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Factors Influencing Color Development in Beef

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Color development over time in beef carcasses is affected by chill length, fat thickness and hot carcass weight. Ultimate color can be accurately predicted after 9-12 minutes.

Summary

Use of color in an objective beef carcass grading system would require accurate color measurement soon after ribbing. Color development of 118 beef carcasses was followed with a portable colorimeter in two commercial slaughter facilities with different (24 and 42-48 hour) chill periods before grading. Redness (a) and yellowness (b*) were estimated with a negative exponential growth model. Linear regression models were used to predict lightness (L*). Color development was influenced by chill time, fat thickness, and hot carcass weight. Lightness was highly variable, while ultimate a* and b* can be accurately predicted after 9-12 minutes.*

Introduction

Implementing carcass sorting systems which use an objective measurement of muscle color to augment current USDA quality grade measurements requires the accurate prediction of ultimate (90 min) color. In commercial slaughter facilities, an estimate of ultimate muscle color must be determined while muscle color is still developing. A determination of factors which influence color development (bloom) over time in beef is therefore required.

The objectives of this study were to determine effects of chilling time, fat thickness, and carcass weight on beef color development and to determine how quickly after ribbing ultimate color could be predicted in carcasses varying in quality grade.

Procedure

The time course of color development (bloom) in ribbed beef carcasses was followed by measurement of L*, a*, and b* with a colorimeter. These are points within a three-dimensional color space which objectively define a specific color. They indicate lightness (L*), redness (a*), and yellowness (b*). Color was determined with a HunterLab Miniscan™ XE Plus Tristimulus colorimeter with a 1-inch port, using illuminate A and 10° standard observer. Carcasses were selected from two slaughter facilities with different carcass chilling lengths prior to grading (plant A, 24 hour and plant B, 42-48 hour), resulting in different internal loin temperatures (40°F and 34°F, respectively). A total of 59 carcasses were studied at plant A, and 39 carcasses at plant B. A second set of carcass data (n=20) was also collected at plant A after an extended, 48 hour weekend chill period. This extra chill time resulted in lower internal loin temperatures (34°F).

Carcass selection was based on a grid which included hot carcass weight (<700 lb or >800 lb), 12th rib fat thickness (<0.4 in or >0.7 in), and quality grade (Select, low Choice, or upper 2/3 Choice). The right sides of the tagged

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carcasses were ribbed normally, while left sides were unribbed. Carcass marbling scores were determined by USDA quality graders after a normal bloom period (10-20 min). Carcasses were then railed off in groups of 10 and left sides were ribbed at one minute intervals by plant personnel until all ten carcasses within the set were ribbed. Color measurements were determined 0, 3, 6, 9, 12, 15, 20, 30, 45, 60, and 90 minutes after ribbing. Two color measurements were averaged, one on each end of the rib-face surface of the *longissimus*. Carcass 12th rib fat thicknesses measurements were measured by University of Nebraska personnel with a fat probe, and internal loin temperatures were determined using a small diameter thermocouple attached to a digital thermometer.

As meat pigments absorb oxygen from the air, meat becomes lighter, redder, and yellower (less blue). A negative exponential growth model was used (Figure 1) to describe the time course of changes in a* and b* for each individual animal. (In the case of L*, the non-linear regression model had a poor fit and a linear model was fit.) Then, we evaluated the effects of chill time, carcass weight, fat thickness, and quality grade on the characteristics of the curves: intercept at time 0, shape (slope) of the response curve, and the ultimate color (asymptote). An estimate of goodness of fit (approximate R^2) of the predicted model with actual raw data was calculated from correlation analysis. This approach allowed us to predict the color development curve; therefore, color measurements taken at a known time after ribbing can be used to predict ultimate color characteristics.

The variation in each color characteristic decreased as meat pigments bloomed. In an attempt to determine the earliest appropriate time for color measurement, variation in a* and b* measurements over time was plotted. An arbitrary value of 10% more than baseline variation was used to suggest the shortest bloom time needed to obtain reliable results.

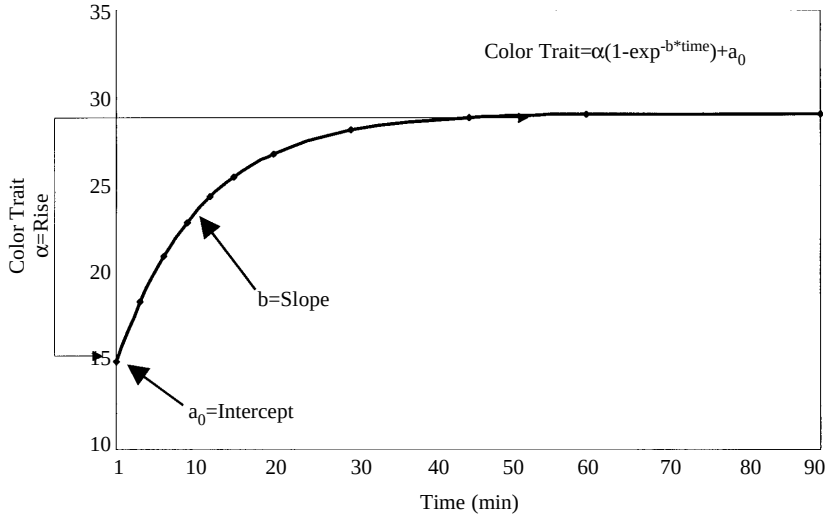
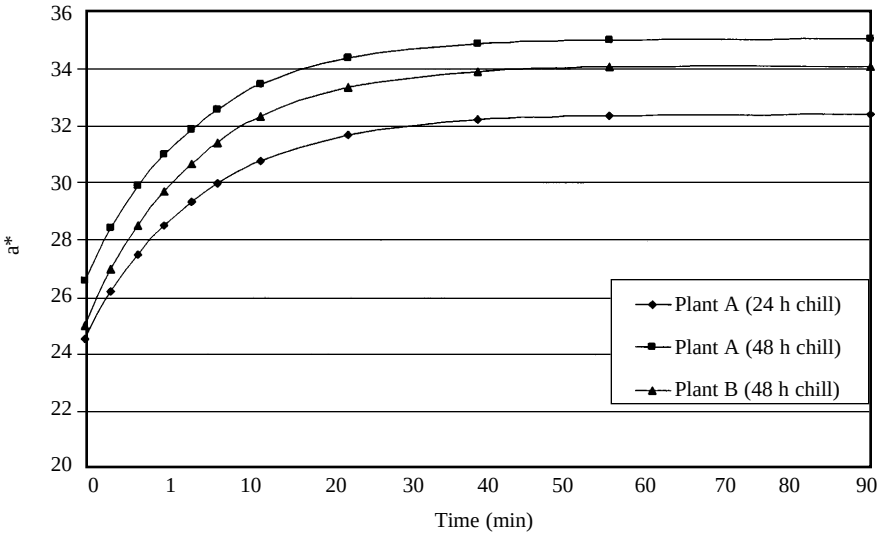
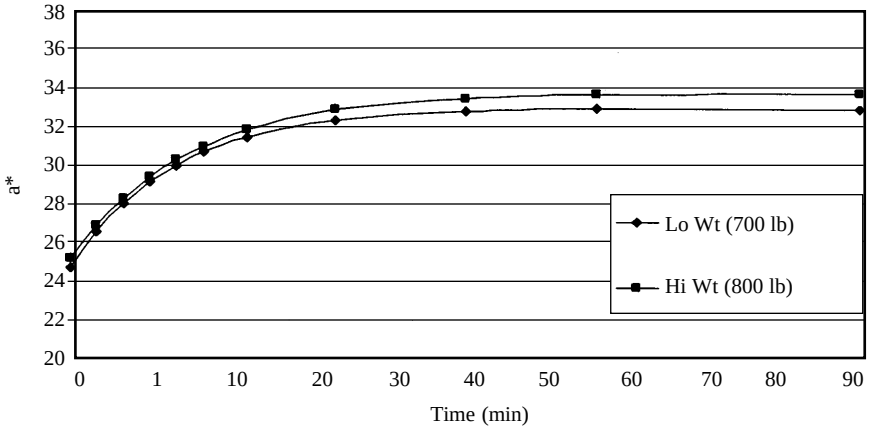


Figure 1. The negative exponential growth model used to define meat color changes after ribbing.

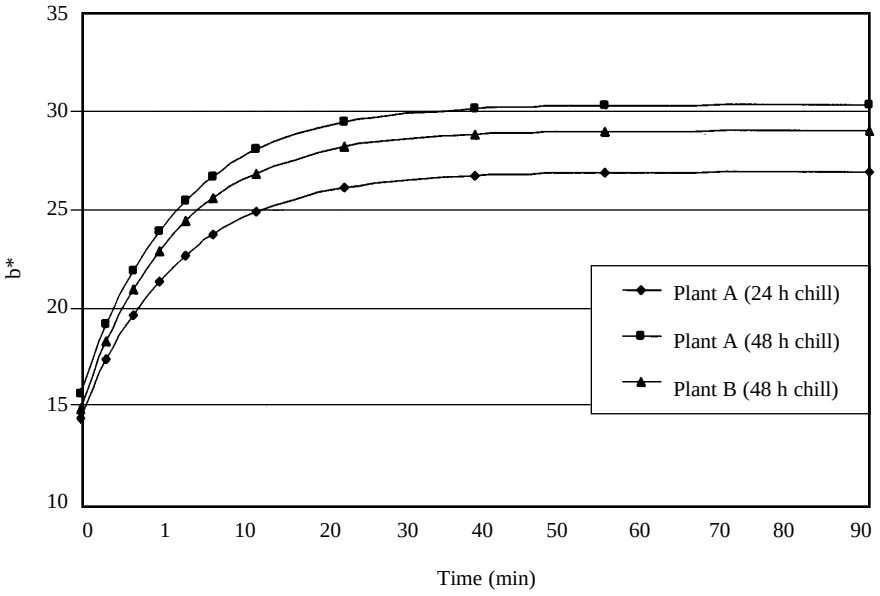


Plant differences in a* color development

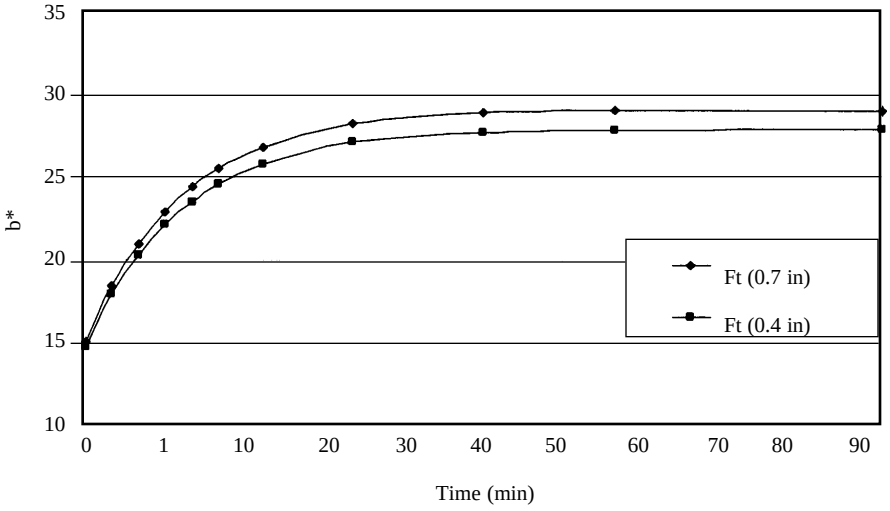


Weight differences in a* color development

Figure 2. Plant and weight differences in a* color development.



Plant differences in b* color development



Fat thickness differences in b* color development

Figure 3. Meat plant and fat thickness differences in b* color development.

Results

The slopes for the nonlinear models of a* and b* the slopes were unaffected by plant chill times. However, plant chill time and hot carcass weight significantly ($P<0.005$) affected a* color development (rise, α) over time (Figures 2 and 3, respectively). A significant ($P<0.001$) increase in the redness of meat will occur with an increase in chill length, or in heavier weight carcasses.

Differences in the standard operating practices may have resulted in increased a* values for plant A (48 hour chill). One noted difference in operating practices was the use of low voltage electrical stimulation (42 V, 21 second duration) in plant A.

Increased carcass weight affects cooling rate of the lean, as lean tissue deep within the interior of a heavy carcass cools more slowly during the chill period. Increased muscle temperature during the pH fall leading to rigor may result in a lower ultimate pH, which may give heavier carcasses greater redness values.

Meat plant and 12th rib fat thickness also significantly ($P<0.05$) affected b* color development; increased ultimate b* values were predicted in the 48 hour chill period versus the 24 hour chill. As with a* values, electrical stimulation and increased chill periods may lead to increased ultimate b* values.

Carcass fat thickness also significantly ($P<0.05$) affected b*. A fat thickness above 0.7 in, compared with a fat thickness less than 0.4 in, increased ultimate (90 minute) b* values. Increases in exterior carcass fat can also elevate lean tissue temperature during the pH fall, increasing measured b* values.

Although equations predicting L* were significantly affected by plant and plant-quality grade interactions, the predictive accuracy of all equations was never higher than 16%, indicating an inability to properly predict L* over time.

These results indicate that color development can be influenced by a variety of carcass traits and plant operation procedures. This suggests use of color in an objective grading system would need to take these intrinsic and extrinsic factors into account, greatly adding to the challenges associated with the application of such technology under commercial conditions.

Inherent in color assessment is the variability in color measurements within a carcass shortly after exposure to oxygen. To minimize the variability in color measurements within a carcass, and to choose the earliest possible time to make proper color assessment, an equation was created to show variation in color measurements over time. Both a* and b* exhibited variability shortly after ribbing, 48% and 38% higher than ultimate color variation, respectively.

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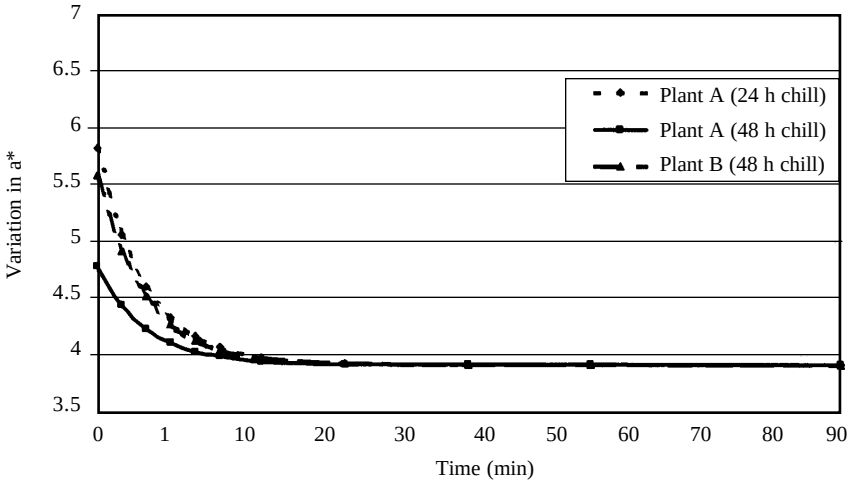
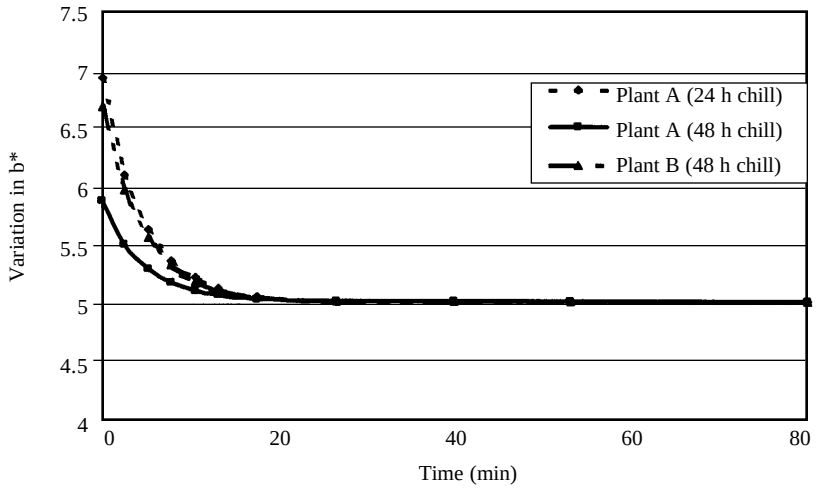


The variation in a* measurement due to plant



The variation in b* measurement due to plant

Figure 4. The variation in a* and b* measurement due to plant.

The variability in color quickly dropped below 10% over the variability in ultimate color (90 min) assessment after 12 minutes for a* and 9 minutes for b* (Figure 4). This suggests that a* and b* color assessment can be made after nine-12 minutes of bloom.

Conclusion

If time is closely monitored, beef color assessment for a* and b* can be made 9-12 minutes after ribbing. Color development, however, is influenced by a variety of carcass and plant operating procedures, making it difficult to use color in an objective grading system.

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