also between control and 15% honey-added meat in wk 8 and 9. Lightness value was lowest for 15% honey-containing samples, followed by 5% honey-containing samples (Figure 2). Honey imparted a dark tint to the meat, which was maintained over 11 wk of storage. However, during 11 wk of storage, all 3 treatments increased in L* value by 3 to 4 units. Visually, controls appeared paler in color as compared with the honey-containing samples. There was no interaction (P > 0.05) between treatment and storage time for redness (a*) and yellowness (b*) values, although a time effect was observed for a* values. There was a decrease in a* values after wk 1 for the 3 treatments, and then a* values remained constant throughout the remaining 11 wk of storage (Figure 3). Pooled over time, the a* values were −2.49, −1.85, and −0.46 for the control, 5%, and 15% honey-added samples, respectively. Negative a* values were observed for the control samples immediately after cooking. The 15% honey-added samples showed a positive a* value just after cooking, which became negative within a week of storage. The low myoglobin content of turkey breast meat, combined with the cooking procedure, might explain the low a* values of the meat. Drawn on a chromaticity diagram (not shown)

### Table 2. Proximate analysis of raw meat, batter (0, 5, and 15% dry honey), and finished product (0, 5, and 15% dry honey)

<table>
<thead>
<tr>
<th>Item</th>
<th>Moisture</th>
<th>Protein</th>
<th>Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>73.93</td>
<td>23.29</td>
<td>1.26</td>
</tr>
<tr>
<td>Batter (0% honey)</td>
<td>75.98</td>
<td>20.73</td>
<td>0.99</td>
</tr>
<tr>
<td>Batter (5% honey)</td>
<td>74.21</td>
<td>18.86</td>
<td>0.93</td>
</tr>
<tr>
<td>Batter (15% honey)</td>
<td>69.63</td>
<td>17.27</td>
<td>0.88</td>
</tr>
<tr>
<td>SE</td>
<td>1.31</td>
<td>1.0</td>
<td>0.088</td>
</tr>
<tr>
<td>Product (0% honey)</td>
<td>72.56</td>
<td>23.17</td>
<td>1.15</td>
</tr>
<tr>
<td>Product (5% honey)</td>
<td>69.89</td>
<td>20.89</td>
<td>0.93</td>
</tr>
<tr>
<td>Product (15% honey)</td>
<td>65.05</td>
<td>19.81</td>
<td>1.08</td>
</tr>
<tr>
<td>SE</td>
<td>1.31</td>
<td>1.0</td>
<td>0.088</td>
</tr>
</tbody>
</table>

Means in the same column within batter and product with the same superscripts are not significantly different (P > 0.05).
these samples fall in the yellow region and, therefore, do not imply greenness, as might be linked to negative a* values. There was a difference ($P \leq 0.05$) in b* values among treatments. The b* value was highest for 15% honey-containing samples, followed by 5%, and then control. Pooled over time, the mean b* values ranged from 10.17 in control to 12.53 and 15.15 for the 5 and 15% honey-added samples, respectively. Addition of honey thus resulted in a more yellow and intense color compared with control. Total color difference, which indicates the magnitude of difference among locations in the International Commission on Illumination L*, a*, and b* color solid, was higher for samples containing honey. The $\Delta E$ values were higher after 11 wk for honey-added samples, compared with $\Delta E$ values after 4 wk. Maillard browning product degradation could be affecting this change in total color.

### Oxidative Stability

Mean TBA values were lower (Figure 4) for honey-added samples, with 15% showing the lowest value throughout storage. Previously, Antony et al. (2000) found that the incremental addition of dry honey to raw ground turkey meat resulted in lower hexanal content and TBA values for cooked meat immediately after cooking and after 48 h of refrigerated storage. This study differed from the current study in that only ground turkey was used, and meat was not processed into a commercial-type chub and sliced but was cooked in sealed polyethylene bags. There was a linear relationship between TBA values and percentage of honey added, with 15% having the lowest TBA value (Figure 5). The TBA numbers of meat tend to increase over the storage period, reach a maximum value, and then decline. This has been

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**Table 3. Sensory score means from trained panel evaluations of a turkey roll containing 0, 5, and 15% dry honey**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Juiciness</th>
<th>Tenderness</th>
<th>Oxidation</th>
<th>Sweetness</th>
<th>Sweetness acceptability</th>
<th>Flavor acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>4.15$^b$</td>
<td>4.57$^b$</td>
<td>5.96</td>
<td>1.42$^b$</td>
<td>5.0</td>
<td>3.85$^b$</td>
</tr>
<tr>
<td>5%</td>
<td>4.92$^{ab}$</td>
<td>5.62$^a$</td>
<td>6.65</td>
<td>1.96$^a$</td>
<td>5.96</td>
<td>6.07$^a$</td>
</tr>
<tr>
<td>15%</td>
<td>5.12$^a$</td>
<td>5.70$^a$</td>
<td>5.88</td>
<td>3.27$^a$</td>
<td>5.85</td>
<td>5.62$^a$</td>
</tr>
<tr>
<td>SEM</td>
<td>0.223</td>
<td>0.171</td>
<td>0.236</td>
<td>0.132</td>
<td>0.354</td>
<td>0.40</td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>5.73</td>
<td>6.26</td>
<td>7.5$^a$</td>
<td>1.5$^b$</td>
<td>5.88</td>
<td>6.31</td>
</tr>
<tr>
<td>5%</td>
<td>5.27</td>
<td>5.81</td>
<td>7.0$^{ab}$</td>
<td>1.83$^b$</td>
<td>5.73</td>
<td>5.85</td>
</tr>
<tr>
<td>15%</td>
<td>5.54</td>
<td>5.96</td>
<td>6.38$^b$</td>
<td>3.35$^a$</td>
<td>5.54</td>
<td>5.38</td>
</tr>
<tr>
<td>SEM</td>
<td>0.21</td>
<td>0.21</td>
<td>0.28</td>
<td>0.17</td>
<td>0.43</td>
<td>0.41</td>
</tr>
<tr>
<td>Trial 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>4.27</td>
<td>5.27</td>
<td>7.0$^a$</td>
<td>1.64$^c$</td>
<td>5.45</td>
<td>6.18</td>
</tr>
<tr>
<td>5%</td>
<td>4.45</td>
<td>5.45</td>
<td>6.63$^{ab}$</td>
<td>2.45$^b$</td>
<td>5.27</td>
<td>5.82</td>
</tr>
<tr>
<td>15%</td>
<td>4.82</td>
<td>5.82</td>
<td>5.64$^b$</td>
<td>3.91$^a$</td>
<td>4.45</td>
<td>5.00</td>
</tr>
<tr>
<td>SEM</td>
<td>0.132</td>
<td>0.135</td>
<td>0.347</td>
<td>0.217</td>
<td>0.278</td>
<td>0.311</td>
</tr>
</tbody>
</table>

$^{**}$Means within the column with the same superscripts are not significantly different ($P > 0.05$); n = 13.
attributed to further reaction of malondialdehyde with meat constituents such as amino groups. Formation of adducts has been shown to occur between malondialdehyde and the amino groups of amino acids or DNA molecules (Shahidi, 1992). The percentage of inhibition of oxidation (formation of malondialdehyde) with respect to control was 49 and 87% for the 5 and 15% honey-added samples after 3 d of storage. Microbial growth has been also suggested to cause increased TBA values. Phagocytic cells may initiate lipid oxidation in muscle tissue from contamination with microorganisms (Spanier, 1992) and explain the increased TBA values for

Figure 3. Redness \( (a^*) \) values during storage for 11 wk of turkey breast meat slices containing 0, 5, and 15% dry honey; vacuum-packed; refrigerated; and exposed to 1,424 ± 250 lx of continuous lighting \((n = 16)\). *\(^{*}\)Redness values with the same letter are not significantly different \((P > 0.05)\).

Figure 4. Thiobarbituric acid values of turkey breast meat slices containing 0, 5, and 15% dry honey during 11 wk of storage at 4°C \((n = 4, \text{ SEM } = 2.14, P \leq 0.05)\). **Thiobarbituric acid values within the same day with the same letter are not significantly different \((P > 0.05)\).
samples showing microbial growth. Bacteria, such as those in the *Pseudomonas* genus, which are abundant in muscle foods, can also completely destroy alka-2, 4-dienals, a group of major contributors to the TBA-absorbing species, at 532 nm and cause a decrease in TBA values (Melton, 1983). However, little bacterial growth was detected in any of the samples; therefore, bacterial growth probably had a minimal effect on TBA values in this study. In addition, the amount of added water, $a_w$, state of water in a food, and other factors influence oxidation (Nelson and Labuza, 1992). Autoxidation occurs rapidly at very low $a_w$ levels, with decreases in oxidation rates as the $a_w$ increases up to 0.4 or 0.5. At low $a_w$ levels, water acts as an antioxidant by causing hydration of the metals, reducing their catalytic activity. Hydration of lipid peroxides or their concentration at lipid-water interface also changes the mechanism of hydroperoxide decomposition and reduces the rate of free-radical formation. At high $a_w$, catalysts are more easily mobilized and possible matrix swelling exposes new catalytic sites, making oxidation rates higher than even the dry state (Labuza, 1971). The addition of honey could alter water activity, thereby indirectly affecting oxidation rate.

Headspace gas chromatography found a lower production of specific aldehydes determined in samples containing 5 and 15% honey. Hexanal significantly correlates to the oxidation rate of meat products (Shahidi, 1998). Hexanal was detected in the highest concentration of all aldehydes, which supports the findings of Antony et al. (2000). An interaction ($P \leq 0.05$) between sample and days was observed. The 15% honey-added samples showed the lowest production of hexanal through 11 wk of storage (Figure 6). There was a difference ($P \geq 0.05$) between control and 15% honey-added samples up to 7 wk of storage. There was no difference ($P \geq 0.05$) in hexanal content among treatments after 49 d of storage. Hexanal content decreased on storage with time after 1 wk. Breakdown of the specific aldehydes into smaller compounds on storage with time could be a contributing factor.

Oxidative stability indexes of samples containing 5 and 15% added honey had longer induction periods than the control samples, indicating their higher stability. The OSI times were 1.19, 7.02, and 7.69 for control, 5%, and 15% samples, respectively. The OSI was designed to measure the oxidative stability of oils and fats; however,
a modified OSI method has been developed for use with meat products (Le Gall, 1995). Mineral oil was used as a carrier for the meat samples, with mineral oil being inert and showing no increase in conductivity during the test period. Studies in our laboratory showed that though the characteristic curve found with pure oil samples is not observed with meat, differences in the slopes of the conductivity profiles for meat in the modified system can be determined. This was the case here, with the 5 and 15% honey-added meat have smaller slopes than meat with no honey added. Hettiarachchy et al. (1996) studied the antioxidative effect of fenugreek extract on ground beef patties using OSI and reported higher OSI time for treated samples. The profiles also displayed lower conductance value with time for the samples containing honey, indicating a lower production of polar compounds, resulting in lower conductivity values. Previous OSI studies on oil samples showed formic acid to be produced in significant amounts as compared with other acids such as acetic acid, caproic acid, and butyric acid. Formic acid has been shown to have a much higher effect on conductivity than acetic acid and the other acids (DeMan et al., 1987).

The presence of honey decreases the amount of oxidized off-flavor volatiles produced and strongly points to an antioxidative effect of honey in processed turkey meat. Greater stability and product quality for processed meat with added honey can lead to better consumer acceptance, benefiting the poultry meat industry.

REFERENCES


