Broiler Skin and Meat Color Changes During Storage

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ABSTRACT The importance of poultry skin and meat color (both absolute and variations in color) in the market place have been well established. It has also been reported that these colors change over time. With the development of computer-assisted vision grading systems, the changes in skin and meat color during and after processing have become important, based on calibrations and assessment values based on color. Four independent experiments were conducted to determine the pattern of color change in broiler skin and meat during processing and storage. Skin color change was measured on subscald (57 C) and semiscald (50 C) breast skin surfaces and on breast and leg meat, on the carcass and following deboning and packaging. A reflectance colorimeter was used to determine lightness (L*), redness (a*), and yellowness (b*) at 20-min intervals for the first 3 h, at 30-min intervals between 3 and 8 h, hourly between 8 and 12 h, and daily up to 8 d postmortem. Results clearly show that color values for both skin and meat changed dramatically for the first 6 h postmortem, after which the changes were less pronounced. The skin from semiscalded birds showed less change than the skin from subscalded birds. These results indicate that on-line vision systems need to take into account the dramatic changes in skin and meat color during the first 6 h postmortem, after which the color changes may be less important.

(*Key words*: skin color, breast meat color, color change during storage)

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INTRODUCTION

The color of poultry carcasses and poultry meat products are important sensory characteristics by which consumers often base product selection and judge quality. Broiler skin color and turkey and broiler meat colors are influenced by numerous live production, handling, and processing factors as reviewed by Fletcher (1989, 1999a) and Froning (1995).

In recent years, the concept of computer-assisted vision and monitoring systems for carcass assessment (for both inspection and grading), as well as meat quality assessments, has been proposed and undergone various degrees of development and application in the meat and poultry industries (Hale, 1994; Swatland, 1999). Some of these technologies are based heavily on surface color assessments, such as those using video image technology and light reflectance properties of the carcass or meat surface to identify quality defects, to sort products, or to orient products for further processing. Barbut (1993) developed a fiber optic method to identify pale, soft, and exudative meat in turkey muscle, based on light scatter. Santé et al. (1996) developed two statistical models to predict color modification of turkey breast meat.

Scalding temperature affects broiler skin color. Graf and Stewart (1953) demonstrated that scalding at 54 C left the epidermal layer of skin (cuticle) intact, and the birds retained a good, uniform yellow color. Broilers scalded at 60 C lost the cuticle during picking and had a bleached appearance.

Dietary xanthophyll pigments deposited in the epidermis are primarily responsible for skin color (Punnet, 1923). Although the biological and processing factors affecting skin pigmentation and consumer acceptance are well documented (Fletcher, 1989), the short- and long-term color changes during processing and storage are not well documented.

Factors affecting poultry meat color and changes that occur during further processing and storage are better documented than those for skin color changes. Variations in raw broiler breast meat color in consumer packages have been reported by Fletcher (1999b). The fact that poultry meat color changes during storage is well established. Numerous papers in the past 2 yr have reported changes in turkey and broiler breast meat colors, as measured at various times postmortem (Le Bihan-Duval et al., 1999; Alvarado and Sams, 2000; Mallia et al., 2000; Owens et

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Abbreviation Key: a* = redness; b* = yellowness; E* = color difference; L* = lightness.

al., 2000a,b,c; Owens and Sams, 2000; Qiao et al., 2001). Although these differences have been reported, most are related to changes between distinct points in time (e.g., 2 and 24 h postmortem) or for only the first 24 or 48 h postmortem.

The purpose of this research project was to measure the change in broiler skin and meat color continuously on a short-term basis (first 12 h) and on a long-term basis during storage every 24 h for an additional 7 d. Emphasis was placed not on actual or absolute color values, because so many factors could affect these values, but rather on evaluation of the magnitude and pattern of color change (i.e., differences in color values during storage).

MATERIALS AND METHODS

Source of Birds and Meat

For each of four experiments, commercially reared market age broilers of mixed sex were obtained from the live bird holding area of a commercial processing plant. The birds were cooped and transported (about 15 min) to the pilot processing plant at the Poultry Science Department, University of Georgia. Birds were killed via conventional unilateral hand-cutting of the jugular vein and the carotid artery and were bled for approximately 2 min.

Experiment 1

After slaughter, 10 broilers were semiscalded at 50 C for 2 min in a pilot-scale batch scalder to allow retention of the epidermis (cuticle) and were then picked in a rotary drum batch picker for 25 s. The non-eviscerated carcasses were chilled in an ice and water mixture and then held, covered with ice, until 8 d postmortem. Skin color measurements were made on the pectoral feather tract and on the pectoral apterium (the area between the pectoral and sternal feather tracts).

Experiment 2

Twelve broilers were processed in the same manner as described for Experiment 1 except that the scalding temperature was 57 C for 90 s (subscalding) to allow for removal of the epidermis. Otherwise, carcasses were handled and color was measured exactly as previously described for Experiment 1.

Experiment 3

Twelve broilers were processed as previously described for Experiment 1. However, before chilling the skin was loosened over the right side of breast to allow for direct color measurement on the breast surface (pectoralis major). The skin over the right thigh was also loosened to allow for direct color measurement on the leg muscle (quadriceps femoris). Between color readings, the skin was placed back over the meat, and the carcass was covered with ice.

Experiment 4

Twelve broilers were processed as previously described for Experiment 1. However, before chilling, the breast fillet and thigh (bone in) were removed from the right side of each carcass, the skin was removed, and the meat was placed in plastic bags. Meat color was measured on the medial surface (bone side) of each breast fillet (pectoralis major) and on the exposed thigh surface (quadriceps femoris). Color was measured through the plastic material to simulate retail display of the meat and to reduce surface drying or color changes due to moisture evaporation from the surface or color changes due to excessive exposure to moisture during holding.

Color Measurement

Color measurement was performed using a Minolta[2] Chromameter CR-300 using illuminant source C and color expressed in terms of CIE values for lightness (L*), redness (a*), yellowness (b*), and color difference (E*). The colorimeter was calibrated throughout the study using a standard white[3] ceramic tile. In Experiment 4, calibration was performed by first placing the standard white tile inside the same plastic bag used to store the meat to negate the color and light reflectance properties of the packaging material. Color difference (ΔE*) is calculated by the colorimeter as follows: $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$; the values of ΔL*, Δa*, and Δb* are the difference in color between the calibration tile and the sample. As such, ΔE* is a nondirectional composite color difference estimate and should not be confused with the subsequent color data transformations.

For skin and meat surface color measurements, areas were selected that were free from obvious defects (bruises, discolorations, hemorrhages, full blood vessels, picking damage, or any other condition that might have affected uniform color reading). These areas, once selected, were marked on the surface such that the same skin or meat surface area was used for repeated color measurements over time. For Experiments 1 through 3, because the birds were held covered with ice, the surfaces of the skin and meat were gently blotted with an absorbent towel to remove excess surface moisture prior to color analyses.

In each of the four experiments, color was determined every 20 min for the first 3 h postmortem, every 30 min between 3 and 8 h postmortem, hourly between 8 and 12 h postmortem, and once a day between Days 1 and 8 (24 to 192 h). The raw color values for L*, a*, and b*, as well as color difference, E*, were transformed to color changes over time, or delta (Δ) as follows:

[2]Minolta Corp., Ramsey, NJ.
[3]Reference number 1353123, Y = 92.7, x = 0.3133, and y = 0.3193.

$$\Delta L^* = L^*_1 - L^*_2$$
$$\Delta a^* = a^*_1 - a^*_2$$
$$\Delta b^* = b^*_1 - b^*_2$$
$$\Delta E^* = E^*_1 - E^*_2$$

where L^*_1, a^*_1, b^*_1, and E^*_1 represents the initial color readings measured at 20 min postmortem, and L^*_2, a^*_2, b^*_2, and E^*_2 represent color parameters measured at each subsequent experimental time. Since many factors can influence the absolute color of skin and meat, the Δ transformations were used to evaluate the patterns in color change, as opposed to determining absolute color differences.

Statistical Analyses

Means and standard errors or the means of the transformed delta values were calculated using the Proc Means option of SAS software (SAS Institute, 1988). The means were determined for each lot of birds within the experiment. The means and standard errors were plotted by experiment for the first 12 h and the 8 subsequent d, as were color difference values (Δ), lightness (L*), redness (a*), yellowness (b*), and color difference (E*) using Sigma Plot[4] Scientific Graphing Software.

RESULTS

The data are presented for each of the four experiments by change in color (Δ) for lightness (ΔL*), redness (Δa*), yellowness (Δb*), and color difference (ΔE*) in Figures 1 to 4, respectively. In each figure, the measurements from Experiment 1 are for semiscalded skin color, Experiment 2 for subscalded skin color, Experiment 3 for intact breast and leg meat color on the carcass, and Experiment 4 for deboned and packaged breast and whole thigh (bone in) meat color and are presented from top to bottom. Note that the y-axes are not on the same scale between experiments within a figure or between figures.

For the first 12 h, lightness values increased, as indicated by positive slopes for the ΔL* values, for all of the skin and meat samples evaluated. Lightness values increased for skin samples regardless of scalding treatment or skin surface location (i.e., color measured on or off the pectoral feather tracts). Lightness increased at a greater rate on the feather tracts, as opposed to the areas between the feather tracts in Experiments 1 and 2. It should be noted that the degree of lightness change was roughly twice that for the subscalded birds in Experiment 2 as compared to the semiscalded birds in Experiment 1. From 24 to 192 h (Days 2 to 8), the L* values for the semiscalded birds in Experiment 1 were relatively stable, but for the subscalded birds in Experiment 2 L* values continued to increase.

Lightness increased for the meat samples in Experiments 3 and 4 during the first 12 h. However, the breast meat lightness was approximately three fold greater in Experiment 3 for the first 12 h than in Experiment 2, and the dark meat was only about 50% lighter for each respective experiment. It is very interesting to note that lightness values continued to increase from 24 to 192 h in Experiment 3 while they decreased during the same time period in Experiment 4.

The changes in skin and meat redness values (Δa*) are illustrated in Figure 2. The magnitude and pattern of a* change was similar for the semi- and subscalded birds, regardless of sampling location in Experiments 1 and 2. For the first 12 h postmortem, there was little change in redness, as exhibited by Δa* values, but for 24 through 192 h, the Δa* values steadily decreased. In Experiments 1 and 2, the magnitude of Δa* ranged from −1 to +1.5, indicating a relatively stable color.

The breast and thigh meat color from the intact carcasses (Experiment 3) exhibited a steady decline in Δa* values throughout the times measured (Figure 2). For the packaged meat (Experiment 4) the thigh a* values were relatively constant during the first 12 h, after which they gradually increased from 24 to 192 h. For the breast meat Δa* in Experiment 4, the values showed no real trend for the first 12 h postmortem, but from 24 to 192 h they tended to decrease.

The change in skin and meat yellowness values (Δb*) is shown in Figure 3. For the semiscalded birds in Experiment 1, there was a pronounced increase in yellowness values from the feather tract area for the first 12 h, after which the change was relatively constant. For the color read between the feather tracts, Δb* was consistent for the entire sampling time (20 min to 192 h). For the subscalded birds from Experiment 2, there was little difference between the sampling locations, on or between the pectoral feather tracts, until approximately 96 h postmortem when the color differences began to diverge.

The Δb* for the breast and thigh meat in Experiments 3 and 4 were very similar during the first 12 h postmortem, during which the values tended to decrease and then plateau at about 3 to 4 h postmortem (Figure 3). From 24 to 192 h, the trends for breast and thigh meat Δb* were similar, with the only exception being the greater relative increase in b* values for the intact breast meat in Experiment 3.

The results for the change in color difference (ΔE*) are presented in Figure 4. The patterns of data represented in Figure 4 are almost identical to those presented for lightness in Figure 1. Because E* represents a single, nondirectional (absolute number) composite color change calculated from the original L*, a*, b* values, it would be expected to be most affected by the magnitude of difference of the color value (L*, a*, or b*) that has the greatest contribution (please refer to the description of E* calculation as described in the Materials and Methods section). As lightness values are so much greater than redness or yellowness, it is not surprising to observe a very strong resemblance between the ΔL* results (Figure 1) and the ΔE* results (Figure 4). This comparison explains why L* values have long been recognized as the most important

[4]Sigma Plot-Scientific Graphing Software, Version 2.0, SPSS Science, Chicago, IL.

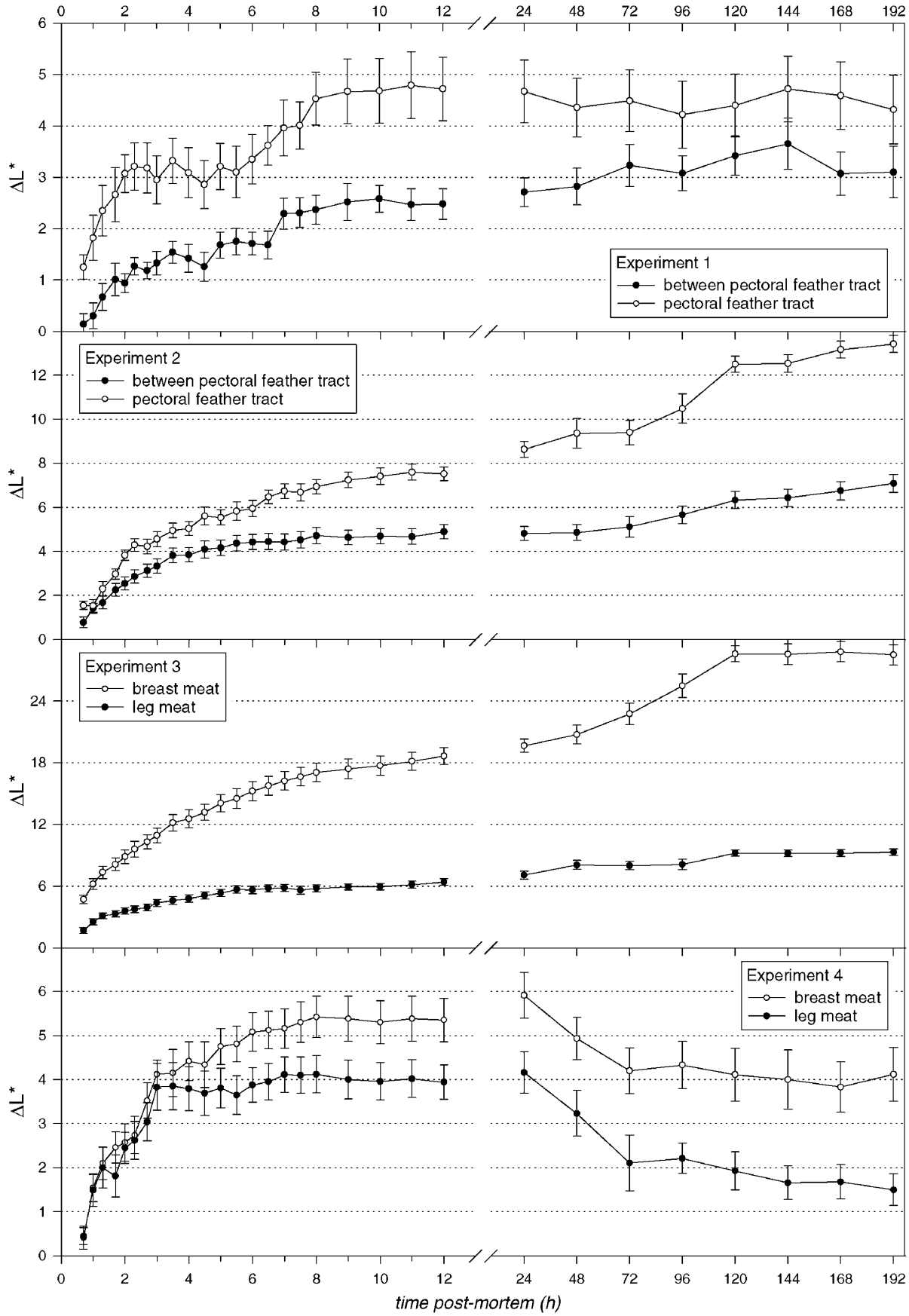

FIGURE 1. Differences in lightness values (ΔL*) between samples taken at 20 min postmortem and those measured at 20-min intervals for the first 3 h postmortem, 30-min intervals between 3 and 8 h postmortem, hourly between 8 and 12 postmortem, and daily between 1 and 8 d for color on and off the pectoral feather tracts of semiscalded birds (Experiment 1), on and off the pectoral feather tracts of subscalded birds (Experiment 2), breast and leg meat on the carcass (Experiment 3), and breast and leg meat in packages (Experiment 4).

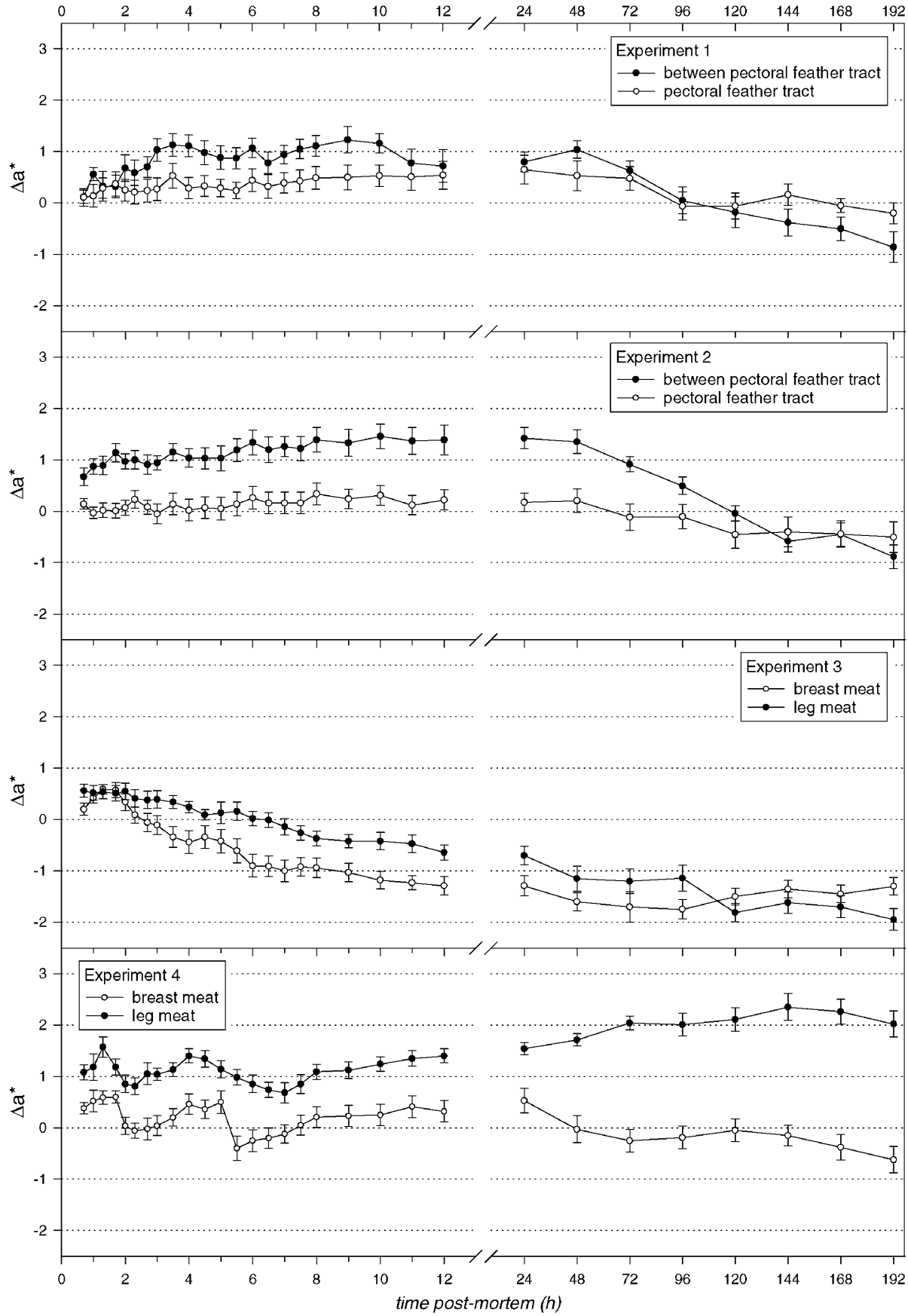

FIGURE 2. Differences in redness values (Δa*) between samples taken at 20-min postmortem and those measured at 20-min intervals for the first 3 h postmortem, 30-min intervals between 3 and 8 h postmortem, hourly between 8 and 12 postmortem, and daily between 1 and 8 d for color on and off the pectoral feather tracts of semiscalded birds (Experiment 1), on and off the pectoral feather tracts of subscalded birds (Experiment 2), breast and leg meat on the carcass (Experiment 3), and breast and leg meat in packages (Experiment 4).

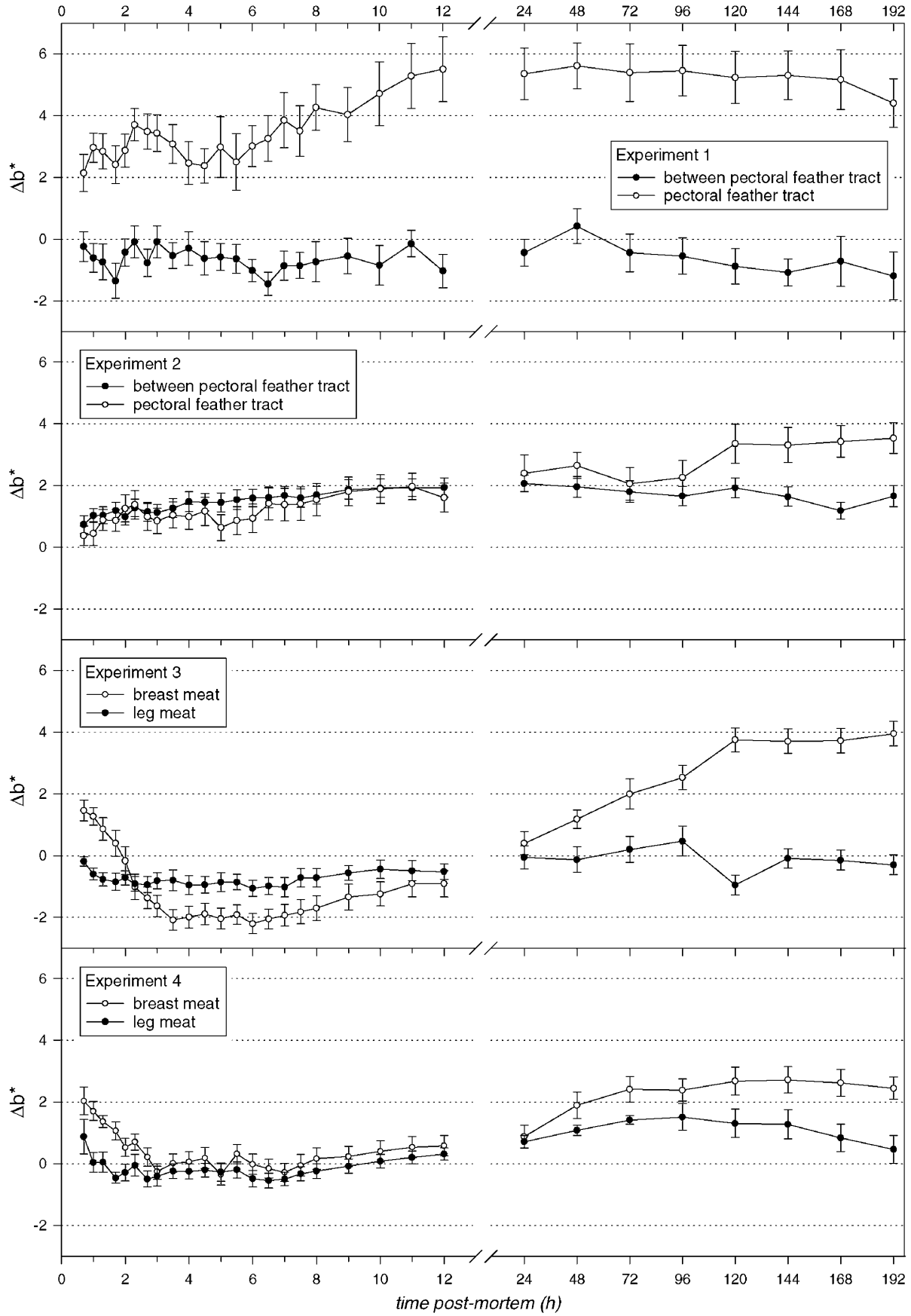

FIGURE 3. Differences in yellowness values (Δb*) between samples taken at 20 min postmortem and those measured at 20-min intervals for the first 3 h postmortem, 30-min intervals between 3 and 8 h postmortem, hourly between 8 and 12 postmortem, and daily between 1 and 8 d for color on and off the pectoral feather tracts of semiscalded birds (Experiment 1), on and off the pectoral feather tracts of subscalded birds (Experiment 2), breast and leg meat on the carcass (Experiment 3), and breast and leg meat in packages (Experiment 4).

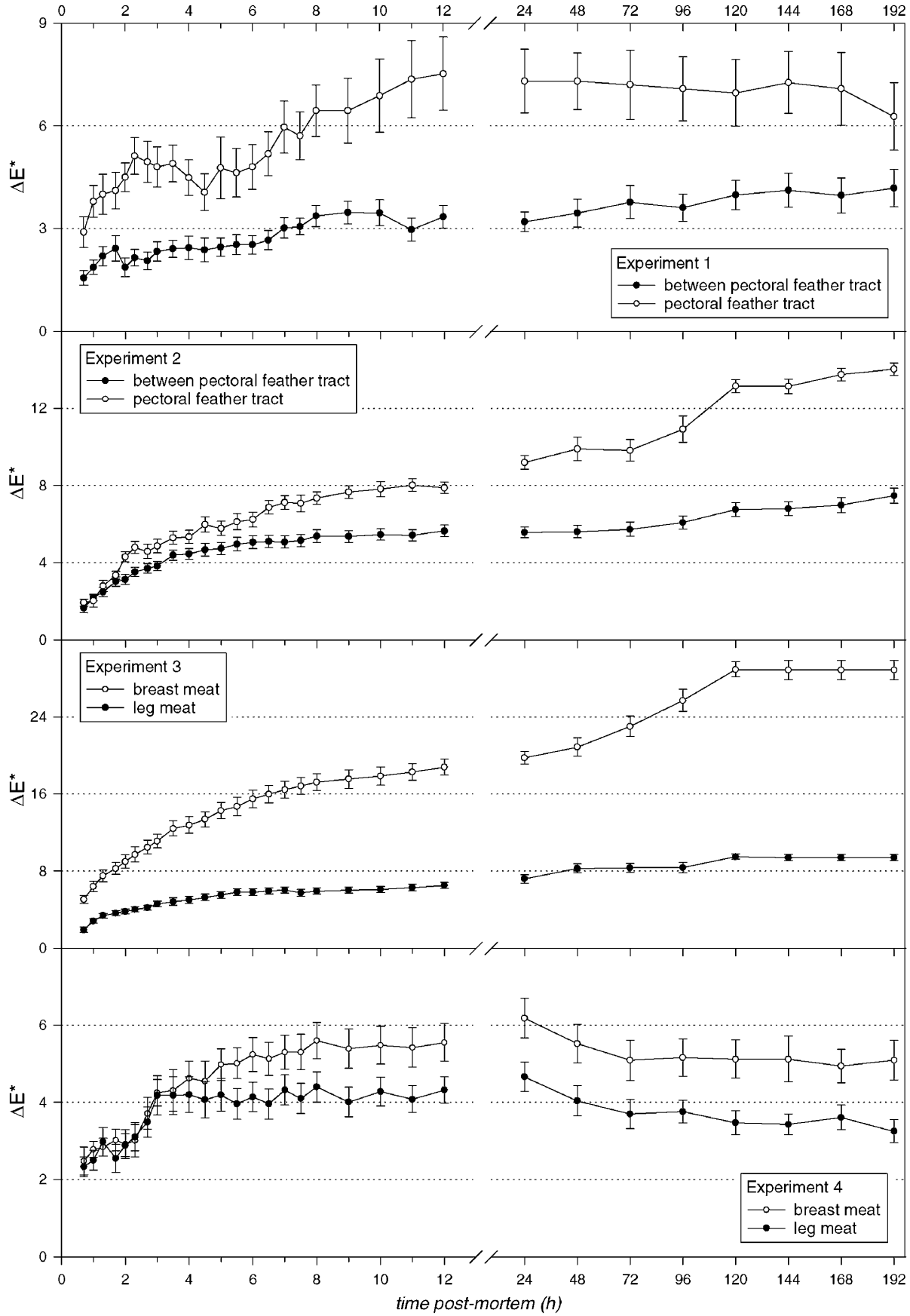

FIGURE 4. Differences in color difference values (ΔE*) between samples taken at 20 min postmortem and those measured at 20-min intervals for the first 3 h postmortem, 30-min intervals between 3 and 8 h postmortem, hourly between 8 and 12 postmortem, and daily between 1 and 8 d for color on and off the pectoral feather tracts of semiscalded birds (Experiment 1), on and off the pectoral feather tracts of subscalded birds (Experiment 2), breast and leg meat on the carcass (Experiment 3), and breast and leg meat in packages (Experiment 4).

CIELAB value when evaluating skin and meat color and is often the only value discussed in terms of meat color.

DISCUSSION

These results have several implications regarding poultry color changes, both early changes associated with processing and longer-term changes associated with storage. It is clear from the results of skin color analyses (Experiments 1 and 2) that regardless of scalding condition or measurement location that skin color changes dramatically in the first 2 h, especially for the subscalded carcasses. The color change, primarily shifting to increasing lightness, is more pronounced in the skin area with greater xanthophyll deposition, as evidenced by differences between Experiments 1 and 2 and by differences between the areas on the skin (on or between the feather tracts, also within and between Experiments 1 and 2). Xanthophyll deposition is greater in the fatty deposits associated with the thicker skin areas of the feather tracts. The difference in magnitude of change between Experiments 1 and 2 may be due to the subscalded birds, with the cuticle removed, having a more pronounced color difference due to a combination of skin difference and the influence of the underlying tissue color changes. This may be evidenced by the similarity in ΔL* and ΔE* values (Figures 1 and 4) for the color changes measured on the skin between the feather tracts (Experiments 1 and 2) and the color changes for breast meat color (Experiment 3).

For meat color analyses, the results, especially for the breast meat samples, are in general agreement with recently published reports in which L* values increased with aging of the meat (Le Bihan-Duval et al., 1999; Alvarado and Sams, 2000; Mallia et al., 2000; Owens and Sams, 2000; Owens et al., 2000a,b,c; Qiao et al., 2001). Meat color changed dramatically during the first 4 h of processing and was greatest for the breast meat with ΔL* values approaching 12 for fillets left on the carcass (Experiment 3) and ΔL* of approximately 4 for the packaged fillets (packaged immediately following slaughter).

Similar results were also reported by Santé et al. (1996), who made color measurements on turkey breast meat at 1, 4, and 24 h, and 2, 5, and 12 d postmortem. Leg meat exhibited similar trends with increasing redness, but L* values were steady between 3 and 24 h. No major differences were reported in breast and leg meat yellowness or in breast meat redness. They reported that turkey breast redness increased until Day 2 and then decreased.

The differences in trends and magnitude of breast meat color from Experiments 3 and 4 are consistent with traditional meat-handling systems relative to the effect of moisture and oxygen on meat lightness (Experiment 3, in which the meat was not protected from excess moisture or oxygen during storage, and Experiment 4, in which the packaged meat was protected from extraneous moisture and was at least partially protected from air). Instrumental screening of breast meat to reduce color variations that may affect further processing will need to account for the rapid breast meat color change and effects of meat handling on these color changes.

In summary, these results indicate that skin and meat color change dramatically, especially during the first 4 h, while the carcasses are still in the processing plant. After 4 h, the colors continue to change but at a slower rate up to 12 to 24 h postmortem. Skin and meat color changes that occur during storage (from 1 to 8 d postmortem) are variable and depend on processing or holding conditions. These results clearly show that vision systems used during processing need to account for these rapid color changes. The effects of these color changes during storage are less critical but are still important for possible effects on product uniformity and consumer acceptance.

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