

Observations on the Absorbancy of Sugar Solution

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Introduction

The evaluation of sugar quality is one of the prime factors in the manufacture of refined sugar. Among the quality tests for sugar, the determination of sugar color is one of the more important ones and, consequently, has received a great deal of attention in recent years.

In spite of the unrepented importance of so-called sugar color, the industry, and with it the consumer, are far from being in agreement on such questions as:

1. What does sugar color mean?
2. How is sugar color precisely measured?
3. What impurity is responsible for the color?
4. How can we relate color to impurity?
5. How can the coloring impurity be removed most economically in the refining process?

Carpenter & Deitz (1)² called attention to the disparity in the objective of measuring so-called sugar color.

The practice of blueing sugar is a well-known method of improving the visual color rating without enhancing real quality. On the other hand, a common European practice of grinding larger sugar crystals to a specific grain size causes a loss of sparkle and luster to visual appearance without changing basic quality.

ICUMSA has proposed several tentative methods for measuring sugar color in solution. However, the scientific evidence to promote specific guidelines such as cell length, sugar concentrations or wavelength respectively is very weak. Most generally accepted is a wavelength of 420 m μ , a concentration of 50% sugar and a cell length of about 5-10 cm.

The objective in the past was primarily an attempt to assess the visual, yet superficial, discoloration rather than to measure the precise amount of color-causing impurities. By sticking too close to the former guidelines, we may forsake the opportunity to expose the answer to our real color problem.

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² Numbers in parentheses refer to literature cited.

Procedures and Discussions

All tests were carried out with a Beckman DU Spectrophotometer with power supply and photomultiplier. Matched sets of 10 mm silica cells accurate to within $\pm 1\%$ T of each other at 100% transmittance filled with double-distilled, deionized water and tested at a wavelength of 220 $m\mu$ were used. Careful cleaning and preparation of the cells were found to be essential to avoid erratic results. Larger cells for solution depth of 5 cm and 10 cm respectively seemed to give fair results above 400 $m\mu$ but were obviously not suitable at the shorter wavelength.

The effect of optical aberration due to a change in the wavelength was investigated and found to be negligible within the scope of this investigation. The slit width was ranged between 0.15 - 0.3 mm for the tungsten lamp and between 0.2 - 0.6 mm for the hydrogen lamp. The pH variations between pH 4.8 - 10.0 had very little effect on absorbancy readings above 250 $m\mu$ for granulated sugars. Below 250 $m\mu$ the high pH sugar solutions gave substantially higher absorbancy readings.

Attenuation indices were similar to those found by Carpenter & Deitz (1) throughout the ultraviolet spectrum when using a hydrogen lamp as a source of energy. However, type 50 invert solution gave peak absorbancy around 280 $m\mu$ while most granulated sugars peaked around 265 $m\mu$.

With a tungsten lamp as a radiation source and a stray energy filter a sharp absorbancy peak was found at 295 $m\mu$ for all specimens tested. Peak absorbancy occurred at 300 $m\mu$ for the tungsten lamp without the use of the stray energy filter. This comparison is shown in Figure 1 for type 50 invert solution.

No explanation is offered at this time for the disparity in spectral response to the two energy sources with and without

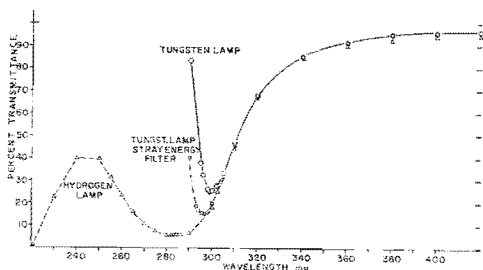


Figure 1.—Transmittance curves for Type 50 Invert. Variation due to different radiation sources with DU Spectrophotometer. 35% sugar solution.

the stray energy filter. The primary objective of this study was to take advantage of the maximum absorbancy with the tungsten lamp at 300 $m\mu$.

Figure 2 compares the transmittance curves over the upper U.V. spectrum for a beet sugar and a type 50 invert sugar produced from the beet sugar through cold inversion. Attention is called to the fact that both sugars had nearly identical attenuation indices at the popular wavelength of 420 $m\mu$ and using the Bernhard-Phoenix Sphere Spectrophotometer.

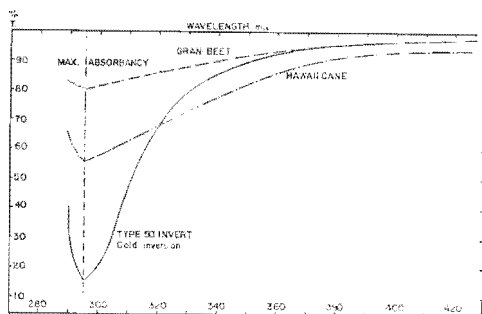


Figure 2.—Transmittance curves for 35% sugar solutions. Model DU, 10 mm cells, tungsten lamp with corex filter below 310 $m\mu$.

However, when viewed through large solution depth, e.g. 10 ft, the type 50 had a more intense yellow cast. It is not unreasonable to expect a certain amount of degradation even through cold inversion. A cane sugar has been added for comparison.

Further treatment of the type 50 syrup over the Cl^- form of a strong base anion resin elevated the attenuation index of the syrup over that for the original sugar.

The impurities thusly removed from type 50 were subsequently stripped from the anion with salt solution. A family of transmittance curves over the U.V. spectrum was prepared from the salt solution to explore maximum absorbancy. Figures 3 and 4 illustrate this comparison.

Note a pronounced peak absorbancy at 295 $m\mu$. Another shallow peak can be observed at 265 $m\mu$. Figure 5 verifies that the color impurities removed from the type 50 syrup obey the law of Beer at maximum absorbancy. Although observance to that law is exhibited at 420 $m\mu$ the steeper slope at 295 $m\mu$ allows for superior measurements.

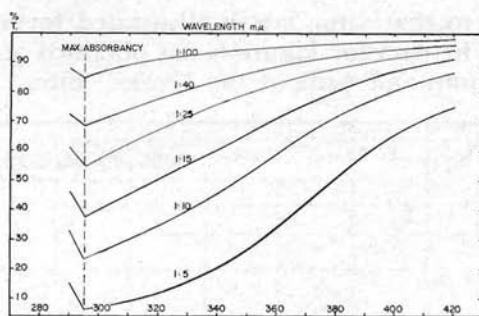


Figure 3.—Transmittance curves for coloring matter isolated from Type 50 invert (cold inversion). Model DU, 10 mm cells, tungsten lamp with corex filter.

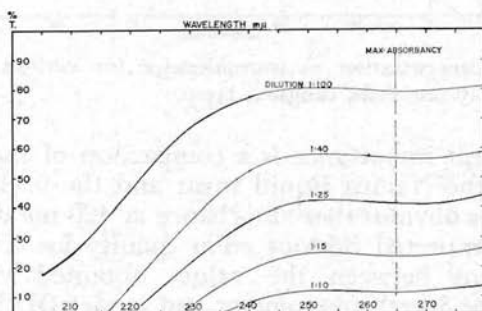


Figure 4.—Transmittance curves for coloring matter isolated from Type 50 invert (cold inversion). Model DU, 10 mm cells, hydrogen lamp.

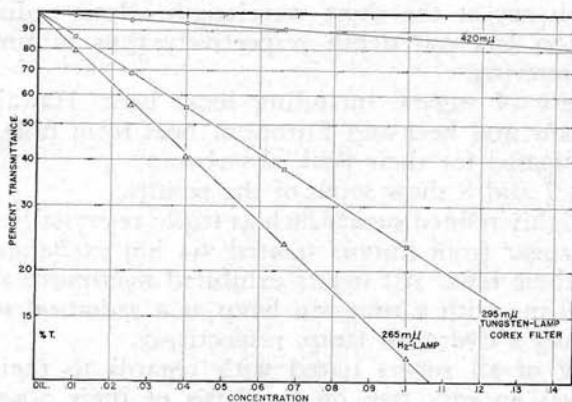


Figure 5.—Concentration vs transmittance for coloring matter isolated from Type 50 invert.

Obedience to that same law is illustrated for various sugars in Figure 6. The data for Figure 6 was obtained at 300 $m\mu$ with the tungsten lamp and without the "corex" filter.

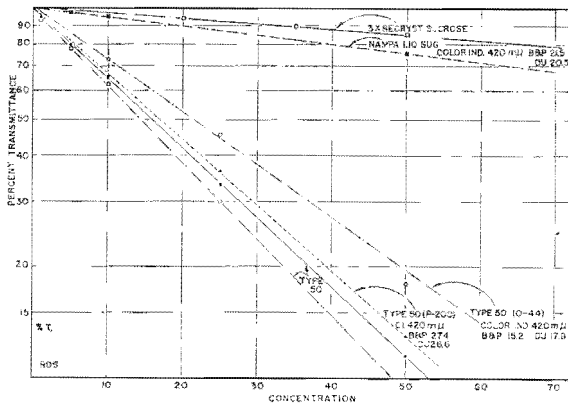


Figure 6.—Concentration vs transmittance for various sugars at 300 $m\mu$. Model DU, 10 mm cells, tungsten lamp.

Of significant importance is a comparison of the color index at 420 $m\mu$ for the Nampa liquid sugar and the 0-44 Type 50 respectively. It is obvious that absorbance at 420 $m\mu$ did not reflect the normally expected inferior color quality for Type 50. The close agreement between the values obtained via Bernhard-Phoenix Sphere Spectrophotometer and model DU Spectrophotometer is also of interest suggesting that turbidity had negligible bearing on these results.

No attempt was made to compensate for the influence of scattering for any of the tests with the D.U. The selection of peak absorbancy at the short wavelength allows reduced sugar concentration and cell depth respectively thus minimizing the effect of scattering.

A variety of sugars, including local beet, Hawaiian cane, Japanese cane and beet and European beet from different areas were investigated for their peak absorbancy.

Figures 7 and 8 show some of the results.

Some highly refined sugars such as triple re-crystallized sucrose as well as sugar from liquors treated via ion exchange were included in these tests. All sugars exhibited maximum absorbancy around 300 $m\mu$ with a tungsten lamp as a radiation source and 265 $m\mu$ using a hydrogen lamp, respectively.

Grading of all sugars tested with regards to their refining qualities was an easy task on the basis of their absorbancy at 295-300 $m\mu$, while grading was somewhat obscured when based on absorbancy at 420 $m\mu$.

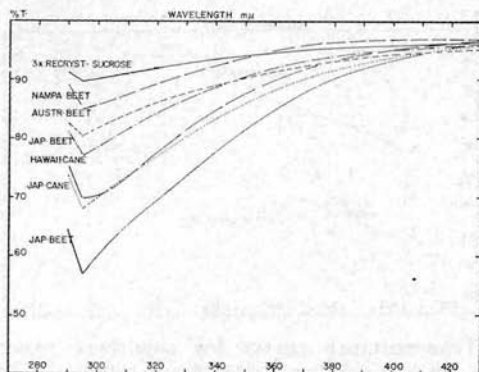


Figure 7.—Transmittance curves for various sugars 35% Model DU, 10 mm cells, tungsten lamp with corex filter.

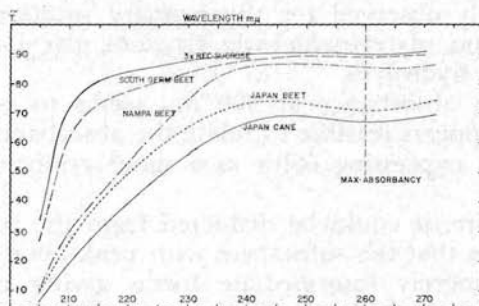


Figure 8.—Transmittance curves for various sugars 20% Model DU, 10 mm cells, hydrogen lamp.

As a rule, cane sugars did not fare as well as beet sugars on this basis. This perhaps can be traced to the relatively high invert load which most cane liquors carry. It is furthermore no secret that the cane industry has a more severe color problem than the beet industry. The two factors, namely invert and color, are undoubtedly connected. Absorbancy at 300 $m\mu$ clearly reveals this problem while absorbancy at 420 $m\mu$ does not contribute towards identification of impurities.

Standard liquor was also investigated for its transmittance spectrum in the U.V. spectrum. Trends similar to that for sugar were found. Figure 9 shows the results.

Prey and co-workers (2,3,4,5) have done extensive pioneering work on the absorbancy of specific model substances which are germane to the liquors in the sugar processing industry. These reaction products, usually degradates of invert, protein

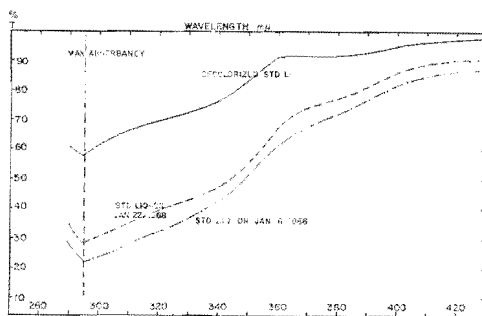


Figure 9.—Transmittance curves for sugarbeet processing liquors I RDS, Model DU, 10 mm cells, tungsten lamp with corex filter.

and pectin, exhibit maximum absorbancy in the U.V. spectrum. According to published data maximum absorbancy around 300 $m\mu$ was usually observed for the primary reaction products of dihydroxyacetone, glycerinaldehyde, fructose, glycyl -1- tyrosin and others during hydrolysis.

Since peak absorbancy at 300 $m\mu$ seems to be specific for all sugars, it appears feasible to relate the absorbancy to a specific impurity thus expressing color as a more realistic quantitative entity.

Furthermore, it could be deduced from the studies of Prey and co-workers that the substances with peak absorbancy around 300 $m\mu$ are merely intermediate forms giving rise to highly colored substances when exposed to further hydrolysis. This seems to be in agreement with the observation that the solution of an inferior sugar discolors faster when heated than a comparable test with a high quality refined sugar. Invert type sugar solutions deteriorate faster yet. The heating test of the Braunschweiger point system is apparently predicated upon this observation.

Conclusions

It appears that impurities with specific absorbancy bands around 300 $m\mu$ and using a tungsten lamp as the energy source are common to all refined sugars.

Although the tungsten lamp is normally not recommended as an energy source for spectral measurements around 300 $m\mu$, its ability to resolve apparent differences in the concentration of colorant impurities suggests its application for sugar quality evaluation at the specified short wavelength.

The possibility of using relatively low sugar concentrations, e.g. < 35%, short cell depth, e.g. 10 mm, at maximum absorbancy

should avoid interference from normal turbidity. Identification of the coloring impurity may allow its expression as a quantitative entity.

Literature Cited

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