Packaging systems: effects on poultry product colour and other quality factors

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Poultry products packaged in transparent and translucent films deteriorate during retail display due to changes in sensitive pigments or lipids as well as microbial activity. In aerobic packages, oxidation of pigments or lipids leads to fading or discolouration and to off-odour and off-flavour development. Although modified atmosphere packaging, vacuum-skin packaging, or use of oxygen barrier films may reduce the rate of product deterioration, lighting environments at display, similar to temperature environments, will provide energy for oxidation to occur. For fresh cut-up poultry, aerobic packaging predominates with shelf life based primarily on initial microbiological quality and display temperature. Antimicrobial rinses and sprays generally have resulted in increased quality retention by delaying off-odour development and colour loss. For fresh ground poultry, modified atmosphere packaging predominates with extra days of shelf life based on use of carbon dioxide to decrease microbial outgrowth. Shelf life extension of cooked, cured poultry products depends on almost complete elimination of oxygen through application of in-film or in-package oxygen scavengers or use of appropriate oxygen-barrier films. Nitrosylhemochrome, the cured pigment, is sensitive to photooxidation and data on retail lighting displays indicate no standardization in lighting between or within stores in a particular grocery chain. Surface reflection spectra for colour of vacuum-packaged cured poultry products show loss of redness and an increase in yellowness as the oxygen transmission rate of packaging films increase. CIE colour values for surface redness (+a*) loss in displayed cured products have shown an Arrhenius-type effect for reaction rate associated with light intensity when packaged in films over a range of oxygen transmission rates. Packaging systems currently utilized and under development for poultry products must meet criteria that are based on differences in the microbial aspects of fresh versus cooked products and differences in meat pigments of fresh versus cured products.

Keywords: packaging; fresh poultry; cured products; colour; pigments; microbial quality

Introduction

The colour of packaged meat at retail display has a strong influence on a consumer's purchasing decision. For fresh poultry, it is considered an important indicator of quality (Elsner *et al*., 1997). Although visual colour may shift during display, spoilage will most likely result from aerobic bacteria outgrowth manifested by production of numerous off-odour compounds (Mead, 2004). Packaging in high oxygen permeable film generally results in higher microbial counts over time since the growth rate of bacteria under aerobic packaging conditions is faster than under anaerobic conditions. Fresh cut-up chicken (skin-on) and fresh ground chicken meat have shown slightly extended microbial shelf life with reduction in packaging film oxygen transmission rate (OTR) from >12,000 cc/m^2/24 h to 30 cc/m^2/24 h (Tsou *et al*., 1997; Dawson *et al*., 1995). Modified atmosphere packaging (MAP) involving CO_2 to decrease the rate of bacterial outgrowth is extensively used for ground poultry and skinless products (Lawlis and Fuller, 1990) and results in extended shelf life as compared to normal aerobic packaging.

The pink to pink-red colour resulting from conversion of myoglobin to nitrosylhemochrome during curing of poultry meat is viewed as an indicator of product freshness for this category of products (Issanchou, 1996). Vacuum packaging cured products to remove oxygen has been shown to maintain quality and increase shelf life. Nitrosylhemochrome, the cured meat pigment, is sensitive to light in the presence of oxygen. Barrier films having an OTR of 15-17 cc/m^2/24 h have been recommended for use in vacuum packaging (Lin *et al*., 1980; Kartika *et al*., 1998). MAP applications for cured meats may involve use of an oxygen scavenger within the barrier package in addition various mixtures of CO_2 and N_2 (as filler) atmospheres. Ultraviolet light (UV) has been reported to affect meat pigments resulting in discolouration for fresh and cured meats. Kartika *et al*. (2005) recently reported that non-filtered UV lighting from fluorescent lighting had no effect on cured colour stability of vacuum packaged slices of turkey pepperoni.

The purposes of this study are to compare aerobic, anaerobic, and modified atmosphere (MAP) packaging systems as applied to some fresh poultry products and to evaluate the effects of packaging film OTR and lighting on colour stability of cured turkey products.

Materials and methods

Fresh chicken thigh meat and chicken drumsticks were obtained on the day of processing from a regional USDA-inspected plant. Boneless thigh meat (2^{o}C) was ground and vacuum packaged in films with aerobic or anaerobic OTRs (13,800 or 16 cc/m^2/24 h, respectively). Packages were displayed at 4+2^{o}C for 12 days with 970 lux of continuous fluorescent lighting. Reflectance spectra (Spectragard II, BYK-Gardner, Silver Springs, MD) were converted to K/S using the Kubelka-Munk equation (Judd and Wyszecki, 1963) and oxymyoglobin and metmyoglobin percentages were calculated following Krzywicki (1979). The Spectragard II spectrophotometer was also used to determine CIE L*a*b* colour coordinates with illuminant C and specular component excluded.

Chicken drumsticks were packaged in films with aerobic or anaerobic OTR (7000 or <10 cc/m^2/24 h, respectively) and displayed at 3^{o}C under 1130 lux of continuous lighting for 12 days. An additional treatment of pre-rinsing of drumsticks with a saturated salt solution prior to packaging in the aerobic films was included in the study. Surface colour of exposed lean for 2 drumsticks per package were measured with a Minolta CR-300 Chroma Meter (Minolta, Ramsey, NJ) using the CIE L*a*b* space with illuminant C. At 3-day intervals in the 12 days of display total aerobic bacteria on duplicate plates were determined following the method of APHA (1992). In a separate packaging experiment, drumsticks pre-rinsed with a saturated NaCl solution or a nisin solution (5000 IU/ml) were packaged in an anaerobic film (OTR = 30 cc/m^2/24 h), displayed at 3^{o}C and evaluated for sensory odour on days 1, 4, 7, and 9. Sensory panel members previously trained in odour evaluation for fresh to spoiled chicken used a 7-point scoring system (7=normal; 1=very pronounced) (see Tsou *et al*., 1997).

The effect of CO_2 as an antimicrobial agent in combination with a high O_2 headspace in a MAP system was evaluated. Fresh, diced turkey breast meat was ground in a modified CO_2-injection grinder (at 35 psi for CO_2) and tray packaged with a MA of >90% O_2. The MAP product was displayed in light at 4^{o}C and analyzed at 2-day intervals for 6 days for surface CIE a* using the Minolta CR-300 Chroma Meter (as above) and for total aerobic bacteria (as above).

Unsliced chubs of turkey bologna processed under USDA inspection were obtained from a distributor, sliced 3 mm in thickness, and individual slices (as samples) were vacuum packaged in films having the following OTRs: 2, 6, 16, 27, and 39 cc/m^2/24 h (25^{o}C, 0% RH, 1 atm). Packages were placed under 840 lux of continuous fluorescent lighting at 4^{o}C for 12 weeks with weekly surface colour measured using the Spectragard spectrometer and the CIE L*a*b* colour space as noted above. Surface reflection was also measured initially and at the end of the 12 weeks in display.

Results and discussion

Surface reflectance spectra of ground chicken thigh meat packaged in aerobic and anaerobic films and displayed in light for 12 days at 4^{o}C are shown in *Figure 1A and 1B*, respectively. Through day 8 the doublet peak (545 and 575 nm) of oxymyoglobin (*Figure 1A*) for meat in aerobic film is evident, with doublet flattening starting to occur at day 8. As the decrease occurs for oxymyoglobin, there is an

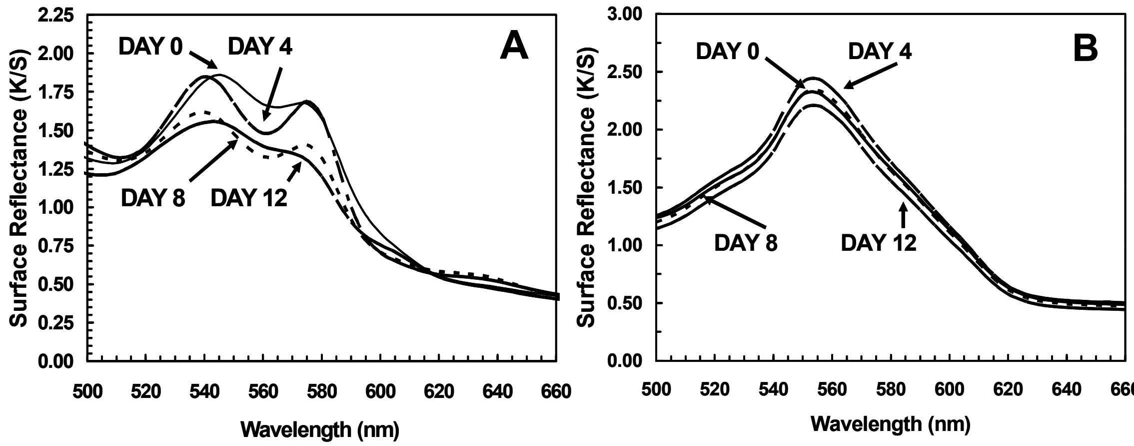

Figure 1 Surface reflection specta for ground chicken thigh meat packaged in films differing in oxygen transmission rate. A: aerobic; B: anaerobic.

emerging broad peak at 630 nm indicative of metmyoglobin formation due to oxidation of Fe++ of the pigment. For meat packaged in anaerobic film, only a singlet peak (555 nm) of native myoglobin is present (*Figure 1B*) and there is no evidence of metmyoglobin formation. As expected, proportions of the pigment interchange among oxy-, met-, and native myoglobin occurs within each packaging system. Calculated amounts of oxy- and metmyoglobin and surface CIE +a* values (redness) are given in *Table 1*. Although an increase ($P<0.05$) of metmyoglobin in meat packaged in aerobic film is

Table 1 Oxymyoglobin, metmyoglobin and surface CIE +a* (redness) of fresh ground chicken thigh meat packaged in aerobic and anaerobic films.

Days of Display	Oxymyoglobin		Metmyoglobin		CIE +a*	
	Aerobic	Anaerobic	Aerobic	Anaerobic	Aerobic	Anaerobic
0	65.2a	30.2a	26.7c	22.7a	7.7c	7.4a
2	67.1a	20.9b	31.7b	22.3ab	7.8c	7.4a
4	68.2a	16.0c	31.8b	21.0b	8.3b	7.5a
8	57.4b	14.2c	42.6a	21.3ab	9.1a	7.6a
12	43.9c	16.1c	44.3a	21.9ab	8.8a	7.4a

[a-d] Column means having the same or one of the same letters are not different ($P>0.05$).

found between days 2-4 to 8-12, CIE +a* (redness) increased to a maximum (8.8-9.1) during this period. No surface redness shift occurred for meat packaged anaerobically. No off-odour or slime production was found when packages were opened at 12 days of display indicating no observable microbial spoilage. This may have been a result of the absence of skin in the ground product.

When fresh broiler drumsticks (skin on) were packaged with aerobic film, aerobic bacteria counts between 6 to 7 $\log_{10}$ CFU/ml were attained at days 6-8 of lighted display whereas drumsticks packaged in anaerobic film were slightly less than 6 $\log_{10}$ CFU/ml at 12 days of display (*Figure 2*). Applying a NaCl solution rinse to the drumsticks prior to packaging in aerobic film delayed aerobic bacteria outgrowth ($P<0.001$) in the initial 6 days of display with counts increasing to slightly greater than 6 $\log_{10}$ CFU/ml at 12 days of display. With the delay of microbial outgrowth by use of an antimicrobial rinse, sensory odour ratings (*Figure 3*) of drumsticks toward unacceptable levels also were delayed for product packaged in the aerobic film. A nisin solution rinse provided the better odour control during 9 days of display compared to the other treatments.

Therefore, the first failure point in product quality for fresh poultry products typically packaged in aerobic systems is microbial outgrowth and any treatment that delays outgrowth aids in increasing overall product shelf life.

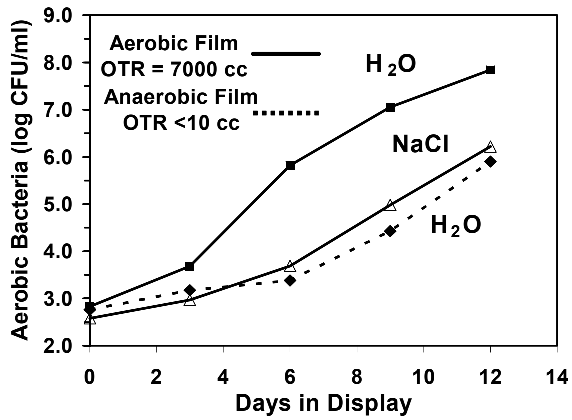

Figure 2 Aerobic bacteria counts for chicken drumsticks from water or sodium chloride solution rinses followed by packaging in aerobic or anaerobic films differing in oxygen transmission rate.

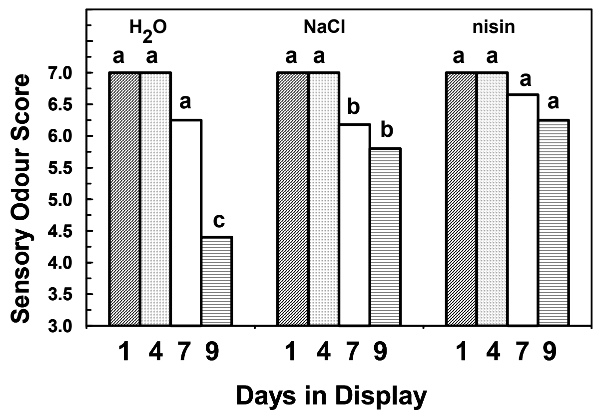

Figure 3 Sensory odour scores for chicken drumsticks from water or sodium chloride or nisin solution rinses followed by packaging in aerobic film. Means within a rinse with the same letter are not different (P<0.05).

The inhibitory effect of CO_2-injection grinding to promote dissolution at low temperatures during maximum tissue surface area exposure resulted in decreased aerobic bacteria counts for ground turkey meat patties during 6 days of display in high O_2 MA packages (*Table 2*). In the first 2 days of display,

Table 2 Days of display and grinding treatment effects on total aerobic bacterial counts (log $_{10}$ CFU/gm) in the three layers of the ground turkey meat patties packaged in high O_2 modified atmosphere.

Days of Package Display	Ground in CO_2			Ground in Air		
	Top	Middle	Bottom	Top	Middle	Bottom
0		3.25c			3.36de	
2	3.65d	3.82d	3.75d	4.45c	4.53c	4.61c
6	5.34b	5.55b	5.62b	6.44a	6.51a	6.37a

[a-e] Means with the same letter or letters are not different (P>0.05).

there was an increase (P<0.05) in total aerobic counts for both meat ground in CO_2 and non-CO_2 ground meat although the increase was less (P<0.05) with CO_2 present. Also, from day 0 to day 6, bacterial counts increased in all layers of the patties at a faster rate for meat ground in air versus CO_2. No layer effect on bacterial counts occurred. Surface CIE +a* (redness) remained more stable in the patties from turkey meat ground in CO_2 compared to patties prepared with meat ground in air (*Table 3*). The redness of the turkey breast meat patties was much less than that expected for ground beef or poultry thigh meat due to the lower concentration of pigment present to form oxymyoglobin.

Table 3 Surface CIE +a* (redness) for ground turkey meat patties packaged in high O_2 and displayed for 6 days.

Treatment	Days of Display			
	0	2	4	6
Ground in CO_2	5.96a	4.33b	4.33b	2.55c
Ground in Air	4.98b	5.01b	2.94c	1.47d

[a-d] Means with the same letter do not differ (P>0.05).

Loss of appearance factors such as colour and presence of in-package purge has a more significant role in determining product shelf life of cooked, cured poultry products. Microbial spoilage develops very slowly due to cooking in or after packaging. Survival of pathogenic species becomes a major concern as these products are marketed "ready-to-eat". The most popular packaging systems currently in use for cooked and cured poultry are vacuum-packaging and modified atmosphere packaging.

The red-to-pink cured colour of sliced turkey bologna is expected by consumers when selecting packages from retail display. An increase in the OTR (2 to 39 cc/m^2/24 h (at 25^{o}C, 1atm, 0% RH)) of packaging films results in an increased (P<0.001) rate of loss of desired surface redness as measured by CIE +a* (*Figure 4*).

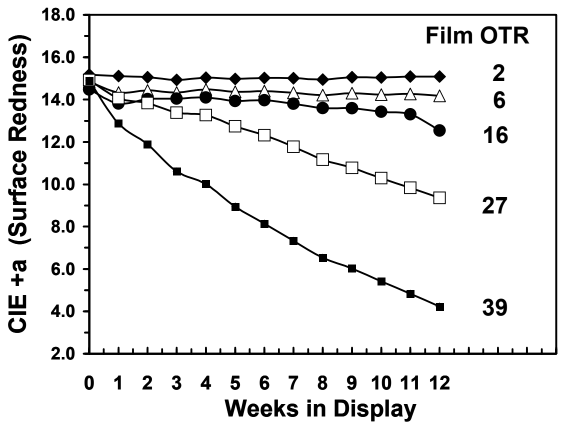

Figure 4 Surface redness (CIE +a*) of sliced turkey bologna vacuum packaged in films varying in oxygen transmission rate (OTR: cc/m2/24 h) and displayed in fluorescent lighting.

Light intensity increase also contributes to nitrosylhemochrome loss and the rate of CIE +a* decline follows an Arrhenius type response similar to temperature effects on reaction rates. For the turkey bologna shown in *Figure 4*, surface reflectance confirms the loss of redness (640-700 nm) and an increase of yellowness (550-600 nm) (*Figure 5*).

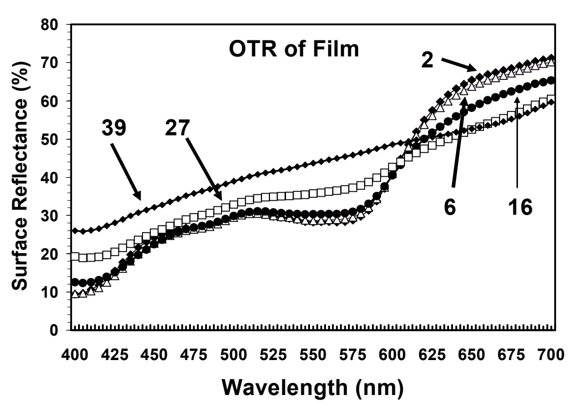

Figure 5 Percent surface reflectance of sliced turkey bologna packaged in films varying in oxygen transmission rate (OTR: cc/m^2/24 h) and displayed in fluorescent lighting.

The extent of discoloration for cooked, cured poultry products is almost directly proportional to the oxygen concentration that diffuses into the package thus promoting nitrosylhemochrome oxidation. The oxidation is accelerated with increasing light intensity and the result is termed "colour fading" in cured meats since the resultant appearance is tan-to-grey to light grey.

Fresh and cured poultry products, while having differing criteria for packaging in relation to oxygen, initially depend on processes that decrease or limit bacterial presence, followed by maintenance of an appealing visual appearance, primary of which is product colour.

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