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Determination of Turkish-type fermented sausage colour by a reflectance method

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An objective method is described for the determination of Turkish-type fermented sausage colour. The method is based on reflectance measurements and specified as $(R_{570}-R_{525})/(R_{650}-R_{525})$. This ratio was simply termed as the TSC value (Turkish sausage characteristics) and was compared with 14 other objective values. The correlation coefficient of the TSC value with panel scores was higher than those of the other objective values except the CIE y value. The other 13 objective values were CIE xz, $L^*a^*b^*$, $L^*C^*H^\circ$ Hunter *Lab*, RSI, NI and percentage nitrosomyoglobin (NOMb) pigment. Correlation coefficients of CIE y and TSC values are −0.901 and −0.875, respectively. TSC value is a measure of both pigment nitrosation and pigment discoloration and more useful than the RSI value. A regression equation was estimated for calculating scores from TSC values. This regression equation was converted to a table to determine the grade for colour of fermented sausages. Copyright © 1996 Elsevier Science Ltd

INTRODUCTION

Colour is one of the most important characteristics consumers use when selecting and purchasing foods. Several methods are available for objectively measuring the colours of fermented meat products and other food products. Some of these methods depend on the extraction of pigments from food products followed by spectrophotometric determination of pigment concentration. Cured fermented meat products contain myoglobin, oxymyoglobin, metmyoglobin and nitrosomyoglobin pigments. These pigments, except nitrosomyoglobin, are also found in meat. Hornsey (1956) employed 80% (v/v) acetone solution to extract nitrosomyoglobin from cooked cured pork and determined the concentration of the nitrosomyoglobin–acetone complex spectrophotometrically. In total pigment determination, Hornsey (1956) used acetone/water/concentrated hydrochloric acid solution (40:9:1, v/v) to extract the four pigments and measured the absorbance of the resulting acid haematin solution. Zaika *et al.* (1976) modified the method by increasing the acetone ratio of the solvent used in the extraction and refrigerating the solvent. Acton & Dick (1977) and Garcia *et al.* (1992) modified the Hornsey method in different ways.

Hornsey's method is a widely used procedure for the determination of haem pigments. The drawbacks with this method are:

1. Because volatile reagents are used, the results are not always reliable.
2. The solvent also extracts proteins and lipids from the sample, which can cause turbidity in the extracts and overestimation of the pigment level.
3. Uncooked or fatty meat products may not give accurate results.
4. Sample preparation should be carried out in a darkened room, and with the minimum of delay.

Various studies have therefore been made on other solvent systems. Warriss (1979) employed 0.04 M phosphate buffer, pH 6.8, as a solvent to extract the haem pigments from fresh meat. Extracted pigments were oxidized to metmyoglobin by potassium ferricyanide. Metmyoglobin was converted to cyanometmyoglobin by the addition of sodium cyanide and the absorbance of the pigment solution was measured. Centrifugation and refrigeration were used to eliminate proteins and lipids from the pigment solution. The main drawback of this method is the use of cyanide, which is extremely toxic.

Krzywicki (1982) also employed 0.04 M phosphate buffer, pH 6.8, to extract the haem pigments from meat, and determined myoglobin, oxymyoglobin, metmyoglobin and total pigment concentrations by measuring the absorbances of the extract at 572, 565, 545 and 525 nm. Absorbance at 730 nm was measured as an indicator of turbidity in the extracts; this absorbance was multiplied

by the correction factor and the resulting value was subtracted from the absorbance obtained at the wavelength used to quantify the pigment. Krzywicki pointed out that the molar absorbance coefficients of myoglobin, oxymyoglobin and metmyoglobin are the same at 525 nm. The relative concentrations of myoglobin and oxymyoglobin in the extract do not reflect their quantities in the meat sample. During the extraction procedure, myoglobin is almost completely oxygenated. In general, however, the concentrations of all three pigments do not change for several hours after preparation of an extract. After lengthy storage, metmyoglobin concentration increases due to oxidation of myoglobin and oxymyoglobin.

Agulló *et al.* (1990) suggested treating the aqueous pigment solutions with trichloroethylene to eliminate turbidity from protein and lipid fractions.

Karlsson & Lundström (1991) used 0.05 M phosphate buffer, pH 7.4, to extract pigments from porcine meat and added sodium hydroxide and the non-ionic detergent Triton X-100 to determine total pigment concentrations. The concentration of alkaline haematin solution was measured at 575 nm. Triton X-100 clarifies the solution and enhances the molar absorptivity of alkaline haematin at the wavelength used. Absorbance at 700 nm was used as a correction factor and the extract was refrigerated to eliminate overestimation from dissolved proteins and lipids. Sodium hydroxide was used to oxidize the Fe(II) of the myoglobin to Fe(III) of metmyoglobin. It also reduced the turbidity, and a clear extract was obtained. Proteins and lipids are much more soluble in alkaline solutions than in acid solutions.

Trout (1991) employed 0.04 M phosphate buffer, pH 6.5, as a solvent to determine total haem pigments of meat. To eliminate turbidity, Triton X-100 was added and the absorbance at 730 nm was used as a correction factor. All pigments were converted to metmyoglobin by the addition of sodium nitrite and the absorbance of the resulting solution was measured.

Since the pigment extraction methods were time-consuming and tedious, some researchers studied simpler methods of colour measurement. Thus, methods which measure the reflected light from the surface of beef were developed. Dean & Ball (1960) determined the percentage reflectances of the meat sample surface at wavelengths of 473, 507, 573 and 597 nm. Percentage reflectance values (R) had been converted to K/S values before the relative contents of myoglobin, oxymyoglobin and metmyoglobin at the surface of beef were evaluated. Dean & Ball (1960) compared pigment extraction and reflectance techniques for quantifying meat pigments. They pointed out that the pigment extraction method overestimated metmyoglobin and oxymyoglobin and underestimated myoglobin due to changes in pigment forms during extraction. Krzywicki (1979) determined the relative contents of myoglobin, oxymyoglobin and metmyoglobin at the surface of beef by measuring reflex attenuance values (the logarithm of the reciprocal of the reflectance) at 572, 525, 473 and 730 nm.

Harrison *et al.* (1980) used differences or ratios of percentage reflectance values at different wavelengths as colour parameters to measure the colour of beef and determined the correlation coefficients between these colour parameters and panel scores. They recommended the use of $R_{630}-R_{580}$ and reported that the use of K/S values instead of percentage reflectances did not improve the correlation coefficients.

Hunt (1980) tabulated correlation coefficients of various objective values with panel scores. These objective values consist of numerous combinations of percentage reflectance values to measure the colour of meat and tristimulus values such as Hunter *Lab*, CIE *XYZ*, Munsell hue, chroma and value.

Eagerman *et al.* (1977) determined the colour of fresh meat by various objective methods and compared correlation coefficients of these objective methods using panel scores. Various combinations related with percentage reflectances and some tristimulus values were used as objective parameters.

Pagan-Moreno *et al.* (1992) measured colour evolution parameters of Spanish dry-cured fermented sausage 'chorizo' during the process. They did not employ time-consuming extraction methods. Instead, they measured tristimulus values such as CIE L^*, a^*, b^*, C^*, Hue*, S^* and reflectance values consisting of NI and RSI. The NI value was specified as R_{560}/R_{500} and considered as a measure of pigment nitrosation. RSI value was formulated as R_{570}/R_{650} and measures pigment discoloration. Similar objective methods were used to measure the colour of other cured meat products (Rodriguez-Lopez *et al.*, 1992; Gago-Gago *et al.*, 1992; Campo-Fernandez *et al.*, 1992).

MATERIALS AND METHODS

Samples

Eleven different sausage products obtained from various modern integrated meat plants having an important market share were taken as the test materials. Products of small plants using traditional methods were not considered since their market shares were insignificant.

Panel

Eleven different sausage samples were ranked according to their surface colour and cross-section colour by ten trained panelists in the order of preference. The most preferred sausage sample in terms of colour was given 10 points, and 0 points was given for the least preferred sample. Panel results were evaluated according to Kramer & Twigg (1984).

Colour measurements

CIE *XYZ*, *xyz*, $L^*a^*b^*$ and $L^*C^*H^\circ$ values were measured by a Datacolour Texflash spectrophotometer using D_{65} illuminant (Hunt, 1987; Hunter & Harold, 1987). Hunter *Lab* values were calculated from CIE *XYZ* values by conversion equations. CIE *y* and Hunter *b* values were also measured with illuminant A. Percentage reflectance values of sausage samples from 390 nm to 700 nm, NI (R_{560}/R_{500}), RSI (R_{570}/R_{650}) and TSC $(R_{570}-R_{525})/(R_{650}-R_{525})$ values were also measured by the Datacolour Texflash spectrophotometer. The measured colour parameters were determined as three replicates.

Haem pigment analyses

Nitrosomyoglobin contents of the samples were determined according to Hornsey (1956). Acetone/water solution (40:6, v/v) was used as solvent. This ratio reached 40:10 with the moisture from the sample. Absorbance of the resulting nitrosomyoglobin–acetone complex was measured at 540 nm and results were found as ppm haematin. A sample of 10.00 g was taken for analysis and 0.5 g of cysteine was added to 46.00 ml of solvent used in extraction.

Total pigment analyses were also accomplished according to Hornsey (1956) and acetone/water/concentrated hydrochloric acid solution (40:5:1, v/v) was used as solvent. A sample of 10.00 g was analysed and the absorbance of the resulting acidic haematin solution was measured at 640 nm. Results were obtained in terms of ppm haematin. Percentage nitrosomyoglobin (%NOMb) was calculated from the nitrosomyoglobin concentration divided by the total pigment concentration. Nitrosomyoglobin and total pigment concentrations were determined as four replicates.

Nitrite analyses

A modified AOAC (1990) method was used to determine the nitrite levels of the sausage samples. Modified Griess reagent was prepared from sulfanilic acid and α-naphthylamine. A sample of 10.00 g was homogenized and introduced into a 250 ml volumetric flask. Then 100 ml of distilled water was added and the contents were heated to 80 °C. Saturated $HgCl_2$ solution (10 ml) was added and left at room temperature. When the contents of the flask reached room temperature, they were diluted to 250 ml and filtered through blue ribbon filter paper. Then 2.00 ml of Griess reagent was added to 50.00 ml of filtrate. After 1 h, the absorbance of solution was measured at 520 nm by a Pye Unicam SP-100 spectrophotometer. Nitrite concentrations of the samples were determined by means of a standard curve. Nitrite concentrations were determined as three replicates.

Lipid analyses

Lipid analyses were carried out according to the method of Folch *et al.* (1957). A sample of 10.00 g was homogenized for 3 min with 150 ml of chloroform/methanol (2:1, v/v). The mixture was filtered and the solid residue resuspended in 150 ml of chloroform/methanol solution and homogenized for 3 min. After filtering, the solid was washed once more with chloroform (100 ml) and once with methanol (50 ml). The combined filtrates were transferred to a separation funnel and 100 ml of 0.4% $CaCl_2$ in water was added. The mixture was shaken thoroughly and allowed to settle. The lower chloroform layer was separated and carefully evaporated until a constant weight was obtained. Lipid analyses were carried out as three replicates.

RESULTS AND DISCUSSION

Eleven different types of sausage samples were ranked in order of colour preference according to panel results. Percentage reflectance values of these 11 samples were measured between 390 and 700 nm (Table 1). Variation of *R* values with wavelength for three sausage samples which were given 10, 6 and 0 points by the panel are illustrated in Fig. 1. *R* values at 570 nm increase obviously, while those at 650 nm decrease with variation from the most preferred sample to the least preferred one. The yellow colour of the most preferred sample is weaker than the others, but the red colour of the same sample is the strongest. Small *R* values at 570 nm indicate large conversion to nitrosomyoglobin. Large *R* values at 650 nm indicate a high percentage of Fe(II) pigments and a low percentage of metmyoglobin. The most preferred sausage sample has the smallest *R* value at 570 nm but the largest at 650 nm since its nitrosomyoglobin and Fe(II) pigments contents are the highest. This suggests that measuring *R* values at both 570 nm and 650 nm will be a good method to determine the colour of sausage samples.

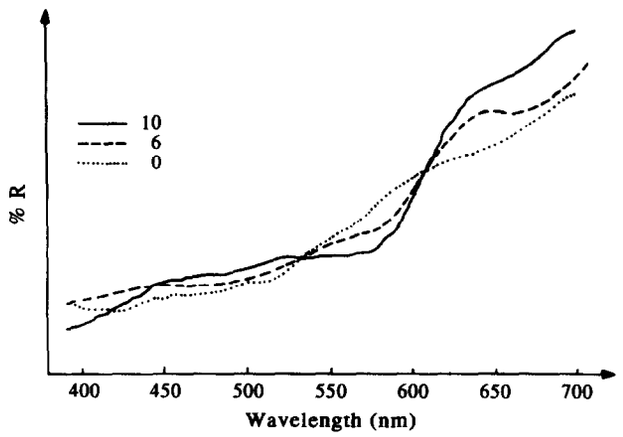

Fig. 1. Percent reflectance curves of sausages which were given 10, 6 and 0 points with respect to colour at the panel. (The percent reflectance values at 525 nm were coincided.)

Table 1. Percentage reflectance values of 11 different Turkish-type fermented sausages between 390 and 700 nm

Wavelength (nm)	Panel scores										
	10	9	8	7	6	5	4	3	2	1	0
390	7.2	8.0	6.9	8.3	8.3	8.3	8.3	9.3	10.7	8.5	9.1
400	7.9	8.5	7.0	8.7	8.6	8.5	8.5	9.4	11.1	8.2	8.8
410	8.7	9.0	7.0	9.0	9.0	8.7	8.7	9.4	11.5	7.8	8.6
420	9.7	9.8	7.2	9.6	9.4	9.1	8.9	9.5	12.1	7.6	8.6
430	11.2	11.1	7.7	10.4	10.1	9.9	9.8	9.8	13.0	7.7	9.2
440	12.7	12.4	8.4	11.3	10.5	10.7	10.5	10.1	13.9	7.8	9.8
450	13.6	13.3	8.7	11.8	10.6	11.1	10.9	10.0	14.4	7.8	10.2
460	14.2	14.0	8.9	12.1	10.6	11.3	11.1	9.9	14.8	7.7	10.6
470	14.6	14.4	9.1	12.3	10.7	11.4	11.3	10.0	15.1	7.8	10.8
480	14.9	14.7	9.3	12.4	10.8	11.6	11.6	10.2	15.5	8.1	11.1
490	15.4	15.2	9.5	12.8	11.2	12.0	11.9	10.5	15.9	8.4	11.4
500	16.0	15.8	9.9	13.2	11.8	12.5	12.3	11.0	16.5	8.9	11.7
510	16.8	16.2	10.3	13.9	12.6	13.3	13.1	11.9	17.5	9.7	12.1
520	17.3	16.3	10.7	14.5	13.5	14.1	14.0	13.1	18.7	10.9	12.7
530	17.3	16.2	10.9	14.9	14.6	14.9	14.5	14.5	19.5	12.5	13.9
540	17.4	15.9	11.1	15.2	15.7	15.7	15.1	16.1	20.3	14.4	15.4
550	17.5	15.7	11.4	15.6	16.8	16.5	15.7	17.8	21.3	16.8	16.9
560	17.8	15.3	11.6	15.9	17.8	17.2	16.3	19.5	22.2	19.1	18.6
570	17.9	15.7	11.8	16.1	18.3	17.5	16.6	20.3	22.6	20.3	20.2
580	18.4	16.0	12.1	16.6	19.3	18.2	17.2	21.5	23.4	21.8	21.8
590	20.9	18.0	13.7	18.7	21.9	21.3	19.1	24.2	25.6	24.6	23.4
600	25.2	21.5	16.2	22.0	25.2	25.4	22.0	27.9	28.3	28.1	24.8
610	30.0	25.7	19.4	25.6	28.7	31.4	25.7	32.4	31.6	32.2	25.9
620	34.8	29.9	22.8	29.2	31.9	36.6	29.7	37.0	34.8	35.9	26.8
630	38.4	33.2	25.7	31.9	34.2	40.0	33.1	40.7	37.4	38.6	27.4
640	41.1	35.8	28.0	33.3	35.7	42.1	36.0	43.6	39.3	40.4	28.1
650	42.5	37.0	29.1	33.4	35.5	42.6	38.0	44.9	39.8	40.9	29.3
660	43.5	37.9	29.9	33.4	35.1	42.9	39.5	45.7	40.2	41.3	30.8
670	44.8	39.3	31.2	34.5	35.1	42.2	41.1	47.2	41.4	42.8	32.6
680	46.3	40.7	32.8	36.4	37.7	45.8	42.7	48.9	43.0	44.7	34.4
690	47.9	42.3	34.6	38.3	39.7	48.0	44.2	50.8	44.6	46.8	35.9
700	49.7	43.9	36.6	40.5	42.2	50.7	45.6	53.3	46.2	49.2	37.3

Table 2. Values of objective parameters obtained for 11 different Turkish-type fermented sausages

Objective parameter[a]	Panel scores										
	10	9	8	7	6	5	4	3	2	1	0
CIE											
x^D	0.388	0.375	0.394	0.386	0.408	0.410	0.397	0.422	0.389	0.439	0.402
y^D	0.357	0.352	0.355	0.356	0.363	0.363	0.361	0.367	0.364	0.376	0.373
y^A	0.392	0.392	0.390	0.395	0.397	0.390	0.394	0.393	0.401	0.396	0.407
z^D	0.255	0.273	0.251	0.258	0.229	0.227	0.242	0.211	0.247	0.185	0.225
L^{*D}	51.8	49.5	42.3	48.0	47.5	51.7	49.2	51.1	53.3	50.3	51.2
a^{*D}	13.7	11.3	13.5	12.6	15.8	17.7	14.2	19.4	11.9	20.4	12.4
b^{*D}	15.0	11.5	13.1	13.7	17.8	19.3	16.4	21.7	17.9	26.2	20.3
C^{*D}	20.3	16.1	18.8	18.6	23.8	26.2	21.7	29.2	21.5	33.2	23.8
$H^{\circ D}$	47.6	45.4	44.1	47.3	48.2	47.6	49.1	48.2	56.3	52.0	58.5
Hunter											
L^D	44.62	43.95	35.87	41.47	42.61	43.26	41.56	44.20	47.37	43.46	45.92
a^D	8.76	6.89	8.22	7.69	10.21	12.65	9.09	14.14	6.86	13.43	7.39
b^D	12.46	10.14	10.04	11.14	13.22	14.73	12.78	15.80	13.99	17.62	15.14
b^A	27.19	25.75	21.94	25.07	27.02	27.64	25.82	29.18	28.85	28.90	28.95
TSC×10	0.238	−0.240	0.495	0.649	1.770	0.939	0.894	1.908	1.527	2.746	4.091
RSI	0.421	0.424	0.406	0.482	0.516	0.411	0.437	0.452	0.568	0.496	0.689
NI	1.11	0.97	1.17	1.20	1.51	1.38	1.32	1.77	1.34	2.15	1.59
%NOMb	78.37	59.89	57.65	71.23	49.75	42.87	54.77	56.03	42.46	81.71	78.18

[a]Superscript letters: A, values obtained by illuminant A; D, values obtained by illuminant D_{65}.
See text for definition of variables.

Total pigment concentrations of sausage samples may be different and this difference causes confusion in comparing samples in terms of colour. To eliminate this confusion, the reflectance curves in Fig. 1 were moved parallel to the x-axis until their R values at 525 nm coincided. Millimolar absorbance coefficients of myoglobin, oxymyoglobin and metmyoglobin are 7.6 at 525 nm (Krzywicki, 1982). The millimolar absorbance coefficient of nitrosomyoglobin is also close to this value, namely 8.2 (Wong, 1989). Consequently, it is possible to assume that the absorbance at 525 nm measures the total pigment concentrations of cured meat products. Coinciding the R values at 525 nm in Fig. 1 thus eliminates the effect of differences in total pigment concentrations of various samples.

The above discussion shows that the $(R_{570}-R_{525})/(R_{650}-R_{525})$ ratio can be a suitable parameter to measure the colour of cured meat products. The correlation coefficient of this ratio with panel scores is −0.875. This ratio was simply termed as the TSC value (Turkish sausage characteristics). This coefficient is significantly greater than −0.700 for the RSI (R_{570}/R_{650}) value. The correlation coefficients for CIE xz, $L^*a^*b^*$, $L^*C^*H^\circ$, Hunter Lab, NI and %NOMb were all smaller than that for the TSC value. But the correlation coefficient of the CIE y value is −0.901, larger than that for the TSC value. The objective parameter values determined for 11 different sausage samples are listed in Table 2. Correlation coefficients of these objective parameters with panel scores are tabulated in Table 3.

As is seen in Table 3, correlation coefficients of CIE y and Hunter b values are −0.901 and −0.809, respectively, if the D_{65} illuminant is used. When illuminant A was used, correlation coefficients of the same parameters dropped to −0.695 and −0.674, respectively. It was concluded that illuminant A was not suitable for the examination of colour of cured fermented sausages.

Regression equation $p = 8.20 - 23.4\text{TSC}$ was estimated between scores and TSC values. The score of any sausage sample in terms of colour can be evaluated from the TSC value using this equation. The grading of the sausage samples will be simplified if a table is obtained from this regression equation (Kramer & Twigg, 1984). It is seen in Table 4 that sausage samples were included in grade A if their TSC values were equal to or less than 0.0513. A grade sausages are the most preferred in terms of colour. Sausages with a TSC value between 0.0517 and 0.1795 were classified as B grade. C grade sausages, with a TSC value of 0.1799 or larger, are the least preferred.

Table 3. Correlation coefficients (r) of various objective parameters with panel scores

Objective parameter[a]	r	Objective parameter[a]	r
CIE		Hunter	
x^D	−0.618	L^D	−0.441
y^D	−0.901	a^D	−0.305
y^A	−0.695	b^D	−0.809
z^D	+0.728	b^A	−0.674
L^{*D}	−0.416		
a^{*D}	−0.360	TSC	−0.875
b^{*D}	−0.808	RSI	−0.700
C^{*D}	−0.682	NI	−0.773
$H^{\circ D}$	−0.821	%NOMb	−0.033

[a] Superscript letters: A, values obtained by illuminant A; D, values obtained by illuminant D_{65}.
See text for definition of parameters.

The sausage samples which were given 10, 9 and 8 points by the panel were also classified as A grade if they were evaluated according to TSC values. The sausage samples with 7, 6, 5 and 4 points were classified as B grade according to TSC values. The samples with 3, 1 and 0 points were of grade C (Table 4). An exceptional behaviour was observed for the sample allocated 2 points by the panel, which corresponds to C grade. However, according to the TSC value, this sample fell in the B grade range in Table 4.

Scoring according to the panel is in perfect agreement with the scoring with respect to the TSC values except for one sample. Consequently, it is more appropriate to determine the scores of sausage samples in terms of colour from the TSC values instead of using a panel, which is a time-consuming subjective method.

The regression equation between CIE y values and scores is $p = 150 - 401y$. Table 5 was obtained from this regression equation. The grade of any sample can be found easily from Table 5 if its CIE y value is known.

It is seen from Tables 4 and 5 that TSC and CIE y values of A grade sausages are smaller than those for B or C grades. Colour scores of sausages decrease as TSC or CIE y values increase. Moreover, when going from a sausage with 10 points to one with 1 point, the TSC values increase rapidly while the CIE y values increase only slowly. The rates of increase for these cases are:

Table 4. Scoring and grading of sausages according to TSC values

A grade		B grade		C grade	
TSC	Score	TSC	Score	TSC	Score
−0.0769	10.00	0.0517	6.99	0.1799	3.99
−0.0342	9.00	0.0940	6.00	0.2222	3.00
0.0085	8.00	0.1368	5.00	0.2650	2.00
0.0513	7.00	0.1795	4.00	0.3077	1.00

Table 5. Scoring and grading of sausages according to CIE y values

A grade		B grade		C grade	
y	Score	y	Score	y	Score
0.34913	10.00	0.35663	6.99	0.36411	3.99
0.35162	9.00	0.35910	6.00	0.36658	3.00
0.35411	8.00	0.36160	5.00	0.36908	2.00
0.35661	7.00	0.36409	4.00	0.37157	1.00

Table 6. Residue nitrite levels (mg kg^{-1} $NaNO_2$) of sausage samples

Panel score										
10	9	8	7	6	5	4	3	2	1	0
4.00	4.50	4.13	6.25	4.50	4.55	3.15	10.0	2.51	5.00	11.3

$$\frac{TSC_1 - TSC_{10}}{TSC_1} \times 100 = \frac{0.3077 + 0.0769}{0.3077} \times 100 = 125\%$$

where TSC_1 is the TSC value for sausages with 1 point and TSC_{10} is the TSC value for sausages with 10 points, and

$$\frac{y_1 - y_{10}}{y_1} \times 100 = \frac{0.37157 - 0.34913}{0.37157} \times 100 = 6.0\%$$

where y_1 is the y value for sausages with 1 point and y_{10} is the y value for sausages with 10 points.

There is a 125% increase in TSC values in contrast to a 6.0% increase in CIE y values. Consequently, using TSC values instead of CIE y values in scoring and grading of sausage samples in terms of colour will give more sensitive results.

Residue nitrite concentrations of 11 different sausage samples are seen in Table 6. These nitrite concentrations are well below the level of 150 mg kg^{-1} as $NaNO_2$ established by national governmental authorities.

The correlation coefficient of NI values with panel scores is −0.773. The NI value is specified as R_{560}/R_{500} and measures the ratio of nitrosomyoglobin concentration to total pigment concentration. However, the %NOMb value also indicates the same ratio, although no correlation between %NOMb values and panel results was observed ($r = -0.033$). %NOMb values were calculated from the nitrosomyoglobin and total pigment contents, which were obtained by the Hornsey (1956) method. Turkish-type sausages are fatty and uncooked products. Lipid contents of sausage samples are seen in Table 7. Thus, it may be concluded that the Hornsey method is not suitable for Turkish-type sausages.

The correlation coefficient of CIE y values with panel scores is −0.901, which is higher than all the remaining objective parameters. The most preferred sausages by the panel have smaller CIE y values than the others and preference decreases as the CIE y value increases. The increase in the CIE y value is the increase in intensity of the 550 nm yellow beam reflected from the surface of the sausage. In other words, preference decreases as the intensity of the yellow colour of sausages increases. It is also seen in Fig. 1 that preference decreases as percentage reflectance at 550 nm increases. There is a good correlation between Hunter b values and panel scores ($r = -0.809$). When the intensity of the yellow colour of sausages and Hunter b values increase, preference decreases. Similarly, preference decreases as CIE b^* values increase and the correlation coefficient is −0.808. An increase in the CIE b^* values indicates an increase in the intensity of the yellow colour. Increases in CIE y, Hunter b and CIE b^* values are all related with the increase in the intensity of yellow colour.

Table 7. Lipid content (g per 100 g) of sausage samples

Panel score										
10	9	8	7	6	5	4	3	2	1	0
32.1	36.8	26.9	29.7	35.0	37.1	41.5	33.5	28.4	33.7	40.9

The correlation coefficient of CIE $H°$ values with panel scores is −0.821. When $H°$ values increase, the colour of the sausages changes from orange to yellow and preference decreases. The CIE z value has a correlation coefficient of 0.728. Preference increases when CIE z values increase. The CIE z value is related to blue beams at 450 nm. It is seen in Fig. 1 that preference decreases when the percentage reflectance at 450 nm decreases. The blue colour of the most preferred sausage sample is more intense than the others.

REFERENCES

Acton, J. C. & Dick, R. L. (1977). Cured color development during fermented sausage processing. *J. Food Sci.*, **42**, 895–897.

Agulló, E., Centurión, M. E., Ramos, V. & Bianchi, M. A. (1990). Determination of total pigments in red meats. *J. Food Sci.*, **55**, 250–251.

AOAC (1990). *Official Methods of Analysis*, 15th edn. Association of Official Analytical Chemists, Washington, DC, 938 pp.

Campo-Fernandez, A. D., Perez-Alvarez, J. A., Sayas-Barbera, M. E. & Aranda-Catala, V. (1992). Spanish dry-cured ham: physical and physicochemical study. Proceedings of 38th International Congress of Meat Science and Technology, Clermont-Ferrand, pp. 471–474.

Dean, R. W. & Ball, C. O. (1960). Analysis of the myoglobin fractions on the surfaces of beef cuts. *Food Technol.*, **14**, 271–286.

Eagerman, B. A., Clydesdale, F. M. & Francis, F. J. (1977). Determination of fresh meat color by objective methods. *J. Food Sci.*, **42**, 707–711.

Folch, J., Lees, M. & Stanley, G. H. S. (1957). A simple method for the isolation and purification of total lipids from animal tissues. *J. Biol. Chem.*, **226**, 497–509.

Gago-Gago, M. A., Perez-Alvarez, J. A., Sayas-Barbera, M. E., Pagan-Moreno, M. J., Rodriguez-Lopez, A., Ballester, A. & Aranda-Catala, V. (1992). Colour study of Spanish 'Salchichon' during fermentation and ripening. Proceedings of 38th International Congress of Meat Science and Technology, Clermont-Ferrand, pp. 479–482.

Garcia, C., Cordoba, J. J., Asensio, M. A., Bermudez, E., Antequera, T. & Ventanas, J. (1992). Heme pigments evaluation during ripening of dry cured Iberian ham. Proceedings of 38th International Congress of Meat Science and Technology, Clermont-Ferrand, pp. 483–486.

Harrison, A. R., Kropf, D. H., Allen, D. M., Hunt, M. C. & Kastner, C. L. (1980). Relationships of spectrophotometric reflectance measurements to beef muscle visual color. *J. Food Sci.*, **45**, 1052–1053.

Hornsey, H. C. (1956). The colour of cooked cured pork. *J. Sci. Food Agric.*, **7**, 534–540.

Hunt, M. C. (1980). Meat color measurements. *Reciprocal Meat Conf. Proc.*, **33**, 41–46.

Hunt, R. G. W. (1987). *Measuring Colour*. Ellis Horwood, Chichester, 221 pp.

Hunter, R. S. & Harold, R. W., eds (1987). *The Measurement of Appearance*, 2nd edn. Wiley, New York, 411 pp.

Karlsson, A. & Lundström, K. (1991). Meat pigment determination by a simple and non-toxic alkaline haematin method. *Meat Sci.*, **29**, 17–24.

Kramer, A. & Twigg, B. A. (1984). *Quality Control for the Food Industry*, Vol. I, 3rd edn. The Avi Publishing Company, Connecticut, pp. 19–41, 143–147.

Krzywicki, K. (1979). Assessment of relative content of myoglobin, oxymyoglobin and metmyoglobin at the surface of beef. *Meat Sci.*, **3**, 1–10.

Krzywicki, K. (1982). The determination of haem pigments in meat. *Meat Sci.*, **7**, 29–36.

Pagan-Moreno, M. J., Perez-Alvarez, J. A., Sayas-Barbera, M. E., Gago-Gago, M. A., Rodriguez-Lopez, A., Ballester, A. & Aranda-Catala, V. (1992). Chorizo: colour parameters evaluation during ripening. Proceedings of 38th International Congress of Meat Science and Technology, Clermont-Ferrand, pp. 563–566.

Rodriguez-Lopez, A., Perez-Alvarez, J. A., Sayas-Barbera, M. E., Pagan-Moreno, M. J., Gago-Gago, M. A. & Aranda-Catala, V. (1992). Colour and colour stability of dry-cured ham. Proceedings of 38th International Congress of Meat Science and Technology, Clermont-Ferrand, pp. 583–586.

Trout, G. R. (1991). A rapid method for measuring pigment concentration in porcine and other low pigmented muscles. Proceedings of 37th International Congress of Meat Science and Technology, Kulmbach, pp. 1198–1201.

Warriss, P. D. (1979). The extraction of haem pigments from fresh meat. *J. Food Technol.*, **14**, 75–80.

Wong, D. W. S. (1989). *Mechanism and Theory in Food Chemistry*. Van Nostrand Reinhold, New York, pp. 178–187.

Zaika, L. L., Zell, T. E., Smith, J. L., Palumbo, S. A. & Kissinger, J. C. (1976). The role of nitrite and nitrate in Lebanon bologna, a fermented sausage. *J. Food Sci.*, **41**, 1457–1460.