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COLOR MEASUREMENT AS PREDICTOR OF CONSUMER RATINGS OF MILITARY RATION ITEMS

EDWARD W. ROSS, CAROL P. SHAW and MARY FRIEL[1]

U.S. Army Soldier Systems Command
Natick Research, Development and Engineering Center
Natick, MA 01760-5018

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ABSTRACT

*Instrumental color measurements were investigated as a method of assessing ration quality after long term storage. Six items were stored at five temperatures from 4 to 60C and withdrawn after 7, 31, 91, 182, 365, 730 and 1095 days. They were assessed for color (CIELAB L*a*b* values, hue angle and chroma), consumer acceptance, and attribute ratings. Color variables varied consistently for only applesauce and cheese spread. L* values were investigated to measure acceptability. Consumer acceptance ratings were divided into two equal sets. The first was used to determine the relationship between the mean score and L* value, then to predict acceptability. Predictions were compared to the second set of scores and type 1 and 2 error rates determined. Although error rates were high by usual statistical standards, they were equal to or lower (although not significantly different) than those based on the mean consumer acceptance score.*

INTRODUCTION

This investigation examines the feasibility of using instrumental color measurements for quality assessments of military rations in long duration storage. Because operational rations are stored throughout the world for emergency situations, they must have a minimum shelf life of three years at 27C. However, they are often subjected to temperatures as high as 50C and as low as subfreezing conditions. Traditionally, the acceptance of ration components is based upon consumer evaluations of a specific food item. In the actual logistics system, veterinary inspectors evaluate stored rations and determine if they can be stored for additional periods of time, if they should be issued and utilized in the near future, or if they are no longer serviceable and must be discarded.

[1]To whom correspondence should be addressed.

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Color is one of the major attributes which affects the perception of quality by the consumer, and, if that color is unacceptable, the consumer may not ever judge the flavor and texture at all (Francis 1995). When food products are stored, especially at abuse temperatures, an obvious sign of deterioration is often a change in color, which can be quantified instrumentally (Solomon *et al.* 1995; Wang *et al.* 1995; Kluter *et al.* 1994; Gnanasekharan *et al.* 1992). If the instrumental measurement can be correlated with consumer evaluations over a range of storage times and temperatures, accept/reject parameters could be established and utilized by veterinary inspectors to assess the quality of the stored items. Even though these color changes might not occur consistently in all the food items in a military ration, it may be feasible to use the color changes in specific products as an indicator of the time and temperature history of the products in that lot.

Many investigators have examined the effects of color variation on the consumer acceptance of various beverages such as orange juice (Tepper 1993), fruit punch flavored beverages (Clydesdale *et al.* 1992), carbonated water (Hyman 1983), and strawberry-flavored drinks (Johnson 1982). With vegetables, Brewer *et al.* (1994, 1995) used color measurements to measure the effects of blanching on green beans and frozen broccoli. Gnanasekharan *et al.* (1992) studied the sensitivity of colorimetry and sensory evaluations in green vegetables as did Eckerle *et al.* (1984) in tomatoes. The peanut industry (Pattee *et al.* 1991; Pattee and Giesbrecht 1994) has color limits (CIELAB L*) placed on the peanut samples, and samples with unacceptable L* values are discarded before sensory evaluation.

If color is to be used as an indicator of quality, the most appropriate color measurement value or values must be determined. Because L* is an indicator of lightness (100 = white, 0 = black) it is perhaps the most obvious parameter to use in products undergoing Maillard, nonenzymatic browning or phenolic browning such as occurs in fruits in long term storage (Kluter *et al.* 1994; Nattress *et al.* 1990). However, Wang *et al.* (1995) found that the L* values in plums increased at 22C vs 4C storage due to anthocyanin degradation. In contrast to the L* value, the a* and b* reflect specific hues. (Positive a* values indicate red, negative a* values indicate green. Positive b* values are yellow and negative b* values blue.) Transforming the a* and b* values into geometric values can be a better predictor of sensory perception (Little 1975). Hue angle can be calculated using the formula $\tan^{-1}(b/a)$. A higher hue angle reflects a higher green color and lower hue angles reflect more orange to red colorations. Hung *et al.* (1995) found that hue angle was a better predictor of sensory color perception than L*a*b* values in Golden Delicious apples. Gnanasekharan *et al.* (1992) found that changes in green color as measured by hue angle could predict sensory perceptions in vegetables stored at higher than normal storage temperatures, although not at normal handling conditions. McLellan *et al.* (1995) show how to interpret the data for hue angle up to and beyond 360 degrees. Chroma, calculated as $(a^2 + b^2)^{1/2}$, is another derived variable used to assess the brightness of color (Gnanasekharan *et al.* 1992).

This report investigates the feasibility of using the colorimetric measurements as a quality assurance tool in ration items stored at various temperatures and times over a three year period. It analyzes the data using the L*, a*, or b* values as well as the hue angle and/or chroma data transformations. It also examines and evaluates the error rates (types 1 and 2) that would occur using this approach. A type 1 error occurs when an unacceptable item is wrongly accepted, whereas a type 2 error consists of erroneously rejecting an acceptable item.

MATERIALS AND METHODS

Six military ration items were chosen for study: applesauce, cheese spread, fig bars, grape jelly, peanut butter and escalloped ham and potatoes. All are components of the Meal, Ready-to-Eat (MRE) except the fig bars, which are in the Ration, Cold Weather (RCW) system. These items were purchased directly from the manufacturers who produce the items for rations according to military specifications. The manufacturer packaged the items as specified in individual serving portions in flexible pouches made of a trilaminate material. Samples were stored at 4, 27, 38, 49 and 60C temperatures and withdrawn from storage after 7, 31, 91, 182, 365, 730, and 1095 days. They were evaluated initially and after each withdrawal by sensory panels and various objective measurements, including CIELAB L*a*b* color values.

The consumer panels consisted of 35 to 40 untrained respondents, chosen at random from a pool of employees (military and civilian) at the U.S. Army Soldier Systems Command, Natick Research, Development and Engineering Center. Panelists were asked to rate how much they liked or disliked the food on a nine-point hedonic scale, ranging from dislike extremely = 1, through neither like nor dislike = 5, to like extremely = 9.

Colorimeter measurements of the CIELAB L*a*b* color values were made using the Hunter MiniScan MS/S model colorimeter manufactured by Hunter Associates Laboratory, Inc. of Reston Virginia. The colorimeter was standardized using a standard white tile (x = 79.7, y = 84.5, z = 90.4). Samples, except for fig bars, were filled into a 6.4 cm diameter glass sample cup and covered with a black opaque sample cover to minimize interference from stray light. The colorimeter was inverted, the glass cup placed on the lens, and the color values read through the bottom of the glass surface. The escalloped potatoes with ham were measured as described except that the samples were pureed in a blender prior to filling the glass container. The fig bars were placed and read directly on the lens of the colorimeter. Two samples of each variable were measured and each value was the mean of four measurements.

MATHEMATICAL MODELS

Correlation and linear regression analyses were done using the variables L*, a*, b*, hue angle, chroma and mean consumer scores. Data were analyzed using MiniTab Statistical Package, Release 10 for Windows produced by MiniTab Inc., State College PA. The data were analyzed to determine the relationship between the color measurements and mean consumer scores obtained at each storage time and temperature. The general form of this relation was assumed to be

$$y = \text{average panel score} = C_o + C_1 L^* + C_2 a^* + C_3 b^* + C_4 (\text{hue angle}) + C_5 (\text{chroma})$$

where C_o to C_5, were constants to be evaluated by regression.

Data Analysis

At each withdrawal for each item, time (t), temperature (T), and score (y), were recorded for each member of the consumer panel. The color parameters, L*, a* and b*, chroma, and hue angle values were recorded for each case and used to see whether they could furnish predictions of the consumer panel scores. For each of the six foods correlations were calculated among the six variables, L*, a*, b*, hue angle $= \tan^{-1}(b^*/a^*)$, chroma $= (a^{*2} + b^{*2})^{1/2}$ and mean consumer panel score. Consumer scores were found to be correlated with the color variables only for applesauce and cheese spread. For the other four foods there was no such statistically significant correlation, leading to the conclusion that for those foods color measurements did not furnish enough information about consumer scores to be useful. Attention was therefore focused on applesauce and cheese spread. Tables 1 and 2 show the data for applesauce and cheese spread in condensed form. The correlations among the six variables for applesauce and cheese spread are listed in Table 3.

For applesauce, consumer score is most strongly correlated with L* and hue angle. For cheese spread, consumer score is about equally correlated with all the variables except hue angle, although these correlations are weaker than for applesauce. The color variable which correlates best with consumer score across both foods is, therefore, L*. Most of the other color variables have rather high correlations with L*, suggesting that they furnish little information apart from that conveyed by L*. A possible exception is chroma in the case of applesauce, which has a rather low correlation with L* (0.685); however, chroma also has

weak correlation with consumer score (0.497), indicating that its impact is small in any case. L* also is an indicator of lightness (white to black) and would, perhaps, be less influenced by red-to-green color variations in applesauce or

TABLE 1.

APPLESAUCE L*a*b* VALUES, CONSUMER PANEL MEAN SCORES

Day	Temp	L*	a*	b*	Chroma	Hue Angle	Consumer Score
0	4.4	44.33	0.80	23.36	24.31	88.04	7.26
7	4.4	47.11	0.96	24.38	24.42	87.66	6.29
31	4.4	45.55	1.08	24.07	24.10	87.39	6.61
91	4.4	44.31	0.81	23.67	23.70	88.07	6.65
182	4.4	43.31	0.12	22.35	22.40	89.75	6.41
365	4.4	45.27	1.03	24.17	24.22	87.64	6.61
730	4.4	44.75	1.08	24.07	24.09	87.46	6.71
1095	4.4	44.37	1.10	23.56	23.59	87.33	6.92
7	26.7	45.55	0.95	24.88	24.92	87.93	5.95
31	26.7	45.75	1.15	23.30	23.33	87.05	6.50
91	26.7	44.64	1.31	24.55	24.63	86.98	5.84
182	26.7	43.74	1.87	24.78	24.87	85.62	6.41
365	26.7	40.14	3.61	25.61	25.85	82.00	6.31
730	26.7	36.19	5.84	25.44	27.10	77.09	6.13
1095	26.7	32.79	6.32	21.96	22.85	73.95	5.69
7	37.8	45.01	1.05	24.56	24.62	87.44	5.76
31	37.8	43.60	1.94	24.05	24.17	85.49	6.11
91	37.8	40.31	3.31	24.81	25.02	82.42	5.95
182	37.8	37.70	5.26	25.34	25.30	78.17	5.78
365	37.8	29.89	8.29	23.45	24.92	70.55	4.58
730	37.8	20.88	9.06	18.53	20.63	63.95	3.21
1095	37.8	17.33	7.69	12.45	14.63	58.30	2.97
7	48.9	44.54	1.31	24.80	24.83	87.00	5.95
31	48.9	42.23	3.65	25.40	25.67	81.71	5.74
91	48.9	36.22	6.62	25.60	26.44	75.54	5.41
182	48.9	29.73	8.60	23.60	25.12	69.98	4.87
365	48.9	23.58	9.54	20.90	22.96	65.56	*
7	60.0	39.88	5.42	25.50	26.07	78.05	5.58
31	60.0	29.95	9.90	22.50	24.58	66.25	4.05
91	60.0	19.06	9.77	17.80	20.32	61.17	*
182	60.0	14.46	8.33	13.20	15.59	57.84	*

TABLE 2.

CHEESE SPREAD L*a*b* VALUES, CONSUMER PANEL MEAN SCORES

Day	Temp	L*	a*	b*	Chroma	Hue Angle	Consumer Score
0	4.4	81.69	4.02	22.43	22.75	79.88	5.66
7	4.4	78.78	5.58	23.16	23.87	76.43	5.42
31	4.4	78.86	5.23	22.81	23.39	77.15	6.11
91	4.4	81.17	4.17	22.15	22.59	79.29	6.11
182	4.4	81.76	3.68	21.26	21,62	80.15	6.22
365	4.4	81.09	4.89	21.74	22.25	77.28	6.03
730	4.4	75.41	7.03	24.49	25.48	74.06	5.71
1095	4.4	75.90	7.23	23.54	24.63	72.93	5.50
7	26.7	81.85	4.02	22.60	22.95	79.96	5.55
31	26.7	80.97	4.57	22.26	22.77	78.35	6.03
91	26.7	75.92	6.51	22.93	23.80	74.16	5.97
182	26.7	77.93	5.63	23.18	23.87	76.43	6.08
365	26.7	75.96	6.99	26.05	26.93	74.93	5.57
730	26.7	71.59	8.42	30.12	31.25	74.41	5.00
1095	26.7	65,90	9.94	30.03	31.63	71.69	4.56
7	37.8	79.86	4.92	22.07	22.64	77.50	4.76
31	37.8	78.37	5.84	23.57	24.30	76.19	5.00
91	37.8	76.33	7.10	26.94	27.82	75.22	5.53
182	37.8	74.42	8.03	30.34	31.39	75.21	5.38
365	37.8	67.50	10.66	33.51	35.17	72.29	4.51
730	37.8	55.91	13.14	34.44	36.85	69.18	*
1095	37.8	53.32	14.35	34.96	37.79	67.68	*
7	48.9	75.80	5.79	22.52	23.24	75.55	5.58
31	48.9	76.20	7.14	26.56	27.53	75.06	5.92
91	48.9	70.83	10.00	32.46	34.00	72.90	5.08
182	48.9	64.88	11.55	34.68	36.59	71.52	4.68
365	48.9	62.21	12.42	33.70	35.91	69.80	*
7	60.0	71.42	9.81	30.67	32.23	72.30	4.68
31	60.0	63.29	13.56	36.89	39.33	69.77	3.61
91	60.0	58.56	13.38	35.57	38.04	69.37	*
182	60.0	56.61	12.61	31.13	33.56	67.95	*

yellow color variations in artificially colored cheese spread. For these reasons L* alone was chosen as the predictor of consumer scores and examined further for these two foods. The mean consumer rating scores and the L* values for both applesauce and cheese spread are depicted in Fig. 1 and 2.

The performance of L* as a predictor was studied by a sampling scheme based on the individual scores at each time and temperature. The consumer acceptance scores for each case were randomly divided into two equal sets (or nearly equal if there was an odd number). The first set was employed to obtain a relationship between average score and L* by means of linear regression. This relation was used to predict the score, Y_p, for each case and to decide whether the item was predicted to be acceptable ($Y_p > y_c$) or not ($Y_p < y_c$). In this context y_c indicates a critical acceptable consumer rating. Customarily the military uses a hedonic rating of five ($y_c = 5$) as the critical measure of acceptability for military rations although other ratings could be used. This acceptability-prediction was compared with the second set of individual scores to see how many times the predictions were correct. If y is any one of the individual scores for the case, then the prediction was correct if $[\{(y > y_c) \text{ and } (Y_p > y_c)\} \text{ or } \{(y < y_c) \text{ and } (Y_p < y_c)\}]$; an error of the first type (E1) occurred when $[(y < y_c) \text{ and } (Y_p > y_c)]$, and an error of the second type (E2) occurred if $[(y > y_c) \text{ and } (Y_p < y_c)]$. The choice of critical value y_c usually affected both the overall error rate and the numbers of errors of each type. The E1 error signifies acceptance of an unacceptable product. An E2 error occurs when an acceptable product would be rejected.

TABLE 3.

CORRELATIONS OF CONSUMER SCORES AND COLOR MEASUREMENT VALUES

	L*	a*	b*	Hue angle	Chroma
APPLESAUCE					
Consumer score	.911	-.834	.674	.917	.497
L*		-.905	.819	.984	.685
a*			-.523	-.952	-.335
b*				.750	.977
Hue angle					.598
CHEESE SPREAD					
Consumer Score	.802	-.814	-.796	.715	-.803
L*		-.972	-.895	.952	-.914
a*			-.959	.965	.972
b*				-.866	.999
Hue angle					-.866

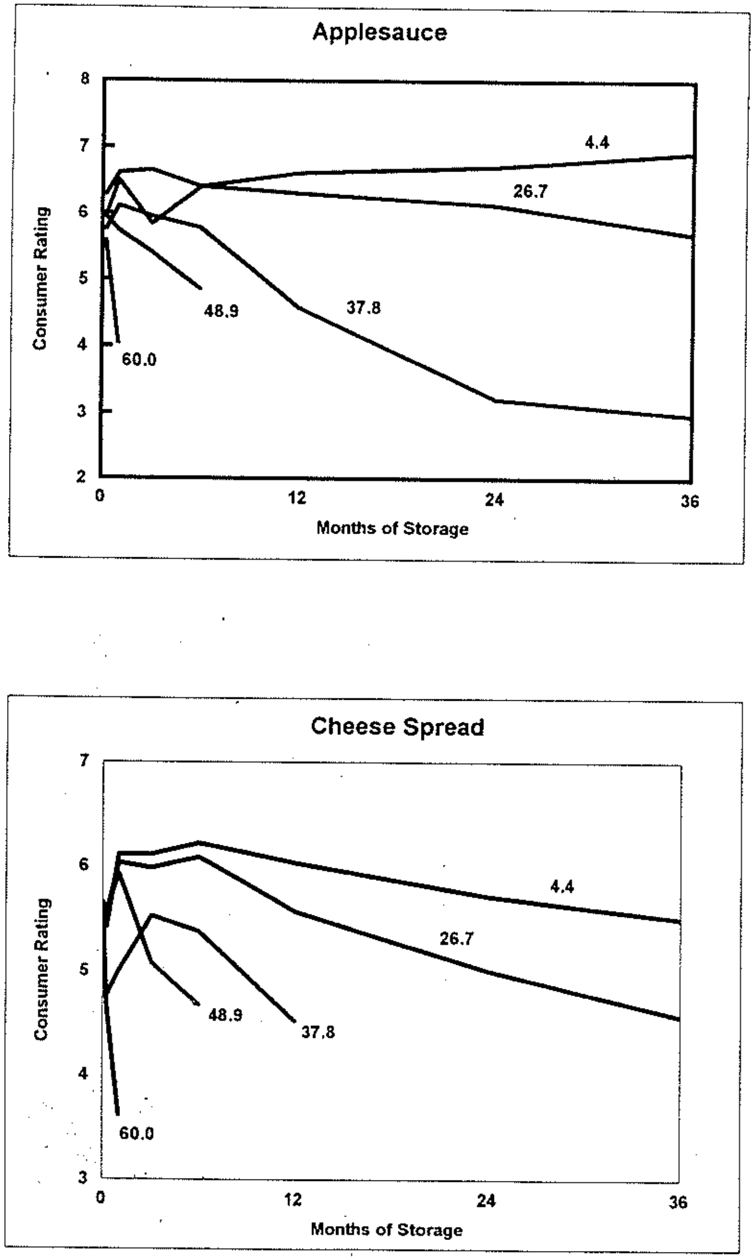

FIG. 1. MEAN CONSUMER RATINGS FOR APPLESAUCE AND CHEESE SPREAD WITH STORAGE AT FIVE TEMPERATURES OVER A THREE YEAR PERIOD
1 = Extremely poor, 9 = Excellent

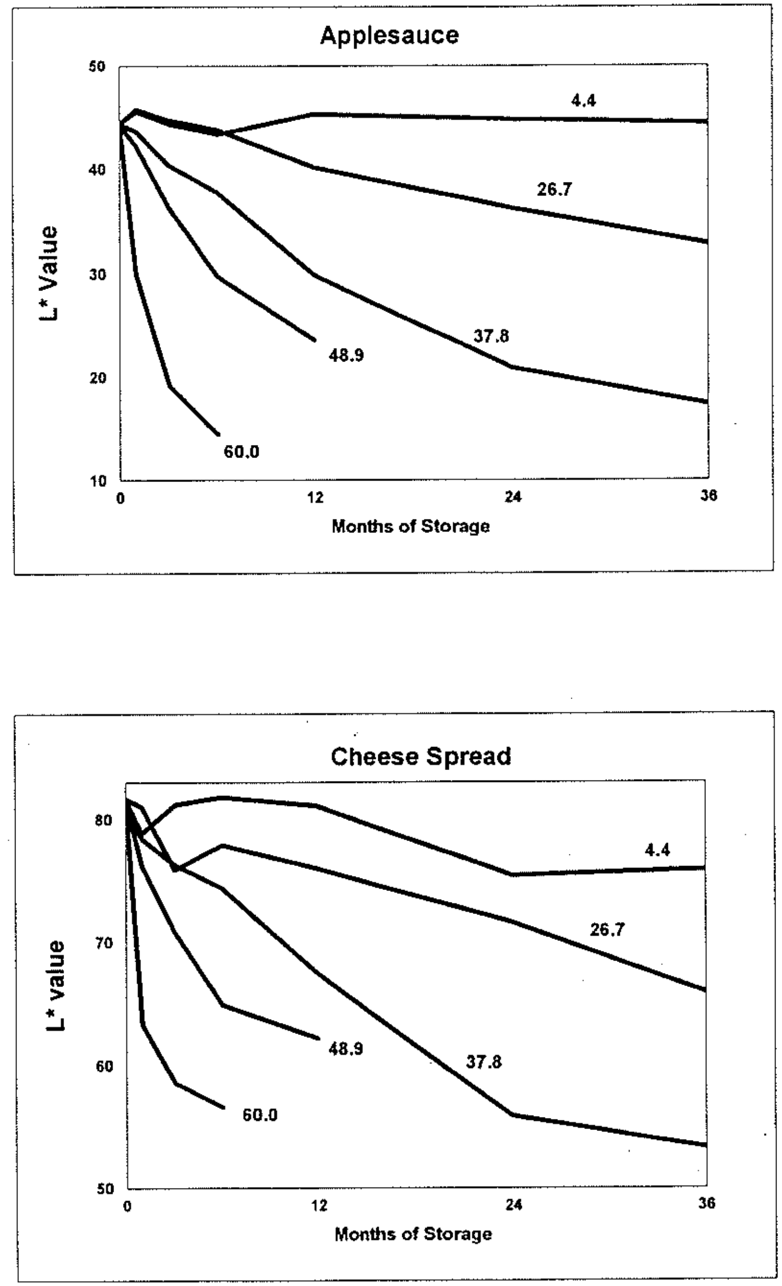

FIG. 2. HUNTER L* VALUES OF APPLESAUCE AND CHEESE SPREAD WITH STORAGE AT FIVE TEMPERATURES OVER A THREE YEAR PERIOD

RESULTS AND DISCUSSION

The regressions of y = average consumer score, based on half the data, led to the results:

$$\text{Applesauce: } Y_p = 1.296 + 0.11114\ L \text{ with } r^2 = 71.1\% \text{ and } s = .478$$
$$\text{Cheese spread: } Y_p = -1.273 + 0.08721\ L \text{ with } r^2 = 45.5\% \text{ and } s = .518,$$

where r^2 is the coefficient of determination and s the average error. The comparison between the acceptance predicted by these formulas and acceptances obtained from the second halves of the data is shown in Table 4 when $y_c = 4$, 5 and 6.

TABLE 4.

ERROR RATES IN PREDICTING CONSUMER SCORES FROM L*

			APPLESAUCE			
y	No. Correct	% Correct	No. E1	% E1	No. E2	% E2
4	437	92.8	32	6.8	2	0.4
5	391	83.0	57	12.1	23	4.9
6	354	75.1	53	11.3	64	13.6
			CHEESE SPREAD			
y	No. Correct	% Correct	No. E1	% E1	No. E2	% E2
4	368	83.4	73	16.6	0	0
5	318	72.1	77	17.5	46	10.4
6	278	63.0	0	0	163	37.0

Table 4 shows the errors in predicting consumer scores from the colorimeter measurement of L* using critical mean consumer acceptance ratings of 4, 5, or 6. For example, Table 4 shows that for applesauce, if one defines acceptability of an individual item as a consumer score of 5 or more (i.e. $y \geq y_c = 5$), there will be 57 or 12.1% E1 errors and 23 or 4.9% E2 errors. That would signify accepting a product that 12.1% of consumers would have rejected and rejecting a product that 4.9% of consumers found acceptable. These errors are high by the usual statistical standard, which would demand error rates of roughly 5% or less. On that basis, it might be concluded that the colorimeter measurements are not a reliable predictor of consumer acceptance. However, another way of looking at the matter is to ask whether the error rate from the color scores is worse than the error rate based on the average panel score. Error rates in consumer acceptability will occur because consumers usually do not all agree on the acceptability of any one sample. To determine the errors in the consumer acceptability ratings, instead of predicting Y_p by using the formula based on L*, take Y_p as the mean value of the consumer scores for each time and temperature, so that Y_p does not depend on L* at all. If this is done, and the frequencies of errors E1 and E2 calculated as above for $y_c = 5$, it is found that for applesauce

$$\%E1 = 12.1,\ \%E2 = 4.9,$$

and the overall error rate is 17.0%. For cheese spread

$$\%E1 = 13.8,\ \%E2 = 16.8,$$

and the overall error rate is 30.6%. These overall error rates are equal to or higher than (though statistically not different from) those based on the color measurements, which were 17.0% for applesauce and 27.9% for cheese spread. In other words, although the color measurements are not as reliable as one would like, they are no worse than those found by using the mean consumer panel scores (if those were known) as the predictor, Y_p. These results suggest that the color measurement procedure is a feasible alternative to consumer panel tests in screening for unacceptable food items when applied to foods that exhibit color deterioration.

The error rate is lower for applesauce than for cheese spread, probably because of the greater randomness of the cheese spread data. For $y_c = 4$ and 5, errors of type E1 are the more frequent, while for $y_c = 6$ errors of type E2 predominate. This is to be expected, because errors E1 can occur only when $Y_p > y_c$ and E2 only when $Y_p < y_c$. Naturally, errors are most numerous when the mean panel scores are near y_c. In practice this implies that errors tend to be infrequent for low temperatures and short times and also for high temperatures and long times, but errors are more profuse for intermediate times and temperatures.

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