KINETICS OF COLOUR LOSS FOR SLICES OF FERMENTED SAUSAGE DISPLAYED IN LIGHT OF VARYING INTENSITY

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Background

Surface colour is an important attribute that consumers use to judge acceptability of meat and meat products. For cured meats, the pink, pink-red, to red-maroon colour is viewed as an indicator of product freshness (Issanchou, 1996). Nitrosylhemochrome, the pigment of cured meats, is sensitive to light in the presence of oxygen. Protecting sliced cured meats, such as fermented sausages, from oxygen is normally done by proper packaging. Colour stability of cured meats is retained for 5-8 weeks when low oxygen transmission rate (OTR) films, generally <17 cc/m^2/24 hr, are utilized with vacuum packaging (Lin et al., 1980; Yen *et al*., 1988; Kartika *et al*., 1998). Light-induced fading occurs more rapidly if residual oxygen remains in packaged cured meats (Andersen *et al*., 1988) as can occur with inadequate vacuum-packaging and if the packaging film has too high an oxygen transmission rate (Lin *et al*., 1980, Yen *et al*., 1988, Kartika *et al*., 1998).

Since colour fading of cured meats is basically a chemical reaction in which nitrosylhemochrome is gradually destroyed by oxidation, the rate of colour change due to destruction could be evaluated as a function of storage temperature of the product. The Arrhenius relationship describes rate constant dependency on temperature and is very useful in determining quality losses in foods (Labuza, 1984). Since a time-temperature relationship reflects an energy input, a light intensity-time relationship would also reflect an energy input at the product surface and potentially resemble an Arrhenius type of relationship for reactions associated with colour loss.

Objectives

The objective of this study was to determine if an Arrhenius-type relationship exists for surface colour fading or colour loss for packaged slices of product placed in light display with lighting of different intensities. Rate constants for CIE L*a*b* as well as CIE C*and h* were obtained for product packaged in a non-oxygen barrier film so that O_2 was not restricted as a reactant in degradation of nitrosylhemochrome.

Materials and methods

Fresh commercial fermented sausage was obtained that analyzed 47.7% moisture, 17.1% protein, 29.7% fat, 3.36% ash, 4.06% NaCl (AOAC, 1995) and had a pH of 4.6. The sausage was classed as “summer sausage” and had been stuffed in chub form weighing approximately 1.36 kg each. The sausage was approximately 7 cm in diameter and was sliced to provide samples 3 mm in thickness. Two slices, each an experimental sample, were vacuum-packaged (72.4 cm Hg) side-by-side in a flexible film pouch using a Turbovac packaging machine (Turbovac B.V., Netherlands). The packaging film had an oxygen transmission rate (OTR) of 12,000 cc/m^2/24hr at 23^{o}C, 0%RH and 1 atm (Cryovac Division of Sealed Air Corporation, Duncan, SC). A high OTR film was used so that oxygen was not a limiting factor for colour fading. This made it possible to examine colour fading or loss of colour stability due to light intensity effects.

The packaged samples were immediately placed in the dark at 2±1^{o}C for 25 min and then initial colour values (0 hr) were measured. The packages were then placed on display under four light intensities: 660, 927, 1822 and 3172 lux at 2±1^{o}C. Continuous lighting was provided by Cool White fluorescent lights. Two packages (4 slices) were placed under each light intensity. Within each of three study replications, a new set of four slices in two packages as described above were prepared and used for colour evaluation.

CIE L* (lightness), +a* (redness), and +b* (yellowness) were measured using a Minolta Chroma Meter CR-300 (Minolta Corporation, Ramsey, New Jersey) at 0.5 hr intervals during display for 2.5 hr using 5 randomly chosen surface points on each slice. CIE C* (chroma), related to colour intensity, and CIE h* (hue angle), the measure of colour in the CIE L*C*h* space were calculated based on +a* and +b*. The Chroma Meter was calibrated with a white calibration plate and CIE Illuminant C was the illuminant source.

Kinetic analysis was conducted using the general linear model regression analysis procedure of SAS (1996). First order reaction kinetics were applied and a linear fit of colour characteristic data at each light intensity was tested using the following first order relationship: $\log y = b_o + b_1x$, where y is the specific colour coordinate value, x is the time of light display (hr), b_1 is the slope and b_o is the intercept. First order rate constants were calculated from the slopes and then used in a second regression analysis to test for an Arrhenius-type relationship due to light intensity given as: $\log k = b_o + b_1(1/\text{lux})$, where k is the rate constant (hr^{-1}), b_1 is the slope, and b_o is the intercept. The coefficient of regression (R^2) and significance of b_1 in the Arrhenius type relationship were used in determining acceptance or rejection of the fit of the data to first order kinetics. In addition to regression analysis, Arrhenius-type plots were prepared from the data.

Results and discussion

The main effects of light intensity, time of display, and the light intensity*time of display interaction were significant factors ($P<0.001$) for decreases in summer sausage surface lightness (CIE L*), redness (CIE +a*) and chroma (CIE C*) and an increase in hue (CIE h*) as determined by general linear models analysis of variance (SAS, 1996). For surface yellowness (CIE +b*), only the interaction was significant. Northcutt et al. (1990) reported that time of light exposure was significant for L*, a* and b* when vacuum-packaged turkey bologna was similarly displayed in a high OTR film. Generally, as light intensity for display increased in the present study, there was a decrease in colour intensity (CIE C*) as the visual colour (CIE h*) shifted from its initial “redness” toward “brown” discoloured characteristics. The major visual hue change shown to occur was associated principally with the redness (CIE +a*) component, typical for highly pigmented cured products, and not the yellowness (CIE +b*) aspect of the hue.

The regressions for rate of change in surface redness, chroma, and hue (TABLE 1), fit a first order reaction mechanism rather than zero or other order and this is in agreement with previous studies of Northcutt et al. (1990) and Mattos et al. (2003). Summer sausage surface lightness (CIE L*) had non-significant ($P>0.05$) slope changes and there was no overall consistent slope pattern for yellowness (CIE +b*) as light intensity increased. All slopes for the response variable redness (CIE +a*), hue (CIE h*), and chroma (CIE C*) were significant ($P<0.0001$). The major observation of the first order rate constants for the significant colour components is that ***the rate constants increase as light intensity increases***. Therefore, light intensity is similar to the temperature effect usually studied for effects on traditional chemical reactions.

In the Arrhenius relationship, a linear relationship exists between the log of the rate constants and the reciprocal of the absolute temperature. When the rate constants of each colour characteristic were used in linear regression analysis for relationship to the reciprocal of light intensity, the coefficients of determination (R^2) showed an acceptable relationship for CIE +a*, h* and C* but not for CIE L* and b* (TABLE 2). Data from TABLE 1 were used to generate Arrhenius-type plots for redness (CIE a*) and hue (CIE h*) (FIGURE 1) to demonstrate that the Arrhenius concept for reaction dependency on temperature is also valid for dependency on light intensity, another form of energy affecting surface colour stability of summer sausage.

Conclusions

Fermented summer sausage slices vacuum-packaged in a high oxygen transmission film and placed in display at 2°C under fluorescent light intensities in the range of 660 to 3173 lux produced decreases in product surface redness and chroma and increases in hue. Plotting first order rate constants of the colour attributes against the reciprocal of light intensity indicated an Arrhenius-type reaction rate fit. This finding confirmed that the Arrhenius concept for reaction dependency on temperature is also valid for dependency on light intensity, another form of energy that can negatively affect the colour stability of cured meats.

References

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TABLE 1. Linear regression and correlation coefficients for CIE colour characteristics of vacuum-packaged summer sausage displayed for up to 2.5 hr under different light intensities.

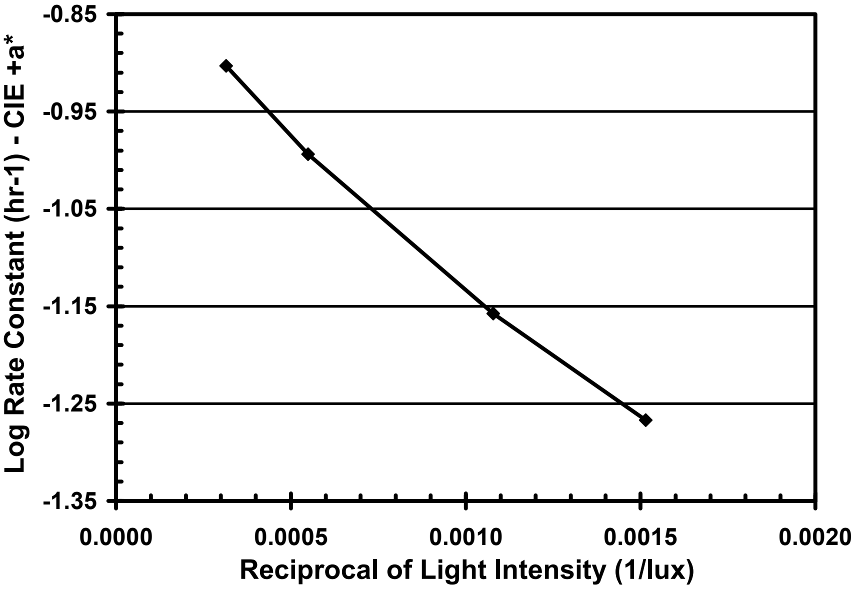
Colour Coordinate	Light Intensity (lux)	Coefficient			Standard Error	Rate Constant
		b_o	b_1*10^2	r	b_1*10^2	$k*10^2$ hr^{-1}
Lightness (CIE L*)	660	1.72	0.0091ns	0.07	0.067	0.2096
	927	1.72	0.0072ns	0.06	0.063	0.1258
	1822	1.73	-0.0002ns	0.00	0.065	0.0046
	3173	1.72	0.0130ns	0.10	0.068	0.2994
Redness (CIE a*)	660	1.23	-2.348***	0.68	0.133	5.408
	927	1.26	-3.021***	0.77	0.131	6.958
	1822	1.25	-4.403***	0.84	0.149	10.141
	3173	1.25	-5.428***	0.85	0.179	12.500
Yellowness (CIE b*)	660	1.05	-0.299*	0.14	0.116	0.689
	927	1.04	0.060ns	0.03	0.114	0.138
	1822	1.05	-0.034ns	0.02	0.109	0.079
	3173	1.04	0.248*	0.13	0.098	0.570
Chroma (CIE C*)	660	1.33	-1.751***	0.67	0.103	4.032
	927	1.33	-2.086***	0.72	0.161	4.804
	1822	1.32	-2.968***	0.81	0.113	6.835
	3173	1.32	-3.451***	0.81	0.134	7.971
Hue (CIE h*)	660	1.49	1.632***	0.56	0.132	3.757
	927	1.50	2.428***	0.74	0.116	5.592
	1822	1.50	3.360***	0.81	0.127	7.739
	3173	1.51	4.287***	0.87	0.128	9.874

Linear regression model: $\log y = b_o + b_1x$ where y = colour attribute, x = display time (0 to 2.5 hr), b_o = intercept, and b_1 = slope. Correlation coefficient (r) of the association between x and y are included. Rate constant $k = | b_1 | * 2.303$. *** $P<0.0001$, * $P<0.05$, ns $P>0.05$.

TABLE 2. Regression coefficients of determination (R2) for colour characteristics of vacuum-packaged summer sausage using the Arrhenius-type relationship of rate constants to light intensity of display.

Colour Attribute	Colour Coordinate	Regression Coefficient		
		b_o	b_1	R^2
Lightness	CIE L*	-3.50	444.5	0.11
Redness	CIE a*	-0.82	-299.4	0.99
Yellowness	CIE b*	-2.78	221.7	0.42
Chroma	CIE C*	-1.03	-249.2	0.99
Hue	CIE h*	-0.91	-333.7	0.99

Linear regression model: $\log y = b_o + b_1x$ where y = k (first order rate constant), x = 1/light intensity (lux), b_o = intercept and b_1 = slope.



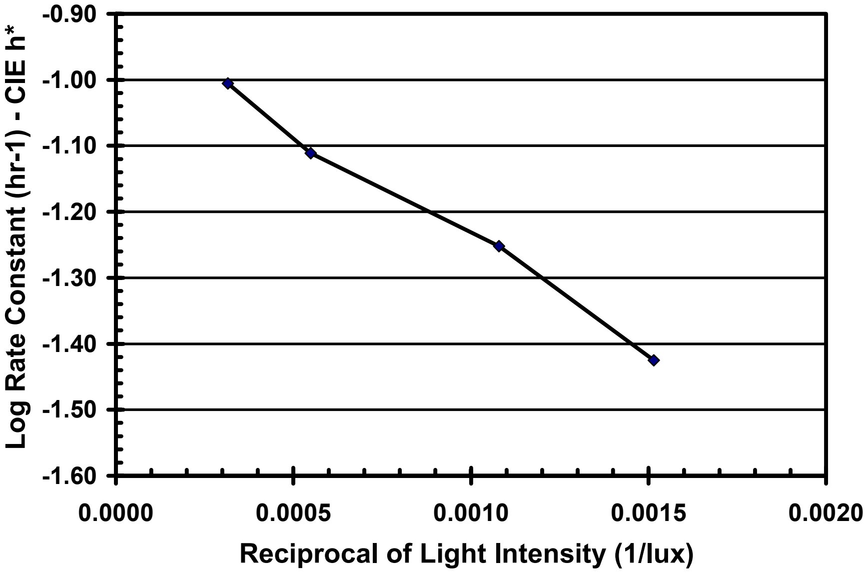


FIGURE 1. Arrhenius-type plots showing the dependency of the first order rate constants (taken from absolute values of slopes) for redness (CIE +a*) decrease and hue (CIE h*) increase as a function of light intensity.