C71

UTILIZATION OF IMAGE PROCESSING TO QUANTITATE SURFACE METMYOGLOBIN ON FRESH BEEF

B.P. DEMOS[1,3], D.E. GERRARD[2], X. GAO[2], J. TAN[2] AND R.W. MANDIGO[1]
[1]University of Nebraska-Lincoln, Lincoln, NE 68583-0908 USA
[2]University of Missouri-Columbia, Columbia, MO 65211 USA

Key Words: Metmyoglobin, beef, color measurement

Background

Discoloration due to pigment oxidation at surfaces of meat is usually measured by assessing relative concentration of metmyoglobin (metMb). Accumulation of metMb is responsible for the undesirable brown color that forms on meat surfaces during short-term fresh retail display. There is a wealth of information available on quantitating surface metMb, however, there is still debate as to reliability of methods in use.

Recent work with image processing has allowed researchers to determine fat percentage of ground beef as well as quality factors of intact muscle due to color differences of samples (Gwartney et al., 1995). This technology has the advantage of capturing the image of an entire sample (e.g. a ground beef patty, a pork loin chop, etc.) as opposed to capturing only a small area as is the case with virtually all other methods.

Objective

To determine feasibility of quantitating surface metMb on ground beef patties with image processing.

Methods

Coarse ground (2.54 cm) beef trim, mechanically recovered lean (MRNL) and dry ascorbic acid (Asc) were combined in the appropriate ratios to yield the following combinations: [1] 0 ppm Asc/0% MRNL, [2] 0 ppm Asc/15% MRNL, [3] 0 ppm Asc/30% MRNL, [4] 1,000 ppm Asc/0% MRNL, [5] 1,000 ppm Asc/15% MRNL, [6] 1,000 ppm Asc/30% MRNL. Combinations were formulated to 20% fat. Each formulation was mixed five min and ground (4.7 mm). Quarter pound patties (114 g) were processed. Patties were placed on styrofoam trays, two per tray, and overwrapped with polyvinyl chloride.

Overwrapped patties were stored at 7°C under continuous warm white fluorescent illumination (700 lux) 5 days (days 0-6, day of manufacture=day 0). Patties were selected at random and measured for surface discoloration on each day of display. A modified method of Kryzwicki (1979) was used to quantitate percentage surface metmyoglobin.

The image processing system used consisted of a Sony XC-711 CCD camera, a Sony PVM-1342Q color video monitor, a Data Translation DT2871 color image frame grabber, a DT2878 advanced processor, AURORA and AIPL programming libraries and 486-50 Hz microcomputer for the development of processing software. The system was programmed in Microsoft C/C++ 7.00. Ground beef sample images were taken individually with a uniform non-glare black background. The color images were 512 x 483 pixels in resolution. Each pixel represented an actual area of 0.134 mm^2. The images were represented in the HSI (hue, saturation and intensity) format. Background segmentation was first performed on the original images to give a uniformly black background. Features characterizing color of the patties were extracted from the image. The histograms of H, S and I were approximately normal. Statistics of these histograms were used as the color features, which were:

Mean:	u_H, u_S and u_I
VMO:	value of most occurrence
Skew3:	third moment of the mean
Sk3:	third moment of the VMO

where the subscripts denote the color components.

To determine the best predictive model, all possible regression models for 12 independent variables were evaluated with correlation coefficients, r-squares, root mean square error (RMSE) and Mallow's Cp statistic. The prediction model selected had maximum r-square, minimum RMSE and a Cp statistic closest to the number of parameters in the model.

Results and Discussion

There are two ways in which image processing can be useful in measuring surface color of fresh beef. One way is to get an indication of the three primary colors red, green and blue (R, G and B, respectively). When the image of the ground beef patty is captured, a distribution of computer pixels is obtained for each of these colors. Since fresh beef is normally bright cherry red, it is logical that we would be most concerned with R values. Currently the most common method of measuring surface redness is the CIE a* value. The a* value measures a color continuum from red to green; a higher number is indicative of a more red color. The CIE a* values, as measured with a HunterLab colorimeter, highly correlated to image processing R mean values ($P<0.01$, $r=.98$, Figure 1). From these data it is apparent that image processing R values can be used to measure surface redness of beef. Theoretically, R mean values should be a better assessment of surface redness because the entire patty is analyzed as opposed to only a one-inch diameter area, as is done with the HunterLab colorimeter.

Since a* values are on a continuum from red to green it is logical to expect them to negatively correlate to image processing G values ($P<0.01$, $r=-.96$). The opposite trend, as seen when a* values were plotted against R mean values, is seen when a* values are plotted against G mean values (Figure 2).

Similar results are apparent for b*, a continuum from yellow to blue, and image processing B mean values (Figure 3). A higher b* value is indicative of greater yellowness, a lower number is indicative of greater blueness. There is a strong negative correlation between CIE b* values and image processing B mean values (($P<0.01$, $r=-.88$), although the variance does not appear to be constant for higher and lower b* values.

The strong correlations among the CIE values and the image processing values are evidence that CIE values as measured by the HunterLab colorimeter, and image processing R, G and B mean values are measures of the same aspects of surface color. The strongest relationship is between a* and R mean values, which is the relationship of most interest in studying surface color of beef.

The second way in which image processing is useful is its ability to measure surface metMb. If it can be shown that certain image analysis values can be used to accurately predict surface metMb, image analysis would likely become a better method because of its ability to measure the entire surface of a meat cut as opposed to the limited area measured by other methods.

In order to achieve this, the most accurate method of quantitating surface metMb that is currently available had to be determined. Based on previous findings it was determined the method of Kryzwicki (1979) was the most accurate (Demos and Mandigo, 1995).

In addition to values for R, G and B, image processing is capable of producing data for hue, saturation and index. A distribution of computer pixels is obtained for each of these components. Four variables are then generated from each distribution: mean, VMO, skew3 and sk3, resulting in a total of 12 variables. Mean is the average for each component, is the value most occurring, skew3 is the third moment of the distribution of the mean and sk3 is the third moment of the distribution of the. In each case, the distribution was normal, so mean is likely the best predictor from each distribution and all other variables are less informative. However, all variables were analyzed to verify which would be good predictors of surface metMb.

The best 3-variable model included the mean hue, mean saturation and mean intensity values. The final prediction equation is as follows:

$$\text{metMb (\%)} = 213.27 + 3.89(\text{hue}) - 0.24(\text{sat}) - 2.07(\text{int}) \quad (R^2 = .93)$$

As a final test of the prediction equation, actual percent metMb was plotted against predicted metMb (Figure 4).

Conclusions

Image processing is a new technology that is an effective tool for use in research situations for assessing percentage surface metMb on fresh beef. The predictions for the varying surface colors were accurate, as demonstrated by the high r-square and RMSE. Image processing is effective on a heterogeneous population of surface colors as well as on a much narrower population.

Pertinent Literature

Demos, B. P. and Mandigo, R. W. (1995). *Meat Sci.*, (submitted).
Gwartney, B.L., Gerrard, D.E., Gao, X. and Tan, J. (1995). *J. Musc. Foods*, (submitted).
Kryzwicki, K. (1979). *Meat Sci.*, **3**, 1.

[3]**Author Demos is currently with Armour Swift-Eckrich, Product Development Lab, Downers Grove, IL 60515.**

FIGURE 1: CIE a* vs image processing red mean value for ground beef patty surfaces.

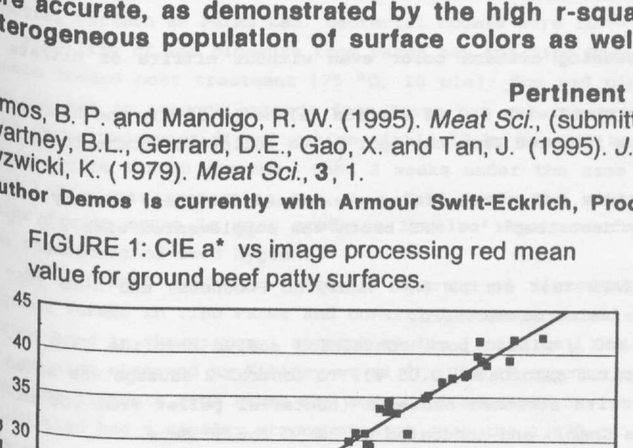

FIGURE 2 : CIE a* vs image processing green mean value for ground beef patty surfaces.

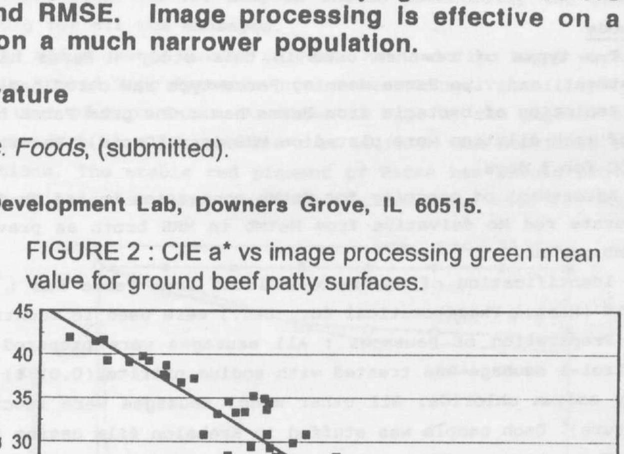

FIGURE 3 : CIE b* vs image processing blue mean value for ground beef patty surfaces.

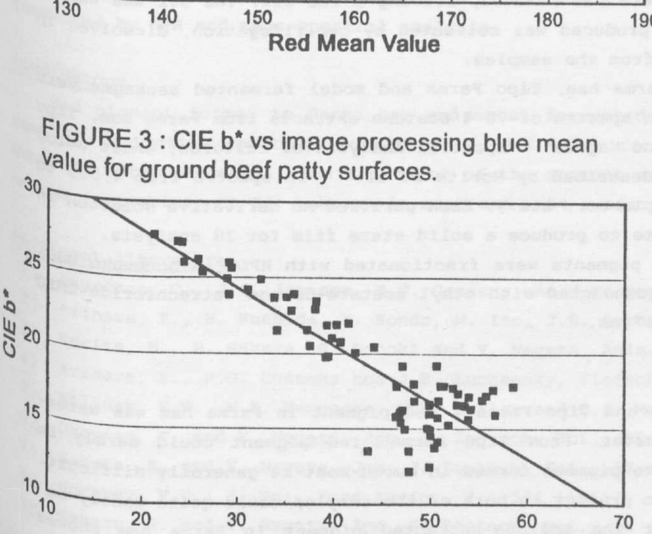

FIGURE 4: Actual vs predicted percentage surface metmyoglobin (metMb) for ground beef patty surfaces.