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# DEFINITIONS OF HONEY COLOR GRADES

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# DEFINITIONS OF HONEY COLOR GRADES[1]


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## INTRODUCTION

Grading according to color has long been an important factor in the marketing of honey. In different countries and by different organizations of beekeepers and honey dealers, various methods have been employed for evaluating and describing the colors of honey. In some instances names of color grades have been used without any attempt to define the grades or to employ standard colors for grading. In other cases colored glasses or bottles of colored liquids (often quite different in color from honeys) have been used. Obviously it is desirable that some accurate method be devised for defining and measuring the color grades of honey and that the same standards be widely used.

## IMPORTANCE OF COLOR GRADING

The most important reason for grading honey by color is that flavors of honeys from any given plant source vary with color, as certain examples will show. In the irrigated regions of the western part of the United States alfalfa honey is produced, usually with an admixture of honey from sweetclover but with less than the customary admixtures of nectars from other plant sources. In those parts of the irrigated region in which the altitude is high the honey from alfalfa and sweetclover is the most delicate and mild obtainable from these plants. In the Imperial Valley, lying below sea level, the honey from these plants is a rather dark amber, and the flavor is stronger and less delicate. It was formerly supposed that these differences were caused by admixtures of other nectars, but it is now known that they are due to the effect of climate, soil, and altitude on the color of the nectar of the plants. If, therefore, a buyer of honey desires either strong or mild alfalfa-sweetclover honey, it is most convenient to designate the color desired, since flavor varies with color.

Similar differences are found in many other honeys. Honey from white and alsike clovers varies from Water White to rather Dark (reddish) Amber, and the flavors differ much as do those of alfalfa-sweetclover honeys, the lighter honeys having the more delicate flavor. For any given plant source, the lightest and mildest honeys usually come from areas near the northern limits of the secretion of nectar from that plant.


[1] Received for publication Jan. 15, 1932; issued December, 1932. The work here reported was carried out during the summers of 1922, 1923, and 1924, while the author was connected with the Bureau of Entomology, U. S. Department of Agriculture, and determinations of light transmissions were made at that time. Later computations were made at the New York State College of Agriculture. A considerable number of persons assisted in the early work. The author is responsible for the final calculations, for the conclusions reached, and for the recommendations of definitions for the honey color grades. The Bureaus of Entomology and Agricultural Economics are responsible for the grades recommended in earlier publications, in the devising of which the author took no part.

With certain exceptions mentioned later, it may be said that in general for any given plant origin of honey, the lighter the honey the more delicate the flavor. It thus becomes important to designate the color of honey, for the color designation is of more value in indicating flavor than the name of the plant or plants from which the nectar is derived. Since there is no way of describing flavors as such, some progress at least will be made toward classification by flavors when accurate color grading is made possible. Color grading is, therefore, not a subordination of flavors but is the most accurate way of designating flavors thus far devised.

There are certain honeys for which the demands of the market can not be met on the basis of color grading. Chief among these in the United States is buckwheat (*Fagopyrum esculentum*) honey. This honey is dark and strong in flavor. Within the limits of the United States there is considerable variation in buckwheat honeys. In southern New York and northern Pennsylvania, buckwheat honey is opaque and dark with a slightly purple cast, while in certain areas of the Mid-West this honey is more transparent and is dark amber in color, red and yellow tones predominating. There is a heavy demand for buckwheat honey by the Jewish trade, chiefly in the eastern cities, and for export; for both trades the demand is for the opaque, dark, purplish honey. It is also required that the honey be granulated with a fine grain, even though for certain purposes for which this honey is used, it is liquefied. The flavors of different buckwheat honeys vary, although all of them are strong; it is the flavor of the opaque eastern honey that is preferred in the markets mentioned. Obviously it is impossible to give a color designation that will properly grade buckwheat honey, especially since the honey must be granulated to meet the demands of the market.

Similar conditions seem to prevail with the heather honey of Europe and perhaps also with the honeydew honeys of central Europe. However, the fact that color grading is not feasible in all instances does not make it any less valuable for grading the majority of honeys.

## PREVIOUS WORK

The United States Department of Agriculture has indorsed a color grader for honey (Sechrist [2] and Sechrist and Samson [3]) which is used in grading all honeys intended for export and to some extent those intended for domestic markets. While this grader has largely superseded others and has brought about greater uniformity in color grading, the instrument is so expensive that it is impractical for most beekeepers to buy it.

Any grading standard should be of such a nature that the different grades can be defined in words and figures. It should not depend on comparisons with some manufactured article, on the use of a piece of apparatus manufactured by one firm, or on the experience and skill

[2] Sechrist, E. L. THE COLOR GRADING OF HONEY. U. S. Dept. Agr. Circ. 364, 8 p., illus. 1925.
[3] ——— and Samson, H. W. UNITED STATES STANDARDS FOR HONEY RECOMMENDED BY THE UNITED STATES DEPARTMENT OF AGRICULTURE... U. S. Dept. Agr. Circ. 410, 32 p., illus. 1927.
——— and Samson, H. W. UNITED STATES GRADES, COLOR STANDARDS, AND PACKING REQUIREMENTS FOR HONEY. U. S. Dept. Agr. Circ. 24, 32 p., illus. 1927.



of a limited number of individuals. The standard honey grader indorsed by the Department of Agriculture is not based on suitable definitions. For the present deficiencies of definition the writer is chiefly responsible, as appears from the following paragraphs. In the published discussion of this grader [4] the percentages of lights of various colors transmitted through 1 cm of honey are given for the darker limits of the several color grades established, from which it might be assumed that these color grades are adequately defined. Such, however, is not the case, for (1) the figures published fail to correspond with the light transmissions measured for the honeys on the darker limits of the several grades, and (2) the official instrument is not based on the published figures.

The foregoing criticism of the definitions of the Department of Agriculture grades calls for some explanation. Before leaving the service of the Bureau of Entomology, the present writer undertook, with the help of his associates in this work, to draw up a table giving the approximate lower limits of light transmissions of three selected wave lengths, as a guide in the establishment of color grades. At the time this table was made it was thought that the limits indicated were fairly satisfactory, and at least moderately accurate. Accordingly, when Sechrist and Samson prepared their circular, they included this table without change except for the omission of figures for two secondary grades. A reexamination of the data for the various honeys studied now discloses the fact that these figures are entirely unsatisfactory, and as definitions for the darker limits of the several grades are practically valueless.

The inadequacy of these figures is indicated by the data shown in Table 1. This table gives the minimum transmission of light for each wave length just as it was prepared by the author and published in part by Sechrist and Samson. After each of these supposedly definitive figures is shown the number of instances among the 290 honeys studied in which the light transmission for the wave length in question is lower than the minimum set by the definition. The total of such cases (two or even more may occur in a single honey) is 269, which is entirely too high a percentage of error to give any validity to the assumed minimum limits. In general, the trends are such as are found in honeys of the several grades, but the actual figures are inaccurate for the purpose for which they were used.[5] It is therefore clear that so far there are no satisfactory definitions of color grades for honeys. The purpose of this paper is to propose such definitions, based on measurements of light transmission through honeys of a wide variety of colors. Aside from the one attempt mentioned, there appears to be no previous publication that defines color grades for honey.

[4] ——— and Samson, H. W. Op. cit. (Circ. 24, p. 29).
[5] The author regrets the necessity of pointing out errors in papers by his former colleagues, but since he is chiefly responsible for the original errors, the blame may be placed where it belongs. Sechrist and Samson are in no way responsible for these figures.

TABLE 1.—*Examination of definitions of honey color grades adopted by the United States Department of Agriculture on a basis of minimum transmission of blue, yellow, and red light, showing the number of cases in which the definitions are defective in the 290 honeys studied*

| Grade | Blue light | | Yellow-green light | | Red light | |
|---|---|---|---|---|---|---|
| | Minimum light transmission in definition | Samples below minimum | Minimum light transmission in definition | Samples below minimum | Minimum light transmission in definition | Samples below minimum |
| | *Per cent* | *Number* | *Per cent* | *Number* | *Per cent* | *Number* |
| Water White | 64 | 8 | 77 | 14 | 81.5 | 13 |
| Extra White | 60 | 9 | 76 | 12 | 80.5 | 11 |
| White | 50 | 19 | 71 | 20 | 78 | 21 |
| Extra Light Amber | 48 | 4 | 70 | 4 | 77 | 4 |
| Light Amber | 34.5 | 15 | 63 | 23 | 73 | 23 |
| Extra Amber [a] | 29 | ---------- | 60.5 | ---------- | 70.5 | ---------- |
| Amber | 15 | 17 | 49 | 22 | 63 | 30 |
| Dark Amber [a] | 6 | ---------- | 43 | ---------- | 59 | ---------- |

[a] The grades Extra Amber and Dark Amber are not included in the U. S. Dept. Agr. Circ. 24, table. p. 29. Exceptions to definitions for these grades must here be included in the primary grades, since the extra grades are not clearly indicated in the series of 290 honeys.

## MATERIAL AND METHODS

The determinations of light transmission through honeys, here recorded were made during the summer of 1922. Previous to and during that summer, beekeepers in all parts of the country were requested to send samples of honey for this study, and each beekeeper was asked to state the chief nectar source or sources from which the honey was derived. Four hundred and fifty-five samples were received and tasted in the laboratory, and the opinions of the producers regarding the sources of the honeys were found to be quite accurate. From all the honeys received, 290 were finally selected for detailed study.

The honeys selected ranged from the lightest produced in the United States to those so dark that practically no light passed through a stratum 1 cm thick. Most of the honeys were of floral origin, but a few of the darker samples doubtless contained some honeydew honey.

In the measurement of light absorption by liquids, several methods are available. One commonly used is to determine the extinction coefficient; that is, the reciprocal of the depth of solution required to reduce the intensity of light of a given wave length to a definite percentage of that of the entering light. Another method sometimes employed is to measure the energy of the light passing through a liquid of definite thickness and compare it with the energy of the light entering it. Measurements of this type were made by Kutzner [6] for a few German honeys, but this method, while perhaps the most exact, presents difficulties and unnecessary complications. The method employed in the present work was to measure, by means of a spectrophotometer, the percentage of light of selected wave lengths passing through a stratum of honey 1 cm thick.

Kutzner claims that this method is accurate only to within 3 or 4 per cent, as compared with the light-energy method, but there are other complications, such as turbidity, which complicate all measurements and which appear to make the method adopted for this work as good as could be chosen. Perhaps the greatest source of error arises from the fact that when the percentage of light passing through a 1-cm stratum of honey is determined by means of the spectrophotometer, the human eye is used to make comparisons of intensities, and this introduces an error which sometimes may be considerable. While determinations were made as accurately as possible, it is useless to assume extreme accuracy, and no such accuracy is necessary, for the honeys of the selected series could often be transposed without material difference in the appearance of the series.

[6] KUTZNER, W. ZUR PHYSIK DER HONIGFARBEN. Arch. Bienenk. 9: 185-195, illus. 1928.



In the early stages of the work, measurements of light transmissions were made for a considerable number of wave lengths, but it was found that there are no regions of the visible spectrum in which unusual absorption occurs (absorption bands), and that when a large number of determinations are made, they form a smooth curve. For practical purposes, therefore, it was found to be entirely satisfactory to confine the routine determinations to three wave lengths, namely, 480, 580, and 680 m$\mu$, these wave lengths being those of the colors blue, yellow-green, and red.[7]

Since the chief purpose of this work was to establish definable color grades for honey, the selected honeys were arranged in series according to their appearance to the eye, from the lightest to the darkest. All the honeys were carefully liquefied to prevent differences due to the deflection of light by included crystals, care being taken not to darken the honeys by overheating.

It is probably true that the proportion of honeys of different color grades in this series, as finally adopted, does not represent the proportion of these grades as they occur in the markets, but such agreement is not necessary. The samples were obtained from all parts of the United States and a majority of them are honeys found in the main honey markets. In the lighter ranges of the series, the gradations were so fine that usually any two adjacent samples might have been transposed without the change being noticed, but in the darker honeys such a transposition would usually have been easily detectable. While the gradations are finer in these honeys, this is permissible because it is chiefly in the lighter honeys that the closer color distinctions are now demanded in the trade.[8] It should also be noted that in the darker honeys of the series the gradations are less clear and the measurements of light transmissions are more erratic. This was due at least in part to the fact that turbidity is usually more pronounced in darker honeys, but it may also have been partly due to the fact that the darker end of the series was less complete than the lighter.

After the honeys had been arranged in order, some of the most experienced honey graders in the country were asked to indicate where in the series the several color grades should begin and end. Everyone found this a difficult matter to determine, especially in the

[7] The measurments of light transmission were made by Bernard Kurrelmeyer, who worked on this problem for two summers. The third summer the work was continued by E. W. Tschudi. Throughout all this work, Prof. A. H. Pfund, of the Johns Hopkins University, freely gave advice and assistance. The arrangement of the 290 honeys in color series was the result of cooperation of the entire staff of the bee culture laboratory, as well as of several experienced honey dealers.

[8] On a uniformly ascending scale of color in the Department of Agriculture honey color grader, the total length of the scale being 14 cm, the following distances are assigned to the various color grades: Water White, 0.8 cm; Extra White, 0.9; White, 1.7; Extra Light Amber, 1.6; Light Amber, 3.5; Amber, 2.9; Dark, 2.6. There are many honeys darker than the darkest part of this scale, so that the actual range of dark honeys is much greater than here indicated. The inequality in length of the different grades is explained by the need for closer color distinctions in the lighter honeys.

lighter honeys. In order that personal prejudice might play no part in the decisions, the floral sources of the honeys were not revealed while the judgments were being passed. To obtain different sets of opinions, the honeys were exhibited at the February, 1923, meeting of the American Honey Producers' League and later at a meeting of beekeepers in Wisconsin. At the meeting of the American Honey Producers' League, a decision as to the limits of the several grades was reached by practically unanimous agreement, separate opinions being taken of a selected set of experienced honey dealers and of all other beekeepers in attendance. These decisions of course referred only to numbers in the exhibited series and had no relation to the actual definitions of the grades.

Previous to this work, different undefined names had been used in the trade for color grades of honeys. The question as to the best designations for the different color grades was discussed at the meeting of the American Honey Producers' League in 1923 and it was decided to retain the names in most common use for the primary color grades.

During this work certain beekeepers insisted that the color grades in common use, especially those for the lighter honeys, were too comprehensive, and that finer subdivisions would be helpful. It appears to be a common experience in the color grading of commodities that with continued use finer and finer subdivisions are demanded. In establishing a grading system, it therefore seemed desirable to make provision for later subdivisions as they might be needed. For such subdivisions of the primary color grades, the additional word "extra" was suggested (except for the lighter subdivision of the dark grade, which is Dark Amber), it being the intention to include in the extra grade about 30 per cent of the lightest part of the primary grade. Thus the grade Extra Light Amber would include about 30 per cent of the lightest honeys of the primary grade Light Amber. The opinion of the honey handlers present at the meeting of the American Honey Producers' League was asked regarding the limits of these, extra grades as well as of the primary grades. The proposed limits were so favorably received that all of them were adopted, except those for the Extra Light Amber grade, which were later changed.

It should be pointed out that the color grades here proposed; or any that might be adopted, are wholly arbitrary, for there are no natural color groupings in honey. Even for honeys of practically pure floral origin, no natural color grouping can be detected, and, furthermore, honeys are so blended in the hive or during extraction that even if natural color groupings occurred in honeys of pure floral origin, the boundaries would be obliterated in the blends. As a result of these facts, there are often border-line cases in which it is impossible to assign a honey definitely to a certain color grade, but in the usual handling of honeys on the market, these cases are less frequent than might be anticipated.

## THE ABSORPTION AND DISPERSAL OF LIGHT BY HONEY

When light passes through honey to the eye, the impression formed through reception of the light stimulus is produced by light of various wave lengths. When white light strikes one side of a jar of honey and penetrates the honey, a considerable proportion of the light is absorbed, but this absorption is not equal for lights of all wave lengths.



The absorbed light does not reach the eye but is changed to some other form of energy, chiefly heat. The light which leaves the honey and reaches the eye is therefore a mixture of lights of various wave lengths, in proportions different from that in which they occur in white light, hence the honey appears to be colored.

If honey were clear, more light would pass through than is usually the case, but honeys contain myriads of minute particles of various sizes which either absorb light or deflect the light rays from their direct course. These particles include masses as large as pollen grains, of which there may be thousands in a pound of honey, or other foreign particles which are accidentally included in honeys. The major part of the deflection of light is caused by the presence in all honeys of matter in a colloidal state. The composition of these honey colloids is not altogether understood, but probably they are chiefly dextrins. Honeys differ widely in the turbidity caused by such colloids, some honeys appearing quite clear and others decidedly turbid. The proportion of light which passes through honey is, then, determined not only by the light-absorbing power of the liquid constituents of honey but also by the suspensions occurring in it. The turbidity of honeys seriously complicates the study of light transmission, and gives rise to difficulty is assigning minimum light transmissions for honeys of the several color grades.

The absorption of light varies of course with the thickness of the jar containing the honey, as does also light dispersion or turbidity. Even a Water White honey shows a distinctly amber color if the jar is of considerable thickness, and it also appears more turbid.

The chief constituents of honey are water and several sugars. As light passes through a solution of such sugars, there is some absorption, but this is negligible so far as giving color to the honeys is concerned. Practically all the liquid ingredients of honeys are colorless, by which is meant that they absorb little or no light and the light absorbed is practically the same for all wave lengths. But in addition to the chief ingredients of honey, there are derived through the nectars certain plant dyes which do not permit light to pass without exhibiting differential light absorption. Since honeys from different plant sources differ in color, and since under varying conditions of climate and soils the honey from any one plant source may vary widely in color, it is clear that the colors of honey are due to materials of plant origin, derived through the nectars.

## MEASUREMENT OF LIGHT TRANSMISSION

After the honeys had been arranged in series according to color, the proportion of light of each of the three selected wave lengths that passed through 1 cm of each of the 290 honeys was measured. In case any honey had begun to show crystal formation before the light transmissions were determined, it was again carefully liquefied.

It is not necessary to record all the measurements made on these honeys, but a few examples will be helpful in an understanding of the difficulties arising from an attempt to correlate light transmissions with the colors as detected by the eye. The lightest honey in the series, as determined by the eye, permitted 77.5 per cent of the blue light (480 $m\mu$) to pass through, 85 per cent of the yellow-green light (580 $m\mu$), and 91 per cent of the red light (680 $m\mu$). This was a honey from black sage (*Romona stachyoides*). These percentages are not, however, the highest for any of the three wave lengths as measured by the spectrophotometer, for an alfalfa honey in the series permitted 80 per cent of the blue light and 96 per cent of the red light to pass. Turbidity in the sage honey caused more of the light to be dispersed, although the sage honey appeared lighter to the eye.

A white-clover honey, classified as White, permitted the following proportions of the light to pass: 480 mμ, 58 per cent; 580 mμ, 74 per cent; 680 mμ, 79 per cent. A comparison of the lightest honey with this white honey from clover shows that the reductions in light transmission are relatively rapid. The darkest honey of the series, of unknown floral origin but probably containing some honeydew honey, allowed the following percentages of light to pass; 480 mμ, 0 per cent; 580 mμ, 0.5 per cent; 680mμ, 15 per cent.

After the honeys had all been measured for the transmission of the lights of the three wave lengths, it was found that the percentages of transmitted light did not fall into a series comparable to that made according to the color appearance of the honeys. This variation is shown in the data from the first 10 lightest honeys of the series. (Table 2.) All 10 of these honeys were so nearly alike in color that it was difficult to tell one from the other. If the data of the light transmissions of these 10 honeys are plotted as curves, a wide band is formed, for the spread is over a range of about 20 per cent.

TABLE 2.—*Percentage of light of different wave lengths passing through the 10 lightest honeys studied*

| Honey No. | Blue light (480 mμ) | Yellow green light (580 mμ) | Red light (680 mμ) | Floral source |
|---|---|---|---|---|
| 58 | 77.5 | 85.0 | 91 | Black sage (*Ramona stachyoides*). |
| 101 | 75.0 | 81.5 | 87 | Sage (*Ramona* spp.). |
| 176 | 70.0 | 80.0 | 85 | Fireweed (*Epilobium angustifolium*). |
| 102 | 67.0 | 76.0 | 85 | Do. |
| 305 | 63.0 | 74.0 | 82 | Do. |
| 306 | 61.0 | 74.0 | 79 | Milkweed (*Asclepias* sp.) |
| 197 | 80.0 | 92.5 | 96 | Alfalfa (*Medicago sativa*). |
| 196 | 70.5 | 80.0 | 91 | Do. |
| 174 | 75.0 | 84.0 | 89 | Do. |
| 37 | 64.0 | 74.0 | 75 | Button sage (*Ramona* sp.). |

In order to show the extreme limits of light transmission that may fall within a single market grade, the following data are given from the honeys that fall within the lighest classification, known as Water White. For blue light (480 mμ) the highest transmission was 80 per cent, the lowest 53 per cent, and the average 66.2 per cent; for yellow-green light (580 mμ) the highest was 92.5 per cent, the lowest 76.5 per cent, and the average 77.2 per cent; for red light (680 mμ) the lighest was 96 per cent, the lowest 73.5 per cent, and the average 82. 7 per cent. Thus it is evident that in honeys which appear similar to the eye, there are considerable differences in the actual transmission of light of different wave lengths. Differences of even greater magnitude are found among darker honeys that are similar in appearance.

The data for honeys that were reported to have come from white clover (*Trifolium repens*) and alsike clover (*T. hybridum*) are shown in Table 3. The numbers in column 1 are those given the samples on arrival in the laboratory and are without significance as to grading.



TABLE 3.—*Percentages of light of different wave lengths passing through the honeys derived from white and alsike clovers*

| Grade and honey No. | Blue light (480 mμ) | Yellow-green light (580 mμ) | Red light (680 mμ) | $\frac{R^a}{B}$ |
|---|---|---|---|---|
| | *Per ct.* | *Per ct.* | *Per ct.* | |
| Water White: | | | | |
| 93 | 61.0 | 77.0 | 75.0 | 1.23 |
| Extra White: | | | | |
| 307 | 54.0 | 69.0 | 74.0 | 1.37 |
| 90 | 75.0 | 90.0 | 95.0 | 1.27 |
| 191 | 70.0 | 86.0 | 93.0 | 1.33 |
| 135 | 58.5 | 73.0 | 79.0 | 1.35 |
| White: | | | | |
| 193 | 61.5 | 79.0 | 89.0 | 1.45 |
| 219 | 59.0 | 77.0 | 80.0 | 1.36 |
| 256 | 58.0 | 74.0 | 79.0 | 1.36 |
| 95 | 45.0 | 59.5 | 63.0 | 1.40 |
| 314 | 50.0 | 73.0 | 77.0 | 1.54 |
| 200 | 56.0 | 77.5 | 84.0 | 1.50 |
| 272 | 50.0 | 73.0 | 80.0 | 1.60 |
| 152 | 49.5 | 70.0 | 75.0 | 1.52 |
| 4 | 58.0 | 77.0 | 80.5 | 1.39 |
| 27 | 55.5 | 76.0 | 80.0 | 1.44 |
| 61 | 56.0 | 76.0 | 80.0 | 1.43 |
| 153 | 52.5 | 74.0 | 81.0 | 1.54 |
| 129 | 52.0 | 73.5 | 80.0 | 1.54 |
| 149 | 48.5 | 64.0 | 73.0 | 1.51 |
| 62 | 36.0 | 63.0 | 71.0 | 1.97 |
| Extra Light Amber: | | | | |
| 236 | 56.0 | 84.0 | 93.0 | 1.66 |
| 91 | 56.0 | 80.0 | 89.0 | 1.59 |
| 79 | 56.5 | 78.0 | 84.5 | 1.50 |
| 108 | 51.0 | 74.0 | 77.0 | 1.51 |
| 110 | 54.0 | 81.5 | 84.0 | 1.56 |
| 200 | 54.0 | 84.5 | 88.0 | 1.63 |
| Light Amber: | | | | |
| 201 | 54.0 | 83.0 | 90.5 | 1.68 |
| 56 | 48.0 | 70.0 | 75.0 | 1.56 |
| 265 | 48.0 | 71.0 | 80.0 | 1.67 |
| 274 | 33.0 | 54.0 | 65.0 | 1.97 |
| 273 | 25.0 | 45.0 | 58.0 | 2.32 |
| 112 | 36.5 | 56.5 | 64.5 | 1.77 |
| 302 | 41.5 | 69.0 | 80.0 | 1.93 |
| 177 | 47.5 | 78.5 | 83.0 | 1.75 |
| 31 | 37.5 | 64.0 | 68.5 | 1.83 |
| 154 | 30.5 | 51.0 | 58.0 | 1.90 |
| 23 | 44.0 | 68.0 | 74.0 | 1.68 |
| 60 | 41.0 | 70.0 | 77.5 | 1.89 |
| 271 | 32.5 | 62.5 | 71.0 | 2.18 |
| Extra Amber: | | | | |
| 45 | 31.0 | 61.0 | 67.0 | 2.16 |
| 68 | 25.0 | 61.0 | 74.0 | 2.96 |
| 96 | 25.0 | 52.0 | 63.5 | 2.54 |
| 216 | 19.5 | 53.0 | 61.0 | 3.13 |
| 192 | 22.0 | 59.0 | 73.0 | 3.32 |
| 121 | 21.0 | 51.5 | 62.0 | 2.95 |
| 184 | 13.0 | 42.0 | 52.0 | 4.00 |
| 38 | 5.5 | 17.5 | 24.0 | 4.36 |
| 30 | 1.0 | 36.5 | 66.0 | 66.00 |
| Maximum | 75.0 | 90.0 | 95.0 | 1.27 |
| Minimum | 1.0 | 17.5 | 24.0 | 24.00 |
| Average | 44.0 | 67.5 | 75.0 | 1.70 |

[a] Ratio of transmission of red light to transmission of blue.

It is evident from Table 3, which shows but a small portion of the original tables, that the color gradations of these honeys, as determined by experienced handlers of honey, fail to correspond with the gradations in light transmission for any one of the three wave lengths measured. So great is the variation in light transmission in honeys of practically the same color that it is necessary to find some other way to indicate differences in color.

It may be assumed that the grading of the 290 samples meets the demands of the American market. If this assumption is correct, the light transmissions for the various primary and secondary grades in these samples may be accepted as characteristic of honeys of the respective grades. Table 4 gives the data in condensed form for all of the 290 samples.

TABLE 4.—*Condensed data on light transmissions of the selected wave lengths for 290 honeys*

| Grade | Samples | Blue light transmitted | | | Yellow-green light transmitted | | | Red light transmitted | | | $\frac{R^a}{B}$ of individual samples | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average |
| | *Number* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* | *Per cent* |
| Water White | 24 | 80 | 53.0 | 66.2 | 92.5 | 67.5 | 77.2 | 96.0 | 73.5 | 82.5 | 1.43 | 1.15 | 1.25 |
| Extra White | 22 | 75 | 47.0 | 60.7 | 91 | 56.5 | 75.2 | 97.0 | 58.0 | 80.2 | 1.45 | 1.23 | 1.32 |
| White | 49 | 63 | 24.5 | 51.4 | 86.5 | 35.5 | 70.1 | 90.5 | 39.0 | 75.9 | 1.97 | 1.31 | 1.47 |
| Extra Light Amber | 13 | 56.5 | 40.0 | 50.4 | 84.5 | 62.5 | 74.4 | 93.0 | 70.0 | 80.9 | 1.85 | 1.48 | 1.61 |
| Light Amber | 68 | 54 | 23.5 | 39.1 | 86 | 41.0 | 65.5 | 90.5 | 50.5 | 73.9 | 2.43 | 1.56 | 1.90 |
| Amber | 84 | 41 | 4.0 | 21.3 | 82 | 17.5 | 55.4 | 92.0 | 24.0 | 66.8 | 14.75 | 1.86 | 3.62 |
| Dark | 30 | 22 | 0 | 3.25 | 58 | .5 | 23.1 | 78.0 | 12.0 | 42.1 | ([b]) | 2.45 | ------ |

[a] Ratio of transmission of red light to transmission of blue. [b] Infinity.

## THE POSSIBLE EFFECT OF RELATIVE SENSITIVITY OF THE EYE TO THE PROBLEM

The human eye does not perceive lights of all wave lengths equally. Table 5, which is taken from the work of Coblentz and Emerson,[9] shows the relative sensitivity of the eye to various colors. It is based on observations with 130 individuals made by detecting the disappearance of flicker when two lights of different colors and intensities were alternated rapidly.

TABLE 5.—*Relative sensitivity of the eye to lights of various colors* [a]

| Wave length (mμ) | Visibility | Wave length (mμ) | Visibility | Wave length (mμ) | Visibility | Wave length (mμ) | Visibility |
|---|---|---|---|---|---|---|---|
| 440 | 0.033 | 520 | 0.710 | 600 | 0.687 | 660 | 0.0645 |
| 460 | .056 | 540 | .954 | 620 | .427 | 680 | .0178 |
| 480 | .125 | 560 | .998 | 640 | .194 | 700 | .0040 |
| 500 | .316 | 580 | .898 | | | | |

[a] After Coblentz and Emerson. Op. cit., Table 5, p. 219.

It is evident from Table 5 that the human eye perceives light most acutely in the region of 560 mμ (yellow-green) and much less acutely at both the violet (440 mμ) and red (700 mμ) ends of the visible spectrum.

It might be suspected that the relative sensitivity of the eye to lights of various colors has some effect on the color impressions arising from the passage of light through honeys. This seems not to be the case, however, for the relative sensitivity is the same for the light either before or after it passes through the honey. No results of value have been obtained from attempts to calculate the light transmission of the various honeys in relation to the relative sensitivity of the eye to colors, since nothing approaching regularity has been found in such computations.

## THE RATIO OF TRANSMISSIONS AS A BASIS FOR GRADING

As previously stated, differential absorption of the white light gives the impression of colors that we get from looking at honeys. If the light which passes through honey has exactly the same relative proportions of the various wave-length components as are found in the original white light which strikes the honey, our impression would be that the honey is white. If some light is absorbed more than others, we get different color impressions, depending on which wave lengths of light pass without absorption.

Before discussing this subject in detail, reference may be made to the "color" often seen in honey from fireweed or willow herb (*Epilobium angustifolium*). This honey would usually be graded as Water White or Extra White, fireweed honey being one of the lightest to be found anywhere. A pure fireweed honey is so nearly devoid of amber

[9] COBLENTZ, W. W., and EMERSON, W. B. RELATIVE SENSIBILITY OF THE AVERAGE EYE TO LIGHT OF DIFFERENT COLORS AND SOME PRACTICAL APPLICATIONS TO RADIATION PROBLEMS. U. S. Dept. Com., Bur. Standards Bul. 14: 167–236, illus., 1918.



color that it often has a slightly gray appearance. This appearance of grayness arises from the fact that all wave lengths of light are absorbed in almost the same proportions, and the light which passes through a stratum of this honey is therefore practically white light. There is, however, some absorption of lights of all wave lengths, so that the amount of light which passes through the honey is less than that which comes around a jar. This reduction in the light as it passes through the honey gives merely an impression of slight grayness, without any noticeable color. Even for fireweed honey there is always slightly greater absorption of blue than of red light, as indicated in Table 2.

It is, then, possible for a honey to give the impression of being white or slightly gray even though a considerable proportion of the light which strikes it is absorbed. Although entirely equal absorption of all wave lengths has not been found for any honey, the human eye gives a color value, however slight, to all honeys. Usually this color is described as some shade of amber, the implication being that the wave lengths of light toward the red end of the visible spectrum pass through the honey more readily than do those of the violet end. An examination of the data for the clover honeys (Table 3) shows that one honey allowed 95 per cent of the red light (680 mμ) to pass through a stratum of 1 cm, whereas the greatest transmission of blue light (480 mμ) was 75 per cent. The averages for the clover honeys were as follows: Blue (480 mμ), 44 per cent; yellow-green (580 mμ), 67.5 per cent; red (680 mμ), 75 per cent. These figures support the previous statement that honeys permit more red light to be transmitted than any other, the violet end of the visible spectrum being most heavily absorbed.

It is possible for two honeys to have the same ratio of light transmission in the several wave lengths and still to absorb quite different percentages of the light of each of the three wave lengths. In such an event the honeys would have the same color, yet one would actually transmit less light than the other. As one goes toward the darker grades of honey, one finds that more and more light is absorbed but that there is a most rapid reduction in the transmission of light toward the violet end of the spectrum. It therefore seems at least theoretically possible to use as a factor in establishing the color grades of honey the ratio obtained by dividing the percentage transmission of red light by the percentage transmission of blue light. This ratio would be a constantly increasing number from the lightest to the darkest honeys.

The clover honeys have been examined on this basis. The lowest ratio found is 1.23 for the lightest honey, and the highest ratio is 66 for the darkest. (Table 3.) There is a steady increase in the ratio from the lightest to the darkest clover honey, but the rate of increase is not entirely uniform because of the smallness of the series. There are also certain variations which can not readily be explained on the basis of measurements with the spectrophotometer alone.

Since the actual figures representing the percentages of light of various wave lengths fail to give any satisfactory means of delimiting the color grades, and since the ratio of red to blue gives a more satisfactory way of indicating these limits, it seems possible that the definitions of the honey color grades might be based chiefly on this ratio. The figures published by Sechrist and Samson [10] seem to be of some service, however, for while they can not be accepted as the lower limits of light transmissions for the several grades, they may still be useful as indicators of the percentage of light absorption to be expected toward the lower limits of the grades. It therefore seems wise not to abandon these figures entirely but to use them as examples. They will serve as a further check, in the event that later attempts are made to devise practical grading instruments for the use of beekeepers and honey dealers.

It may be admitted that no optical physicist would probably ever think of using such a ratio of light transmissions as is here suggested. However, since the ratio seems to serve as a useful method for defining the honey color grades, being far superior to any other attempt made to define them, there seems to be no valid reason for refusing to accept it merely because the method is unusual.

The reduction in light transmission is seen to be regularly such that the red exceeds the yellow-green and the yellow-green the blue. On the basis of the suggestion made earlier, it might then be possible to use the factor $\frac{R}{B}$, $\frac{R}{Y}$, or $\frac{Y}{B}$. These factors appear to be equally valid, but of course the one should be chosen that gives the most consistent and definite results. As might be expected, the extremes best meet this requirement.

It would also be possible to get still larger numbers for the ratio if wave lengths other than 480 m$\mu$ and 680 m$\mu$ were chosen. For example, if 440 m$\mu$ and 700 m$\mu$ were used, the ratio would be larger, but in that event the wave lengths measured would approach the limits of human vision, which would make the measurements less definite. Since the selection of any two measurements is wholly arbitrary, it is necessary only to get data on wave lengths far enough apart to show significant ratios.

By computing the three factors mentioned for all the honeys in averages for groups of tens, all light transmissions for each group being averaged, the usefulness of these three factors has been tested. For $\frac{Y}{B}$ there are five instances in which a group of 10 honeys give a ratio on this basis which is lower than that of the group of 15 honeys immediately adjacent on the light side. For $\frac{R}{Y}$, there are 10 such exceptions. For $\frac{R}{B}$ there are found only 3, perhaps as good a showing as can be found for any grading scheme for honeys. These ratios are given in Table 6.

[1] Sechrist, E. L., and Samson, H. W. Op. cit.



Table 6.—*Average percentage light transmission for the lightest 260 honeys in groups of 10 each, with computed ratios as indicated*

[The 30 darkest honeys are omitted]

| Group No. | Percentage transmission of— | | | $\frac{R}{B}$ | $\frac{R}{Y}$ | $\frac{Y}{B}$ |
|---|---|---|---|---|---|---|
| | Blue light | Yellow-green light | Red light | | | |
| 1 | 70.3 | 80.1 | 86.0 | 1.23 | 1.08 | 1.14 |
| 2 | 62.7 | 74.2 | 78.9 | 1.26 | [a] 1.06 | 1.19 |
| 3 | 63.4 | 76.8 | 82.2 | 1.30 | 1.07 | 1.21 |
| 4 | 58.1 | 71.7 | 76.7 | 1.32 | 1.07 | 1.24 |
| 5 | 62.4 | 79.2 | 84.1 | 1.35 | [a] 1.06 | 1.27 |
| 6 | 58.7 | 75.1 | 81.5 | 1.39 | 1.10 | 1.29 |
| 7 | 50.8 | 69.0 | 74.2 | 1.46 | [a] 1.08 | 1.36 |
| 8 | 54.4 | 75.1 | 80.9 | 1.49 | [a] 1.08 | 1.38 |
| 9 | 45.5 | 64.7 | 70.5 | 1.55 | [a] 1.09 | 1.42 |
| 10 | 42.7 | 64.6 | 73.0 | 1.72 | 1.13 | 1.52 |
| 11 | 51.2 | 75.6 | 80.6 | [a] 1.58 | [a] 1.07 | [a] 1.48 |
| 12 | 43.8 | 66.6 | 75.0 | 1.73 | 1.13 | 1.53 |
| 13 | 40.6 | 66.3 | 75.0 | 1.88 | 1.14 | 1.64 |
| 14 | 41.4 | 67.2 | 74.8 | [a] 1.81 | [a] 1.12 | [a] 1.62 |
| 15 | 38.4 | 67.1 | 74.1 | 1.94 | [a] 1.11 | 1.75 |
| 16 | 37.7 | 64.2 | 74.2 | 1.99 | 1.16 | [a] 1.72 |
| 17 | 34.0 | 62.0 | 69.9 | 2.56 | [a] 1.13 | 1.83 |
| 18 | 32.6 | 63.0 | 71.7 | 2.20 | [a] 1.14 | 1.94 |
| 19 | 29.3 | 61.5 | 70.1 | 2.44 | [a] 1.15 | 2.13 |
| 20 | 25.0 | 58.0 | 68.5 | 2.84 | 1.19 | 2.39 |
| 21 | 24.8 | 55.6 | 65.6 | [a] 2.67 | [a] 1.18 | [a] 2.27 |
| 22 | 22.6 | 56.0 | 71.6 | 3.33 | 1.28 | 2.74 |
| 23 | 21.7 | 55.7 | 69.2 | 3.48 | [a] 1.25 | [a] 2.66 |
| 24 | 17.4 | 54.6 | 66.6 | 4.09 | [a] 1.23 | 3.35 |
| 25 | 14.5 | 47.0 | 60.5 | 4.34 | 1.30 | 3.35 |
| 26 | 11.4 | 47.0 | 60.4 | 6.32 | [a] 1.29 | 4.85 |

[a] These ratios show irregularities in the progression from the lighter to the darker honeys.

If this proposed grading plan is subjected to still another test an examination of the ratios $\frac{R}{B}$ for the individual honeys of the entire series only six cases will be found of honeys which have a ratio higher than the average ratio of the next lower grade. These six exceptions should be contrasted with the 263 exceptions found on examination of the definitions of grades formerly published. Three of these exceptions occur in the Water White grade and three in the White grade. None appear in the darker grades, and in both instances the exceptions occur because of the interpolation of secondary (extra) grades.

## CONCLUSIONS

As a result of a study of the transmission of light of three wave lengths through 290 honeys which had been arranged in series and marked as to their proper market grade by expert honey graders, the definitions for honey color grades shown in Table 7 are proposed.

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TABLE 7.—*Proposed definitions of honey color grades based on transmission of blue, yellow-green, and red light and on the ratios between the transmissions of the red and blue lights*

| Grade | Approximations of light transmission for the lower limits of the grades | | | Ratio of red light transmission to blue $\left(\frac{R}{B}\right)$ | |
|---|---|---|---|---|---|
| | Blue light (480 mμ) | Yellow-green light (580 mμ) | Red light (680 mμ) | Maximum | Average |
| | *Per cent* | *Per cent* | *Per cent* | | |
| Water White | 64.0 | 77.0 | 81.5 | 1.43 | 1.25 |
| Extra White | 60.0 | 76.0 | 80.5 | 1.45 | 1.32 |
| White | 50.0 | 71.0 | 78.0 | 1.61 | 1.47 |
| Extra Light Amber | 48.0 | 70.0 | 77.0 | 1.97 | 1.61 |
| Light Amber | 34.5 | 63.0 | 73.0 | 2.43 | 1.90 |
| Extra Amber | 29.0 | 60.5 | 70.5 | [a] 4.20 | ([a]) |
| Amber | 15.0 | 49.0 | 63.0 | 8.00 | 3.62 |
| Dark Amber | 6.0 | 43.0 | 59.0 | [a] 9.83 | ([a]) |
| Dark [b] | ([b]) | ([b]) | ([b]) | ([c]) | ? |

[a] Averages are not given for the grades Extra Amber and Dark Amber, since no definite division points for these grades were designated in the 290 honeys studied. The maximum ratios are based on estimates of the probable maximum if the secondary grades are to include roughly 30 per cent of the primary grades.
[b] All honeys darker than Amber (or Dark Amber).
[c] Infinity.

The figures in Table 7 for maximum ratio of red light transmission to blue light transmission differ from those given in Table 4 for the same grades in three instances. These changes are proposed because the extreme figures for ratios in Table 4 were those of three honeys toward the lower end of the respective grades (White, Extra Light Amber, and Amber) which may as well be allowed to fall into darker grades. In no case did these exceptional honeys lie farther than two or three from the darker limits of the grades. These changes are proposed also because the ratios of the particular honeys which gave abnormally high ratios are considerably higher than those of honeys immediately adjacent to them in the series.

If color-grading rules based on these figures are adopted, it is believed that it will be possible for any properly equipped manufacturing concern to make a honey color grader that will meet the demands of the definitions. Moreover, the color grades will be accurately defined, which so far has not been the case.

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