THE YOLK COLOR INDEX*

ONE of the important phases in egg quality work has been the determination of yolk color. Various experiment stations and investigators have adopted standards and devices for measuring the color of egg yolks, but at the present time none of these methods has been generally adopted. The methods used by Parker, Grossman, and Lippincott (1920), the experimental department of Purina Mills (1932), the research department of the Larson Farms (1932), Stewart, Gans, and Sharp (1932), and Wilhelm and Payne (1934) are all somewhat different. These investigators have not adopted the same gradation of color and no uniform method for reading the color has been prescribed.

It is necessary in studies of this type that the determinations be made under definitely standardized conditions, and that accuracy, speed and convenience be considered for any system of standards which is adopted.

The Color Rotor is a device which was developed at the Washington Agricultural Experiment Station for mounting color standards with these requirements in mind. The chromatic scale was developed by combining proportions of white, Chinese yellow, orange and rich red Duco paints. The proportions of the various pigments are given graphically in Figure 1.

By combining the colors as indicated, a series of 24 colors was obtained ranging from almost pure white to brick red. The paints were accurately weighed and thoroughly mixed and finally painted in a thin layer on the concave surface of watch glasses 1 1/2 inches in diameter. The glasses were then placed before an electric fan and rapidly dried. Five coats of paint were applied in this manner. The glass standards were then mounted on a wooden disk 14 inches in diameter and arbitrarily numbered from 1 to 24. The most convenient angle for using this disk was found to be 20°.

The Color Rotor turns freely on its axis and makes possible the rapid selection of colors.

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Figure 1. The pigment combinations used in preparing the chromatic scale on the Color Rotor. The vertical axis shows the weight of the paint in grams; the horizontal axis shows the Color Rotor index. By erecting a line perpendicular to the color index, the quantity of the respective paints may be read directly from the scale on the left. The dots on the curves indicate the color of paint which that curve represents.
The Yolk Color Rotor has been found to be more rapid and accurate in determining the yolk color than other devices previously described.

The yolk color is observed from a fixed point under standard lighting conditions. The Color Rotor is portable and adapted to both laboratory and field work.

Figure 2. The Color Rotor in use.

from the combinations that are always before the observer. In reading these colors a desk lamp with an aluminum reflector and a 100-watt daylight bulb is placed 12 inches above and 4 inches in front and to the left of the line of vision between the egg and the eye.

In reading the color of the yolk, the egg is placed on a glass plate with a black background so that the observer can see the yolk and the color standard at the same time.

The use of watch glasses on which to mount the color standards makes it possible to obtain surface curvature and surface conditions similar to those on the egg yolk, and the observer can see the light reflected from the surface of the egg yolk and the color standard in this manner.

The Color Rotor is shown in Figure 2. It is made in the form of a box which can be kept closed while the apparatus is not in use, thus reducing to a minimum the effect of light upon the standards. The fact that the apparatus is easily portable adds to its convenience for both research and extension work.*

Note: The writers are indebted to Dr. P. E. Sharp, Cornell University, for suggesting the use of the four Dove points used in preparing the Yolk Color Rotor.

References

* A limited supply of these Color Rotor standards are available.
Development and Use of Color Standards for Egg Yolks

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For some years poultry scientists have been engaged in nutrition studies on the effects of various grains fed to laying birds. Some of these studies have been concerned with the effect of grain or combinations of grains in determining yolk color. The desired yolk color for home use varies with the geographical location and customs of the people, but in general a light yolk color is preferred. On the other hand users of yolks such as noodle manufacturers and cake bakers pay premium prices for dark colored yolk. It is therefore more profitable for the egg producer if he accurately maintains the yolk color within the desired range for his particular market.

Since verbal color descriptions are ambiguous it is necessary to have standards for egg yolk colors in recording and communicating the results of poultry diet research. The only color chart available in Canada was one which had been produced by the Federal Department of Agriculture based on the work of Heiman and Carver (1935). The colors were painted on watch dials mounted on a large black wheel.

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They had changed markedly through constant use and exposure to direct sunlight and several were missing through breakage. These defects, together with the fact that the wheel was cumbersome, meant that satisfactory comparison of yolks on any standardized basis was practically impossible.

Meanwhile other workers in this field had rejected pigmented coatings as a basis for yolk color measurement. Turner and Conquest (1939) stated that pigments were not translucent, they faded during storage and were not usually mixed in a quantitative manner. Although some of these objections may have been valid at the time, the pigment manufacturers have since greatly improved the light fastness of their products. Although translucence is troublesome, the correct contour of the colored surface can reduce the problem. It has been found that the flat painted paddles referred to could never duplicate the natural appearance of yolks. The rejection of paint led to the development of methods for chemical estimation of color. The colored matter in the yolks was extracted with acetone and compared, visually at first, and later by colorimeter, Kahlenberg (1949) with solutions of potassium dichromate. Further work along these lines led to the present AOAC method in which the acetone extract is compared to carotene solutions (1960).

These methods, however, have defects
since they appear to be more applicable to broken yolks such as frozen and dried yolks. In the work reported here it was found that the color of the broken yolk is not the same as the whole yolk. In addition the chemical estimation of color does not always correlate with the visual rating. Carlson et al. (1951) report one case where paprika deepened the visual color of yolks without showing any increase by the extraction method. Conversely a high carotene diet doubled the color rating by extraction but had little influence on the visual color.

Because of the defects in both systems, the Poultry Division, Production and Marketing Branch, Department of Agriculture requested the assistance of the Paint Laboratory, Division of Building Research, National Research Council, in preparing a series of standard colors for use by visual comparison which would cover at least the range of yolks produced in Canada. It was initially considered that 15 sets of 15 colors would be sufficient for the Department of Agriculture and other interested parties working on yolk colors. Work on the sets began but before the initial batch was completed, it became evident from inquiries that there was great interest in these color standards, not only in Canada and the United States, but in other countries as well. A further 20 sets were produced but these have not been sufficient to meet the demand. While steps are being taken to make these standards available in quantity, it is considered desirable, due to the extensive interest, that the colors and techniques should be described in a manner which will provide a sound basis for proper reproduction and standardization. This paper, therefore, outlines the trials necessary to achieve a satisfactory set of colors and gives the form which was finally adopted. Since the colors cannot be reproduced exactly by adherence to the particular formulations used, they are described more precisely in color co-ordinates obtained from measurements on a spectrophotometer. Factors affecting the reproduction, maintenance and use of the standards are discussed.

DEVELOPMENT OF TRIAL COLORS

It was considered necessary in order to obtain colors that resemble egg yolks to match colors visually against whole yolks under a standard light source. Instrumental measurements of real yolk colors were not taken because it was not considered feasible to design a reflectance head for a color instrument that would eliminate external light and provide the correct angles of illumination. In addition, it was known that instrumental readings do not always correlate with visual determinations of color.

From preliminary tests four pigments were selected to make yellow, orange, white and black enamels for intermixing to obtain different yolk colors. The particular yellow and orange pigments were chosen because of their resistance to darkening. The resinous binder in the enamels was an air-drying alkyd sorted to have good color and gloss retention. Baking-type enamels were not used because baking causes a color change which makes it more difficult to estimate what the wet color should be to obtain a certain baked color.

When not in use, eggs which were opened for color matching were stored in glass jars in the refrigerator with the yolks covered with egg white. Unfortunately the yolks tended to change color, especially on the top surface. If the egg was fresh when broken it could be used for about two weeks, but if the egg itself had been stored for some time the yolk began to change 3 to 4 days after breaking. In the latter case it meant that before a good match could be produced, the original color was no longer available. It was also found that if a yolk was broken top, the rest of the origin...
are described by co-ordinates in a system designed on a spectrophotometric chart showing the reproduction of the colors of the standards and the effects of light source and angle of illumination.

OF TRIAL COLORS

a color chart resembling egg yolk colors was used against whole egg yolks. Instrumental measurements of the yolk colors were made as not considered feasible. It was known that the results do not always correspond to the color of the yolk. Enameled metal panels were chosen because of their ease of cleaning. The red enamels were air-dried to have good color and baked-type enamels were found to be better. Baking causes a color change, making it more difficult to keep the yolk color on the egg.

SELECTION OF FORM

First attempts at matching egg yolk colors showed that it was impossible to obtain satisfactory color matches when the yolk was applied to a flat surface. The upper surface of a watch glass, which has a color similar to an egg yolk on a plate, was found to be very suitable for laboratory use. Glass, however, was not considered acceptable in the field because of possible breakage. The original request was for a flat aluminum sheet with a hole in the center that could be held over the yolk. The Paint Laboratory suggested a convex form similar to the watch glass which would be placed beside the yolk. A second suggestion was to combine both ideas—a convex shape with the center punched out. Six of each of these new types of forms were made of aluminum and trials were run to determine the best shape and the best method of coating them. The Paint Laboratory preferred the solid form because it could be mechanically dipped. The Department, however, chose the ring form which had to be sprayed to avoid ridges and sags around the opening. A diagram of the ring form finally adopted is given in Figure 1.

SELECTION OF COLORS

A great many enamel intermixes were made by the Paint Laboratory in the course of trying to match as many different-colored yolks as possible although there was some difficulty in obtaining yolks at the extreme ends of the color range. These intermixes were checked at the Central Experimental Farm when a great many eggs were being broken. From the intermixes, 35 colors were selected which matched one or more yolks, but many of these were too similar to those unfamiliar with color to distinguish. Fifteen of the colors were chosen to cover the range with distinguishable color differences. More colors with correspondingly smaller differences were deliberately placed in the central portion where it was expected most of the egg yolks would fall. A preliminary set of colored watch glasses was submitted to the Poultry Department of the Ontario Agricultural College. They suggested adding a color on each end and dropping two in the middle.

Following these changes, 35 sets of aluminum rings were coated and subjected to field trials at the Ontario Agricultural College, the Central Experimental Farm and the Poultry Marketing Services. A few months later it was reported that lighter colors were needed and that some of the yolks were too similar. The latter complaint was easily remedied by removing one color and altering another in the middle of the range. The other difficulty resulted from the difference between using a watch glass or solid form that is placed beside the yolk and a ring held over the yolk thus shading it. Back had to be added to six of the lighter colors to compensate for the shadow cast by the ring. Two very light colors were also included although none of the eggs opened by the Paint Laboratory had ever been that pale.

When modifications were complete the second series of colors was again submitted for field trials. The Department reported that those using the standards thought that two of the numbers should be reversed. Because color is three dimensional it is rather difficult to arrange a one-dimensional system to everyone's satisfaction. On looking at a color, paint chemists tend to think of it in terms of the pigments needed to produce it. Consequently, the yolk colors were numbered by the Paint Laboratory in order of their composition. At one stage in the system, however, some observers thought that one color with more white appeared
darker than the following color. It was considered necessary to change the order so that the users would be satisfied with the arrangement. One of the colors was altered slightly to emphasize the correct order.

**COLOR DESCRIPTION**

It is not possible for purposes of standardization to describe the colors finally chosen in terms of the formulations and proportions of the basic enamels used. Small differences in dispersing the pigments can lead to differences in color even in successive batches made from exactly the same ingredients. This is well known to paint technologists and, in practice, final color matches are generally obtained by tinting using some standard for comparison. As a matter of interest, however, the proportions of the base enamels used to prepare the final colors are given in Table 1.

Other difficulties in color standardization are that the technique of preparing and the manner of viewing the standards affect the results. The nature of the substrate and base coat, the wet film thickness and the conditions of drying must all be carefully controlled to produce identical colors even from the same batch of enamel. The shape of the surface, the quality of the illumination and the method of viewing can also have an effect on the judgment of color. It is necessary in color standardization, therefore, to define carefully the conditions of preparation and the conditions of viewing.

A more objective basis for color standardization can be provided by photoelectric methods to determine the color curve. Such curves for TS glass were prepared by the Radiator Division of Appleton Research Council. The General Electric record for using standard TS glass is for average glaze required to obtain the visible color readings. The diffuse reflectance curves are plotted for the TS colors and are two commonly used standards that of the International Illumination (C.I.E.) system by Adams (Judd, 195).

<table>
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<tr>
<th>Color Number</th>
<th>Yellow Enamel</th>
<th>Oxide Enamel</th>
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</thead>
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<td>100</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
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<td>12</td>
</tr>
<tr>
<td>15</td>
<td>100</td>
<td>18</td>
</tr>
</tbody>
</table>

**Fig. 1. Diagram of ring form.**
COLOR STANDARDS FOR EGG YOLKS

1907

preparation and the conditions of illumination and viewing.

An objective basis for color standardization can be provided by physical measurements to determine the spectral reflectance curve. Such curves for the final colors were prepared by the Radiation Optics Laboratory, Division of Applied Physics, National Research Council. The instrument was a General Electric recording spectrophotometer using standard illuminant C which corresponds to average daylight. The calculations required to obtain the three-dimensional color readings from the spectral reflectance curves are quite complicated.

They were carried out using the weighted ordinate method as described by Judd (1952). The color co-ordinates obtained from measurements on the spectrophotometer for the 15 colors are given in Table 2 in two commonly used systems. One system is that of the International Commission on Illumination (C.I.E.) (Judd, 1952), and the other is the uniform color space proposed by Adams (Judd, 1952). The C.I.E. co-ordinates were transformed into the L, a, b system by use of the formulae given in A.S.T.M. method D1536. Either system may be used as a basis for standardization. At least one authority, however, has stated that the same make of spectrophotometer must always be used for complete standardization.

A further complication in standardization of these colors was introduced by the adoption of the curved rings. Only flat, uniform surfaces can normally be used in a spectrophotometer. The readings in Table 2 apply to the films produced on flat forms and cannot be obtained from films produced on the curved forms. It is necessary, therefore, to specify and to control carefully the method of preparation and drying of the films on both surfaces in order that the colors finally produced on the curved forms may be properly controlled in relation to the physical measurements specified which have to be made on flat forms.

The methods of film preparation, together with the complete details of the formulations, which may be of use to paint technologists who may be called upon to produce the colors described, are given in another paper (Ashton, 1961).

USE OF STANDARD COLORS

Use of the forms is illustrated in Figure 2. Because the original color matches were made against unbroken egg yolks illuminated by artificial daylight, the colors must be used with the same type of illumination.
Fig. 2. Determining yolk color with standard color form (Canada Department of Agriculture).

or with natural north daylight. With other light sources such as incandescent bulbs the color may not resemble actual yolks. Extremely yellow lights, e.g. Macbeth horizon yellow, reduce the apparent differences between successive colors.

When being used, the enameled forms should be handled with care so that they may retain their original color. The most common soil is egg white which is easily removed if washed with warm water before it has dried. More resistant stains may be washed with a mild detergent solution followed immediately by rinsing and drying. Brushes, abrasive cleaners or solvents should not be used for cleaning. The forms should not be left in strong sunlight longer than necessary and should not be exposed to high temperatures. Immediate replacement in a covered container will help avoid unnecessary contamination or exposure.

ACKNOWLEDGMENT

The contribution to the development of these color standards was made by all those who co-operated in the trials leading to the selection of suitable colors and the special assistance given by Dr. G. W. Wyszecki of the Division of Applied Physics, National Research Council, in the measurement of the spectral reflectance curves are gratefully acknowledged. This is a joint publication of the Production and Marketing Branch, Canada Department of Agriculture and the Division of Building Research, National Research Council.

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Heiman, V., and J. S. Currier, 1945. The yolk color index, U.S.


The Effect

R. H.

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INTRODUCTION

Studies which polar birds and geologically sterile were reviewed by Sir attempt to determine the hydrate's birds do not factors were responsible for environmental micro-thermal of Antarctic during the 1957-1958 Expedition (Sieburth bacteriologically sterile, typical lactose- Bacillus coli were as shown in penguins and the non-lactose-former 7 - was suppressed in intestinal contents. A studded the anterior granules of pygoscelid pet the phytoplankton-laden of euphausids (Euphausia were the sole diet of U During the trip into the antarctic colonials to half the water sam was dense a heat-stable, bacterial substance with P-see positive and gra.
The Effect of Acrylic Acid Salts on Growth of Chicks

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INTRODUCTION

Studies which reported that certain polar birds and animals have “bacteriologically sterile” intestinal contents were reviewed by Sieburth (1961a). In an attempt to determine if “bacteriologically sterile” birds do exist, and if so what factors were responsible, a study on the gastrentestinal microflora and dietary materials of Antarctic birds was conducted during the 1957-1958 Argentine Antarctic Expedition (Sieburth, 1959a). Although bacteriologically sterile birds were not found, typical lactose-fermenting strains of Escherichia coli were not observed in pygoscelid penguins and in certain specimens the non-lactose-fermenting coliform microflora were suppressed in the anterior gastrointestinal contents. A substance which inhibited the anterior gastrointestinal microflora of pygoscelid penguins was traced to the phytoplankton-laden stomach contents of euphausiids (Euphausia superba) which were the sole diet of the penguins studied. During the trip into the Weddell Sea a green autochthonous colonial alga, which occurred in half the water samples, was found to possess a heat-stable, water-soluble antibacterial substance which inhibited both gram-positive and gram-negative test organisms (Sieburth, 1958b).

Field studies conducted aboard the Hydrographic Ship ARA Chiriguano during the 1958-1959 Argentine Antarctic Expedition (Sieburth and Burkholder, 1959) confirmed the antibacterial activity of certain phytoplankton blooms; identified the responsible alkal as Phaeocystis pouchetii, and yielded material needed to isolate the active principle. This acidic volatile substance which polymerizes on concentration to form inactive residues has been extracted as the sodium salt and identified chemically, physically, and biologically as acrylic acid, CH₂ = CH - COOH (Sieburth, 1960). The antibiotic properties in vitro and in vivo of acrylic acid have been described (Sieburth, 1961b). The broad spectrum of activity at concentrations of 0.012-12.0 mg./ml. by filter paper disc assays was enhanced by acid reactions approximating those of the avian gut. Chick trials conducted in an attempt to explain the suppression of Escherichia coli in pygoscelid penguins indicated that acrylic acid levels as low as one-fifth (0.01%) of those estimated to be ingested by penguins under natural conditions suppressed E. coli and permitted its partial replacement by Aerobacter aerogenes. Acrylate feed levels be-
The 'Roche Yolk Colour Fan'—An Instrument for Measuring Yolk Colour

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(Received for publication August 12, 1968)

INTRODUCTION

Increasing importance is being given to the colour of egg yolk when judging the quality of eggs. Besides the customary standards of measurement such as shape and weight, firmness of the shell, freshness, structure of egg white and yolk etc., the colour of yolk and its year round constancy are decisive criteria in the maintenance of standardized egg quality (Farnsworth and Nordskog, 1953; Brunnich, 1962, 1966; Bartlett and Podger, 1962; Snyder, 1962; Tagwerker, 1961; Scholtysek, 1962, 1964; Scholtysek and Bohn, 1962; Torgers, 1964; Mehnert et al., 1965; Brown, 1964; Schmidt, 1963). In the last ten to fifteen years a number of papers appeared which are concerned especially with pigmentation of the yolk, e.g. by Reschleit (1953); Steinberger and Zenetti (1957, 1959); Steinberger et al. (1957); Rauch (1959, 1960, 1961); Scholtysek et al. (1961, 1960); Smetana (1961); Brown (1964); Carlson et al. (1961); Treat (1963); Buguth and Caenicki (1962); Malaguy and Rouqué (1965); Hartfalk and Schmitt (1965, 1966); Blommaart and Stenius (1963).

The numerical definition of colours according to present concepts is not a simple, pictorial representation such as scalar variables, e.g. mass, time, volume.

The measurement of colour, or in other words the determination of values characterizing a colour perception, translates the functions of human vision with the help of physical measuring instruments. The laws of additive colour mixing show that any colour perception can be produced by mixing three suitable spectral stimuli or primaries in the proper ratio. The human eye seems to judge the visible part of the electromagnetic spectrum by only three different spectral sensitivity functions, which are experienced by the observer as a single effect or colour perception. Thus three numbers or quantities are required in order to clearly define any one colour perception. Colours may therefore be understood as local vectors in a colour space. Each point within this colour space characterizes a colour according to hue (wavelength of identical hue), saturation (proportion of spectral light in the mixture of spectral and white light) and luminosity (intensity of light perception connected with colour perception). These are the three properties which any observer with normal vision would attribute to "colour" as a sensual perception.

In the following, the "tristimulus values" of the standard C.I.E. system as defined by the International Commission on Illumination (C.I.E.) (1931) as a conventional reference system for colour measurements, will be used (D.I.N. 333, sheets 1–8. See also Mackinney and Little, 1962). The three quantities which characterize a colour perception with a defined illuminant are symbolized by X, Y and Z (transformed, unreal primaries); from these, chromaticity coordinates x, y, z can be calculated as follows:

\[ x = \frac{X}{X + Y + Z} \quad y = \frac{Y}{X + Y + Z} \quad z = \frac{Z}{X + Y + Z} \]
and therefore:

\[ x + y + z = 1. \]

If the derived values of \( x \) and \( y \) are plotted in a rectangular co-ordinate system, a very convenient representation according to hue and saturation results; the luminosity, not defined in the diagram is expressed by adding the tristimulus value of \( Y \) to the coordinates \( x \) and \( y \). The chromaticity diagram of the C.I.E. is shown in Fig. 1.

The chromaticity co-ordinates \( x, y \) of the spectral colours form an enclosed continuous curve. The straight line connecting its end points is called "purple line".

Each real colour has its colour locus within the surface defined by this curve. For reflectance measurements, the colour of the illuminating light is considered...
dromatic. All degrees of saturation of a 
colour hue lie on the connecting line be-
tween the location of the illuminant and 
the corresponding point on the spectral 
curve (line of constant dominant wave-
length).
Several measuring principles can be 
employed for the practical evaluation of 
colours. At the present time, the spectral 
method is generally considered to be the 
most accurate, being less dependent on the 
characteristics of measuring instruments 
than other methods. The measuring pro-
cess and evaluation are, however, tedious, 
because the colour perception to be de-
duced is understood as a sum of spectral 
stimuli. The tristimulus values, X, Y, and 
Z, can be represented by the following inte-
grals:

\[
X = \frac{1}{k} \int_{\lambda}^{\lambda} \phi_\lambda \delta_\lambda \, d\lambda, \quad Y = \frac{1}{k} \int_{\lambda}^{\lambda} \phi_\lambda \gamma_\lambda \, d\lambda, \quad Z = \frac{1}{k} \int_{\lambda}^{\lambda} \phi_\lambda \zeta_\lambda \, d\lambda
\]

Limits of integration are the short-wave 
(K) and long-wave (L) limits of the 
visible spectrum \( \phi_\lambda \) is the colour stim-
ulus function in the wavelength range 
\( \delta \lambda \), i.e., an amount of light energy acting 
on the eye, which depends on the radia-
tion function \( \phi_\lambda \) (spectral energy distribu-
tion) and on the reflectance function \( \phi_\lambda \) (re-
fectance curve) of the surface colour 
(sample); therefore \( \phi_\lambda = \delta \lambda \phi_\lambda \). The terms 
\( \phi_\lambda \) and \( \delta \lambda \) are the distribution co-
efficients which relate the energetic value \( \phi_\lambda \) to the 
three equal energy distribution curves of 
the C.I.E. standard observer.

In practice, integration is replaced by 
summation of a number of readings, e.g., 
with intervals of 5 nm or 10 nm (weighted 
formula method). The measurement of 
colour is then reduced to the following 
operations:

\[
X = \sum_{\lambda=380 \text{ nm}}^{\lambda=718 \text{ nm}} \beta_\lambda (\delta_\lambda \gamma_\lambda)
\]
for standard illuminant \( \mathbf{N} \)

\[
Y = \sum_{\lambda=380 \text{ nm}}^{\lambda=718 \text{ nm}} \beta_\lambda (\gamma_\lambda \zeta_\lambda)
\]
for standard illuminant \( \mathbf{V} \)

\[
Z = \sum_{\lambda=380 \text{ nm}}^{\lambda=718 \text{ nm}} \beta_\lambda (\zeta_\lambda \delta_\lambda)
\]
for standard illuminant \( \mathbf{N} \)

The expressions in brackets are tabu-
lated for the C.I.E. standard illuminants.
The values of \( \beta \) at 80 or 40 different wave-
lengths are to be measured and the 
products and sums formed. The whole mea-
suring process is actually an approxima-
tion or estimation, and becomes less 
accurate with a decreasing number of mea-
suring points. Therefore, depending on 
which apparatus or measuring method is 
used, the results obtained for the three 
values will differ for one and the same 
colour. It may be possible to obtain con-
sistent results between different investi-
gators by fixing the type of instrument 
and the method of calculation; but this 
procedure is rather difficult to put into 
practice and is not suitable for serial ex-
amination of egg yolks.

Besides objective measurement of the 
tristimulus values, there is another pos-
sibility of evaluating colours, i.e., by com-
parison with colour charts. According to 
DIN 5033, sheet 5, it is permissible to 
define colours by means of direct compari-
son with sample collections, provided that 
each time an absolutely identical sample 
can be found. Such sample collections 
have been developed e.g., by Ridgway 
(1912), Munsell (1915), Ostwald (1917), 
Maerz and Paul (1930), Prase (Baumann, 
1927), and Hickethier (1952). However,
these charts are hardly suitable for measuring the yellow colour of egg yolk. These collections contain a relatively large number of colour samples in order to cover the whole range of real colours, and yet there remain within the relatively small range of yolk colour only a few samples, the gradation of which is in most cases unfavourable for measuring the yolk.

The real purpose of measuring the colour of egg yolks however is not in fact to obtain an accurate colorimetric definition of egg yolk colour, but to make a selection according to quality. It seems feasible to replace the accurate reflectance measurement by a subjective assignment to classes with similar characteristics. With this method, all those colours are allotted to a class which in the observer’s eye show only a slight deviation from a certain standard colour. The standard colour forms so to speak the centre of the class. If it were possible to choose standard colours in such a manner that each yolk colour could be attributed subjectively without any doubt to one, or in exceptional cases, to two adjoining classes, and if it could be demonstrated that these standard colours really show the usual range of yolk colours, then all the requirements of grading according to quality would be met.

The colorimetric studies on egg yolk by Boguth and Czernicki (1962) have shown that it should certainly be possible to develop such a scale of standard colour samples. It was found, for example, that the yolk colours of eggs consumed in Germany, were all within a closely limited area of the C.I.E. chromaticity diagram. Mainguy and Rouquès (1965) published similar findings on conditions prevailing on the French market. For the establishment of a colour scale it is sufficient to select as standard colours certain colour samples situated within this zone, perhaps in such a way that the colours are perceived subjectively as being at equal intervals. Then the standard colour situated at one end of the zone, e.g. the one with the lowest saturation, is marked class No. 1, and the following standard colours numbered consecutively. The scale obtained in this way covers practically all eggs available on the market and can be used to define them clearly. Besides these eggs with yolk colours situated more or less within the zone defined by Boguth and Czernicki (1962) or Mainguy and Rouquès (1965), there may be eggs which do not fit into this scale; the colour of these eggs yolk is characterized by a strong greenish, or a slight dirty red-orange tinge. These egg colours are usually the result of very particular feeding conditions, and most consumers refuse them. Yolk colours which cannot be classified with the scale described, must be designated “off” colours.

Even before the studies by Boguth and Czernicki (1962), many attempts to develop such a scale were made. Probably the first suitable scale was described by Kupsch (1934). It consisted of ten grades, from white-yellow to orange-yellow corresponding to shades chosen from the Ostwald colour atlas. The colour samples were rectangular sheets fixed to each other in fan-like fashion and numbered on the back from 1 to 10.

At about the same time, the ‘yolk colour index’ was produced in the United States by Heiman and Carver (1935). Coloured watch-glasses fixed to the edge of a circular black plate served as standard colours. The lacquer was applied on the concave side of the glasses, and they were fixed with the convex side pointing upward, to give the impression of whole yolks. The colour scale ranged from yellowish-white through yellow to red.

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*References omitted for brevity.*
Roche Yolk Colour Fan

and is referred to as "Roche Yolk Colour Fan Edition 1965".

DESCRIPTION OF THE 15-GRADE 'ROCHE YOLK COLOUR FAN'

1. Outer Shape. The shape of the original 12-grade colour fan was maintained for the 15-grade 'Roche yolk colour fan'. The colour layer is applied on flat cardboard lamellae. Turner and Conquest (1939) pointed out that colour layers of this type cannot completely reproduce the colour impression of egg yolks. Ashton and Fletcher (1962) gave their standard colour holders a convex shape, as did also Heimann and Carver (1935). There are, however, very important reasons against viewing the whole undisturbed egg yolk. The undisturbed egg yolk is very glossy on the surface. This makes it difficult to measure the colour objectively, and also to evaluate subjectively with the help of colour scales. This difficulty can hardly be avoided by giving the reference standard a special shape. Another point is that egg yolks are slightly transparent; colour impression is imparted via a certain depth of the layer. It would be very difficult technically to reproduce these conditions on a model, unless a method using standard yolks for this purpose could be found. Finally, egg yolk is formed in the developing egg in concentric layers. About fourteen days are required to develop a complete yolk. If during this period, there is a change in the ration, it is quite possible that the outer layers will have a colour different from the center. In this case it would lead to wrong conclusions to look only at the undisturbed egg yolk. If, however, the yolk is separated from the egg-white, then homogenised and poured into a small petri-dish, the above-mentioned difficulties do not apply, and the layer obtained for observation of the colour can be
regarded as infinitely thick. It is now possible to select the best matching colour sheet; under these circumstances it is even possible at any time to check the validity of the visual choice objectively, as the colour locus of the homogenised yolk and of the colour sheet can be defined by the same measuring method, e.g., that described by Boguth and Czernicki (1962). This is impossible with any other technique of visual comparison, because a series of auxiliary hypotheses would be required to relate it to the instrumental measurement.

2. Colour Holders. The choice of the colour holder depended on the colouring method used. Preliminary studies with transparent foil were unsuccessful, because the required high saturation could not be obtained. Only opaque materials which could be printed on both sides were found satisfactory. We decided on white Bristol cardboard.

3. Printing Method. Experience showed that even small differences in the thickness of the colour layer altered the chromaticity coordinates \(x\) and \(y\). This effect is particularly pronounced with colour samples of high saturation. The colour layer was, therefore, applied by the screen printing technique. This method has a high covering capacity and yields a reproducible thickness of layer. Furthermore, it is suitable for serial production of colour sheets. However, the screen printing had to be performed with colour pastes of the thickest possible consistency to get into the range of high saturation. These pastes could only be handled by using coarser-meshed screens than the usual ones and by filling the screen before the actual printing.

4. Printing Colours. Theoretically, carotoids such as they occur in egg yolk, would be the ideal pigments for a colour fan. However, they had to be rejected because they are not light-fast. We used, therefore, very light-fast organic pigments of the type Hansa-yellow, permanent yellow, permanent orange and molybdate orange light-fast. The low degree of saturation also contains titanium dioxide as a white component. A special alkyd resin resistant to yellowing was chosen as binding agent.

5. Tristimulus Values. Our first studies showed that with each new edition of the colour fan, in spite of identical prescriptions for colour mixture, differences in the instrumentally determined chromaticity coordinates of individual colour sheets were liable to occur. Therefore, it was decided not to define the sheets of the colour fan by the chromaticity coordinates \(x\) and \(y\), but by the chromaticity coordinates \(x\) and \(y\). These chromaticity coordinates must be regarded as ideal values. Each edition of the colour fan may deviate very slightly, as shown in Fig. 2. But for the visual evaluation of yolk colour with the fan, these differences are of no consequence.

At first it seemed obvious to refer exclusively to the study by Boguth and Czernicki (1962) when choosing these ideal coordinates. However, this did not prove practicable. On the one hand consideration had to be given to what could be realised with the pigments and printing methods chosen, on the other hand the customary yolk pigmentation in each different country had to be considered. Particularly within the range of high saturation, a shift of the hues towards orange had to be extended somewhat further than planned by Boguth and Czernicki (1962).

The procedure in detail was as follows:
ney occur in egg yolks, deal pigments for a colour they had to be rejected be- cause not light-fast. We used light-fast organic pigments Hansa-yellow, permanent orange and molybdate st. The low degrees of molybdate as a yellow. A special alkyd resin flooding was chosen as bind.

Values. Our first studies through each new edition of the take of identical prescrip- tion, differences in the determined chromaticity, individual colour sheets occur. Therefore, it was de- llived at the sheets of the colour on of colour mixtures, but too the coordinates x and y ordinates must be obeyed. Each edition of a y deviate very slightly, 2. But for the visual eval- uation with the fan, these no consequences. It appeared obvious to refer to a study by Boguth and when choosing these. However, this did not. On the one hand could be given to what could be pigments and printing on the other hand the pigment in each had to be considered. in the range of high t of the hues towards extended somewhat fur- by Boguth and Cer- n detail was as follows:

First a series of pigment mixtures were produced, trying to keep prescriptions as simple as possible, so that the mixtures could be produced at any time. At the same time, eggs from different sources were supplied to the colourist. Some of the eggs came from the market, some were chosen because their yolks had particularly weak or strong colours due to special rations. Printings were made of the pilot mixtures obtained, and their chromaticity coordinates determined by reflectance measurement. All proofs which visually impressed as successful representations of yolk colours were also found to have the correct hue when measured objectively (chromaticity coordinates x and y). There were, however, considerable differences in luminosity in comparison with the egg yolks (value L). Attempts to decrease the luminosity by addition of black pigment or by printing on grey or black cardboard were not successful. The brightness was indeed decreased by these measures, but at the same time the chromaticity coordinates x and y were altered. This shift always occurred toward lower saturation. Thus it became altogether impossible to produce sheets having both high saturation and the same luminosity as egg yolks. The sheets of lower saturation, though perhaps with regard to chromaticity, were of much poorer quality visually than the sheets with the above-mentioned difference in brightness. Some not clearly definable differences in the structure of the egg yolks and the colour sheets probably cause these discrepancies in the results of reflectance measurement. The choice of proofs were, therefore, made dependent on their suitability by visual evaluation; the objective measurement served merely as
the test for correct chromaticity. The coordinates \( x \) and \( y \) of the colour sheets obtained in this manner lie within the zone of the chromaticity diagram defined by Boguth and Czernecki (1962). The values \( x \) and \( y \) of these selected proofs are given in Table 1; as these numbers represent at the same time ideal values for the different editions of the improved 'Roche yolk colour fan', they were tabulated without the appertaining value of \( Y \) for luminosity.

Fig. 2 shows the course of these colour points in a section of the chromaticity diagram.

Table 2 contains the results of reflectance measurements on proofs of the latest 1965 edition. The values of the 1963 edition are quoted for comparison; a graphic representation is included in Fig. 2. Agreement with the ideal values of Table 1 is excellent.

The reflectance measurements were performed with two spectrophotometers "Zeiss PMQ" with reflectance attachment RA 3° in position A (diffuse sample illumination; measurement of the vertically reflected light). One instrument was provided with a glass monochromator M1 G2i; measurement was carried out between 380 and 770 nm from 5 to 5 nm (evaluation for standard illuminant C). The other instrument was fitted with a quartz monochromator M4 Q2L; measurement was carried out from 10 to 10 nm within the same range of wave lengths.

With the usual smooth shape of the reflectance spectrum, the results of the measurements were identical with both instruments.

### Table 1: Chromaticity coordinates \( x \) and \( y \) for the improved 'Roche yolk colour fan'

<table>
<thead>
<tr>
<th>Sheet No.</th>
<th>( x )</th>
<th>( y )</th>
<th>Sheet No.</th>
<th>( x )</th>
<th>( y )</th>
</tr>
</thead>
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<td>0.393</td>
<td>0.417</td>
<td>9</td>
<td>0.291</td>
<td>0.457</td>
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<tr>
<td>2</td>
<td>0.407</td>
<td>0.428</td>
<td>10</td>
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</tr>
<tr>
<td>3</td>
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<td>11</td>
<td>0.309</td>
<td>0.448</td>
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<td>0.439</td>
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</tr>
<tr>
<td>7</td>
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<td>0.458</td>
<td>15</td>
<td>0.330</td>
<td>0.407</td>
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<tr>
<td>8</td>
<td>0.483</td>
<td>0.458</td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>

### Table 2: Results of reflectance measurements of 2 editions of the 'Roche yolk colour fan'

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<th>( x )</th>
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<th>( Y )</th>
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<td>0.448</td>
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<td>0.464</td>
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<tr>
<td>0.473</td>
<td>0.457</td>
<td>5.996</td>
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<tr>
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<tr>
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<td>0.514</td>
<td>0.472</td>
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<tr>
<td>0.523</td>
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</tr>
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<td>0.331</td>
<td>0.409</td>
<td>4.093</td>
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</table>

<table>
<thead>
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<th>( x )</th>
<th>( y )</th>
<th>( Y )</th>
</tr>
</thead>
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<td>0.427</td>
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<td>0.436</td>
<td>0.444</td>
<td>5.907</td>
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<td>0.450</td>
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<td>6.136</td>
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<tr>
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<td>0.454</td>
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<td>0.453</td>
<td>6.084</td>
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<tr>
<td>0.479</td>
<td>0.453</td>
<td>5.954</td>
</tr>
<tr>
<td>0.488</td>
<td>0.456</td>
<td>5.959</td>
</tr>
<tr>
<td>0.500</td>
<td>0.454</td>
<td>5.395</td>
</tr>
<tr>
<td>0.507</td>
<td>0.444</td>
<td>5.448</td>
</tr>
<tr>
<td>0.514</td>
<td>0.435</td>
<td>4.999</td>
</tr>
<tr>
<td>0.518</td>
<td>0.428</td>
<td>4.724</td>
</tr>
<tr>
<td>0.527</td>
<td>0.419</td>
<td>4.574</td>
</tr>
<tr>
<td>0.512</td>
<td>0.407</td>
<td>4.031</td>
</tr>
</tbody>
</table>
provements in the use of the 1963 edition; a graphic solution in Fig. 2, deal with the handling of Table measurements were spectrophotometers spectrophotometrically in accord with the vertically oriented spectrophotometer M4, which was carried out between 5 and 5 nanometers. The illuminant was fitted with a suitable M4 filter; measurements from 10 to 10 nm of wave length. Each point represents the results of the measurements with both in-

**Fig. 3.** Colour points of the standard glasses of the yolk colour index by Heiman and Carver, in comparison with the 18 grade 'Roche yolk colour fan'.

The yolk colour index

<table>
<thead>
<tr>
<th>y</th>
<th>Y</th>
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<tbody>
<tr>
<td>0.415</td>
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<tr>
<td>0.427</td>
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<td>6.641</td>
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<td>6.597</td>
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<td>6.536</td>
</tr>
<tr>
<td>0.450</td>
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<tr>
<td>0.455</td>
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<tr>
<td>0.455</td>
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<tr>
<td>0.456</td>
<td>5.741</td>
</tr>
<tr>
<td>0.457</td>
<td>5.703</td>
</tr>
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<td>0.458</td>
<td>5.612</td>
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<td>5.589</td>
</tr>
<tr>
<td>0.458</td>
<td>5.452</td>
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<tr>
<td>0.459</td>
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</tr>
<tr>
<td>0.459</td>
<td>5.275</td>
</tr>
<tr>
<td>0.460</td>
<td>5.168</td>
</tr>
</tbody>
</table>

**COMPARISON OF THE 'ROCHE YOLK COLOUR FAN' WITH OTHER YOLK COLOUR SCALES**

I. Standard Colour Values Shown on Diagrams. Fig. 3 shows the colour points of the standard glasses of the 'yolk colour index' by Heiman and Carver (1933), in
comparison with the 15-grade 'Roche yolk colour fan'. The values for the 'yolk colour index' were determined by other investigators\textsuperscript{1} using the 10 selected ordinate method. The first four glasses of the 'yolk colour index' show very low colour saturation and are used only rarely, because they represent yolk colours resulting from carotenoid-free feeding. Glasses No. 5-12 are within the range of yolk colours, the following glasses, however, move too soon, i.e. with too low a saturation, into the orange region. The first, 12-grade 'Roche yolk colour fan' had the same deficiency, as demonstrated in Fig. 4. The break in the progression of the colour points at fan sheet No. 7 meant that only

\textsuperscript{1} Dr. John V. Spencer, Food Technology Section, Department of Animal Sciences, Washington State University, Pullman: private communication.

strongly pigmented or red-tinged yolks could be allotted to classes No. 7-12, the higher saturations of pure yellow accumulating in class No. 6.

Fig. 5 represents a comparison between the Fletcher colour scale and the 15-grade 'Roche yolk colour fan'. The chromaticity coordinates of the Fletcher rings are quoted from the study by Ashton and Fletcher (1962). Both colour scales cover essentially the same zone of the standard colour chart; the Fletcher colour scale shows a rather irregular progression, which may be due to the technique of colour application by spraying.

2. Attempt to Correlate Different Yolk Colour Standards. Any attempt to select standards representing identical quality from the different yolk colour scales, has
Roche Yolk Colour Fan

Fig. 5. Comparison between Fletcher colour scale and 13-grade 'Roche yolk colour fan'.

to be regarded as a rough approximation, because colour samples are assorted according to subjectively established similarity. As the colour glasses of the 'yolk colour index' and the Fletcher colour

Table 3—Arrangement of classes with different scales by visual comparison

<table>
<thead>
<tr>
<th>Roche yolk colour index</th>
<th>Roche fan (12 grades)</th>
<th>Fletcher colour rings</th>
<th>Yolk colour index (Hemaine-Carver)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 2*</td>
<td>5 (1)</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>3 3*</td>
<td>3 (2)</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>4 4*</td>
<td>4 (3)</td>
<td>10 11 12</td>
</tr>
<tr>
<td>4</td>
<td>5 5*</td>
<td>6 (4)</td>
<td>12 13</td>
</tr>
<tr>
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<td>6 6*</td>
<td>8 (5)</td>
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<tr>
<td>6</td>
<td>7 7*</td>
<td>9 (6)</td>
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<td>18 19</td>
</tr>
<tr>
<td>8</td>
<td>9 9*</td>
<td>11 (8)</td>
<td>20 21</td>
</tr>
<tr>
<td>9</td>
<td>10 10*</td>
<td>12 (9)</td>
<td>22 23 24</td>
</tr>
<tr>
<td>10</td>
<td>11 11*</td>
<td>13 (10)</td>
<td>25 26 27</td>
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<tr>
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<td>12 12*</td>
<td>14 (11)</td>
<td>28 29 30</td>
</tr>
<tr>
<td>12</td>
<td>13 13*</td>
<td>15 (12)</td>
<td>31 32 33</td>
</tr>
</tbody>
</table>

* Colours more vivid than.
** Saturation insufficient.
*** Saturation much lower.

rings were at our disposal at different moments and only for a limited period, the most similar standard colours were determined by direct visual comparison with the 'Roche yolk colour fan'. These results are given in Table 3.

Somewhat different results are obtained if egg yolks are evaluated at the same time with different colour scales, instead of comparing colour scales directly. Such an experiment was carried out by Marsich et al. (1964). Two observers evaluated the same yolks with different scales; their evaluations were averaged. Table 4 shows the values obtained. The difference between the 'Roche yolk colour fan' and its predecessors becomes more apparent here. With the older colour scales, it was not possible, as with the new fan, to assign yolks to classes 8, 9 and 10, because the
corresponding degrees of saturation of yellow were lacking. They were, therefore, assigned to class 6 or 7 of the 12-grade Roche fan 1962, or class 13 of the 'yolk colour index'. The assignment to higher classes of these scales required a marked shift of the yolk colour towards red.

**SUMMARY**

The 'Roche Yolk Colour Fan' has been re-designed to match more closely the average egg yolk. Fifteen colour grades with chromaticity coordinates situated within the range of normal egg yolk colours have been selected and defined by hue and saturation in the C.I.E. system of colour measurement.

A comparison is drawn between the 'Roche Yolk Colour Fan' and other yolk colour scales.

**ACKNOWLEDGEMENT**

We are indebted to Professor W. Boguth, Giessen, for valuable suggestions, and for carrying out a series of reflectance measurements.

The fan was produced jointly with Dr. Finckh & Co. Ltd., Schwelzerhalle (Mr. G. Jegher), and Tagafa, Eptingerstrasse 4, Basle (Mr. H. K. Schaub).

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