Assessing Natural vs Synthetic Red Food Dyes

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Background

Red Food Dye:
Colorants have been a part of our world for a long time. They have been used in textiles, medicines, hair products, cosmetic products, and specifically food. Food coloring is an important sensory cue to how we expect foods and drinks to taste. There are synthetic and natural dyes that help us gain the bright color we associate with our food. Natural dyes are made from vegetables, fruits, plants, and sometimes insects. Synthetic dyes are made from the synthesis of chemicals compounds. Customers and vendors look for a dye that is vibrant, heat and light stable, low cost, provides health benefits, and no added flavor. Natural dyes tend to provide more health benefits than synthetic but are more costly and less stable. Synthetic, red dye 40 specifically gives the vibrant red along with the pH stability necessary to remain that color but has been flagged with potential health hazards. This research will investigate the advantages and disadvantages of natural and synthetic red food dyes, specifically red dye 40, Allura Red, (Figure 1) and a natural red dye alternative, derived from red beets (Figure 5).

Perception of color:
The visual sensation of color is due to the chemical interaction with light which triggers our perception of color. The color we perceive is due to the absorption of complimentary wavelengths of color (Figure 9). Green is absorbed at a wavelength of 560- 490 nm which reflects red at a wavelength of 800-650 nm. The number of conjugated double bonds relates to the different emissions of wavelength and therefore different colors reflected. The more conjugated bonds a molecule has the higher the wavelength. FD&C Red No. 40 has 11 conjugated double bonds while betanin has 7 conjugated double bonds. That helps emit and retain their color.
The HOMO-LUMO gap explains the difference in energy between the highest occupied orbital and lowest unoccupied orbital [18]. The more conjugated bonds a compound has, the smaller the HOMO-LUMO gap is. This lowers the frequency and lengthens the wavelength [18]. This relates to why red dyes needs more conjugated bonds to give off the bright red color.
Highly acidic solutions or conditions lead to the reflection of the color red, while highly basic conditions lead to the reflection of blue. The protonated compound (Figure 1) causes the compound to be more acidic and therefore more red.

Methods

Literary Search:
A literary search was conducted via the use of two databases: CAS SciFinder^n (Figure12) and ScienceDirect (Figure 13) to understand the background of dyes, what makes color, and toxicology information. Key words were searched including, “Red beet” , “Food coloring”, “Allura Red”, “Food Dye”, “Allergies”, and “Toxicology.”

Proposed Experiments:
If the proposed topic was implemented, multiple experiments would be conducted to compare FD&C Red No. 40 (Figure 1) and Betanin in Red Beets (Figure 5) and their properties.

- **Concentration:** HPLC will be run on FD&C Red No. 40 powder (Figure 3), red Gatorade, red beet juice, and Red Beet extract powder (Figure 7) to find the concentration of the dyes used in these specific products.
- **Cost:** Red Beet extract diluted with Dextrin costs $82 for 25 g [16]. FD&C Red No. 40 costs $113 for 25g [17].
- **Vibrancy:** UV-vis spectrometer will be obtained to find the absorbance peak intensities to analyze the differences in hues.
- **Light stability:** These dyes will be held under UV light for 1 hour and compared to the control through UV spectroscopy to determine the light stability and fade resistance of these dyes.
- **pH stability:** The dyes will be tested by creating solutions varying in pH levels of acidity and basicity to compare the level of pH the dyes are color stable.
- **Toxicology:** The toxicology of the dyes will be tested through the addition of the dyes to living organisms, fish eggs.

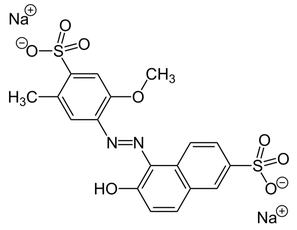

Figure 1. Structure of Allura Red, FD&C Red Dye 40 [14]

Advantages	Disadvantages
• Freely soluble in water at all pH • Resistant to oxygen and environmental factors • Stable to light and heat • Low cost • 11 conjugated double bonds • Scored high in social and economic stability [20] • SDS no toxicology report [21]	• Does not give any nutritional value • Acceptable daily intake (ADI) limit of 7 mg/kg [1] • linked to allergies, migraine [1] • Linked to mental disorders in children such as ADHD [1] • Linked to cancer in rats at high level [2] • Scored lowest in environmental stability [20]

Figure 2. Advantages and Disadvantages of FD&C Red Dye 40

Figure 3. Synthetic FD&C Dye No, 40 [15]

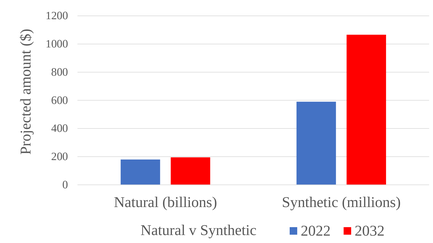

Figure 4. Market Projection of Natural and Synthetic Food Coloring. Selective Data from [10][11]

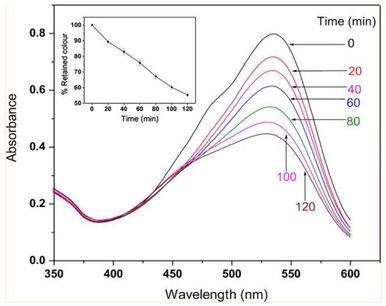

Figure 14. UV Spectrum for Betanin in DI Water at 75 ℃ over time [19]

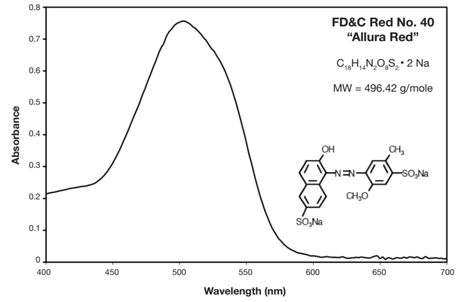

Figure 11. UV Spectrum for FD&C Red No. 40 [12]

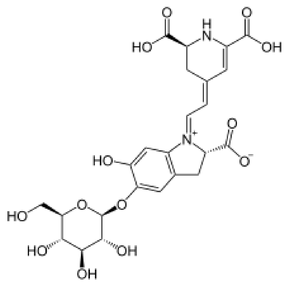

Figure 5. Structure of Betanin, Red Pigment in Red Beets [13]

Advantages	Disadvantages
• Has no ADI limit • Ecofriendly • Phenolic hydroxy group – high antioxidant activity [3] • Betanidin can help reduce inflammation [3] • Free radical scavenging ability [3] • Ability to neutralize reactive oxygen species	• Color can change with change in pH • Degrades when subjected to light, heat, or oxygen

Figure 6. Advantages and Disadvantages of Betanin Dye in Red Beets

Figure 7. Natural Source of Betacyanin Red Food Color Powder [7]

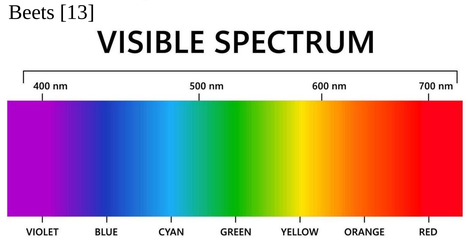

Figure 8. Visible Light Spectrum [8]

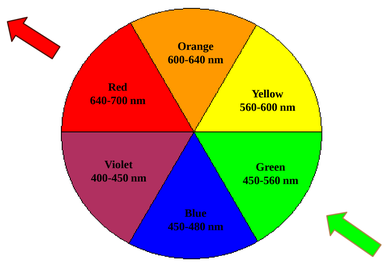

Figure 9. Color Wheel [9]

Figure 10. Preferred Article from ScienceDirect Search, % Evangelicals in Spain of 1.61% [1]

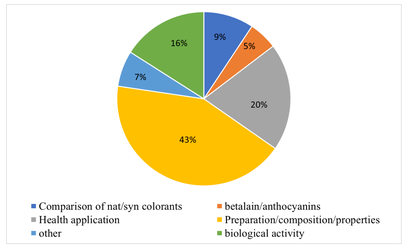

Figure 12. Results of CAS SciFinder^n - "Red Beet and Food Coloring"

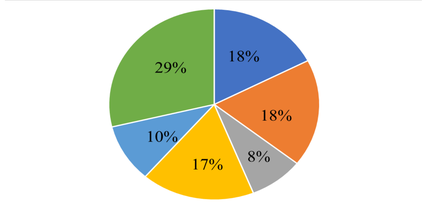

Figure 13. ScienceDirect "Allura Red and Toxicology and Food Dye and Affects"

Research Question

The purpose of this study is to compare the characteristics of natural and synthetic red dye, specifically FD&C Red No. 40 powder and red beet powder from betacyanin based on their light stability/vibrancy, pH stability, health advantages, and cost. The results of this research will further the knowledge of the benefits and disadvantages of natural or artificial dyes.

Results and Conclusions

Structural Groups:
Phenol groups found in betacyanin (Figure 5) are responsible for the major health benefits seen in the food dye such as antioxidants [3]. The sulfonic groups found in FD&C Red No.40 (Figure 1) are responsible for the water solubility of the dye.

Market Data:
The global food color market for synthetic dyes was 590 million in 2022 and is projected to be 1066 million in 2032 (Figure 4). The global food color market for natural dyes was 1.8 billion in 2022 and is projected to be 1.95 billion 2032.

Biblical integration:
The importance of color and the beauty of God’s creation can be seen throughout the whole Bible. God’s glory shows through the beauty and brightness He gave us through flowers, sunsets, rainbows, and all of nature. Red specifically is used in the Bible to symbolize sacrifice, judgement, love and authority. Matthew 27:28 states, “An they stripped him, and put on him a scarlet robe,” (KJV) and Matthew 26:28 states, “For this is my blood of the new covenant, which is shed for many for the remission of sins” (KJV). One of the main ways the Lord used red was in relation to Jesus’ sacrifice and atonement for our sins. Red is often used in reference to humanity and is symbolic of God’s love for us, so that through Jesus’ sacrifice we may have eternal life with Christ.

Future Work

Similar experiments will be performed on the comparison of the dyes on a variety of different market products: Fruit loops, icing, fruit snacks and Jello. They will be analyzed for FD&C Red No. 40, FD&C Red No. 3, betanin, and carmine extract.

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