ABSTRACT

The objective of this study was to measure the antioxidant activity of peach skin and test the antioxidant effect of peach skin powder on cooked ground turkey meat during 12 d of refrigerated storage. Antioxidant activity of 3 cultivars of peaches grown in South Carolina was first evaluated by 3 antioxidant assays. The peach variety O’Henry showed the greatest antioxidant effect and therefore was used for further study. Two levels of peach skin powder (0.5%, 1%) and 0.01% butylated hydroxyanisole (BHA) were applied to ground turkey meat. Oxidation of cooked turkey meat was measured by detection of hexanal using gas chromatography-mass spectrometry. Results indicated that all levels of peach skin powder used in this study had an antioxidant effect on ground turkey with a greater effect at the higher concentration. O’Henry peach skin powder was as effective as BHA in preventing oxidation at the levels tested.

Key words: peach skin, ground turkey, lipid oxidation, antioxidant, shelf life

INTRODUCTION

Lipids are a component of meat products related to the development of product flavor, texture, and color. Lipids can be easily degraded by oxygen, leading to a chain of chemical reactions resulting in the formation of undesirable flavors and off odors (Gray et al., 1996). Hydroperoxides formed during peroxidation decompose to secondary reaction products such as volatile aldehydes, ketones, acids, alcohols, and hydrocarbon compounds, which yield off odor and flavor (Yu et al., 2002). Shahidi and Pegg (1994) found that hexanal and pentanal were the dominant volatile aldehydes in cooked meat products resulting from oxidation.

Inhibition of lipid oxidation can increase quality and shelf life of meat products and major strategies employed to retard lipid oxidation include using antioxidants and restricting oxygen content in packages (Ahn et al., 1998; Lund et al., 2007). Synthetic antioxidants such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and tert-butyl hydroquinone (TBHQ) have been widely applied in the food industry for many yr. However, public concern about the potential toxic effects of synthetic antioxidants has resulted in a search for natural alternatives (Kahl and Kappus, 1993; Williams et al., 1999; Botterweck et al., 2000). The increasing interest in natural alternatives is reflected in 2 recent articles in Meat Science reviewing the use of plant extracts as antioxidants in meat and poultry (Karre et al., 2013; Shah et al., 2014). As discussed in these reviews, many antioxidants exist; however, their use is limited by regulations in the United States, including the Federal Food, Drug, and Cosmetic Act, Meat Inspection Act, Poultry Inspection Act, and state laws (Mikova, 2001 and Haidi and Zhong, 2005). Internationally, the European Parliament and Council Directive number 95/2/EC and Codex Alimentarius regulates use of antioxidants in food (Mikova, 2001).

Use of natural antioxidants such as extracts from rosemary (Yu et al., 2002), green tea (Bozkurt, 2006), grape (Mielnik et al., 2006), potato (Kanatt et al., 2005), cherry (Britt et al., 1998), pomegranate (Devatkal and Naveena, 2010), and citrus (Fernández-López et al., 2005) in meat products have been investigated in the past. Rosemary extract showed significant inhibition of lipid oxidation and color change in cooked turkey meat (Yu et al., 2002). Similarly, grape seed extract significantly improved oxidative stability during heating and storage of minced turkey meat (Mielnik et al., 2006). Various spices also have been tested as antioxidants in meat, including oregano (Rojas and Brewer, 2007; Rojas and Brewer, 2008). El-Alim et al. (1999) tested marjoram, clove, peppermint, nutmeg, curry, cinnamon, basil, sage, and thyme as antioxidants in raw chicken and pork.

Antioxidant activity of plant extracts is often attributed to phenolics compounds, which are in especially high concentration in the pigmented part of the plant including the skin of fruits. Various fruit extracts have been tested as antioxidants in meat, including...
plum (Lee and Ahn, 2005; Nunez de Gonzalez et al., 2008), grape seed (Rojas and Brewer, 2007; Ahn et al., 2007; Kulkarni et al., 2011), cranberry (Lee et al., 2006), and pomegranate (Naveena et al., 2008; Devatkal and Naveena, 2010). Although considerable research has been devoted to antioxidant effects of various natural antioxidants on meat products, no published research was found using peach skin in meat products. The objective of this study was to assess the antioxidant activity of peach skin and the anti-antioxidant effect of peach skin powder on cooked ground turkey meat during storage.

MATERIALS AND METHODS

Materials

Three varieties of fresh peaches grown in South Carolina, named O’Henry, Red Globe, and Scarlet Prince, were obtained from local farms for preparation of peach skin powder. Fresh ground turkey (Butterball 93% lean) was obtained from a local store the day before the start of each experiment replication. 2, 2-Diphenyl-1-picrylhydrazyl (DPPH), iron chloride hexahydrate (FeCl₃·6H₂O), Folin & Ciocalteu’s phenol reagent, 2, 4, 6-Tris (2-pyrodyl)-s-triazine (TPTZ), L-ascorbic acid, and sodium carbonate were purchased from Sigma (St. Louis, MO). Ethyl alcohol (absolute, anhydrous, ACS/USP Grade) was purchased from Pharmco-AAPER (Shelbyville, KY).

Preparation of peach skin powder samples

For each variety, 3 boxes of fresh peaches harvested in late July 2014 were used for sampling. Peach skins were knife-peeled by hand and then placed in marked sample bags, sealed, and frozen at −80°C. Then the frozen peach skin samples were lyophilized, ground into powder, packed separately by batch, and held in a desiccator until use.

Estimation of peach skin powder antioxidant activity

Antioxidant components were extracted from peach skin powder (PSP), using 50% ethanol in the ratio of 1:20 (10 g: 200 mL) based on Lim et al. (2007). Samples were first blended for 6 s, homogenized 30 s, and then exposed to ultrasonic treatment for 30 min. Moisture contents of PSP were measured using a moisture analyzer (Model HB43-S Mettler Toledo, Griefensee, Switzerland). Homogenization was performed using a model PT 10/35 polytron with a model PCU 11 power control unit (Kinematica, Switzerland). The homogenized solution was placed in an ultrasonic unit (model 5510R-DTH Ultrasonic unit [Output 42 KHz ± 6%, Branson Ultrasonics Corporation, Danbury, CT]) and extracted for 30 min at room temperature. Later, the extraction was centrifuged (Beckman Coulter Avanti J-26S XPI Centrifuge, Jersey City, NJ) at 15,008 g, 5°C for 15 min. Antioxidant activity of PSP was measured by total phenolics content assay, DPPH free radical scavenging assay, and ferric reducing antioxidant power assay.

Total phenolics content assay

Total phenolics contents of PSP were determined with Folin–Ciocalteu reagent according to the method of Singleton et al. (1999). Briefly, 0.04 mL of extract was diluted with distilled water (3.16 mL). Folin–Ciocalteu reagent (0.2 mL) was added and then mixed thoroughly. Within 8 min, 0.6 mL of Na₂CO₃ (20%) was added, mixed, and incubated for 30 min in a 40°C water bath. The absorbance was measured at 765 nm with a spectrophotometer (Model 4001/4 Genesys 20 Thermo Fisher Scientific, Waltham, MA). Results were expressed as gallic acid equivalent (GAE) (mg Gallic Acid/g dried extract).

Ferric reducing antioxidant power assay

Reducing power of PSP was determined by ferric reducing antioxidant power (FRAP) assay as described by Benzie and Strains (1996). Briefly, 300 mM acetate buffer (pH 3.6), 10 mM TPTZ in 40 mM HCl, and 20 mM FeCl₃• 6H₂O were freshly prepared. FRAP reagent was also freshly prepared by mixing acetate buffer, TPTZ, and FeCl₃• 6H₂O in the ratio of 10:1:1 at the time of use. 100 ul of each peach skin extract was mixed with 3 mL of FRAP reagent and kept at 37°C in a water bath for 4 min. The absorbance was measured at 593 nm with a spectrophotometer (Model 4001/4 Genesys 20 spectrophotometer, Thermo Fisher Scientific, Waltham, MA). The reducing power was expressed as ascorbic acid equivalent (AE-FRAP) (mg ascorbic acid/g dried extract).

DPPH free radical scavenging assay

Radical scavenging activity of PSP was measured according to the method of Molyneux (2004). Briefly, 0.4 mL of extract at various concentrations was added to 2 mL of a DPPH solution (0.2 mM in 50% ethanol) and kept for 30 min at room temperature. The absorbance was measured at 517 nm with a spectrophotometer (Model 4001/4 Genesys 20 spectrophotometer Thermo Fisher Scientific, Waltham, MA). Results were expressed as ascorbic acid equivalent (AE-DPPH) (mg ascorbic acid/g dried extract).

Preparation of ground turkey meat samples for GC-MS analysis

Fresh ground turkey meat was divided into 4 different treatments: (1) Control (fresh meat without any additives); (2) BHA (fresh meat with 0.01% BHA); (3) 0.5% O’Henry (fresh meat with 0.5% O’Henry PSP); and (4) 1% O’Henry (fresh meat with 1% O’Henry PSP). Zero g of meat was thoroughly mixed by hand for 30 s, sealed.
with Teflon septa and aluminum caps in 15 mL GC vials (9 g of meat for each vial), and then cooked at 100 °C in a water bath for 15 min. After cooking, samples were stored at 4 °C and sampled on d 0, 3, 6, 9 and 12. Each sealed vial was placed into a headspace auto sampler HP7694 (Hewlett Packard, Wilmington, DE), then the vial headspace was automatically injected into the head of HP5-MS 95% dimethyl-siloxane copolymer capillary column (30 mx 250 µm x 0.25 µm) (Agilent Technologies, Inc., Santa Clara, CA) with a flow rate of 1.5 mL/min and integrated with a gas chromatograph (HP6890 GC-MS system, Hewlett Packard, Wilmington, DE). Injected samples were initially held at 35 °C for 10 min. For the first ramp, the temperature was increased to 70 °C at 3 °C /min, then in the second ramp the temperature was increased to 190 °C at 6.5 °C /min. The GC system was equipped with mass selective detector (HP5973, Hewlett Packard, Wilmington, DE) running in an electron ionization mode. The electron multiplier voltage was 75 ev and mass range was 40 to 300 m/z. Peak integration was performed on a personal computer using HP vectra Xm software. Spectra were matched with the Wiley library and NIST library of mass spectra and subsets. (Hewlett Packard, Wilmington, DE) to identify volatiles. Peak areas were recorded for hexanal, nonanal, oten-3-ol, and octenedione and compared between treatments.

Statistical analysis

JMP Version 11 (2013) software was used to perform all the statistical analyses, using a significance level of 0.05. Student’s t test was applied to compare the mean of antioxidant activity among different varieties of PSP. Meat storage data (peak area of volatiles) were analyzed using two-way ANOVA with treatment and storage age time as main effects.

RESULTS AND DISCUSSION

Antioxidant activity of PSP

Results of all the assays showed that there is an increase of antioxidant activity after freeze-drying (Table 1). This result was consistent with McSweeney and Seetharaman (2015) in that lyophilization is an effective method for drying without loss of antioxidant activity. The higher antioxidant content of PSP compared to fresh peach skin samples may be due to the fact that these samples were lyophilized before testing, which prevents antioxidant degradation during processing and handling. Zhang et al. (2015) found that for 13 peach varieties, the skin from Scarlet Prince, Red Globe, and O’Henry varieties contained the most phenolics and displayed the highest antioxidant activity. Peach skin powder was not tested in the previous study and results from the current study found that the antioxidant activity of O’Henry PSP was significantly (P ≤ 0.05) higher than Red Globe and Scarlet Prince (Table 1). Therefore, O’Henry PSP was used for further testing on the storage of ground turkey meat.

Antioxidant effect of PSP on storage of ground turkey meat

Hexanal was used as the primary marker related to the onset of warmed-over flavor development in meat since its peak area increases more rapidly than other aldehydes during storage. The use of hexanal as an indicator of lipid oxidation in meat has been supported by several previous studies. Dupuy et. al. (1987) demonstrated the adequacy of the GC-MS method for quantitation of aldehydes and pointed out that the concentration of hexanal increased more rapidly than other aldehydes and therefore could be used as a marker of lipid oxidation while other aldehydes and ketones could be used for confirmation. Wu and Sheldon (1988) also found that hexanal is a major volatile component that increased with refrigerated storage of turkey meat. A good correlation between hexanal values and thiobarbituric acid reactive substances (TBARS) values was obtained from several previous studies (Ahn et al., 1998; Jensen et al., 1998; Wu and Sheldon, 1988; Brunton et al., 2000), which indicated that the method of measuring hexanal content was as reliable as TBARS test for evaluating lipid oxidation. While hexanal concentration was not quantitatively measured, peak area is directly proportional to concentration, and the comparison of peak area for the antioxidant treatments with the control samples (as well as among antioxidant treatments) can be attributed to differences in the rate of oxidation.

Hexanal was not detected in fresh raw ground turkey in any samples; however, after cooking 15 min in a 100 °C water bath, hexanal was detected in the meat samples having no antioxidant (Table 2). This implies that heating initiated oxidation and the production of hexanal and that oxidation was inhibited in treatments

<table>
<thead>
<tr>
<th>Variety</th>
<th>Total phenolics assay GAE mg/g dry weight</th>
<th>FRAP assay AE mg/g dry weight</th>
<th>DPPH assay AE mg/g dry weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Globe</td>
<td>17.84 ± 0.17&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>10.92 ± 0.16&lt;sup&gt;b&lt;/sup&gt;</td>
<td>17.33 ± 0.16&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Scarlet Prince</td>
<td>17.02 ± 0.26&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.71 ± 0.09&lt;sup&gt;b&lt;/sup&gt;</td>
<td>15.77 ± 0.14&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>O’Henry</td>
<td>19.87 ± 0.28&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.25 ± 0.21&lt;sup&gt;c&lt;/sup&gt;</td>
<td>20.23 ± 0.20&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Data represent the mean and standard deviation of 3 replications.

<sup>b</sup>Means in the same columns with different superscripts are significantly different (P ≤ 0.05).
The main effects of antioxidant treatment and storage time as well as the interaction of treatment and storage time, all significantly \((P \leq 0.001)\) affected hexanal peak area. Hexanal peak areas from BHA and PSP treated meat were significantly lower than for the control group. Results also indicated that the antioxidant effect of 0.1% PSP was similar to that of 0.01% BHA (Table 3). Storage period had a significant influence on the development of lipid oxidation in ground turkey meat resulting in an increase of hexanal peak area during 12 d of storage (Table 4). The interaction between treatment and storage period emphasized the importance of adding antioxidant to reduce lipid oxidation in turkey meat. Other volatile compounds such as nonanal, 1-octen-3-ol, and 2,3-octanediol also were detected during 12 d of storage. Effect of treatment and storage time on those volatile compounds is illustrated in Figure 1(a), (b), (c). Similarly, peak area increased with storage time and was reduced by the addition of BHA and PSP.

Nunez de Gonzalez et al. (2008) tested 3 and 6% dried plum puree, 3 and 6% dried plum/apple puree, and 0.2% BHA/BHT to slow the oxidation of precooked pork sausage patties. Precooked pork sausage patties treated with 3 and 6% dried plum puree, or 3 and 6% dried plum and apple puree delayed oxidation in TBARS values compared to the control (untreated) after 28 d of refrigerated (4°C) storage. Lee and Ahn (2005) reported that 3% dried plum extract inhibited the oxidation of irradiated (3 kGy) turkey breast rolls compared to turkey with no added plum extract. Yildiz-Turp and Sedaroglu (2010) reported that 0, 5, 10, and 15% plum puree added to low-fat beef patties reduced TBARS values during 48-h storage at 4°C. Aln et al. (2002) reported that grape seed extract ActiVinTM (InterHealth, Benicia, California) added at 0.05 and 0.1% to ground beef (20% fat, fresh meat basis) before cooking then held for 3 d at 4°C significantly reduced \((P \leq 0.05)\) hexanal content compared to controls and was equal to samples treated with a combination of BHA/BHT at 0.02%. Hexanal values increased \((P \leq 0.05)\) the greatest for control, rosemary- and \(\alpha\)-tocopherol-treated samples over the 3-d period. Fruits contain antioxidants and often the peel or rinds contain the greatest concentration within the fruit body since pigments are in high levels in the peel. Pomegranate peel has a variety of polyphenolic pigments including tannins, anthocyanins, and flavonoids (Neveena et al., 2008). These researchers reported that adding 10 mg tannic acid eq./10 g fresh chicken then prepared and cooked as chicken patties had 68% lower TBARS values that BHT (100 mg/100 g) over 100% lower than control samples after 15 d of refrigerated storage (4°C). An important note for the current study was that peach skin antioxidants were not extracted prior to addition to the ground turkey but the whole peach skin was freeze-dried then ground into a fine powder and added directly. This differs from many previous studies that have tested extracts of various plant sources.

### Table 2. Effect of adding peach skin powder or BHA to ground turkey meat on hexanal peak area during 12 d of storage.

<table>
<thead>
<tr>
<th>Storage time</th>
<th>Hexanal peak area (\times 10^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2.60(^a)</td>
</tr>
<tr>
<td>0.5% O’Henry PSP</td>
<td>4.86(^{b,a})</td>
</tr>
<tr>
<td>1% O’Henry PSP</td>
<td>8.51(^{a,b})</td>
</tr>
<tr>
<td>0.01% BHA</td>
<td>10.88(^{a,b})</td>
</tr>
</tbody>
</table>

\(a,b\)Means not having the same letter superscript are significantly \((P \leq 0.05)\) different.

### Table 3. Effect of adding peach skin powder or BHA to ground turkey meat on hexanal peak area during 12 d of storage.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Hexanal peak area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>18979076(a)</td>
</tr>
<tr>
<td>0.5% O’Henry PSP</td>
<td>9834594(b)</td>
</tr>
<tr>
<td>1% O’Henry PSP</td>
<td>2823837(c)</td>
</tr>
<tr>
<td>0.01% BHA</td>
<td>2597802(d)</td>
</tr>
</tbody>
</table>

\(a,b,c\)Means not having the same letter superscript are significantly \((P \leq 0.05)\) different.

### Table 4. Effect of storage time on hexanal peak area pooled for all treatments in turkey meat with added peach skin powder or BHA.

<table>
<thead>
<tr>
<th>Storage Time</th>
<th>Hexanal Peak Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 0</td>
<td>82290(^{c})</td>
</tr>
<tr>
<td>Day 3</td>
<td>5237890(^{c})</td>
</tr>
<tr>
<td>Day 6</td>
<td>8943642(^{c})</td>
</tr>
<tr>
<td>Day 9</td>
<td>13027162(^{c})</td>
</tr>
<tr>
<td>Day 12</td>
<td>15030118(^{c})</td>
</tr>
</tbody>
</table>

\(a,c\)Means not having the same letter superscript are significantly \((P \leq 0.05)\) different.

BHA = butylated hydroxyanisole.

with PSP or BHA. In raw meat, rancidity is often not detected for several wk to mo of cold storage. However with cooked meat, there is an increase in the oxidation of phosphatidyl ethanolamine and the tendency to oxidize can result in faster oxidation rates in cooked meat and occurs even during freezer storage (Pearson and Gray 1983).
CONCLUSION

Generally, application of PSP powder to cooked ground turkey meat retarded lipid oxidation during 12 d of refrigerated storage. The efficiency of antioxidant effect increased with the increased concentration used in this study. Specifically, 1% O’Henry PSP could be a natural alternative to synthetic antioxidants such as 0.01% BHA. As peach skin is regarded as a by-product of the peach processing industry, producing natural antioxidant, PSP, from this waste stream could bring economic benefit to those industries.

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Figure 1. (a) Nonanal peak area (b) 1-Octen-3-ol peak area (c) 2,3-Octanedione peak area for ground turkey meat with added peach skin powder or BHA over 12 d of storage (4 °C). Result of no peak detected was expressed as 0.
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