ESTIMATION OF ENDPOINT TEMPERATURE OF COOKED MEAT WITH MULTIPLE ESTIMATORS

Louis L. Young, Ph.D., S. D. Senter, Ph.D., and G. K. Searcy, B. S.

Richard B. Russell Agricultural Research Center
P. O. Box 5677
Athens, Georgia 30604-5677 U. S. A.
Tel. 706.546.3416
Fax 706.546.3633
e-mail lly@negia.net

Abstract

Under USDA regulations, beef imported from some countries must be cooked to an endpoint temperature (EPT) of 79.4° C. Compliance with these regulations is currently monitored by squeezing incoming sample logs and visually observing the exudate for signs of redness. Inherent subjectivity of visual color assessment could lead to erroneous results, so other indicators of EPT have been developed. However, in many cases, utility of these indicators for compliance purposes has been hindered because precision of EPT estimates by these indicators has not been proven. The objective of this research was to use combined indicators for assessing EPT of cooked beef.

Beef logs were cooked to internal temperatures near 79.4° C. Exudates from the logs were assayed for residual glutamic-oxaloacetic transaminase (GOT) activity as well as Hunter L*, a*, and b* values, chroma and hue. The data were fitted to a linear multiple regression using 1, 2, 3, 4, 5, or all 6 as independent variables. The coefficient of determination (R^2) was used to find subsets of the independent variables which yielded the best estimate of EPT. Estimated EPTs of 12 independent logs were calculated from the best 1, 2, 3, 4, 5, and 6 term regressions.

The coefficient of determination increased significantly as the number of independent variables in the model increased up to four. Adding more than four variables did not significantly improve the fit.

INTRODUCTION

Many exotic diseases in cattle and other meat animals are rarely or never found in the United States, but remain prevalent in some of the countries from which meat is imported. In order to prevent the inadvertent importation of pathogens responsible for these livestock diseases, the Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture has established regulations requiring that such products be treated in a manner approved by the U.S.D.A. that will inactivate the pathogens of concern (Title 9, Code of Federal Regulations). One such disease is Aphthous Fever or "foot and mouth disease" (FMD), a widely distributed and highly contagious condition of cloven hoved animals with strong epitheoliotropic features. Typical signs of FMD include Erosion of the epithelium of the dorsum of the tongue and lameness. In young animals, acute gastro-enteritis and myocarditis leading to high mortality are common features. However, in older animals which have been previously exposed to the virus, mortality is usually low. Outbreaks are thought to occur through *per os* exposure to the virus in infected tissues found in garbage or animal by products. Outbreaks of the disease in disease-free areas are controlled by prevention of exposure to the virus (Smith, *et al.*, 1972).

Under APHIS regulations, beef imported from countries where FMD is found must be heat processed to an endpoint of 79.4° C. Compliance is assured by sampling the cooked meat at the port-of-entry, squeezing the sample, and evaluating the color of the exudate (the "squeeze juice test"). If the exudate exhibits any hint of red color, the product is deemed under processed and entry into the U. S. is denied. Use of this test is not entirely satisfactory because of the obvious subjectivity. Mechanical temperature indicators can also be used for assuring compliance (Blackwell, 1996), but these devices can be expensive and are subject to fraud. The U. S. Government and the meat industry have conducted studies to development more objective and inexpensive indicators of EPT. These developments have resulted in various enzyme inactivation and objective color tests for evaluating EPT (Davis, *et al.* 1988; Davis and Townsend, 1994; Searcy, *et al.*, 1994). However, these tests have often been too imprecise for field use. The objective of this study was to evaluate use of multiple indicators for estimating EPT.

METHODS & MATERIAL

Sample Preparation.

Four bottom round beef roasts were procured locally and manually cut into cubes measuring approximately 5 cm. in each dimension. Thermocouples were inserted into the geometric center of four of the cubes in each batch. The cubes from each roast were then manually stuffed into four thermostable, moisture-proof polyethylene casings (10 cm. by 40 cm.). In commercial trade, these fabricated roasts are referred to as "logs". Since preliminary experiments indicated that meat near the top of the logs cooked faster than meat near the bottom, the four cubes which were equipped with thermocouples were placed at 7.6 cm. intervals in order to monitor temperature of the meat at different locations in the logs.. The logs were then cooked vertically in hot water (98°C) until the thermocouple 22.8 cm. from the top recorded 79.4° C. Upon reaching that temperature, the logs were chilled in ice water overnight. The cubes which were equipped with thermocouples were then recovered and subjected to objective color value analysis and residual glutamic oxaloacetic transaminase (GOT) determination.

Color Value Analysis and GOT Assay.

The cooked cubes were manually chopped, and the free moisture ("squeeze Juice") was expressed with a mechanical vise. C.I.E. color values as well as chroma and hue were immediately determined using a Minolta model CT-310 Chromameter. Residual GOT activity was evaluated in 0.2 mL of the squeeze juice with a Sigma Diagnostics Procedure Kit (No. 505) (Sigma Chemical Co., St. Louis, MO, USA) which was originally developed to determine transaminase (ALT/GPT and AST/GOT) activities in serum, plasma, and cerebrospinal fluid. Resultant oxaloacetic acid activity in the reaction was indicative of GOT activity at 505 nm after formation of the hydrazide derivative with 2,4-dinitro phenyl hydrazine (Searcy, *et al.*, 1994). Results were recorded as Sigma-Frankle Units (SFU) of GOT activity per mL of squeeze juice (Senter, *et al.*, 1995).

Statistical Analysis.
The data were fitted to all possible 2, 3, 4, 5, 6, and 7 term models of the form,

$$T_i = a + b_1 X_{1i} + b_2 X_{2i} + b_3 X_{3i} + b_4 X_{4i} + b_5 X_{5i} + e_i$$

where,

T_i = endpoint cooking temperature of the i^{th} meat cube
a = the y intercept
b_1 = regression coefficient of L* on T
X_{1i} = L* value of the i^{th} observation
b_2 = regression coefficient of a* on T
X_{2i} = a* value of the i^{th} observation
b_3 = regression coefficient of b* on T
X_{3i} = b* value of the i^{th} observation
b_4 = regression coefficient of hue (h) on T
X_{4i} = hue value of the i^{th} observation
b_5 = regression coefficient of chroma (C) on T
X_{5i} = chroma value of the i^{th} observation

and

e_i = error associated with the i^{th} observation.

Analyses were performed using the SAS reg procedure (SAS Institute, 1987). The best fit of all model sizes was selected using the coefficient of determination (R^2) as the proportion of variation in EPT which is included in the non-error terms of the models. Statistical differences among R^2 values was calculated using student's t-test.

Results & Discussion

Regression coefficients and coefficients of determination (R^2) of the best two, three, four, five, six, and seven models are presented in Table 1. The best two-term model included the intercept and hue values and yielded an R^2 of 0.62. Thus 62% of the variation in EPT was included in non-error terms in the model and 48% was in the error term. As more terms were added, R^2 increased to 0.73 (four terms). Thus 74% of the variation in EPT was included in non-error terms and 26% was in the error term. Adding more terms than four did not improve the model. This four term model requires estimates of the intercept, b*, h, and C, all of which are easily determined with simple colormetric equipment. However, the imprecision in the estimate, even though improved over lower order models, might inhibit use of these multiple estimators alone for estimating EPT. Future studies should evaluate effects of other, easily measured parameters and alternative, higher order models.

Table 1. Regression Coefficients and resultant Coefficients of Determinations for the Best 1, 2, 3, 4, 5, and 6 term models for estimating EPT.

	COEFFICIENTS							R^2
MODEL	INTERCEPT	a*	b*	L*	h	C	GOT	
One Term	+47.8				+0.47			0.62
Two Term	-10.3	+1.30			+1.20			0.68
Three Term	+11.37		-2.68		+0.97	+2.57		0.70
Four Term	-1.35		-3.50		+1.11	+3.56	+0.01	0.73
Five Term	+4.29		-3.41	-0.05	+1.09	+3.44	+0.01	0.75
Six Term	+4.47	-0.02	-3.43	-0.05	+1.09	+3.46	+0.01	0.76

References

Blackwell, J. H., 1996. Regulatory use of temperature indicator devices. J. Muscle Foods 7:315-321.

Davis, C. E., Search, G. K., Blankenship, L. C., and Townsend, W. E., 1988. Pyruvate kinase activity as an indicator of temperature attained during cooking of cured pork. J. Food Prot. 51:773-778.

Davis, C. E. And Townsend, W. E., 1994. Rapid fluorometric analysis of acid phosphatase activity in cooked poultry meat. J. Food Prot. 7:1094-1097.

SAS Institute Inc., *SAS/STAT Guide for Personal Computers, Version 6 Edition,* Cary, NC: SAS Institute Inc., 1887

Searcy, G. K., Senter, S. D., and Wilson, R. L., 1995. Glutamic-oxaloacetic transaminase activity: a potential end-point-temperature indicator of imported cooked beef. J. Food Prot. 58:686-688.

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