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Analyzing the Optical Properties of Carom Water at Different Temperature and Concentration

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Abstract

Carom water, infused with the seeds of Ajwain (Carom seeds), has been traditionally used for its medicinal properties. Its optical characteristics, such as transmittance and absorbance, can provide valuable insights into its composition and the effects of various external factors. This study investigates the optical properties of carom seed-infused water (carom water), focusing on the effects of soaking duration, sugar concentration, and temperature on transmittance and absorbance. After the preparation of sample of carom water, a Theremino spectrometer is used to measured transmittance and absorbance within the visible spectrum (380-700 nm) at various condition [various soaking periods, seed concentrations, and temperatures (30°C and 60°C)]. The study revealed that over time, transmittance decreases and absorbance increases as organic compounds from the seeds dissolve into the water, with higher seed concentrations accelerating this process. The addition of sugar altered the optical properties, with higher sugar concentrations leading to larger colloid formation and reduced transmittance. Temperature also influenced the optical characteristics, with higher temperatures promoting finer particles and increased transmittance. The findings suggest that soaking duration, sugar concentration, and temperature are key factors affecting the optical properties of carom water. Future research should focus on the molecular interactions between sugar and carom seed compounds and extend the spectral analysis to a broader wavelength range to gain deeper insights into these dynamic light-sample interactions.

Keywords: Transmittance, Absorbance, Theremino spectrometer, Temperature, Carom, Wavelength, Sugar etc.

Introduction

Trachysperum ammi (L.) Sprague, often known as Ajwain, is an annual herbaceous plant that is a treasured member of the extremely significant *Apiaceae* family of medicinal plants

(Dhiman et al., 2014 and Khedekar et al., 2022). Although ajwain is native to Egypt, it is grown and marketed widely over the world, including Iran, Pakistan, Afghanistan, India, and Europe. In some areas of Nepal, it is also grown. Ajwain's fruits and seeds are typically regarded as nutritious and medicinal (Chauhan et al., 2012). They have a grayish brown color. Fiber (11.9%), carbohydrates (24.6%), tannins, glycosides, moisture (8.9%), saponins, flavors, and another component (7.1%) involving calcium, phosphorus, iron, cobalt, copper, iodine, manganese, thiamine, riboflavin, and nicotinic acid are the various chemical constituents of caromed seeds (Ranjan et al., 2012). Due to their diverse composition, carom seeds are used in a wide range of medical applications.

Traditional medical systems have long employed Ajwain for a range of pharmacological and therapeutic purposes (Lateef et al., 2006). Ajwain was well-known in Traditional Persian Medicine (TPM) for thousands of years. The most beneficial element of the plant employed by Persian practitioners was the seeds. In the realm of neurology, oral administration of seed has been claimed to be beneficial for tremor, palsy, paralysis, and other neurological problems. Additionally, Persian practitioners used an ocular and ear drop made from Ajwain seeds to treat hearing weakness and develop infected diseases. Ajwain has been reported to be useful in the treatment of cough, pleurisy, and dysphonia in the respiratory system.

The phenomena known as the absorption process occurs when atoms and molecules interact with electromagnetic radiation, absorbing some of the field's energy and transforming it into internal energy that is expressed in terms of energy levels. When light is absorbed by a material's atoms or molecules, its energy is transformed into different forms, like heat. Transparency allows light to travel through materials without being absorbed, a process known as transmission. Refraction, which affects phenomena like the bending of light in lenses, is the process by which light changes direction when it moves from one medium to another as a result of variations in optical density. Here, light must undergo refraction since Ajwain water serves as the medium. Last but not least, the law of reflection states that light bounces off a surface when it reaches a boundary without being absorbed or transmitted. Together, these phenomena affect a variety of domains, from optics to daily experience, and how we view and engage with light (Insero et al., 2023).

Trachyspermum ammi (ajwain) and its major component, thymol (THY), exhibit significant medicinal properties. Arkob et al. demonstrated ETA and THY’s strong membrane-stabilizing and clot-lysis capacity, with THY showing superior efficacy (Arkob et al., 2024). Chahal et al. highlighted ajwain’s key constituents and pharmacological benefits (Chahal et al., 2017). Goli et al. synthesized oxalipalladium (OX) nanoparticles using ajwain extract, revealing potent anticancer activity against HCT116 colon cancer cells (Goli et al., 2024). Das et al. investigated THY’s antimicrobial potential against Mycobacterium smegmatis

(Das et al.,2024), showing its inhibitory effects on biofilm formation, synergy with TB drugs, and strong interactions with efflux pump proteins, indicating its promise in combating drug-resistant tuberculosis. Obesity is a major global health challenge caused by an imbalance between energy intake and expenditure, leading to severe conditions such as insulin resistance, diabetes, cardiovascular diseases, and psychosocial problems (Rahaman et al., 2025). The lack of effective drugs and complications associated with modern treatments highlight the need for safe, natural anti-obesity agents. Traditional Unani medicine classifies obesity as a phlegmatic disease and advocates herbs like cinnamon, garden rue, cumin, ajwain, and marjoram for weight management. Herbal plants, valued for their medicinal and aromatic properties, hold a $62 billion global market, projected to reach $5 trillion by 2050, yet their cultivation remains limited due to inadequate knowledge of optimal growth conditions (Sarwar et al., 2024). Among these, Trachyspermum ammi (ajwain) has gained attention for its rich thymol content and diverse pharmacological benefits (Goyal et al., 2022), including antibacterial, antihypertensive, bronchodilator, and antihyperlipidemic effects. Despite its medicinal potential, challenges persist in optimizing its efficacy, necessitating advanced drug delivery systems like nanoparticles and liposomes to enhance therapeutic outcomes and integrate herbal medicines into modern healthcare (Siddiquie et al., 2024).

Methods and materials

The electromagnetic spectrum emitted by a light source is examined using a Theremino spectrometer. Theremino spectrometer as Theremino setup is shown in figure 1. The created technology extracts the spectral components of light by passing it through a sample. The experiment is conducted within an acrylic container covered in black paint. The sample is inserted into a hole drilled into the board's surface. Outside the chamber, the light source is positioned above the sample. Once the light has passed through the sample, it is directed onto a spectrograph located within the chamber. A camera and a diffraction grating make up the spectrograph. A webcam collects the data as the diffraction grating divides the light into a spectrum with many wavelengths. A spectrometer disperses light using grating after producing a collimated beam of light using a mirror. Simultaneously, the spectrum that hits the webcam is measured. The Theremino spectrometer program analyzes the captured data (Jothiraj et al., 2021).

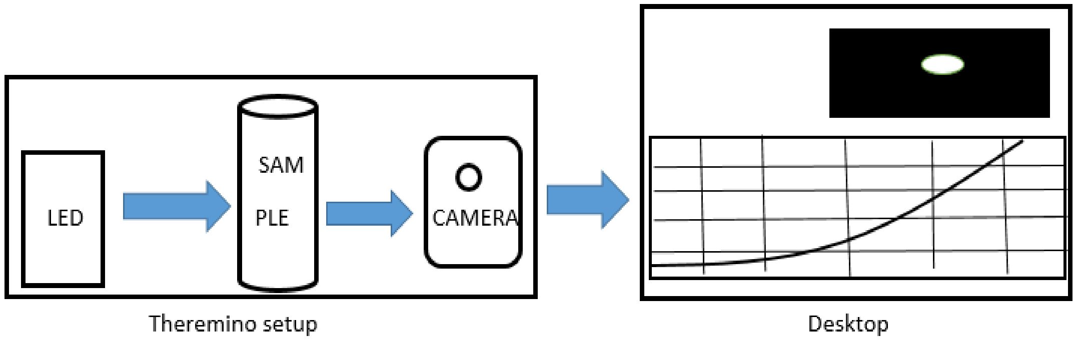

Figure 1: Sketch diagram of an experiment to study the Transmittance and Absorption coefficient of carom water sample

We can determine what percentage of the light entering the sample was discovered to be departing the sample by measuring the intensity of the beam of light entering our sample (I_o) and comparing it with the intensity of the beam of light exiting our sample (I). This allows us to calculate the ratio I/I_o. We refer to this ratio as the transmittance.

Transmittance: $T = \frac{I}{I_0}$ ....**Equation 1**

Samples Preparation

Preparation of Carom Seed Extract (S1–S5): Fresh carom (Ajwain) seeds weighing 1 g, 2 g, 3 g, 4 g, and 5 g were separately transferred into 200 ml borosilicate beakers, each containing 100 ml of distilled water. The mixtures were allowed to soak for 24 hours at room temperature. After 24 hours, the solutions were filtered using A1 King filter paper, and the resulting filtrates were designated as S1, S2, S3, S4, and S5, corresponding to 1 g, 2 g, 3 g, 4 g, and 5 g of carom seeds dissolved in 100 ml of distilled water. These samples were then used for further testing under various conditions.

Preparation of Carom Seed Extract with Sugar Solution (S6–S10): A new sugar solution was prepared by dissolving 1 g, 2 g, 3 g, 4 g, and 5 g of sugar separately in 100 ml of distilled water. The respective sugar solutions were then added to the previously prepared samples S1–S5, forming a new set of testing samples labeled as S6, S7, S8, S9, and S10, which were analyzed for the effect of sugar addition.

Result and discussion

Optical properties of non-sugar carom water

The study focuses on the optical properties of carom seed-infused water, examining transmittance and absorbance across five soaking durations. Variations in these properties highlight the influence of organic compound transfer and particle behavior in the solution. Differences in transmittance and absorbance measurements are primarily due to impurities in the carom water. These impurities scatter or absorb light differently, altering the overall spectral profile. This distinction emphasizes the role of particulate and dissolved organic materials in modifying the optical properties of the solution. Figure 2 presents the optical properties of the S1 sample, observed over a period of 5 days. The transmittance exhibits a decreasing trend from day 1 to day 4, indicating the gradual release of organic compounds from the seeds into the water. As a result, the solution becomes increasingly opaque, leading to reduced light transmission. By day 5, transmittance shows a slight recovery due to sedimentation, where particles settle at the bottom, leaving the upper layers clearer.

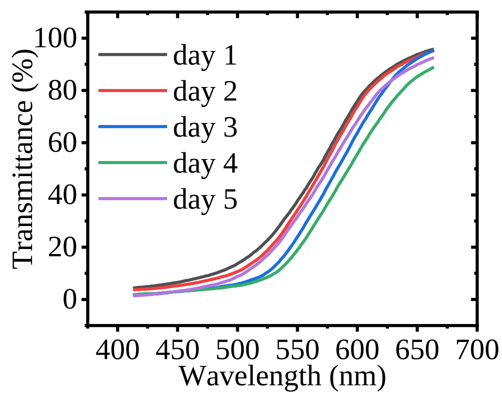

Figure 2. Optical properties of S2 samples over a periods of 5 days

The visible spectrum (380–700 nm) of carom water exhibits distinct behavior. Transmittance increases steadily up to 550 nm, suggesting reduced absorption at lower wavelengths. Beyond 550 nm, it rises sharply, peaking at 670 nm. This pattern may correlate with the specific absorption and scattering properties of the dissolved compounds. The use of the Theremino spectrometer restricted the spectral analysis to the 380–700 nm range, omitting data from the ultraviolet (UV) and infrared (IR) regions. These regions could provide deeper insights into the interaction of carom water with light, but equipment constraints prevented their inclusion. The study reveals how organic compound dissolution and sedimentation affect the optical properties of carom water over time. The spectral patterns observed could guide further research on natural extracts and their interactions with light. Future studies might overcome current limitations by employing spectrometers with broader wavelength ranges. The UV-Visible spectra of carom (Trachyspermum ammi) plant extract reveal no absorbance peak corresponding to selenium nanoparticles. The absorbance decreases with increasing wavelength, indicating a rise in transmittance (Qamar et al., 2020), and our study confirms that carom-extracted water exhibits similar optical properties in visible region.

Figure 3 presents the optical properties of S3 observed over period of 5 days. The spectrum covers a broader range of observations compared to optical properties of S2 sample, yet the overall behavior remains similar. The transmittance on day 1 is higher than on day 4, indicating a gradual decrease over the soaking period. This decrease reflects the transfer of organic compounds from the seeds to the water, which increases the absorbance and reduces light transmission. By day 5 (d5), transmittance is further reduced, signifying an even greater transformation of compounds into the solution. Compared to S2 sample, the transmittance in S3 sample shows a more pronounced decrease over time. This suggests that the higher quantity of seeds (3 g versus 2 g) accelerates the transformation and breakdown of organic compounds into the water. The sequential decrease in transmittance highlights a more robust interaction between the seeds and water in S3 sample, likely due to the increased concentration of organic material.

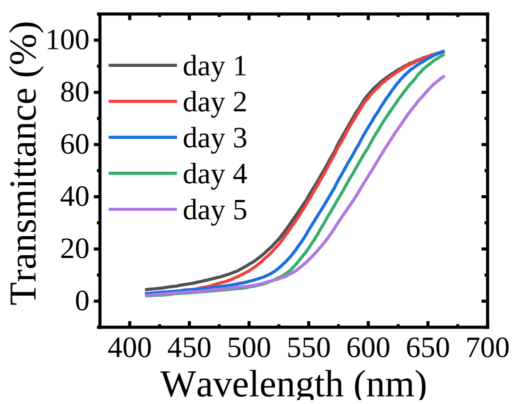

Figure 3. Optical properties of S3 sample over a period of 5 days

The findings demonstrate the influence of seed quantity on the optical properties of carom water. S3 sample exhibits a greater and faster reduction in transmittance than S2 sample, reflecting the enhanced transfer of organic compounds. These results underline the role of concentration and soaking duration in determining the optical characteristics of natural extracts. Further studies could explore the quantitative relationship between seed mass and compound dissolution. Only the optical properties of S2 and S3 samples is take here without sugar because the nature of other S1, S4 and S5 samples are same.

Optical properties of carom water with sugar

Figure 4 presents the transmittance of S6 samples over period of 5 day and the observation shows transmittance measurements exhibit a noticeable distinction between the early days (day 1 and day 2) and the later days (day 3 to day 5). This suggests the presence of two distinct particle types in the S6 sample. During day 1 and day 2, finer and smaller particles dominate the interaction, resulting in higher transmittance. In contrast, the formation of colloids between organic compounds and sugar particles over time leads to larger particle aggregates, reducing transmittance on day 3 through day 5.

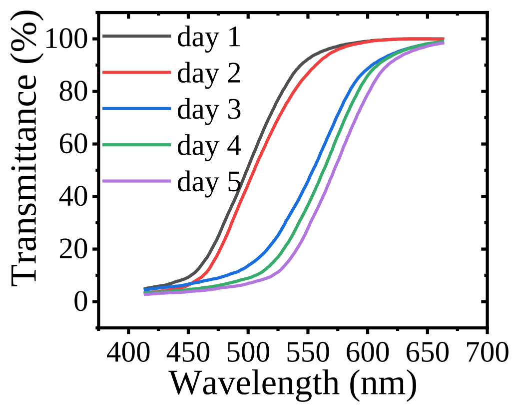

Figure 4. Optical properties of S6 sample over periods of 5 day

The transmittance and absorbance spectra show a gradual increase up to 450 nm, followed by a more rapid rise between 450 and 550 nm. This pattern reflects a noticeable change in the sample's optical characteristics, likely due to evolving interactions between light and the colloids formed in the solution. Beyond 550 nm, the increase stabilizes, but temporal fluctuations between 550 and 600 nm suggest dynamic changes in particle composition and light scattering properties during the later days of testing. The addition of sugar alters the interaction dynamics within the carom water sample, as evidenced by changes in particle behavior and colloid formation. The distinct spectral patterns highlight how sugar influences the optical characteristics over time. These findings suggest a complex interplay of organic compounds and sugar particles, affecting both transmittance and absorbance. Further investigation could quantify the impact of sugar concentration and particle size distribution on light-sample interactions.

Figure 5 illustrates the transmittance of S10 sample and the observation shows S6 and S10 samples has distinct optical characteristics influenced by its higher sugar content. These differences emphasize the impact of sugar concentration on particle behavior and light interaction in the solution. The transmittance spectrum reveals three distinct particle types based on their evolution over the soaking period. Also, optical properties of S10 sample were tested over a period of 5 days. The observation of day 1, the solution contains highly fine particles, resulting in higher transmittance due to minimal scattering and absorption. For, days 2 to day 4, transitional particles dominate. These particles represent intermediate states, with some breaking down to contribute to the smaller particles observed in day 1, while others aggregate, preparing for larger colloid formation. By day 5, the solution predominantly contains larger colloidal particles. These larger particles scatter and absorb more light, resulting in lower transmittance.

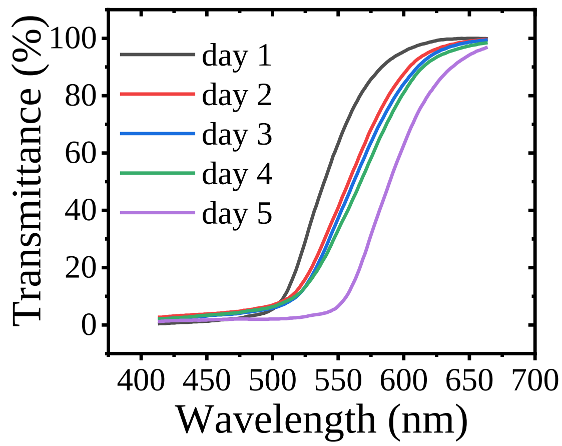

Figure 5**:** Optical properties of S10 sample over period of 5 days

The higher sugar content in S10 sample compared to S6 sample has significantly affects on optical properties. Stronger interactions between sugar molecules and organic compounds from the carom seeds enhance the formation of larger colloids. This results in distinct changes in the transmittance and absorbance spectra, driven by variations in light absorption and scattering behavior. The spectral data for S10 sample reflects gradual changes over time. The transition from fine particles to larger colloids, influenced by sugar concentration, leads to temporal fluctuations in optical characteristics. The higher sugar content intensifies these interactions, resulting in a more pronounced effect on transmittance and absorbance patterns. S10 sample highlights the critical role of sugar concentration in influencing the optical properties of carom water. The stronger interactions between sugar and carom seed compounds lead to distinct particle dynamics and spectral changes compared to S6 sample.

These findings underscore the importance of sugar quantity in shaping light-sample interactions. Future research could investigate how varying sugar and seed concentrations quantitatively affect solution optics and particle behavior. The optical properties of the S7, S8, and S9 samples exhibit a similar trend. In this study, only the effects of the lowest and highest concentrations of carom water, along with the influence of sugar, were analyzed.

Optical properties of carom water with temperature

Figure 6 shows the transmittance spectrum of S8 sample at 30 °C and 60 °C. The transmittance at 60 °C is higher than at 30 °C, indicating that the particles formed at higher temperatures are finer and more uniform. This results in less scattering and greater light transmittance within the visible wavelength range. Between 450 and 600 nm, a sharp rise in both transmittance and absorbance is observed at both temperature levels, highlighting changes in the solution's optical characteristics.

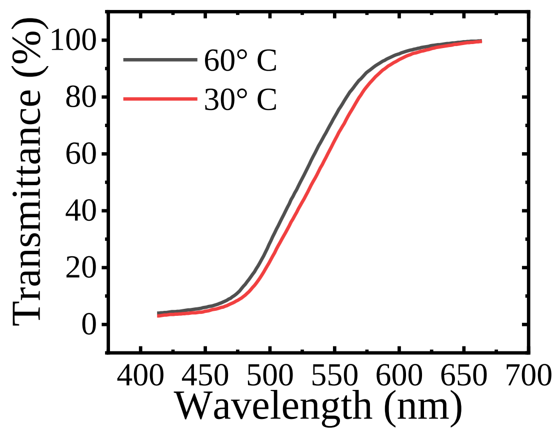

Figure 6. Transmittance of S8 sample at different temperature

Figure 7 illustrates the transmittance spectrum of sample S2 sample at 60 °C and 30 °C, the transmittance is almost identical, suggesting that sugar-free samples exhibit more consistent particle dynamics. The dominance of sugar molecules in S8 sample likely contributes to variations observed in the optical properties between the two samples. As the temperature rises, the absorbance of carom water decreases in both samples. This is attributed to increased molecular randomness and stronger interactions between chemical compounds in the solution. The higher molecular activity at elevated temperatures reduces light absorption, correlating with increased transmittance. Conversely, at lower temperatures, the absorbance increases and transmittance decreases due to reduced molecular motion and larger particle formation. The findings highlight the significant influence of temperature on the optical properties of carom water, with and without sugar. At higher temperatures, finer particle formation and increased molecular interaction enhance transmittance and reduce absorbance. The presence of sugar further modifies these effects, emphasizing its role in particle behavior and optical characteristics. Future studies could examine the precise molecular interactions responsible for these temperature-dependent changes.

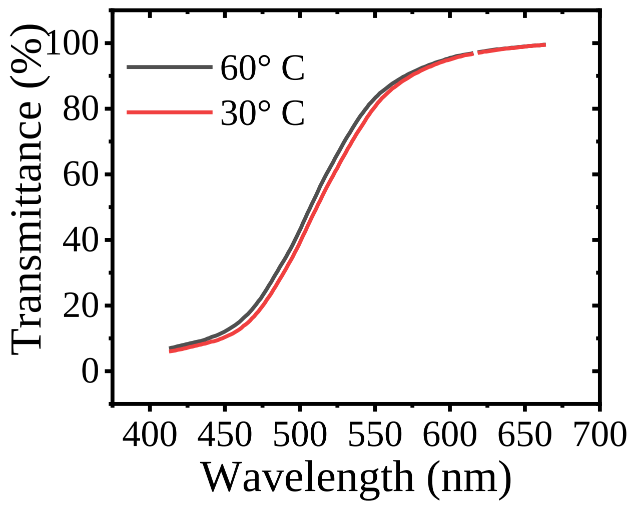

Figure 7**.** Transmittance S2 sample at different temperature

The findings depicted in figures 6 and 7 highlight the effect of temperature on transmittance of carom water. As the temperature rises, the transmittance increases. This behavior is attributed to increased molecular interaction and greater randomness at elevated temperatures. At higher temperatures, such as 60 °C, the chemical compounds in the carom water interact more actively, breaking down larger particles into finer ones. This process enhances the uniformity of the solution, allowing more light to pass through, thereby increasing transmittance and reducing absorbance. Conversely, at lower temperatures, reduced molecular motion leads to less interaction between the chemical components. This results in the formation of larger particles or aggregates that scatter light more effectively, leading to increased absorbance and decreased transmittance. These observations underscore the dynamic nature of light-sample interactions in carom water, influenced significantly by temperature-induced changes in particle size and molecular activity.

Comparison of optical properties of carom water

Table 2 and related experimental findings illustrate the transmittance and absorbance characteristics of carom water samples with and without sugar at various wavelengths. The data offer insights into how sugar concentration and wavelength influence the optical properties of these solutions, correlating with the behavior of similar compounds in water.

At a wavelength of 450 nm, the transmittance of samples S6–S10 is at its minimum, with a range starting at 1.3%. This suggests a high absorption of light in the shorter wavelengths of the visible spectrum for these samples, particularly those with added sugar. Conversely, at 650 nm, the transmittance peaks at 99.8% for the same range, indicating minimal absorption of light at longer wavelengths. This pattern implies that carom water with sugar absorbs more light in the shorter wavelength range, likely due to specific interactions between sugar molecules and organic compounds in the solution.

***Table** 2. Comparison of Transmittance of different sample of carom water with pure water*

Wavelength (nm)	Transmittance (T%)	
	S1-S5	**S6-S10**
450	1.8-6.6	1.3-9.2
500	4-13.9	2.1-51.9
550	16-73.3	6.7-92.4
600	48-95.2	62.9-99.2
650	77.3-99.4	94.1-99.8

The transmittance of different samples at certain wavelength is given in table 2 but vary in magnitude. Notably, samples with sugar (S6–S10) exhibit a broader range of transmittance values compared to sugar-free samples. This variation highlights the impact of sugar on light absorption and scattering properties within the solution. The experimental evidence reveals that the absorption coefficient of carom water decreases as the wavelength increases. This trend aligns with the typical behavior of various organic compounds and drugs, where longer wavelengths are less absorbed due to reduced energy interactions with the solution. Comparing transmittance of S2 and S6 samples with pure water confirms this behavior, with minimum and maximum absorbance values of 0.0039 and 1.5229, respectively. The samples demonstrate higher absorption and lower transmittance, with S6–S10 samples exhibiting the lowest transmittance (1.3%). Transmittance increases significantly, peaking near 99%, indicating lower absorption in this range. On added sugar (S6–S10 samples) exhibit distinct absorption and transmittance profiles compared to sugar-free samples, emphasizing the role of sugar in altering optical properties.

The comparison of absorbance values with the absorbance data of pure water (as reported by Buiteveld et al., 1994) reveals a clear trend: absorbance decreases as the wavelength increases. This behavior is attributed to the diverse chemical constituents present in carom water, which interact differently with light across various wavelengths. At shorter wavelengths, higher absorbance is observed due to the stronger interaction of light with organic compounds in the carom water. As the wavelength increases, the energy of the light decreases, leading to reduced interactions and, consequently, lower absorbance. This trend aligns with the behavior of numerous organic and chemical solutions. Additionally, the introduction of ingredients like sugar causes fluctuations in absorbance properties. Sugar molecules interact with the organic compounds in carom water, altering the light absorption characteristics. These fluctuations suggest that sugar concentration plays a significant role in modifying the optical behavior of the solution. This finding highlights the complex interplay of chemical composition and external additives, such as sugar, in determining the absorbance characteristics of carom water. Further exploration could quantify the specific contributions of individual components to these optical changes.

Conclusion

The optical properties of carom water, highlighting the impact of soaking duration, sugar concentration, and temperature on transmittance and absorbance. The results show that over time, organic compounds from carom seeds dissolve into the water, decreasing transmittance and increasing absorbance. The addition of sugar alters these properties, with higher sugar concentrations leading to more significant changes in particle behavior, colloid formation, and light interaction. Temperature also plays a crucial role, with higher temperatures promoting finer particle formation and increased molecular activity, thereby enhancing transmittance and reducing absorbance. The presence of sugar further modifies these temperature-induced effects. The study underscores the importance of concentration and soaking duration in determining the optical characteristics of carom water. Future research could delve deeper into the molecular interactions between sugar and carom seed compounds, providing more insights into how these factors influence light-sample interactions across a broader wavelength range.

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