COLOUR MEASUREMENT IN MEAT AND MEAT PRODUCTS

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Colour, colour stability and discoloration of meat and meat products are of primary importance in consumer purchase, particularly in extended-life chilled products (e.g., modified atmosphere and vacuum packaged). Tenderness and microbiological problems have been studied extensively and can be overcome. However, research on colour and colour stability is only just beginning to solve some of the problems in the colour area in extended-life chilled products. This is because (a) these are relatively new technologies which have been taken up by industry, and (b) in the past there have been difficulties due to the inadequacy, expense and/or unavailability of colour measuring devices.

Over the last two years there have been rapid developments in the technology of colour measuring devices, particularly with the development of cheaper, portable devices such as the Minolta Chromameter. This device was compared with a Hunter LabScan Spectrocolorimeter in evaluating discoloration of venison steaks, and although the two different instruments tended to give different absolute values for the same colour coordinates, they both related well to human responses and could be used to predict colour as assessed by a trained panel. The instruments are quick and do not become fatigued as do humans; this is very useful when a large number of samples need to be assessed.

These instruments, provided they are tested and calibrated compared to human responses, can be used in product development, description or specification to meet set criteria and ensure optimum quality assurance. The Minolta Chromameter has the advantage of portability and is less expensive than the Hunter LabScan Spectrocolorimeter, but the former does not have the comprehensive testing ability of the latter.

WHY DO WE WANT TO MEASURE MEAT COLOUR?

Meat colour is of particular concern because the colour of muscle foods, as with most other foods, is critically appraised by consumers and is often their basis for product acceptance or rejection (Hunt and Kropf, 1985). Palatability, microbiology, and functional characteristics of a product are very important, but primary purchase of a product is based on appearance, particularly colour. Colour measurements, whether for product development, description, or specification, should be considered as important as other physical traits, and in some products, the most important attribute.

In previous work with venison it was found that dramatic changes in colour and colour stability were occurring with increased storage time in both frozen (Stevenson *et al.*, In Prep. (a)), and chilled venison (Seman *et al.*, 1988; Seman *et al.*, 1989). It was found that colour deteriorated in chilled vacuum packaged venison more rapidly when stored for 12 and 18 weeks than for 1 and 6 weeks (Seman *et al.*, 1988; Seman *et al.*, 1989). Fresh or chilled for 1 week, the venison had an initial display life of about 5 days, with acceptable red colour, up until the end of the five-day testing period when its colour started to become slightly dark or brown. With increased storage time the number of days required to reach an unacceptable colour (slightly dark or brown) decreased. After 6-12 weeks of chilled storage it took 2-3 days to reach an unacceptable colour, and after 18 weeks the colour had become slightly dark or brown after just one day of display. Similar results have been found with chilled lamb after similar storage under vacuum and under CO_2 (Moore and Gill, 1987). A method of measuring colour that could be standardized so that measurements could be duplicated in other locations (particularly in overseas markets), and at various times, was sought.

METHODS/TECHNIQUES OF COLOUR MEASUREMENT

Colour, or more correctly, visual appearance, is a sensory attribute, and instrumental evaluation must relate to sensory assessment (Setser, 1984). Visual scoring by either trained or consumer panels is the preferred method of visual colour analysis (Hunt and Kropf, 1985). All humans do not taste and smell in a similar manner, but assuming they have normal colour vision, they do see every colour in a nearly identical manner (Setser, 1984). But, even though visual appraisals come closest to duplicating consumer judgements and set the benchmark for instrumental measurement comparisons, they are often difficult to perform and control, costly, time consuming, prone to subjective errors, and limited in the number of evaluations which can be made at one time. Also, although we may see things in the same way, we may not describe them in the same way and may not be consistent from day to day. Instrumental techniques have to be applied to compensate for a relatively poor colour memorizing ability of humans (Hunter and Harold, 1987). Instruments are more likely to be available whenever needed than a sensory panel and can be standardized. And, since we can see far more colours than there are words to describe them, there is a need for other ways of saying what they are.

Colour Order Systems

Many individuals have addressed themselves to the task of developing colour systems. One approach has been to make an orderly arrangement of all possible colours as printed samples on paper, and to give a unique designation to each one (Billmeyer and Saltzman, 1981). These are similar to the paint charts commonly used by home decorators. Despite their usefulness, these colour order systems have several limitations. One problem is that there are several different and unrelated systems in use, each with their own colour designations, just as each paint manufacturer puts out its own chart. Another problem is that they tend to fade with age, depending on how they were made and how well they are looked after. A single colour order system for identifying colours by this method would be very useful; however, everyone would have to agree upon it. This has not happened. However, of all the systems proposed, one of the most widely used and internationally accepted is the Munsell Colour order system, developed by A.H. Munsell, an American artist, in 1905 (Munsell, 1981). It is a system where colours are identified by assigning letters and numbers to the various steps in a three-dimensional colour chart, appropriately called the Munsell Colour Chart. Obviously there is a physical limitation on the number of colour chips which can be economically produced; hence, the need for orderly arrangement and uniform spacing. In the Munsell Book of Colour (which would cost you about $1,000 to $1,500 and hence would probably be well looked after), the arrangement of samples is based on their Hue (i.e. red, blue, etc.), Value (i.e. "lightness"), and Chroma (i.e. "saturation").

Each page in the book contains only samples of one particular hue with the various value and chroma possibilities. A Munsell designation such as 5 PB 6/8 would mean the page containing all the samples of hue 5-Purple-Blue and the particular sample with a value of 6 and a chroma of 8 (Weatherall, 1989). In order to give a colour its correct Munsell designation, one must find the matching sample in the book. By this method, some five thousand colours can be given unique designations, but, as one may imagine, going through the pages of the colour book to find the appropriate match can be quite a laborious and time-consuming task. The need to relate a visual system to a fundamental physical system of measurement is necessary because the chips may fade with time and some colours may look different under various light sources (i.e., metamerism) (Francis and Clydesdale, 1975; Hunter and Harold, 1987).

If a visual system is to be used in food applications, the Munsell system is the most logical and although there are many visual colour solids systems, the Munsell is probably the most successful of these

used in the food industry (Francis and Clydesdale, 1975). Wouldn't it be easier to use an instrument where all you had to do was press a button or flick a switch on an instrument and not have to rely on any human evaluation?

Instrumental Measurement

As the technology in the field of colour measurement has developed, the price of instruments has decreased and their availability has increased. A state-of-the-art model such as a Hunter LabScan 6000 Spectrocolorimeter is one of the top of the range at around $60,000 whereas a relative newcomer such as the hand-held, portable Minolta Chromameter CR200b is around $10,000.

Novices to the field of colour measurement desiring to purchase colour measuring devices for research or quality control would probably survey the available array of instruments and choose one to suit their individual needs. The data obtained could then be reported in terms of the read-out system for that particular type of instrument, and colour specifications could be set accordingly. In such a system, they need never be concerned with other colour scales.

If, however, their work was directed toward specifications of colour as a supplier, and a customer or prospective customer were to present desired colour specifications in another system, they would then be faced with the problem of converting from one colour system to another. This is a very common occurrence in the paint, plastics and textile fields (Francis and Clydesdale, 1975).

The types of colour measuring devices that have been employed widely in food applications in America are the Hunterlab instruments, the Gardner series, the Colour-Eye, the Colormaster, and the Tintometer (Francis and Clydesdale, 1975). Conversion of data from each type of instrument to another is usually via the CIE (Commission Internationale de l'Eclairage) XYZ system, and equations are provided with instructions from each manufacturer.

The International Commission of Illumination (CIE) is an international body which makes recommendations on all matters concerning light and colour and it has adopted methods for the measurement and specification of colour which include:

- The use of standard light sources as prescribed by CIE definition.
- Exact conditions for the observation of measurement of sample colour.
- The use of appropriate mathematical units in which to express the colour of an object.
- Definition of "standard observer" curves or tables relating objective measurement to visual response and thus, measuring what the eye sees.

Theory of Instrumental Measurement

The theory of instrumental measurement of meat colour involves many chemical and physical factors which must be considered in attempting to relate to the psychophysical interpretations of colour received by the eye and brain. These cannot be ignored and are discussed elsewhere by Billmeyer and Saltzman (1981), Francis and Clydesdale (1975), Hunter and Harold (1987) and Little (1976).

Basically, by adjusting amounts of red, green and blue coloured primary lights on a screen, each observer can match any colour and we will see it in the same way. This process of combinations of the primary colours is the basis of the so-called standard observer response: a random sample of persons provided the red, green, and blue values for each wavelength of light in the visible spectrum (from 400 to 700 nm) (Francis and Clydesdale, 1975). These amounts are called tristimulus values X, Y and Z and for colour readings these are translated into coordinates (CIE 1976 L* a* and b*) whose spacing correlates more closely with colour change as perceived by the human eye (Hunter and Harold, 1987; CIE, 1978). The L* values of L* represent lightness from white to black on a scale of 0 to 100, a* represents redness

greenness on a positive to negative scale and b* represents yellowness to blueness on a positive to negative scale. CIE 1976 a*, b* chroma and hue-angle may also be calculated a psychometric correlates of perceived chroma and hue (Hunter and Harold, 1987; Setser, 1984). When specifying a colour, one must specify all three dimensions, whether they be L*, a* and b*, or L*, chroma and hue-angle.

COMPARISON OF METHODS

A 13-member colour evaluation panel was trained and selected to judge venison on the basis of colour and acceptability (subjective evaluation). A scale of 1 to 5 was used for colour evaluation with:

5 = bright fresh venison colour,
4 = bright venison colour,
3 = slightly dark or brown,
2 = moderately dark or brown and
1 = extremely dark or brown.

For acceptability, a scale of 1 to 3 was used, with:

3 = purchase without reservation,
2 = purchase with reservation and
1 = would not purchase.

A study was conducted over four days in which venison steaks were frozen then thawed at different time intervals to provide samples of a wide range of surface discoloration. Panellists viewed the surfaces of the steaks under soft white fluorescent lighting (1800 lux) in a refrigerated display case. The steaks were evaluated by the trained panel, and measurements were made using a Hunter LabScan 6000 Spectrocolorimeter (Stevenson *et al.*, 1989) and a Minolta CR200b Chromameter (Stevenson *et al.*, In Prep. (b)) on three out of the four days. The mean values of the 13 individual panel assessments were used in comparisons with mean values of 10 readings taken on different locations on the surface of each steak with each instrument (objective measurements), and the results from those data (52 steaks) are discussed here. The results for the total 72 steaks and discussion of the relationship between colour deterioration and the Hunter LabScan measurements and variation between samples are presented elsewhere (Stevenson *et al.*, 1989).

RESULTS

The steaks had colour and acceptability scores covering the complete range of the rating scale, giving an appropriate set of data with which to work. Colour scores were highly correlated to acceptability scores ($r = 0.97$); a colour score of 3 (slightly dark or brown) corresponded to an acceptability score of just less than 2 and this was considered unacceptable as had been found in previous studies (Seman *et al.*, 1988; Seman *et al.*, 1989; Stevenson *et al.*, In Prep. (a)).

The a* values from the two instruments were highly correlated to each other and covered a similar range of the CIE scale. The chroma and hue-angle values were also highly correlated between the two instruments, but their ranges differed markedly. There was a moderate correlation and a dislocation in range when comparing the L* and b* values from two instruments and these differences were thought to be due to the different measurement geometries of the two instruments (Stevenson *et al.*, In Prep. (b)).

Panel scores were regressed against L*, a* and b* values from the Hunter (Stevenson *et al.*, 1989) and Minolta (Stevenson *et al.*, In Prep. (b)) and for both instruments it was found that perceived colour (as rated by the trained panel) was highly correlated with a*, chroma and hue-angle. However, as mentioned previously, it is considered inappropriate to present only one of the CIE coordinates, although there was a very high correlation for a* (the regression relationship for Study 1 with the Minolta Chromameter had an $R^2 = 0.79$; Fig. 1).

A further study with a similar set of data (Stevenson, Unpublish.) produced a different regression relationship (Study 2; Figure 1) although with a similar correlation coefficient. Using a regression equation involving L*, a* and b* gave a better prediction of perceived colour ($R^2 = 0.86$) for the first study and also a similar relationship for the second set of data (Fig. 2); the three component regression equation developed for Study 1 could have been used with the data from Study 2 to predict the panel colour scores with the same degree of accuracy. Regression

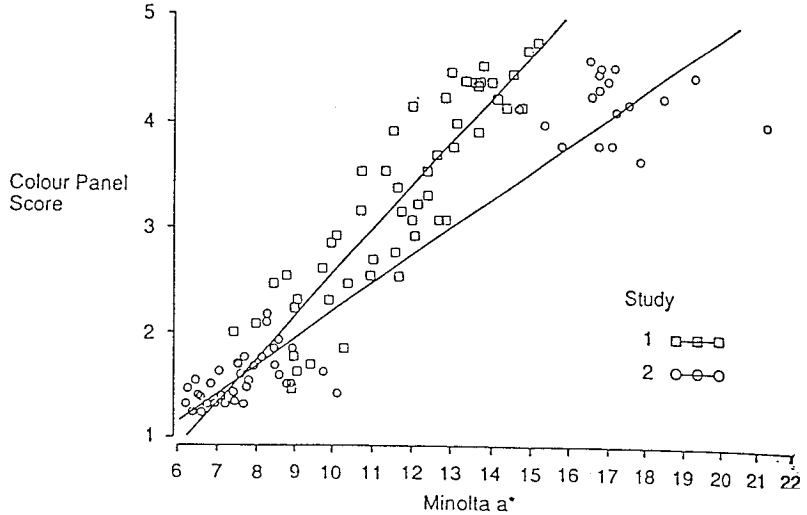

Figure 1. Comparison of Colour Panel Scores vs Minolta Chromameter a values.*

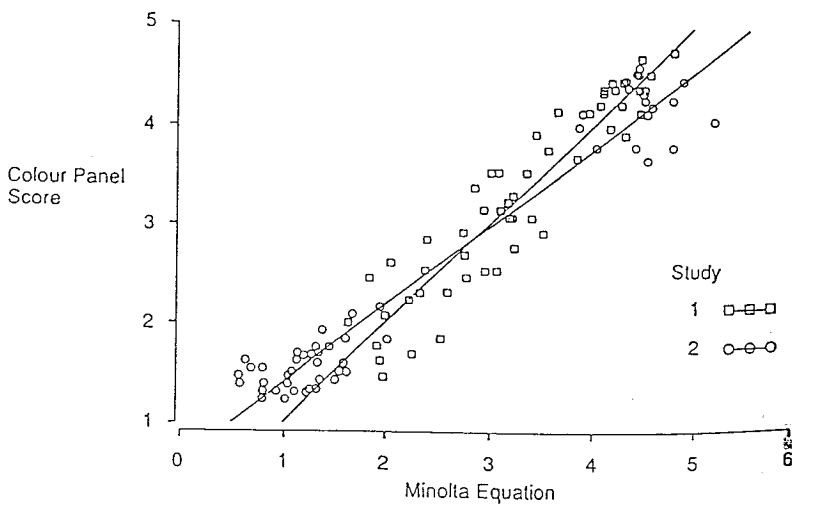

Figure 2. Comparison of colour panel scores vs Minolta Chromameter equation values.

equations using L*, a* and b* gave similar accuracy of perceived colour prediction to those using L*, chroma and hue-angle for both instruments (Stevenson *et al.*, 1989; Stevenson *et al.*, In Prep. (b)) and decision to use one over the other was arbitrary.

Rikert *et al.* (1957) reported that with a Hunter Color Difference Meter, a_L values gave the best estimate of visual colour of fresh meat. Jeremiah *et al.* (1972) related colour difference values to consumer acceptability of beef colour. Their study was designed to measure the preferred intensity of colour from oxymyoglobin. They found that a Macbeth-Munsell Disk Colorimeter, a Gardner Colour Difference Meter and a Bausch and Lomb Spectronic-20 spectrophotometer predicted visual muscle score with almost equal accuracy ($R^2 = 0.68$ for all). Strange *et al.* (1974) reported a linear correlation coefficient of r = 0.91 (n = 277) between the Gardner Color Difference Meter a value and hedonic scale panel scores. Eagerman *et al.* (1977) reported linear regressions with HunterLab a values of 0.76 for lamb and 0.72 for beef. Their best multiple regression equation for beef was one of 12 variables (r = 0.80). They concluded that their derived formulas and multiple regression equations found to correlate with visual scores for these meats were not sufficiently accurate to be used in place of visual judgements for those meats. They did find with pork that correlations were much higher (up to r = 0.881), and thus they concluded that some of the equations correlating the highest with visual color could be used, particularly for accept/reject decisions. The correlation and regression coefficients achieved with both the Hunter LabScan 6000 and Minolta Chromameter reported here were better than those achieved by other researchers (Setser, 1984; Harrison *et al.*, 1980; Jeremiah *et al.*, 1972; Strange *et al.*, 1974; Eagerman *et al.*, 1977).

This work supported the findings of other researchers (Hoke and Davis, 1970; Setser, 1984) that the use of L*, a* and b* or L*, hue and chroma rather than any one or pair of these variables yields a significantly better relationship. It was concluded that the three component equations could be used in place of a trained colour panel as long as the characteristics to be evaluated were clearly defined. Both the Hunter LabScan 6000 and the Minolta Chromameter CR200 required less than 30 seconds per measurement and could therefore be employed for large numbers of samples.

We are also currently testing the Minolta Chromameter (whose main advantage over the Hunter LabScan is that it is portable) in slaughter plants on carcasses in an attempt to determine the age of animals from which carcasses are coming.

CONCLUSIONS

Measurement of meat colour is important. Colour is a matter of perception, and of subjective interpretation. To express the same colour, different people will draw upon different references and express the exact same colour in different words. Human judgements may not be repeatable from day to day and can be influenced by personal preference, lighting, and appearance factors other than colour (e.g., texture and sample presentation). It is very important to train the panel and to refresh and test them to achieve consistent results. Instrumental methods can provide repeatably accurate results, but because colour is a human perception, instrumental techniques must be related to human evaluations.

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REFERENCES

Billmeyer, F.W., Jr. & Saltzman, M. (1981) Principles of Colour Technology. Interscience Publishers, New York.

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

Francis, F.J. & Clydesdale, F.M. (1975) Food Colorimetry: Theory and Applications. AVI Publishing Co., Inc. Westport, CT.

Harrison, A.R., Kropf, D.H., Allen, D.M., Hunt, M.C. & Kastner, C.L. (1980) Relationships of spectrophotometric reflectance measurements to beef visual color. J. Food Sci. **30,** 64.

Hoke, K.E. & Davis, C.E. (1970) Lighting conditions for evaluation of beef marbling and color. Food Technol. **25,** 283.

Hunt, M.C. & Kropf, D.H. (1985) Fresh and cured meat colour analyses. Muscle Foods Symposium - Institute of Food Technologists Annual Meeting. Paper 151.

Hunter, R.S. & Harold, R.W. (1987) The Measurement of Appearance. John Wiley and Sons. New York.

International Commission of Illumination (CIE) (1978) Recommendations on Uniform Colour Spaces, Colour Difference Equations, Psychometric Colour Terms, Supplement No. 2 to CIE Publication No. 5 (E - 1.3.1, 1971/TC 1.3) Bureau Central de la CIE, Paris.

Jeremiah, L.E., Carpenter, Z.L. & Smith, C.G. (1972) Beef color as related to consumer acceptance and palatability. J. Food Sci. **37,** 476.

Little, A.C. (1976) Physical measurements as predictors of visual appearance. Food Technol. **30,** 74.

Moore, V.J. & Gill, C.O. (1987) The pH and display life of chilled lamb after prolonged storage under vacuum or under CO_2. N.Z.J. Agric. Res. **30,** 449.

Rikert, J.A., Bressler, L., Ball, C.O. & Stier[illegible] (1957) Factors affecting quality of pre-packa[illegible] meats. II. Colour Studies. C. Effects of a[illegible] oxygen under different pressures upon colo[illegible] product. Food Technol. **11,** 625.

Seman, D.L., Drew, K.R., Clarken, P.A. & Littlej[illegible] R.P. (1988) Influence of packaging method[illegible] length of chilled storage on microflora, tender[illegible] and colour stability of venison loins. Meat[illegible] **22,** 267.

Seman, D.L., Drew, K.R. & Littlejohn, R.P. (198[illegible] Packaging venison for extended chilled stora[illegible] comparison of vacuum and modified atmosph[illegible] packaging containing 100% carbon dioxi[illegible] Food Prot. **52,** 886.

Setser, C.S. (1984). Colour: Reflections transmissions. J. Food Qual.. **6,** 183.

Stevenson, J.M., Seman, D.L., Weatherall, I[illegible] Littlejohn, R.P. (1989) Evaluation of veni[illegible] colour be an objective methods using CIELA[illegible] values. J. Food Sci. **54,** 1661.

Stevenson, J.M., Drew, K.R., Duncan, S.J., Sem[illegible] D.L. & Littlejohn, R.P. (In Prep. (a)) Effect[illegible] frozen storage on venison quality of farmed re[illegible] deer.

Stevenson, J.M., Littlejohn, R.P., Seman, D.[illegible] Weatherall, I.L. (In Prep. (b)) A comparison o[illegible] two different instruments for measuring CIELA[illegible] values and colour assessed by a trained panel[illegible]

Strange, E.D., Benedict, R.C., Gugger, R.E., Metz[illegible] V.G. & Swift, C.E. (1974) Simplifi[illegible] methodology for measuring meat color. J. Food Sci. **39,** 988.