A Research Note

Component Recognition in Beef Chuck Using Colorimetric Determination

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ABSTRACT

The potential for increasing the utilization of lower quality grades and cuts of beef was dependent on controlling the level of objectionable components, such as connective tissue and developing an economical means of creating starting material for further processing. Colorimetric methods were used to distinguish connective tissue and all other objectionable components in beef chuck slices. Using the tristimulus color values (L, a_L, and b_L) and the color difference indices for total color difference (E), chromaticity (ΔC) and the yellowness index (YI), each component was optically differentiated. These discriminations, coupled with decision models directing disposition of the various components, can be used to control an excision system for providing suitable starting material for further processing chucks into products such as restructured beef.

INTRODUCTION

UTILIZATION of beef chuck is currently limited by the lack of an economical method to provide a suitable raw material for further processed beef products (e.g., restructured beef). The development of a process that yields beef from chuck that is free from objectionable components, especially heavy connective tissue and bone, and controls the particle size and content of lighter connective tissue and fat, would enhance consumer acceptance and, therefore, increase carcass value. Recio et al. (1986), for example, showed that hand-trimming all heavy connective tissue significantly improved tenderness and palatability of flaked and formed beef from shoulder clods. Labor intensive operations such as hand trimming, however, must be limited to minimize production costs.

Heiland et al. (1987) conceived an automatic, continuous process for identifying and separating all objectionable material from sliced beef chuck. This process incorporates optical scanning techniques for the identification of all the beef components and the excision of the objectionable material by means of a microprocessor-controlled water-jet knife.

The objective of this study was to demonstrate that tristimulus color measurements could be used to optically differentiate the various beef components.

MATERIALS & METHODS

TWO USDA CHOICE GRADE, square-cut chucks (#113; NAMP, 1984), from grain fed, maturity A, Yield Grade 2 steers, weighing approximately 45 kg each, were purchased locally and sliced into 1-inch (2.54 cm) thick slices on a BIRO Model 33 Chuck Band Saw (Biro Manufacturing Co., Marblehead, OH). A total of 18 slices was obtained from each chuck. One chuck was evaluated immediately while slices from the second chuck were vacuum-packaged and stored for 5 months at −20°C prior to colorimetric analysis. Cylindrical samples for each color measurement were obtained using a #12 cork borer. Bone samples were removed using a 19 mm hole saw.

Color difference measurements were made using a Gardner XL23 Digital Colorimeter with a 19 mm aperture plate. Samples were equilibrated at 25°C for 30-45 min prior to evaluation. The cylindrical samples were inserted in a #12 rubber stopper which had been bored with a 19.8 mm hole to allow for precise, reproducible placement over the sample port and to stabilize the sample. The stopper/sample system was placed in a glass cup ensuring total contact between the sample face and the cup. Tristimulus color values (L, a_L, and b_L) were determined for each sample. A white plate (XL23-033-B; L = 91.97, a = − 1.43, and b = 1.47) was used to standardize the colorimeter.

Three indices of color difference were analyzed: the total magnitude of the color difference (E, Eq. 1) chromaticity (ΔC, Eq. 2) and yellowness index (YI, Eq. 3),

$$E = (\Delta L^2 + \Delta a_L^2 + \Delta b_L^2)^{1/2} \quad (1)$$

$$\Delta C = (\Delta a_L^2) + (\Delta b_L^2) \quad (2)$$

$$YI = 100/Y\,(1.277X - 1.06Z) \quad (3)$$

where X, Y and Z are the CIE values related to L, a_L, and b_L (Billmeyer and Saltzman, 1966).

The state of myoglobin oxidation was not addressed in this study due to rapid and consistent sample handling times. The potential for this mechanism confounding the color measurements in a continuous system would be minimal.

The design variables that were analyzed for their contributions to the color differences were chuck treatment, slice location, component, sample location and sample orientation. The analysis of chuck treatment consisted of comparing the fresh versus the frozen chuck. Each chuck was subdivided into three general *slice locations* comprising the posterior portion [six 1 in. (2.54 cm) thick slices from the fifth to the third rib], the medial portion (the second set of six slices) and the anterior portion (remainder of the chuck).

Plugs of each component were taken from four randomly selected *sample locations* within each slice location. The components evaluated were lean, marbled lean, connective tissue bands (0.8 to 1.5 mm thick), fat bands (2.4 to 6.4 mm thick), heavy connective tissue and tendons (1.5 mm thick), fat, arteries, ligaments, light, red and white bones. The effect of sample fiber orientation (parallel vs perpendicular) was taken into account by making four color measurements of each sample, with a 90° rotation between each measurement.

System repeatability was evaluated by pooling the variability of paired comparisons (n = 302) of duplicate samples using Eq. (4) for the estimate of the variance.

$$s^2 = \frac{\Sigma (E_1 - E_2)^2/2}{n} \quad (4)$$

where $E_1 - E_2$ = differences of duplicate samples.

An analysis of variance was performed to evaluate the impact of each raw material component on color differences using the model

$$y = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \gamma_k + \alpha\gamma_{ik} + \beta\gamma_{jk} + \alpha\beta\gamma_{ijk} + \delta_{(ijk)} + \epsilon_{ijkl} \quad (5)$$

where y = overall magnitude of color difference, μ = mean effect, α_i = chuck, β_j = slice, γ_k = component, δ_1 = location (nested in chuck, slice and components), and ϵ_{ijkl} = orientation.

Evaluation of the separability of the components using the E, ΔC, and the YI indices was made using the Tukey multiple comparison method (SAS, 1985).

RESULTS & DISCUSSION

THE ANOVA ($p = 0.05$) for the overall magnitude of the color difference, with the nested portion of the model in Eq. (5) used for the error mean square, showed that component was the only raw material factor significantly contributing ($P < 0.01$, $n = 1056$) to the overall variance. In all cases the mean square, due to component, was one to six orders of magnitude greater than that of the other effects in the model. The estimate of the variance for the colorimetric system was 0.29 with a coefficient of variance (CV) = 0.96%.

The potential for discriminating between and among com-

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Table 1—Mean separation (Tukey) of beef chuck components by color difference indices E, ΔC, YI

Group[e]	E[b] Mean	Component[a]	Group[e]	ΔC[c] Mean	Component[a]	Group[e]	YI[d] Mean	Component[a]
P	68.33	Artery	P	253.18	Ligament	P	77.87	Lean
P	68.25	Lean	Q	153.83	Artery	P	71.70	Artery
Q P	65.23	Marbled lean	Q	133.31	Light bone	Q P	69.90	Marbled lean
Q	64.11	Red bone	R	101.81	Fat bands	Q R	56.64	Con. tissue bands
R	59.83	Con. tissue bands	R	94.86	Lean	R	54.95	Ligament
S	51.08	Fat bands	S R	89.46	Marbled lean	S R	53.24	Light bone
S	49.82	Light bone	S R T	82.48	Con. tissue bands	S R	49.95	Fat bands
S	47.15	Hvy con. tissue	S R T	80.04	Hvy con. tissue	S R	49.03	Red bone
T	39.95	Ligament	S T	64.22	Red bone	S	40.16	Hvy con. tissue
U	33.97	Fat	T	57.87	Fat	T	24.98	Fat
U	30.82	White bone	U	17.67	White bone	U	10.15	White bone

[a] n = 96 observations for each component.
[b] E = Total magnitude of the color difference, std error of mean=0.88.
[c] ΔC = Chromaticity, Std error of mean = 6.60.
[d] YI = Yellowness Index. Std error of mean = 2.98.
[e] Within given index, means with same letters are not significantly different.

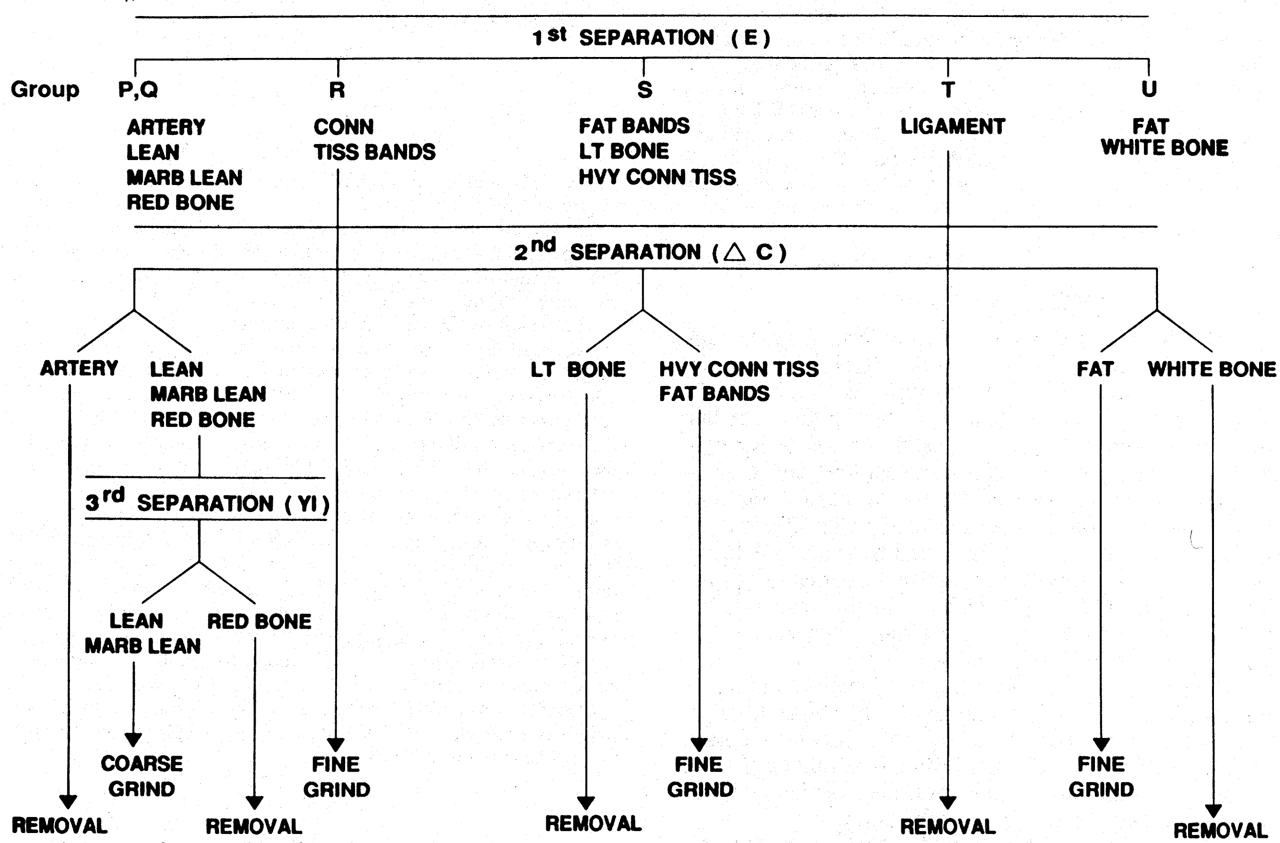

Fig. 1—Scheme of separation of beef chuck components for a restructuring process. Groups are identified in Table 1.

ponents, using the Tukey multiple comparison test, is shown in Table 1. All three indices must be applied to effect separation. The initial separation (E) yields five groupings and allows immediate discrimination of the connective tissue bands and the ligament. The three remaining groups, categorized by their E values, are further separated in terms of the chromaticity index. Final discrimination between red bone and marbled lean is accomplished by evaluation of the yellowness index. A separation scheme, using the appropriate decision models, and the disposition of each of the components in a restructuring process is shown in Fig. 1. In this scheme, the lean and marbled lean would be coarsely ground or flaked to maximize the textural properties of this unobjectionable material. Fat and connective tissue would be cut into finer particles to reduce the negative textural aspects and provide a format for uniform dispersion into the final product. Components such as bones, arteries and ligament would be removed for alternate uses.

Component identification, using tristimulus color measurements and suitable indices of color difference, is feasible. Decision models, based on these component discriminations, can be determined to control not only the connective tissue but all objectionable material in the beef chucks as well. Although further study will be required to refine the separations, the concept of optically differentiating beef components, in the context of raw material preparation for a restructured beef process, is viable.

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Ms received 2/12/88; accepted 2/18/88.

The authors acknowledge J.G. Phillips and R.W. Bruch for their invaluable assistance in this work.

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