Do we want to be in a Manichean, puritan, computerized world which prostitutes and rejects pleasure, desire, emotion and the mysterious meaning of our living flesh? Or will we recognize that man's creativity lies not only in his objectivity and logic, but also in the poetic intuition that he touches through the difficult body he has to assume when he lives seriously with what is hidden in the night of pleasure?

To be-have is to be and to have at the same time. Having must not destroy being.

Instrumental assessment of food appearance

By D. B. MacDougall, *Agricultural Research Council, Meat Research Institute, Langford, Bristol BS18 7DY*

The appearance of a foodstuff depends on diverse physical causes, refraction, absorption, light-scatter, etc., and although the aspects of appearance, colour, gloss, etc., can be separately described (Hunter, 1962, 1963; ASTM, 1966), they are subjectively integrated, each with greater or lesser importance, when a quality judgment is made. The basic problems involved in objectively assessing the appearance of materials are firstly, the separation of these components one from the other, for example transparency from opacity, colour from surface phenomena (MacDougall, 1968) and secondly, the translation of the physical information into psychophysical units and their spacing into psychological scales of uniform increments of perception, or quality tolerance. The most commonly used colour order system, based on visual perception, is that of Munsell (Newhall, Nickerson & Judd, 1943), in which the colour solid is divided into lines of constant hue and constant chroma or saturation at equal lightness value increments. A method of designating colour names within the system has been developed as an aid to verbal description (Kelly & Judd, 1955).

The CIE system

Three factors are involved in the perception and hence the measurement of the colour of any object; the spectrum of the material, the spectrum of the illuminant and the response of the observer's vision to the light stimulus entering the eye. For an observer with normal colour vision, any coloured light stimulus can be matched by a suitable mixture of three primaries, red, green and blue. From the results of colour matching experiments using monochromatic primaries, the Commission Internationale d'Éclairage (CIE) have defined the response of a hypothetical observer, the so-called 'standard' observer, to light stimuli at 2° and 10° fields of view. The red, green and blue primaries were replaced by a set of unreal primaries, X, Y and Z and the fundamental specification of any colour is given by the amounts of these primaries required to match the colour stimulus (Mackinney & Little, 1962;

Judd & Wyszecki, 1963; Billmeyer & Saltzman, 1966; Wyszecki & Stiles, 1967; Wright, 1969). The most important advantage in this system is the adoption of the spectral distribution of Y equal to the spectral sensitivity curve of the eye for day-light (photoptic) vision. Y, therefore, is a measure of the lightness or luminous reflectance of the object. Lightness and the chromaticity co-ordinates x and y, which are the ratios of X and Y to X+Y+Z, define colour in 1931 CIE terms. The one disadvantage of this system is that colours are not uniformly spaced, and the size of colour differences are not linearly related to Y, x and y. This has been over-come by mathematical transformations of the 1931 system giving uniformly-spaced values to the psychological attributes, lightness, hue and saturation. Hue is the term used to describe the scale red to orange to yellow to green etc. and saturation is the amount of grey contained in the colour, and they are together known as 'chromaticness'. Wyszecki & Stiles (1967) have listed the available scales along with the conversion formulas which relate them to CIE units of colour difference. Particular attention is drawn to the 1964 CIE U^*, V^*, W^* system which was recommended by the CIE to be used whenever more uniform spacing than that provided by the Y, x, y system is desired. Similarly, the Hunter L, a_L, b_L scale is used in some colour difference meters for application to foodstuffs, for example, in the determination of colour changes in meat during storage (Fellers, Wahba, Caldano & Ball, 1963; Snyder, 1964), in the grading of tomato juice (Francis, 1963; Yeatman, 1969), in relating pigment content to colour in vegetables (Francis, 1969) and in assessment of the colour of citrus products (Wenzel & Huggart, 1969).

Methods of measurement

The most informative method of measuring colour is by conversion of the reflect-ance or transmittance spectrum to the CIE tristimulus values for a specified source of illumination (Robertson, 1967). The calculations are time-consuming unless the information from the spectrophotometer can be computed automatically, or an abridged sampling of the spectrum is adequate for the particular application. The next most effective method is the use of colour meters or colour difference meters whose source–filter–photocell combinations approach the CIE specification for the standard observer (Hunter, 1942). Filter instruments range from simple photo-meters measuring in the X, Y, Z system to automatic colour difference meters where the information is presented in uniform lightness and chromaticness scales. Reflect-ance measurements require reference standards, and MgO and $BaSO_4$ are commonly used as working standards in spectrophotometry. Calibrated coloured tiles whose chromaticities lie close to the objects are used with colour difference meters (Bill-meyer, 1969). The variations between instruments are continually being investi-gated. However, different spectrophotometers and different colour difference meters are likely to produce a variety of results from the same standard (Adams & Bergling, 1964; Billmeyer 1969; Robertson & Wright, 1965). The British Ceramic Research Association have recently made available sets of coloured tiles which should improve inter-instrument standardization (Sinclair & Wright, 1969).

Sample variables

The major factors which control colour are light absorption by pigments and light scatter by structural or particulate components in the material (Kubelka & Munk, 1931; Kubelka, 1948). The absorbing and scattering characteristics vary with wavelength and determine the spectrum of transmitted or reflected light which in turn produce the colour stimulus (Duncan, 1949). The light-scattering characteristics also have a marked effect on the transparency or translucency of the material (MacDougall, 1968). The Kubelka and Munk analysis distinguishes between the transmitted and scattered components and is finding increasing use in the characterization of food appearance properties, for example in the measurement of the translucency of fruit sauces (Little, 1964) and the opacity of bacon (MacDougall, 1970).

Foodstuffs have every possible sample presentation problem; the surface may be matt, smooth or glossy, flat, curved or rough, powdery, granular, fibrous, wet or dry, homogeneous or made up of several intermixed constituents or, for lack of a better term, double surfaced, e.g. the surfaces of many fruits have a bloom or fuzz of one colour on top of a skin of another. The initial problem to be solved is, therefore, standardization of sample preparation to ensure reproducible results (Little & Mackinney, 1969). This may require that the sample is graded for particle size, ground and sieved to a constant thickness, or exposed for a given time in a controlled environment, etc. These techniques, although improving reproducibility between samples, may alter the visual appearance of the material as it is presented to the instrument. Variations in the illuminating and viewing geometry also alter the reflectance spectrum and hence the colour co-ordinates obtained. Changes in the angles of illumination and view have been shown to alter the spectrum of pork (Elliott, 1967). Goniophotometry (ASTM, 1963) is the technique used for measuring the light distribution from the sample surface and the appearance attributes of gloss, mattness or semi-mattness have characteristic polar curves (Billmeyer & Marcus, 1969; Robertson, 1967; Wright, 1969).

Interpretation of measurements

To illustrate the difficulties in adequately defining the appearance of a foodstuff, values for two samples of fat, lard and beef dripping, are presented (Tables 1, 2 and 3) with their polar distribution curves at two temperatures (Fig. 1). The fats were filled into tins 2 cm deep and the surface flattened by passing a straight edge over the lip of the tin. Thin samples for the determination of the Kubelka and Munk absorption coefficient K, scatter coefficient S and internal transmittance T_i were prepared by spreading the fat over black and white backgrounds in metal mounts with a 2 mm recess. The samples were then cooled to 10° or heated to 25°. Reflectance spectra were obtained using an Optica CF4DR spectrophotometer, using normal illumination and diffuse light collection by an integrating sphere with the specular excluded, and $BaSO_4$ reference white. The CIE 2° field 1931 tristimulus values were calculated for source C (Mackinney & Little, 1962), and K and S obtained with 1 mm thickness defined as unit thickness for X, Y and Z. T_i was

calculated for the 2 mm layer. The polar distribution curves of the 2 cm deep samples were obtained with a Gardner goniophotometer standardized at 0°/45° with a calibrated white tile and viewed through a Y filter. Directional reflectance (Fig. 1) is plotted in terms of the perfectly reflecting perfect diffuser equal to 100%. Lard is
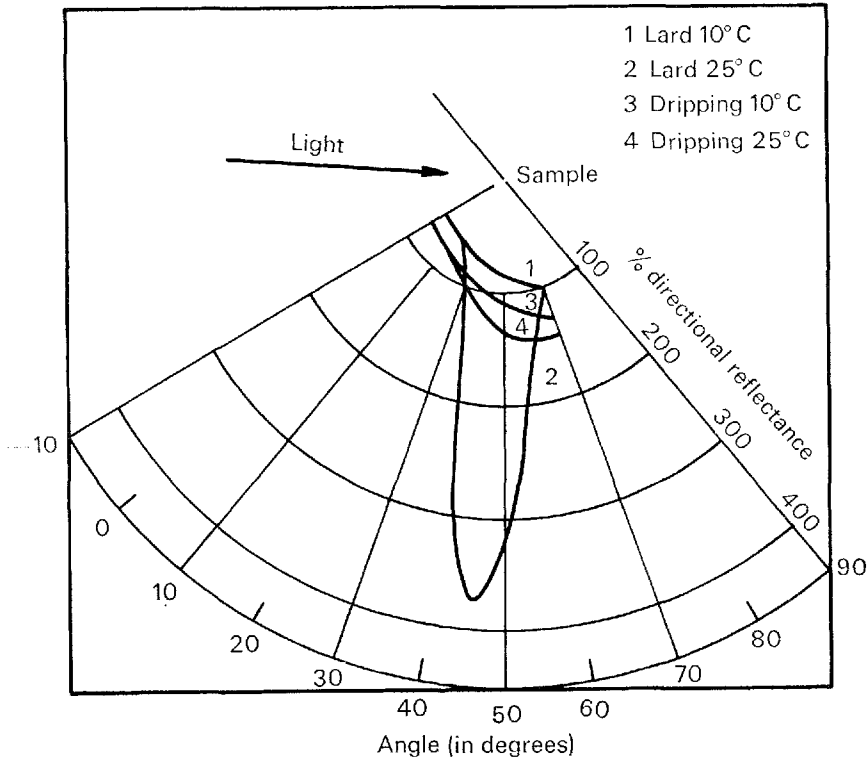

Fig. 1.   Goniophotometric curves of lard and dripping at 10°C and 25°C.

softer than dripping (iodine values were lard 54 and dripping 36) and the effect of temperature rise on the development of the specular component (45°) is entirely different for the two fats; lard was nearly 400% while dripping was less than 150% at 25°C. This illustrates the necessity of limiting receptor field angles in colour-

Table 1.   1931 *CIE Colour Spacing of lard and dripping at* 10°C *and* 25°C

		Lard		Dripping	
		10°C	25°C	10°C	25°C
Tristimulus values	X	69·5	63·1	75·1	72·0
	Y	71·7	65·4	80·3	76·6
	Z	74·2	68·5	69·2	69·2
Chromaticity co-ordinates	x	0·3226	0·3203	0·3344	0·3306
	x	0·3329	0·3320	0·3575	0·3517
Dominant wavelength (nm)	λd	573·7	571·8	570·6	570·3
Excitation purity	pe	0·077	0·069	0·172	0·145

measuring instruments, and the inadequacy of using tristimulus values on their own to describe surface appearance.

The 1931 CIE specification of the thick samples (Table 1) does not successfully describe the colour of the two fats, and a first inspection of the data could easily lead to erroneous conclusions. The measured lightness (Y) is greater for dripping than lard but subjectively lard is whiter and lighter. The larger numerical value for dripping is attributable to its greater light scattering power and greater opacity (Table 2), but its yellow pigmentation makes it appear less white. Yellowness is produced by blue absorption and the value of the absorption coefficient for the blue tristimulus value (Z) is greater for dripping than lard, and the ratio of K for Z to K for X and Y is also greater for dripping. The excitation purity p_e, a measure of

Table 2. *Kubelka and Munk analysis of tristimulus values of lard and dripping at 10°C and 25°C*

		Lard		Dripping	
		10°C	25°C	10°C	25°C
Absorption coefficient K for	X	0·05	0·04	0·03	0·03
	Y	0·05	0·05	0·02	0·02
	Z	0·09	0·09	0·11	0·10
Scatter coefficient S for	X	0·73	0·39	0·90	0·86
	Y	0·65	0·43	1·01	0·98
	Z	1·33	0·85	1·60	1·60
Internal transmittance of 2 mm layer T_i for	X	0·40	0·51	0·33	0·34
	Y	0·38	0·49	0·31	0·32
	Z	0·20	0·30	0·16	0·17

saturation, is greater for dripping but the value of p_e is not immediately informative of yellow intensity. Increasing the temperature from 10° to 25° reduces the scatter coefficients for the softer lard by about one-third, but only marginally for the harder dripping. Lard at the higher temperature is therefore more translucent and looks greyer.

Transforming the 1931 values to 1964 uniform lightness and chromaticness co-ordinates makes interpretation simpler (Table 3). Dripping is still objectively lighter

Table 3. *1964 CIE uniform lightness and chromaticness spacing, and whiteness and yellowness indices of lard and dripping at 10°C and 25°C*

		Lard		Dripping	
		10°C	25°C	10°C	25°C
Uniform lightness	W*	86·9	83·7	90·9	89·2
Uniform chromaticness co-ordinates	U*	+2·7	+1·2	+1·3	+0·8
	V*	+8·2	+7·3	+19·7	+16·7
Hue angle (tangent $= V*/U*$)		71·8°	80·7°	86·2°	87·3°
Saturation $(U^{*2}+V^{*2})^{\frac{1}{2}}$		8·6	7·4	19·7	16·7
Whiteness index $4(Z/1·181) - 3Y$		36·1	35·8	-6·4	4·6
Yellowness index $(1 - (Z/1·181)/Y)$		12·4	11·3	27·0	23·5

than lard (W* is a function solely of Y), but the co-ordinates U*, V* and saturation $(U^{*2}+V^{*2})^{\frac{1}{2}}$ are scaled in perceptual units equivalent to W*. $\triangle$ W* between the two fats at 10°C is 4·0 units but the difference in saturation is 11·1 units, demonstrating that the effect of yellowness is nearly three times as great as lightness. The whiteness and yellowness indices (ASTM, 1967) included in Table 3 show the lard now to be numerically whiter and the dripping yellower. These indices successfully detect the noticeable colour changes with temperature and aid interpretation of the direction of the change.

Colour-measuring instruments provide physical information which can, with care, be interpreted into scales of appearance. Appearance is of prime importance in acceptance, and acceptance is a powerful factor in nutrition. For every commodity the appearance scales must be calibrated in units of quality acceptance.

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