Moisture Loss and Lipid Oxidation for Precooked Ground-Beef Patties Packaged in Edible Starch-Alginate-Based Composite Films

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ABSTRACT: Edible films of starch-alginate (SA), starch-alginate-stearic acid (SAS), SA-tocopherol, SAS-tocopherol, tocopherol-coated SA film, and tocopherol-coated SAS film were evaluated for their effectiveness in maintaining quality of precooked beef patties stored at 4 °C. Patty weight loss, moisture loss, 2-thiobarbituric acid-reactive substances value, the formation of hexanal, pentane, and total volatiles of samples differed with film composition. SAS-based films were more effective (P < 0.05) in controlling moisture loss than lipid oxidation. Tocopherol-treated films were more effective (P < 0.05) in inhibiting lipid oxidation than nontocopherol films. Most of the tested edible films were not as effective as polyester vacuum bags in retarding moisture loss and lipid oxidation.

Key Words: edible films, tocopherol, precooked meat, moisture loss, lipid oxidation

Introduction

The demand for precooked, refrigerated, or frozen ready-to-eat meat products in expected to increase in both the retail sector and the public catering food-service sector as a result of changed consumer attitudes towards convenience foods (Mielche and Bertelsen 1994; Hollingsworth 1994). Meat flavor deterioration (MFD), formerly described as warmed-over flavor (WOF) (Tims and Watts 1958; St. Angelo and Bailey 1987; Love 1988), limits sensory quality and influences the shelf life of these products. MFD, an overall increase in off-flavor notes and a loss in desirable meat flavor quality, occurs rapidly after cooking and during storage as a result of both lipid oxidation and the deterioration of the inherent desired meat flavor of cooked meat products (Spanier and others 1988). Moisture changes in precooked meat products, as in many other types of foods, can also have adverse effects on their texture, wholesomeness, and saleability (Kester and Fennema 1986; Rockland and Nishi 1980).

Edible films prepared from polysaccharide, protein, and lipid materials may serve as oxygen and/or moisture barriers and can be used to maintain food quality (Guilbert 1986; Gennadios and Weller 1990; Koelsch 1994; Guilbert and others 1996; Krocha and De Mulder-Johnston 1997; Miller and Krocha 1997). Composite polysaccharide-lipid films, in emulsion or laminated forms, combine structural integrity and oxygen-barrier characteristics of polysaccharide films with moisture-barrier properties of lipid films (Kamper and Fennema 1984a, 1984b, 1985; Kester and Fennema 1989a; Hagenmaier and Shaw 1990; Koelsch and Labuza 1992; Wong and others 1992; Debeaufort and others 1993; Park and others 1994; Sapru and Labuza 1994; Callegarin and others 1997). Most of the edible polysaccharide-lipid films reported in the literature have been methylcellulose (MC) and hydroxypropyl methylcellulose (HPMC)-based films. MC and HPMC films are good oxygen and moisture barriers, but information on their application to foods has been limited.

Edible films and coatings preserve fresh and frozen meat products and have been summarized in several review papers (Gennadios and others 1997; Baker and others 1994; Debeaufort and others 1998; Krocha and De Mulder-Johnston 1997). However, less work has been done on precooked meat products. The use of alginate coating (Wanstedt and others 1981), starch-alginate coating (Handley and others 1996; Hargens-Madsen and others 1995; Ma-Edmonds and others 1995), and corn-zein coating (Hargens-Madsen and others 1995) to inhibit lipid oxidation and the formation of WOF in precooked meats has been reported. Recently, Wu and others (2000a) demonstrated that coating with wheat gluten, soy protein, carrageenan, or chitosan reduced moisture loss in precooked beef patties. Also, coating with wheat gluten or soy protein and both coating and wrapping with carrageenan effectively retarded lipid oxidation in the patties. There has been no published work to date with respect to the application of edible composite polysaccharide-lipid films on precooked meat products.

Besides their barrier properties, edible films and coatings can act as carriers for functional food additives such as antioxidants (Cuppert 1994). Tocopherols have been incorporated into gelatin films, starch-alginate, or acetylated-monoglyceride (AMG) coatings and used to protect margarine from lipid oxidation (Guilbert 1988), to retard the formation of WOF in precooked pork chops (Hargens-Madsen and others 1995), and to delay the oxidative rancidity of walnuts (Mate and Krocha 1997), respectively. Ascorbyl palmitate has also been added to AMG coatings to inhibit the oxidative rancidity of walnuts (Mate and Krocha 1997). Rosemary oleoresin, an oleoresin extract of spice with antioxidant activity, has been added into starch-alginate coatings to inhibit the lipid oxidation and WOF development in precooked pork chops (Handley and others 1996) and beef patties (Ma-Edmonds and others 1995). Whey-protein-isolate coatings with antioxidatnts (citric acid and ascorbic acid) overspray delayed the onset of lipid oxidation and reduced the peak peroxide values in frozen king salmon (Stuchell and Krocha 1995). A corn-zein film with butylated hydroxyanisole (BHA) has been reported to control the lipid oxidation in precooked turkey breast (Herald and others 1996).
In a previous study (Wu and others 2000b), a starch-alginatesteearic acid composite film was found to have lower water-vapor permeability than the control starch-alginate film. This research studied the effect of film type on moisture loss and lipid oxidation from precooked ground-beef patties. Film types were starch-alginate (SA), starch-alginatesteearic acid (SAS), SA-tocopherol (SAT), SAS-tocopherol (SAST), tocopherol-coated SA (SATC) film, and tocopherolcoated SAS (SASTC) film. The ability of SA and SAS films to carry and distribute tocopherols on patty surfaces was also evaluated by comparing the reduction in lipid oxidation among edible film treatments.

Materials and Methods

Materials

The following materials were used in the study: modified starch (CstarEmCap 0637; Cerestar USA Inc., Hammond, Ind., U.S.A.); sodium alginate (Kelco Division of Merck and Co., Rahway, N.J., U.S.A.); glycerin (Mallinckrodt Baker Chemical, Phillipsburg, N.J., U.S.A.); stearic acid, thioctinurate (20% w/w of starch and alginate). A SAS-film emulsion was prepared by adding stearic acid (20% w/w of starch and alginate) into the SA-film solution with lecithin (30% w/w of fat acid). These film solutions and emulsions were heated, boiled at 78°C with stirring. SAT and SAST films were prepared by adding mixed tocopherols (2% w/w of total solution or emulsion) into the cooled (40°C) SA solution and SAS emulsion with additional lecithin (30 w/w of mixed tocopherols). Each type of film solution or emulsion was then homogenized using an Ultra-Turrax T25 homogenizer (Janke & Kunkel GMBH & Co. KG, Stauken, Germany) at 9,500 rpm for 2 min, strained through 8-layered cheesecloth (grade 40; Fisher Scientific, Pittsburgh, Pa., U.S.A.), and poured onto a leveled Teflon-coated glass plate (21 cm x 35 cm). Film thickness was controlled by casting volumes of solutions having the same amount of solids (8.82 g) onto each plate. Films were allowed to dry at ambient conditions for about 24 h. Then they were peeled from the plates.

SATC and SASTC films were prepared by coating mixed tocopherols (2 g) on dried SA and SAS films before use to package meat samples. The tocopherols mixture was coated on the film surface facing the meat sample by spreading with a glass rod. The amount of tocopherols mixture in either emulsified or coated films was about 0.004 to 0.005 g/cm².

After films were ready to be used as packagings, they were folded and sealed to form bags. Since films with stearic acid were heat sealable (Wu and others 2000b), they were heatsealed using a heat sealer (Model 150. P-5, Packaging Aids Co., San Rafael, Calif., U.S.A.). Films without stearic acid were sticky sealed using the SA-film solution as the sealing glue. All bags had a size of 15 cm x 16 cm and an opening for inserting meat samples.

Meat Sample Preparation and Packaging Application

Ground-beef patties (20% fat), obtained from a local supermarket, were grilled on each side for approximately 4 min on a flat Hobart griddle (Model HG-4, Troy, Ohio, U.S.A.) set at 171 °C to an internal temperature of 71°C. After cooking, the patties were blotted and put into plastic bags, cooled to 0°C with ice, and immediately transferred into the film bags. Film packages were then evacuated with a vacuum pressure of 7 kg/cm² using a vacuum pump (Model L-79200; Thomas Compressors & Vacuum Pumps, Sheboygan, Wis., U.S.A.) attached with a vacuum tube on which a modified polyethylene transfer pipette was connected and either heat sealed or sticky sealed as described above. Packed meat samples were immediately refrigerated (4°C) and stored for 6 d. Two controls were used in this study: control-A, patties without packaging and control-B, patties packaged in polyester (PET) vacuum bags (Kapak Co., Minneapolis, Minn., U.S.A.), which were evacuated and heat sealed as were the stearic-acid-containing film bags. Patty weight loss, moisture loss, and lipid oxidation were analyzed at 0, 2, 4, and 6 d storage. Analyses on d 0 were performed within 2 h of initiation of storage.

**PWL**

PWL was determined by subtracting the patty weight after storage (PWAS) from the patty weight before storage (PWBS) and was calculated as:

\[
PWL (%) = \frac{(PWBS) – (PWAS)}{PWBS} \times 100\%
\]

**RML**

Moisture content (MC, wet basis) of samples was determined and calculated using AOAC standard method 950.46 (AOAC 1990) with some modifications. Duplicate ground samples (2 g each) were oven dried at 102°C for 18 h. Samples were then cooled in a desiccator to room temperature and reweighed. MC was determined on cooked samples before (d 0) and after storage for 2, 4, and 6 d at 4°C. RML was calculated as:

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

**TBARS Test**

The TBARS test was conducted during refrigerated storage using the method of Tarladgis and others (1960) as modified by Pikul and others (1984). BHT was added during sample preparation. Malonaldehyde (MDA) and other aldehydes in the precooked beef patties were measured and reported as values of TBARS in unit of MDA/kg sample. Duplicate samples from each patty were analyzed.

**Headspace Gas Chromatographic (HS-GC) Analysis**

Volatile analysis 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.) equipped with a fused silica capillary column (30 m x 0.320 mm inner dia, 1.00 μm film, DB-5; J & W Co., Folsom, Calif., U.S.A.)
U.S.A.) and a flame ionization detector. A 6-g sample was sealed in a 22-mL glass headspace vial with a sample phase fraction value of 0.5 and equilibrated at a platen temperature of 120°C for 15 min in the headspace autosampler. Duplicate samples from each patty were analyzed, and BHT was added during sample blending.

The degree of lipid oxidation was measured as the peak area counts for pentane, hexanal, and total volatiles using a Hewlett Packard integrator (Model 3396A, Avondale, Pa., U.S.A.). Pentane and hexanal were identified by comparing the retention times with standards obtained from Sigma Chemical Co.

Experimental Design and Statistical Analysis

The study used a randomized complete block design with storage time (d) as repeated measurements. Three replications were done with each replication representing a block and beef patties subjected to each treatment as the replicated experimental units. The General Linear Model procedure in the SAS program (SAS Institute Inc. 1990) was used to compute means from 3 replications (blocks) and contrast analysis. Fisher’s protected least significant differences were calculated to indicate differences among treatment mean values. Significance was accepted at a level of $P < 0.05$.

Results and Discussion

PWL and RML

After 0, 2, 4, and 6 d storage at 4 °C, PWL and RML of different treatments of precooked beef patties were compared (Figure 1 and 2). In general, PWL and RML for all treatments over the 6-d storage period showed similar changing patterns. The 2 variables were highly associated with a correlation coefficient of $r = 0.85$ and were affected by the change of moisture content in samples during storage.

As shown in Figure 1, patty weight of control-A (without any packaging) decreased over time more than 25%. It was visually noticeable that the samples gradually became drier from the patty surfaces to their centers. In contrast, the PWL in control-B patties (packaged with PET vacuum bags) was maintained at less than 0.3%, which was the lowest value among all treatments, and no visual dryness was observed throughout the storage time. This may be attributed to the excellent moisture-barrier property of the PET film (Newton 1997; Paine and Paine 1992).

Patty weight of samples packaged in the edible films decreased during storage, and the sample surfaces became drier (visual examination) to some extent over the 6-d storage period. However, with the stearic-acid film and tocopherol-treated packagings, beef-patty samples lost weight over time slower than samples without packaging or packaged in SA film (Figure 1). In general, the patty weight-loss pattern of edible film treatments varied depending on the film compositions. The more hydrophobic material such as stearic acid and tocopherol that was incorporated into the film, the slower the weight loss in film-packaged patty samples.

Repeated measurement on d effect revealed a significant interaction between d and treatment effects for PWL, indicating that the treatment effect on PWL behaved differently over time. When compared to the control-A, all edible films significantly reduced the PWL of samples on d 2, 4, and 6, with the exception of SA-film treatment on these d and SAT treatment on d 4 (Figure 1). SA films, like other films made from hydrophilic materials (Guilbert 1986; Gennadios and others 1994; Wu and others 2000a), absorbed moisture from samples and swelled during storage, which resulted in their loss of structural integrity and may have contributed to the high PWL and dryness in SA-film-packaged samples.

The addition of stearic acid into SA film significantly reduced PWLs in SAS, SAST, and SASTC film packaged samples during storage when compared to SA film, although light swelling was still observed in SAS and SAST films. The significant effectiveness of stearic acid was even shown in d 0 samples after 2 h of storage (Figure 1). In a previous study (Wu and others 2000b), SAS films were found to have lower water solubility and water vapor permeability than SA films. Several polysaccharide-lipid films have been shown to be effective moisture barriers when applied on brownies (Greener and Fennema 1989) and some multicomponent food products (Rico-Pena and Torres 1990; Kamper and Fennema 1985; Kester and Fennema 1989b; Fennema and others 1990).

The addition of tocopherols into SA and SAS films significantly decreased PWL as evidenced in SAT-film-packaged samples on d 2 and 6 and SAST, SASTC, and SATC-film packaged samples on all d when compared to nontocopherol films. Tocopherol-coated SA or SAS films were more effective in retarding PWL than films with tocopherols incorporated into them. Among tocopherol-treated edible films, SASTC was the best in controlling PWL. Tocopherols with their fat-soluble nature may improve the moisture-barrier property of the films. The higher PWL in SAT and SAST may be attributed to the plasticizing effect of the incorporated lipids including stearic acid and tocopherol oil mixture (Callegarín and others 1997). Generally, plasticizers reduce inter-

![Figure 1—Patty weight loss of precooked beef patties not packaged (C-A); packaged in polyester vacuum bags (C-B); and packaged in edible films of starch-alginates (SA), starch-alginates-stearic acid (SAS), SA-tocopherol (SAT), SAS-tocopherol (SAST), tocopherol-coated SA (SATC), or tocopherol-coated SAS (SASTC) during 6-d storage at 4 °C. Means within different ellipses are different ($P < 0.05$).](image-url)
molecular forces and produce an increase in the moisture permeability of edible films (Guilbert 1986; Gennadios and Weller 1990; Callegarin and others 1997). The type and quantity of plasticizers in edible films are of importance to the barrier and mechanical performance of films (Gennadios and Weller 1990).

Although the SA-lipid composite films in this study exhibited some effectiveness in limiting PWL, they were not as effective as the PET plastic bags (Fig. 1).

Generally, the changes of PWL in edible film treatments differed depending upon the film composition and the method of adding tocopherols. Table 1 shows the results of contrast analysis between different edible film treatment groups. Over the 6-d storage period, SAS-based films significantly lowered the PWL (Figure 1); tocopherol-treated films were more effective in lowering PWL than nontocopherol films, with tocopherol coating being the most effective.

A significant d x treatment interaction was also found for RML. As shown in Figure 2, no significant difference in RML between treatments was found on d 0, and the addition of fatty acid into SA films reduced RML, but only on d 2. Also, on d 4 and 6, all film treatments reduced RML independent of film composition when compared to control-A. The RML for all treatments except for control-B increased over the storage period (Figure 2). The overall RML in this study seems less sensitive than PWL to the packaging composition (Table 1) and was better controlled by using edible films. The PWL resulted from the patty surface moisture loss, while RML indicated patty internal moisture change.

### TBARS Values

TBA test is widely used for measuring the extent of oxidative deterioration of lipid in muscle foods (Melton 1983; Shahidi 1994). Figure 3 shows that freshly cooked and packaged beef patties had the lowest TBARS values, and TBARS values increased over the 6-d storage in all treatments. TBARS value in control-B patties, however, increased much slower than that in other treatments.

In terms of TBARS formation, the treatment effect was different across different storage times as indicated by a significant d x treatment interaction. No significant differences were found between treatments on d 0 (Figure 3). PET vacuum bags (control-B) exhibited an excellent gas-barrier property for the cooked patties, as TBARS produced in the control-B samples were lowest among all treatments on d 2, 4, and 6. On d 2, SAT, SATC, and SASTC films decreased TBARS formation when compared to the control-A, while films of SA, SAS, and SAST showed no effect. There were no significant differences found between edible film treatments and control-A as well as between edible film treatments on d 4 and 6.

Apparently, increasing the hydrophobicity of the film
through the incorporation of stearic acid into the SA films
did not help to control the lipid oxidation of the cooked
meat. The structural integrity of these films may still be af-
fected by the hydrophilic nature of the film matrix, and
hence, the barrier property of the films may have changed.
Wong and others (1992) studied chitosan-lipid films and re-
ported that the diffusion rate of gases was not greatly affect-
ed by hydrophobicity of the film but depended mostly on
the matrix.

In the present study, a waxy-paper-like appearance was
visually noted for SAS-based films, such as SAS and SAST
films. These films were not as strong as SA-based films and
were easily bent during handling. This may be related to the
lipid plasticizer effect as discussed previously. Waxy appear-
ance and decreased tensile strength and percentage elonga-
tion at break in soy-protein/fatty-acid composite films have
been observed by Rhim and others (1999). In general, lipid
films lack the structural integrity of protein or polysaccha-
ride films as evidenced by decreased tensile or puncture
strength of films (Krochta 1992; Gontard and others 1995).
Weakened mechanical strength of fatty-acid composite films
may also affect their structural integrity and thus their gas-
barrier property. As a result of film swelling and mechanical
strength weakening, loss of the vacuum was also visually not-
ed in some of these edible film packagings during the later
storage periods, which may explain the similar TBARS values
for all treatments on d 4 and 6.

Table 1 shows the contrast analysis for tocopherol treat-
ments against nontocopherol treatments and tocopherol-in-
corporation treatments against tocopherol-coating treat-
ments. The overall tocopherol effect was significant on d 2
independent of the application method, suggesting that SA-
and SAS-based films were good carriers for the antioxidant,
and tocopherols were effective in reducing TBARS formation
no matter how they were added to the films. The lower
TBARS values in samples packaged in SAT, SATC, and SASTC
films may be due to the improved barrier properties, or
more to the antioxidant activity of tocopherols. Hargens-
Madsen and others (1995) reported that tocopherols de-
creased TBARS values in SAT- and corn-zein-tocopherol-
coated precooked pork chops on d 9 of refrigerated storage
when tocopherols were incorporated into the SA- and corn-
zein-coatings. Tocopherols were reported to be as effective
as tertiary butyl hydroquinone (TBHQ) in decreasing
thiobarbituric-acid numbers and retarding lipid oxidation in
restructured beef systems over 12-mo frozen storage
(Crackel and others 1988).

Volatile Analysis

Hexanal (Figure 4), pentane (Figure 5), and total volatile
compounds (Figure 6) from the beef patties were measured
and compared. Hexanal is 1 of major products of linoleic-
acid oxidation and has been used as an indicator of lipid ox-
idation since it correlated very well with WOF (Shahidi 1994).
Among all treatments in the present study, polyester packaged control-B, as expected, kept hexanal production quite stable and lowest during the storage period. For the unpackaged control-A and all edible film treatments, hexanal values rose over time as shown in Figure 4.

An interaction of storage d x treatment was found for the hexanal values. No significant differences in hexanal values existed among treatments on d 0 (Figure 4). Hexanal formation in control-A samples was highest among all treatments on d 2 but not on d 4 and 6. The changing pattern of hexanal during later storage periods may be due to the further oxidative breakdown of hexanal into other oxidative products (Loliger 1990; Shahidi 1994). Herald and others (1996) observed hexanal content of cooked turkey was less in samples stored 3 d than for those stored 1 d.

As shown in Figure 4, all edible film treatments, except for SA and SAS treatments, had lower hexanal values than control-A on d 2. The hexanal value in SASTC treatment was even as low as that in control-B. The overall tocopherol effect was significant on d 2 as shown in Table 1. On d 4, SAT- and SASTC-film packaging resulted in less hexanal in samples than the control-A and other edible film treatments but higher than the control-B. However, the tocopherol effect was lost by d 6 (Figure 4). All tocopherol treatments had similar hexanal values on all d (Table 1), and no differences in hexanal values were found between SAS-based films and SA-based films.

A loss in film integrity as discussed above may have contributed to the higher hexanal values in SA- and SAS-packaged samples. SA and SAS films seemed to act as good antioxidant carriers, but their carrier property could be affected by the film structural integrity, thus influencing the effect of tocopherol-treated films during later storage periods. The breakdown of hexanal in control-A at the later stage of the storage may also affect the treatment effect during those time periods. The use of edible coatings/films as carriers for antioxidants to retard hexanal production has been reported in several studies. Mate and Krochta (1997) used AMG coating with tocopherols and/or ascorbyl palmitate to delay the oxidative rancidity and reduced hexanal in walnuts. Precooked turkey breast wrapped in a corn-zein film with butylated hydroxyanisole (BHA) had decreased hexanal content and WOF after 3-d storage (Herald and others 1996). Reduced hexanal values and WOF were also found in SA-rosemary-oleoresin-coated precooked pork chops (Handley and others 1996) and beef patties (Ma-Edmonds and others 1995) over 9-d storage.

Pentane is another volatile marker of lipid oxidation (Seo and Joel 1980) and may be a more reliable measure of oxidation than the aldehydes due to its inert short-chain hydrocarbon structure, which does not undergo any further reactions (Loliger 1990). Pentane was the major volatile identified in each of the samples in this study. This agreed with the findings of Handley and others (1996) and Ma-Edmonds and others (1995). As shown in Figure 5, pentane increased in all treatments except in control-B after 6-d storage. The in-
crease of pentane in patties of SAST and SASTC treatments, however, was much slower than in those of control-A and other film treatments. These results suggest that tocopherols may be effective in controlling the formation of pentane over time.

The above finding was further confirmed by the multiple comparisons of the treatment effects within each testing d. Again, a d x treatment interaction existed for pentane in beef patties. As shown in Figure 5, no significant differences were found among treatments on d 0. Patties packaged with SAT, SATC, and SASTC films retarded the formation of pentane on d 2, while those packaged with SAST, SAT, and SASTC films had lower pentane values than that in control-A on d 4. But on d 6, only SATC-, SAST-, and SASTC-film packages resulted in lower pentane values in samples than control-A. In general, tocopherol-treated films were more effective in inhibiting pentane formation than nontocopherol films no matter how the antioxidants were added to the films (Table 1). A significant effect of tocopherol-treated SAS-based films was also found on d 4 and 6 (Table 1), suggesting these 2 films may be better tocopherol carriers due to their hydrophobic nature, which is more similar to tocopherol. Pentane formation in precooked pork chops was lowered during 9-d storage at 4°C by using a coating of corn zein plus tocopherol mix as reported by Hargens-Madsen and others (1995). Edible corn zein was used as a carrier for the natural antioxidant in this study. A starch-alginate coating with rosemary, a natural antioxidant extract, had been applied on precooked beef patties and decreased the pentane values in the samples over the 9-d storage period (Ma-Edmonts and others 1995). Except for control-B, total volatiles increased throughout the 6-d storage (Figure 6). Total volatiles in all treatments generally followed the same pattern as for pentane. Correlation analysis revealed that pentane and total volatiles were highly correlated (r = 0.98). In general, tocopherol-treated films gave better protection for the beef samples from oxidation than nontocopherol films on d 2 and 4 (Table 1) with SASTC films the best, which even resulted in a total volatile value in patties as low as that found in control-B patties. No significant difference was found between the application methods of the antioxidants.

Conclusions

Edible Films Used in This Study differed in Limiting Moisture Loss and Lipid Oxidation of precooked beef patties depending upon the film composition. The barrier properties of SA films improved with the incorporation of stearic acid. Stearic-acid-based films were more effective in controlling moisture loss than lipid oxidation in precooked meat. Tocopherol-treated films, especially tocopherol-treated stearic-acid films, were more effective in inhibiting lipid oxidation than were nontocopherol films. All edible film packagings were generally not as effective as polyester vacuum bags in controlling moisture loss and lipid oxidation. Results of tocopherol film treatments suggested potential application of edible films as antioxidant carriers. Tocopherol may be either incorporated into or coated on edible films to retard lipid oxidation.

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