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# Assessment of Tinctorial Power of Food Colourants

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*ABSTRACT*

*Two model food systems were developed to assess the tinctorial power of colourants. Using synthetic colourants typically found in foods, and at appropriate concentrations, a range of colours was produced in each of the systems. The colours were measured as Hunter* L, a, b *values and plotted to define the region within the colour solid wherein acceptable food colours lie. Two natural colourants were tested in the model systems and the concentrations at which they exhibited acceptable colours determined. The systems are useful for assessing the tinctorial power of natural compounds in a quantitative and meaningful manner.*

## INTRODUCTION

Despite consumer pressure for naturally coloured food, the use of natural colourants has been hindered by their low tinctorial power and lack of stability. In assessing the colour potential of natural compounds, stability to typical food ingredients can be measured fairly easily but the determination



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of tinctorial power is more difficult. Tests tend to be subjective and the only commonly quoted objective parameters, the molar or 1% absorption coefficients, are unsatisfactory as they represent the absorption at one particular wavelength and give little indication of overall tinctorial power nor the colour as perceived by the human eye. In addition, determination of absorption coefficients in natural colourants is sometimes difficult as certain preparations do not exhibit distinct $\lambda_{max}$ values and the choice may involve an arbitrary decision.

Rather than use the absorption spectrum to assess colour, tristimulus colorimetry is preferred (Francis & Clydesdale, 1975) as the values obtained are based on human responses to colour. This technique provides quantitative data which, on the Hunter scale, gives values for the lightness ($L$), red–green ($+a$ to $-a$) and yellow–blue ($+b$ to $-b$) co-ordinates. Plotting these data in three dimensions produces a colour solid where the 'poles' represent black ($L = 0$) and white ($L = 100$) and shades of grey are located on the $L$ axis between the 'poles'. Colours are located within the solid and distance from the origin ($L = 50$, $a = 0$, $b = 0$) represents colour saturation (chroma) while the angle subtended from the $+a$ axis represents hue. 'Weak' colours are contained in the 'core' of the solid while 'strong' colours are closer to the surface.

This paper sought to determine the range of 'acceptable' colours produced by synthetic colourants in two model food systems. The amounts of colourant incorporated were consistent with the levels found in beverages (System 1) and confectionery, cereals and snack foods (System 2). The co-ordinates of the colours were plotted on the $L$, $a$, $b$ axes in an attempt to define that region of the colour solid where 'acceptable' colours lie. The potential of natural colourants for food use can then be assessed by determining the concentration required to achieve co-ordinates in the 'acceptable' region. Commercial grape and beet colours were tested in this way.

## MATERIALS AND METHODS

### Materials

Synthetic food colours used were FD&C Red No. 3 (Erythrosine), FD&C Yellow No. 6 (Sunset Yellow FCF). FD&C Blue No. 2 (Indigo Carmine) (Cyanamid Fine Chemicals, New York, USA) and FD&C Red No. 40 (Allura Red), FD&C Yellow No. 5 (Tartrazine), FD&C Blue No. 1 (Brilliant Blue FCF) and FD&C Green No. 3 (Fast Green FCF) (Warner-Jenkinson, St. Louis, Missouri, USA). Mixtures suggested for food use

(Jacobs, 1947; Woodroof & Phillips, 1981) were also prepared in the proportions below (v/v).

| | | | | |
|---|---|---|---|---|
| Lime | 95% | Yellow No. 5 | 5% | Blue No. 1 |
| Grape mixture | 90% | Red No. 40 | 10% | Blue No. 1 |
| Strawberry | 50% | Red No. 40 | 50% | Yellow No. 6 |
| Green mixture | 60% | Green No. 3 | 40% | Yellow No. 5 |
| Yellow mixture | 60% | Yellow No. 5 | 40% | Yellow No. 6 |
| Purple | 60% | Blue No. 2 | 40% | Red No. 3 |
| Blue mixture | 50% | Blue No. 1 | 50% | Green No. 3 |
| Royal Blue | 80% | Blue No. 1 | 20% | Red No. 40 |

**System 1**

Stock solutions (100 mg litre$^{-1}$) of the seven synthetics were prepared and the additional eight colours above were mixed from the stock solutions. Dilutions were made with distilled water to give solutions with concentrations of 100, 75, 50, 25, 12·5 and 6·25 mg litre$^{-1}$. The colour of these solutions was measured in a Gardner XL-23 Colorimeter (Gardner Instruments, Bethesda, Maryland) using the transmission attachment and a 10 mm path length cell. The instrument was calibrated using a water blank and set to $L = 100$, $a = 0$, $b = 0$.

**System 2**

Stock solutions (1000 mg litre$^{-1}$) of the seven synthetics and the mixtures were prepared. Portions were made up to 100 ml and added to 14 g of instant potato flakes (Price Chopper, Boston, Massachusetts) so that the concentration in the total mixture was 350 or 100 mg litre$^{-1}$. The mixture was homogenised for 10 s in a domestic blender at room temperature and the slurry immediately poured into a Gardner sample cup and allowed to set. Measurements were taken on the Gardner XL-23 in reflectance mode using a white standard tile to calibrate the machine.

**Natural Colours**

Enocianina (Grape extract, Double strength, Hartog, New York, USA) and Color Treme R-111 (Beet juice concentrate; Beatrice Foods Co., Chicago, Illinois, USA) were obtained in the liquid form. Solutions suitable for spectrophotometry were prepared in 0·1M HCl (grape) or pH 5 citrate/phosphate buffer (beet) and the absorbance at 520 nm and 535 nm, respectively, was determined (Lambda 3 UV/VIS Spectrophotometer, Perkin-Elmer, Norwalk, Connecticut, USA).

Using the molar absorption coefficient for malvidin 3,5-diglucoside (37 700; Francis, 1982) the concentration of the commercial grape colourant was expressed as malvin equivalents (ME). Solutions containing 150 to 12·5 mg litre$^{-1}$ ME were prepared in distilled water for colour measurement in System 1 and solutions with ME in the range 350 to 25 mg litre$^{-1}$ were used in System 2.

The concentration of the beet juice sample was expressed as betanin equivalents (BE) using a $E^{1\%}_{1cm}$ value of 1120 (FAO/WHO, 1984). Solutions of 108 to 6·75 mg litre$^{-1}$ BE were prepared in distilled water for use in System 1 while, in System 2, concentrations of 100 to 12·5 mg litre$^{-1}$ were used.

## RESULTS AND DISCUSSION

### System 1

Colour measurements were taken for each colourant at each of the dilutions. The values obtained showed the expected trends in that $L$ values increased and chroma decreased as the solutions were diluted. There were exceptions to this trend with the chroma values for Green No. 3, Grape mixture, Green mixture and Blue mixture showing an initial increase in chroma followed by a decrease. Dilution also caused shifts in hue angles for some of the compounds.

Since 75 mg litre$^{-1}$ is the mean concentration of synthetic colourant used in beverages and 12·5 mg litre$^{-1}$ represents the lower level of usage (Marmion, 1979) the values for these two concentrations were plotted in an attempt to define the acceptable region within the colour solid. To simplify the task of three-dimensional plotting, two plots were used, namely, $a$ versus $b$ and $a$ versus $L$. The results are shown in Figs 1 and 2 where colours and colour mixtures described in the 'Materials and Methods' section are identified by abbreviations such as GP (Grape mixture), R3 (Red No. 3) and YMIX (Yellow mixture). For the $a$ versus $b$ plot, it can be seen that the values for the 75 mg litre$^{-1}$ and 12·5 mg litre$^{-1}$ concentrations generally lie on a smooth surface, the Grape mixture and Blue No. 2 being the exceptions. However, Blue No. 2 at 12·5 mg litre$^{-1}$ appeared so dilute that it was no longer acceptable and was therefore discounted. Grape mixture, although pale, was acceptable and has been accommodated on the diagram. The $a$ versus $L$ plot (Fig. 2) is more complex but the two concentration levels can be distinguished quite readily. If the two plots are combined, then those areas where overlap appears to exist (e.g. Green No. 3 in Fig. 1) can be resolved by reference to the other plot and it becomes apparent that a region within the colour solid is defined. Smoothing the line produces the solid line plots in

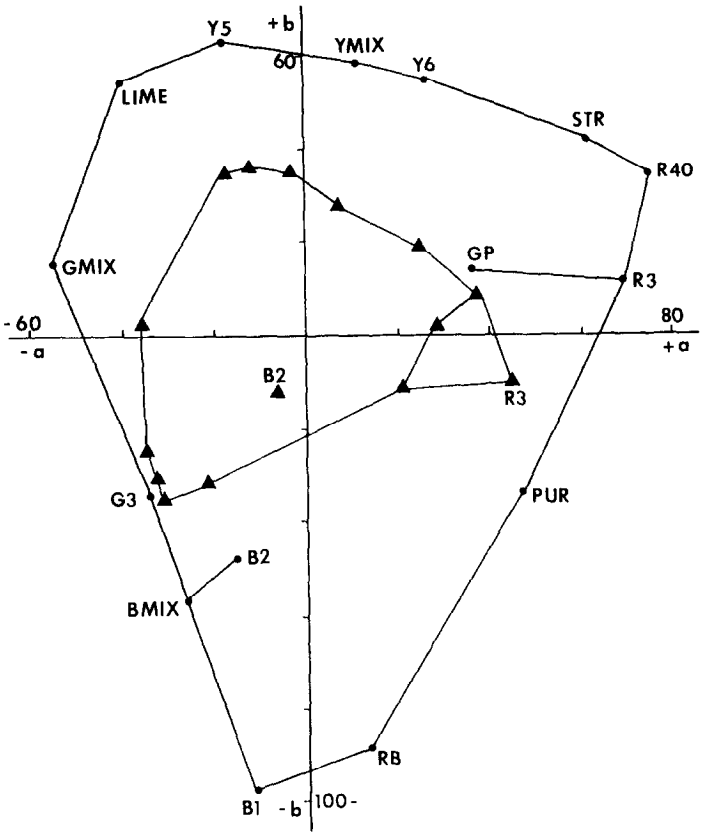


**Fig. 1.** Hunter *a* versus *b* plot for 75 mg litre$^{-1}$ (●) and 12·5 mg litre$^{-1}$ (▲) synthetic colours in System 1. Colours at the 12·5 mg litre$^{-1}$ level occur in the same order as at the 75 mg litre$^{-1}$ level and can be identified by cross reference.

Figs 3 and 4. These lines mark the inner limit of acceptability in the two dimensions and any colour that falls outside this limit is deemed acceptable for use in solution.

## System 2

Colour measurements for each sample were taken at concentrations of 350 and 100 mg litre$^{-1}$ using reflectance mode on the Gardner XL-23. The results showed that dilution always increased the *L* value but did not affect chroma greatly. Neither was there such a large shift in hue angle as observed in System 1. The plots of *a* versus *b* and *a* versus *L* (Figs 5 and 6) show substantial overlap between the concentration levels, suggesting that the colours at the two concentrations were similar. This was confirmed by observation. When the overlaps were taken into account, the inner limit of

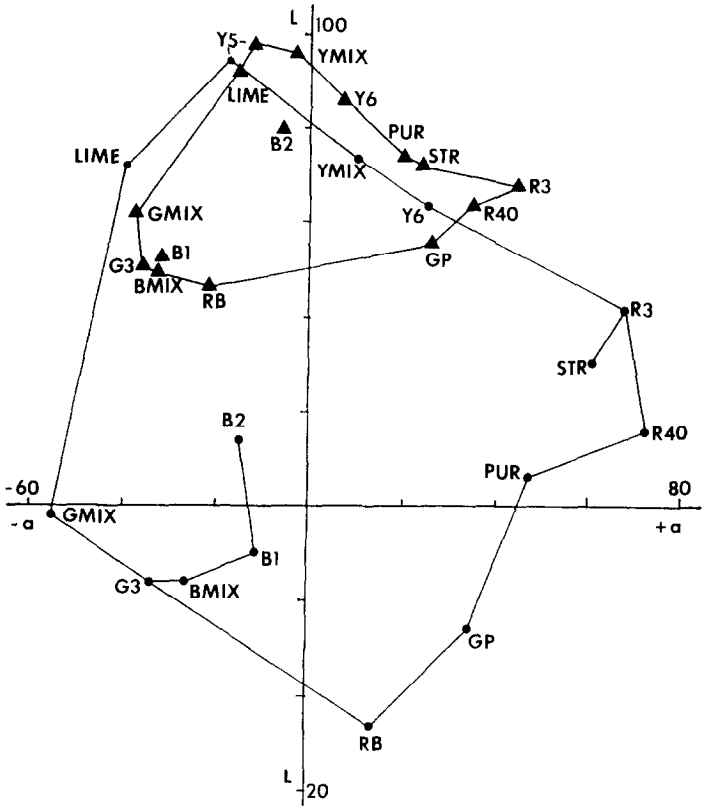


**Fig. 2.** Hunter *a* versus *L* plot for 75 mg litre$^{-1}$ (●) and 12·5 mg litre$^{-1}$ (▲) synthetic colours in System 1.

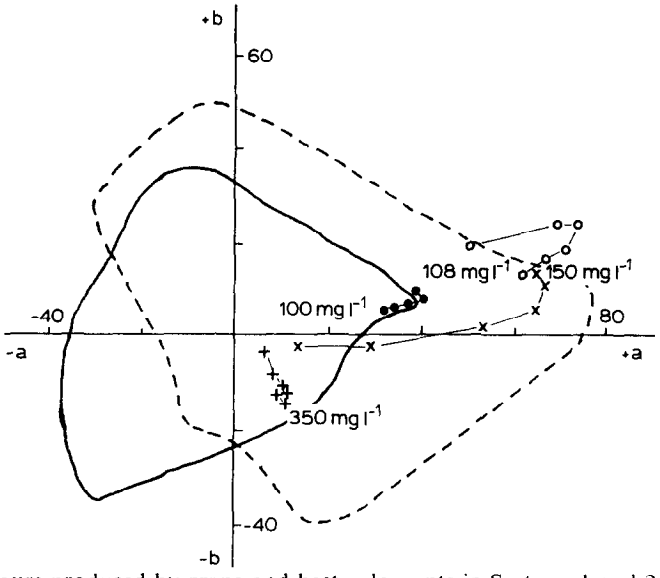


**Fig. 3.** Colours produced by grape and beet colourants in Systems 1 and 2 compared to acceptable colours. *a* versus *b* plot. ——, limit of acceptability for System 1; – – –, limit of acceptability for System 2; ×, grape colourant in System 1 (150 to 12·5 mg litre$^{-1}$); +, grape colourant in System 2 (350 to 25 mg litre$^{-1}$); ○, beet colourant in System 1 (108 to 6·75 mg litre$^{-1}$); ●, beet colourant in System 2 (100 to 12·5 mg litre$^{-1}$).

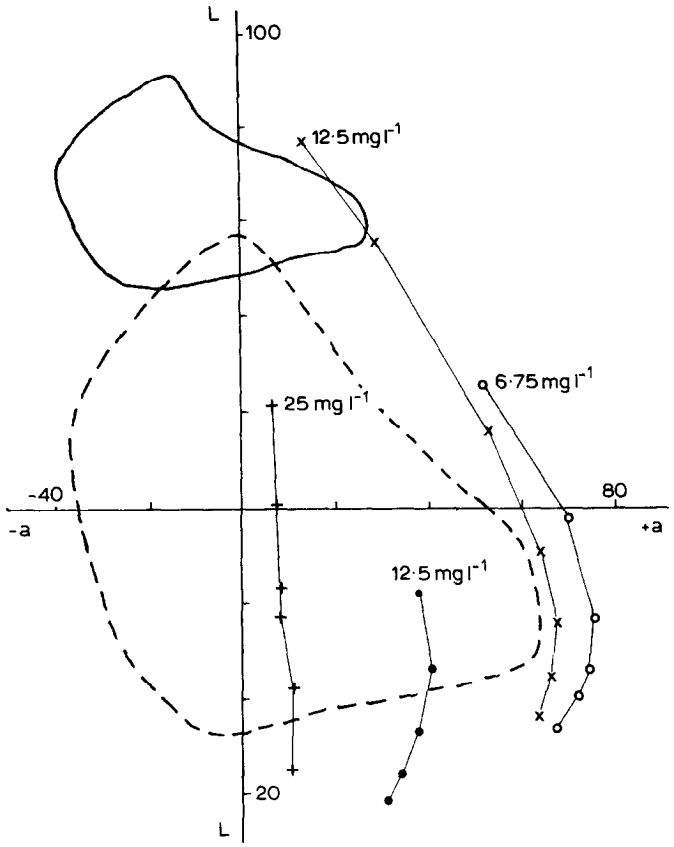


**Fig. 4.** Colours produced by grape and beet colourants in Systems 1 and 2 compared to acceptable colours. *a* versus *L* plot. (Key as in Fig. 3.)

acceptable colour for use in System 2 was defined by the dotted lines in Figs 3 and 4.

## Natural Colours

With the acceptable regions of colour defined by synthetic mixtures for aqueous and solid systems, the co-ordinates of the natural colours in the two systems were plotted to determine which concentrations, if any, fell within the acceptable regions. Figures 3 and 4 show the plots for grape extract and beet concentrate.

For Grape extract in System 1, the values on the *a* versus *b* plot lie within the acceptable region until, somewhere between 25 and 12·5 mg litre$^{-1}$, the limit is crossed. Turning to Fig. 4, the plots again show the points well outside the inner limit until the concentration approaches 25 mg litre$^{-1}$. Thus, grape extract has sufficient tinctorial power to colour aqueous systems

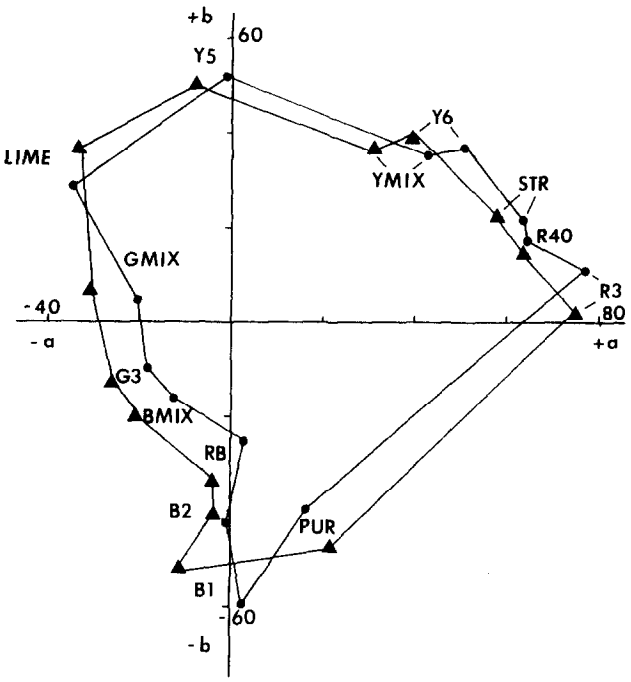


**Fig. 5.** Hunter *a* versus *b* plot for 350 mg litre$^{-1}$ (●) and 100 mg litre$^{-1}$ (▲) synthetic colours in System 2.

at an acceptable level provided the concentration is greater than 25 mg litre$^{-1}$ ME. Visual inspection of the samples confirmed this.

In System 2, the colour values for grape extract on the *a* versus *b* plot all lie in the unacceptable region and on the *a* versus *L* plot only the 350 mg litre$^{-1}$ value is considered acceptable. Thus, it is unlikely that grape extract will be suitable for colouring solid systems unless concentrations in excess of 350 mg litre$^{-1}$ are used. Indeed, the purple colours obtained were all dull and, at low concentrations, appeared to be unacceptably 'dirty'.

Beet concentrate in System 1 had colour co-ordinates well outside the limit and all concentrations (108–6·75 mg litre$^{-1}$) produced acceptable colours. This is also the case for the *a* versus *L* plot. The visual appearance of the beet concentrate solutions was certainly superior to that of the grape extract and was expected as the grape anthocyanins were not at their optimal pH while beet colour was more pronounced at the pH of the two systems.

In System 2 all the colour co-ordinates for beet concentrate fell in the unacceptable region on the *a* versus *b* plot but, on the *a* versus *L* plot, three points were deemed acceptable. This kind of discrepancy was to be expected as the definition of the colour solid in two planes assumes that the solid is regular. In practice, colour solids are irregular and cannot be represented

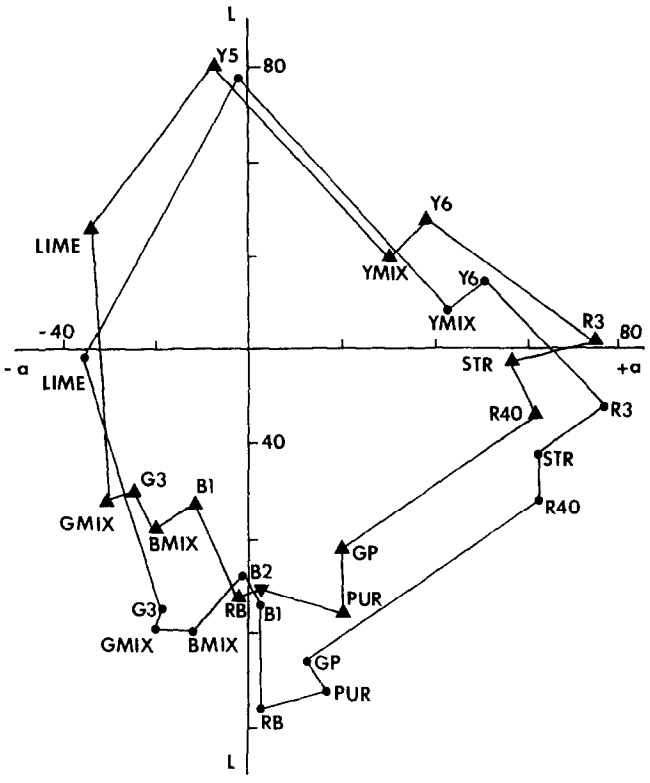


**Fig. 6.** Hunter *a* versus *L* plot for 350 mg litre$^{-1}$ (●) and 100 mg litre$^{-1}$ (▲) synthetic colours in System 2.

adequately by the simple *a* versus *b* and *a* versus *L* plots. They do, however, permit facile representation of the colour solid in two dimensions.

## CONCLUSIONS

By using model systems and synthetic colourants at concentrations typically found in foods, it has proved possible to define those regions of the colour solid where 'acceptable colours' exist. Two natural colourants have been assessed using the definitions and grape extract has been shown to be suitable for use in solution at concentrations greater than 25 mg litre$^{-1}$ but unsuitable for use in 'solid' foods except perhaps at the highest concentrations tested (350 mg litre$^{-1}$ ME). Beet concentrate has greater colouring power in solution but again is marginal in 'solid' systems. The results agree with the known usage and properties of these compounds. With beet concentrate, instability and the high solids content of the concentrate

are major problems, rather than lack of tinctorial power. Grape extract is best used in acid foods as low pH not only enhances anthocyanin colour but stabilises the molecule as well. It would not be expected to perform optimally at the pHs found in Systems 1 and 2 (pH 4–6). The model would benefit from true three-dimensional representation which would allow more accurate definition of the limits. As it stands, it provides a rapid method of determining the tinctorial power of potential colourants in a meaningful, quantitative fashion.

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