Moisture Loss and Lipid Oxidation for Precooked Beef Patties Stored in Edible Coatings and Films

Y. WU, J. W. RHIM, C. L. WELLER, F. HAMOUZ, S. CUPPETT, AND M. SCHNEPF

ABSTRACT: Edible/biodegradable wheat gluten (WG), soy protein (SP), carrageenan (CA) and chitosan (CH) films and coatings were used on precooked beef patties. After 3 d of refrigerated storage, no difference was found in moisture loss between WG, SP, and CH film-wrapped patties and unpackaged patties (control-A). All coatings were as effective as polyvinyl chloride film (control-B) in reducing moisture loss. CA film decreased moisture loss but not as effective as control-B. WG, SP, and CA coatings and CA film reduced thiobarbituric acid-reactive substances and hexanal values compared to control-A. WG-coated patties had lower hexanal values than control-B samples. WG, SP, and CH films were not effective in controlling lipid oxidation.

Key Words: edible/biodegradable coatings, edible/biodegradable films, precooked beef patties, moisture loss, lipid oxidation

Introduction

Precooked meat products are susceptible to lipid oxidation, which leads to rapid development of rancid or stale flavor, denoted as warmed-over flavor (WOF), during refrigerated storage (Tims and Watts 1958; St. Angelo and Bailey 1987; Love 1988). Moisture loss is a critical factor affecting the quality and shelf life of precooked meats. As consumer demand for more convenience food has grown rapidly (Hollingsworth 1994), much effort has been devoted to improving quality of precooked meat products. Among many techniques used to control the quality of precooked meats, appropriate packaging is a common solution for maintaining precooked meat quality.

Edible/biodegradable coatings and films produced from polysaccharides, proteins, and/or wax and lipid derivatives can function as efficient barriers to moisture and/or oxygen. Edible barriers are environment-friendly without the negative effects caused by nonrenewable food packaging materials (Guilbert and others 1996; Debeaufort and others 1998; Krocha and De Mulder-Jonston 1997). Therefore, they may represent methods of alternative packaging that can be used to maintain the quality and prolong the shelf life of foods. Various types of coatings and films have been tested in an attempt to maintain the quality of meat products, including fresh beef and pork (Allen and others 1963; Williams and others 1978); lamb (Lazarus and others 1976); poultry (Meyer and others 1959; Allen and others 1963); and also frozen products, such as beef (Rice 1994), pork (Wanstedt and others 1981), and fish (Stuchell and Krocha 1995; Hwang and others 1997). However, the application of edible/biodegradable coatings and films on precooked meat products has not been as extensively studied as has their applications on fresh and frozen meat products (Gennadios and others 1997). Wanstedt and others (1981) reported that alginate-coated precooked, frozen stored pork patties had improved sensory qualities and were more desirable than control patties. Lipid oxidation was inhibited and WOF was eliminated in the coated patties. Coatings of starch-alginate, starch-alginate-tocopherol, and starch-alginate-rosemary have been shown to reduce effectively WOF in precooked, refrigerated pork chops and beef patties (Hargens-Madsen and others 1993; Ma-Edmonds and others 1995; Handley and others 1996). Lipid oxidation and WOF formation were also controlled by corn zein and corn zein-tocopherol coatings in precooked, refrigerated pork chops (Hargens-Madsen and others 1993). Pork chops and beef patties in these studies were juicier than uncoated control samples as judged by sensory scores. Hernandez and others (1996) wrapped precooked turkey breast slices in corn zein films containing butylated hydroxyanisole (BHA) and reported that turkey breast wrapped in corn zein films had less WOF than samples packaged in polyvinylidene chloride (PVDC) plastic wrap. However, edible coatings of soy protein were not found to be as effective as phosphate in retarding the formation of WOF in precooked chicken breast (Kunte 1996).

This study was conducted with the objective of evaluating the effectiveness of coatings and films made with wheat gluten (WG), soy protein (SP), carrageenan (CA), and chitosan (CH) against moisture loss and lipid oxidation in precooked ground beef patties.

Results and Discussion

Apparent characteristics of coatings and films

Coatings and films made from two types of polysaccharides and two types of protein were used in this study. Table 1 shows the apparent characteristics of these coatings and films on precooked beef patties at the beginning of storage and after storage. Changes in apparent characteristics of these coatings and films after use on beef patties and being stored for 3 d at 4 °C were associated with their barrier properties as discussed below.

Relative moisture loss

After 3 d of storage at 4 °C, there was a significant treatment effect in relative moisture loss (RML) (%) of beef patties (Fig. 1). Unpackaged control-A patties exhibited the highest RML and became dry on the surface (visual observation). Significant reduction of RML by 79%, 57%, 61%, 92%, and 66% over control-A was observed in polyvinyl chloride (PVC) -packaged patties (control-B), WG, SP, CA and CH-coated patties, respectively. All coated patties had similar RML to that of control-B patties, and no visual dryness was observed in these patties. PVC is known to be effective in retarding the passage of water vapor (Brody 1997) and widely used in food service systems (Doshi 1997). The effect...
of coatings on RML, especially CA and CH coatings, which were in the form of high-moisture gelatinous coatings (Table 1), may be due to their function as moisture-sacrificing agents instead of moisture barriers, that is, the coatings gave up their moisture prior to any significant desiccation of the packaged food products (Kester and Fennema 1986). Thus, the loss of product moisture could be delayed until the moisture contained within the gel had been evaporated. CH coatings have been shown to reduce water loss and prolong the storage life of fruits and vegetables (El Ghout and others 1991a, 1991b). Alginate coatings have been reported to be effective in reducing moisture loss and improving the juiciness of fresh beef steak, pork chops, skinned chicken drumstick meat (Allen and others 1963), and lamb carcasses (Lazarus and others 1976). Precooked pork chops and ground beef patties coated with starch-alginates were juicier than uncoated samples as judged by the sensory scores (Hargens-Madsen and others 1995; Ma-Edmonds and others 1995).

As shown in Fig. 1, CH, WG, and SP film wrappings did not lower RML in patties when compared with control-A. Patties wrapped with these films had higher (p < 0.05) RML than those with coatings and the control-B patties and became dry on the surface during the storage. Due to their hydrophilic nature, films primarily composed of polysaccharides or proteins are highly sensitive to moisture and show poor water vapor barrier properties (Guilbert 1986; Kroc'h 1992; Gennadios and others 1994; Guilbert and others 1996). All film wrappings in this study, except CA film, absorbed water and slowly swelled (Table 1). Film swelling is believed to be due to the conformational changes involving structural relaxation (Slade and others 1989). These may have contributed to the observed higher RML in those wrapped samples. Interestingly, CA film did not absorb water and swell when applied to beef patties. Though they were not as effective as PVC packaging, and dryness was also observed on the surface of CA-film-wrapped patties, CA films lowered the RML in patties with a 41% reduction over control-A. In a study conducted by Hwang and others (1997), swelling of CA films was not noted when being used on mackerel mince patties, and the film did not show any ability to reduce moisture loss. Water vapor transfers through hydrophilic films by sorption and diffusion and is affected by many factors (McHugh and others 1997). Therefore, the mechanism involved in the water vapor transfer through the CA films may need to be studied further.

The effectiveness in reducing moisture loss between coating and wrapping treatments and between protein and polysaccharide treatments was compared with contrast tests. In general, coatings were significantly more effective in preventing moisture loss than wrappings, while protein materials were less (p < 0.05) effective than polysaccharide materials. This may be attributed to the different moisture transfer behaviors of the coatings and films discussed above.

Values of TBA-reactive substances

The 2-thiobarbituric acid (TBA) test has been widely used to estimate the extent of lipid oxidation in meat and meat products (Shahidi 1994). Thiobarbituric acid-reactive substances (TBARS) of patties in control-A, control-B, and patties coated or wrapped with CA, CH, WG, and SP were determined and compared as shown in Fig. 2. TBARS of PVC-wrapped patties (control-B) were 23% lower (p < 0.05) than those of control-A. This may be due to the good O2 barrier properties of PVC (Paine and Paine 1992). Different film and coating treatments in our study showed different effects in TBARS. Coating with WG, SP, or CA and wrapping with CA was as effective (p < 0.05) as wrapping with PVC in reducing TBARS, while the TBARS in WG-coated samples were the lowest. This suggests that the oxidation of precooked beef patties may be controlled to some extent with these treatments. Among the treatments tested, coating with WG may be the most effective method in controlling lipid oxidation. WG-based films are known to be good O2 barriers. Their potential use as packaging materials for perishable foods has been suggested (Gennadios and others 1993; Herald and others 1995; Park and Chinnan 1995). Reportedly, WG coatings have been applied on eggs (Herald and others 1995) and resulted in Grade A quality shell eggs maintaining quality for 30 d at room temperature. The WG coating used in our study became a visible integral film after storage (Table 1), which may contribute to its barrier properties. Soy protein films have also been found to be very effective O2 barriers (Brandenburg and others 1993). The antioxidant activity contained in soy protein preparations has been well established (Bowers and Engler 1975; Romijn and others 1991). Incrementally adding either a textured soy protein (Bowers and Engler 1975) or SP (Romijn and others 1991) into ground beef produced progressive decreases in TBA values in the cooked beef systems. Similarly, when Kunte (1996) tumbled 7S soy protein with raw chicken breast, less lipid oxidation and less WOF in the cooked chicken were detected. In the same study, however, edible coatings of 7S soy protein did not retard the formation of WOF in precooked chicken breast. The different types of soy protein, food products, and techniques for film formation used in these studies may account for the discrepancies noted between our data and those in the literature. Although carrageenan coatings or films have not been used on cooked meats, carrageenan films have been successfully used to inhibit the oxidation of fresh mackerel mince patties as measured by peroxide values and TBA.

Table 1—Apparent characteristics of coatings and films of wheat gluten (WG), soy protein (SP), carrageenan (CA) and chitosan (CH) on precooked beef patties at the beginning and after 3-d storage

<table>
<thead>
<tr>
<th>Coatings/films</th>
<th>Appearance on patties at the beginning of storage</th>
<th>Appearance on patties after 3-d storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>WG-coatings</td>
<td>sticky gel</td>
<td>visible film</td>
</tr>
<tr>
<td>SP-coatings</td>
<td>sticky gel</td>
<td>visible gel-like film</td>
</tr>
<tr>
<td>CA-coatings</td>
<td>solidified clear gel</td>
<td>invisible film</td>
</tr>
<tr>
<td>CH-coatings</td>
<td>solidified clear gel</td>
<td>invisible film</td>
</tr>
<tr>
<td>WG-film</td>
<td>translucent dry film</td>
<td>swelled gel</td>
</tr>
<tr>
<td>SP-film</td>
<td>transparent dry film</td>
<td>swelled gel</td>
</tr>
<tr>
<td>CA-film</td>
<td>transparent dry film</td>
<td>not swelled</td>
</tr>
<tr>
<td>CH-film</td>
<td>transparent dry film</td>
<td>transparent dry film</td>
</tr>
</tbody>
</table>

Fig. 1—Relative moisture loss of precooked beef patties not packaged (A), packaged in polyvinyl chloride (B), and packaged in edible/biodegradable coatings and films of wheat gluten (WG), soy protein (SP), carrageenan (CA) or chitosan (CH) after 3 d of storage at 4°C. Letters a through e indicate relative moisture loss means are significantly different (p < 0.05).
Coating with CH or wrapping with CH, WG, or SP did not significantly reduce TBARS when compared with control-A. All these treatments had higher (p < 0.05) TBARS than control-B. No significant differences were found among these treatments. A higher O₂ permeability may contribute to the higher TBARS from these treatments. After being applied on patties and during the 3 d of storage, the CH, WG, and SP wrappings absorbed moisture from meat samples and swelled (Table 1). The plasticizing effect of water molecules may have changed the barrier properties of the edible films (Gontard and others 1996; Krochta 1997) and resulted in higher O₂ permeability and even loss of film integrity. The composition of the CH film might also contribute to its higher O₂ permeability. Chitosan is water-insoluble but is readily soluble in dilute organic acid (Rodriguez-Sanchez and Rha 1981). Formic acid was used as solvent to form CH film in our study. Formic acid was used as solvent for the production of CH films (Hosokawa and others 1999; Butler and others 1996) but acetic acid CH film has a strong vinegar flavor, which probably would prevent them from being used in edible films (Rhim and others 1998b). With their gas semipermeable properties (Nisperos-Carriedo 1994), CH coatings have been reported to be effective in retarding and prolonging storage life of tomatoes, cucumbers, bell pepper fruits, and fresh strawberries without affecting their ripening characteristics (El Ghaouth and others 1991a, 1991b). CH by itself has been shown to have chelator antioxidant activity in cooked ground beef to inhibit WOF when mixed with the meat samples (St. Angelo and others 1988). However, they were not effective, as shown in our study, when they were applied on the meat surface as coatings or films.

Generally, coatings may be more (p < 0.0511) effective in reducing TBARS than wrappings in the present study: Edible coatings of alginate (Wanstedt and others 1981) and starch-alginate (Hargens-Madsen and others 1995; Ma-Edmonds and others 1995; Handle and others 1996) were reported to be effective in reducing TBA values or TBARS in precooked frozen stored pork patties (Wanstedt and others 1981), precooked, refrigerated stored pork chops (Hargens-Madsen and others 1995; Handle and others 1996) and beef patties (Ma-Edmonds and others 1995). Corn zein coatings also resulted in lower TBARS for precooked pork chops than uncoated control after 6 and 9 d of refrigerated storage (Hargens-Madsen and others 1995).

Moreover, there was a trend showing a significant (p < 0.0609) difference in TBARS between protein treatments and polysaccharide treatments in our study, implying that protein treatments may be more effective in reducing TBARS than those of polysaccharides. This may be attributed to the better O₂ barrier properties of protein films, in general (Krochta 1997).

Hexanal value

Hexanal has been shown to be one of the dominant volatile products of oxidized lipid that contributes to the WOF (Shahidi and others 1987; St. Angelo and others 1987; Shahidi 1994). The hexanal value of all treatments was varied depending on the type of packaging used in the present study (Fig. 3). Similar to those results for TBARS, coating with CH, and wrapping with CH, WG, or SP did not significantly reduce hexanal values when compared with control-A, which had the highest hexanal value. No significant differences were found between CH, WG, and SP wrapping treatments. However, coating with WG, SP, or CA and wrapping with CA significantly decreased hexanal values in the patties. Among these four treatments, CA and SP coating and CA wrapping resulted in similar hexanal values as the PVC packaging, while CA wrapping gave rise to a higher (p < 0.05) hexanal value than PVC. The hexanal value of the WG-coated patties was even lower (p < 0.05) than that of the PVC-wrapped patties, suggesting WG coating may be more effective in controlling lipid oxidation and WOF than the plastic PVC.

The effectiveness of edible films and coatings in inhibiting the formation of hexanal and the development of WOF in precooked meats has been reported when applying starch-alginate coatings on pork chops (Handle and others 1996) or beef patties (Ma-Edmonds and others 1995) and using corn zein films with butylated hydroxytoluene (BHT) to wrap turkey breast (Herald and others 1996). The corn zein films used in the study of Herald and others (1996) were demonstrated to be even more effective than polyvinylidene chloride wrapping in reducing the formation of hexanal. However, films without BHT were not tested in their study. Results from our study showed that coatings, in general, were significantly more effective than films in retarding the formation of hexanal. There was also a trend showing that protein films may be better O₂ barriers than polysaccharide films. The average hexanal values of...
protein treatments were significantly lower than that of polysaccharide treatments.

Conclusions

Coatings were more effective in controlling RML than wrappings. Coating with WG, CA, or SP and wrapping with CA was effective in controlling lipid oxidation, with WG coating being the most effective. These coatings and films afford potentials as oxygen barriers for precooked meat products. Further research needs to be conducted on edible/biodegradable films to improve moisture barrier properties and the application of such films on food products.

Materials and Methods

Materials

The following materials were used: wheat gluten, (DO-PEP; ADM Arkady, Olathe, Kan., U.S.A.); soy protein isolate (Supro 620; Protein Technologies International, St. Louis, Mo., U.S.A.); chitosan (minimum 85% deacetylated; Sigma Chemical Co., St. Louis, Mo., U.S.A.); κ-carrageenan (Hankook Cabbage Industry, Soon Chun, Chonnam, Korea); ammonium hydroxide, formic acid, glycerin, and sodium hydroxide (J.T. Baker Inc., Phillipsburg, N.J., U.S.A.); ethyl alcohol (USP 95% to 98% proof; McCormick Distilling Co. Inc., Weston, Mo., U.S.A.); thiobarbituric acid, butylated hydroxytoluene (BHT), and hexanal (Sigma Chemical Co., St. Louis, Mo., U.S.A.); potassium chloride (Fisher Scientific, Pittsburgh, Pa., U.S.A.); and polyvinyl chloride (PVC) food wrap film (Nugget Distributors Inc. Stockton, Calif., U.S.A.).

Preparation of coatings and films

WG film-forming solutions were prepared using the formula of Gennadios and others (1993). WG (10 g) was dispersed in a solution of 95% ethanol (48 mL) and glycerin (4 g) by heating and stirring on a magnetic stirrer/hot plate and slowly adding 32 mL distilled water and 8 mL of 6N ammonium hydroxide. The end point of the dispersion was visually determined by a significant decrease in solution viscosity when the temperature of the solution was 75 to 77 °C. Films prepared using this method had a thickness of 0.078 to 0.124 mm and a WVP value of 4.57 to 5.09 g mm/m² d KPa (Rhim and others 1996). The solution was then heated to boiling (about 100 °C) to dissolve the components on a magnetic stirrer/hot plate until the solution became clear. Films prepared using this method had a thickness of 0.047 to 0.059 mm and a WVP value of 22.03 to 190% proof; McCormick Distilling Co. Inc., Weston, Mo., U.S.A.;) and polyvinyl chloride (PVC) food wrap film (Nugget Distributors Inc. Stockton, Calif., U.S.A.).

CA was effective in controlling lipid oxidation, with WG coating being the most effective. These coatings and films afford potentials as oxygen barriers for precooked meat products. Further research needs to be conducted on edible/biodegradable films to improve moisture barrier properties and the application of such films on food products.

Relative moisture loss (RML)

Moisture content of samples was determined using AOAC standard method 950.46 (AOAC, 1990). Duplicate 2-g samples were oven-dried at 102 °C for 18 h. Samples were then cooled in a desiccator to room temperature and reweighed. Moisture content was determined on cooked samples before and after storage for 3 d at 4 °C. RML (%) was calculated as:

\[ \text{RML} \% = \left( \frac{\text{initial MC} - \text{final MC}}{\text{initial MC}} \right) \times 100 \]

2-Thiobarbituric acid (TBA) test

The TBA test was conducted on day 3 of refrigerated storage using the method of Tarladgis and others (1960) as modified by Pikul and others (1984). BHT was added during sample preparation. Malondialdehyde (MDA) and other aldehydes in the precooked beef patties were measured and reported as values of thiobarbituric acid-reactive substances (TBARS) in units of MDA/kg sample. Duplicate 10-g samples were analyzed.

Headspace gas chromatographic (HS-GC) analysis

An analysis of volatiles was performed using the HS-GC method developed by Handle and others (1996) and modified by Wu and others (1998) with a Tekmar 7000 headspace autosampler (Cincinnati, Ohio, U.S.A.) attached to a Hewlett Packard gas chromatograph (Model 5890; Avondale, Pa., U.S.A.).
U.S.A. equipped with a fused silica capillary column (30 m × 0.230 mm inner diameter, 1.00 µm film, DB-5; J & W Co., Fol- som, Calif., U.S.A.) and a flame ionization detector. Triplicate 6-g samples were analyzed. The sample was sealed in a 22-mL glass headspace vial with a sample phase fraction of 0.5 and equilibrated at a platen temperature of 120 °C for 15 min in the headspace autosampler.

The degree of lipid oxidation was measured as the peak area for hexanal using a Hewlett Packard integrator (Model 3396A; Avondale, Pa., U.S.A.). Hexanal was identified by comparing the retention times with hexanal standards obtained from Sigma Chemical Co. (St. Louis, Mo., U.S.A.).

Statistical analysis

Data were analyzed as a randomized complete block design with 8 treatments and 2 controls (1 negative control and 1 positive control). Three replications were completed, with each rep- lication representing a block and beef patties as the replicated experimental units. All data collected were subjected to analysis of variance. The General Linear Model Procedure developed by Statistical Analysis System (SAS Institute Inc. 1985) was used to compute means, standard deviations, and contrast analysis. Fisher’s protected least significant differences was calculated to indicate differences among mean values. Unless otherwise stated, the significance level was accepted at p < 0.05.

References


Hollingsworth P. 1994. Processed foods have moved to center stages in the competition to be the world’s food. Food Processing. 55 (7):61-62.


