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Optical Characterization of Adulterants Stingless Bee Honey Samples Using Tunable Laser Source

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Abstract

The study focuses on the optical characterization of adulterants in stingless bee honey samples using a Tunable Laser Source (TLS) at a wavelength of 1540 nm. Stingless bee honey, a highly prized natural product, is frequently adulterated, demanding excellent detection techniques. This project investigates the use of (TLS) at a wavelength of 1540 nm for detecting. This wavelength was chosen because it interacts effectively with honey's molecular components, allowing for the sensitive observation of changes in composition. When glucose corn syrup is added to honey, it changes its optical properties, such as refractive index and peak power, which the TLS can detect. The methodology set up the TLS system and testing of honey samples contaminated with glucose corn syrup at concentrations varying from 0%, 10%, 20%, 30%, 40% and 50%. The spectral data were analysed utilizing an Optical Spectrum Analyzer (OSA), and the peak power at 1540 nm was recorded for each concentration. A linear relationship was observed between the adulterant concentration and the peak power, with pure honey displaying the minimum peak power and elevated concentrations of glucose corn syrup leading to an increase in peak power. These results were additionally corroborated by refractive index measurements, which similarly aligned with the levels of adulteration. The findings illustrate the efficacy of the TLS in the detection and quantification of adulteration in stingless bee honey. The system adeptly recognized alterations in optical properties caused by glucose corn syrup, thereby offering a dependable and non-destructive method for the analysis of adulteration. This research highlights the potential of TLS for quality assurance in honey production.

1. Introduction

Stingless bees are a fascinating and unique species that have been overlooked for many years. These small, harmless bees are found in tropical and subtropical regions around the world and play a vital role in pollination. They also produce a special type of honey known as stingless bee honey, which has gained popularity in recent years for its unique taste and potential health benefits [1]. The impact of stingless bee honey on the market has been significant in recent years, with growing consumer interest in natural and organic products [2]. Stingless bee honey is prized for its rich flavour profile, which is often described as more complex and floral than traditional honey [3]. It is also believed to have higher antioxidant levels and antibacterial properties, making it a popular choice for health-conscious consumers [4]. Research shows that honey from stingless bees is a powerful source of antioxidants, mainly owing to its high levels of phenolic compounds. A publication in the

Journal of Food Science revealed that the honey derived from Heterotrigona itama significantly surpassed the honey from Apis mellifera in total phenolic content (TPC) and total flavonoid content (TFC). In particular, the TPC varied from 52. 64 to 74. 72 mg GAE/100 g, and the TFC ranged from 10. 70 to 25. 71 mg QE/100 g2. These compounds play a crucial role in eliminating free radicals, which helps to decrease oxidative stress within the body. Additionally, another detailed review emphasized that the antioxidant activity found in stingless bee honey may differ based on the plant source of the nectar. For example, DPPH tests demonstrated antioxidant values between 19. 7 to 31. 4 mM TE/mg, reflecting a significant ability to counteract free radicals3. The existence of flavonoids like quercetin and kaempferol further improves its antioxidant characteristics, establishing it as a beneficial addition to diets focused on enhancing health and wellness [5]. However, nowadays the growing popularity of stingless bee honey has raised concerns about adulteration and quality control issues. Honey adulteration, where honey is diluted or mixed with other substances, is a major challenge that can undermine consumer confidence and the integrity of the stingless bee honey market.

To overcome these problems, various analytical methods have been investigated for the detection and quantification of honey adulteration such as Visible-near-infrared (Vis-NIR) spectroscopy [6], near-infrared (NIR) [7-8], and laser-induced breakdown spectroscopy (LIBS) [9] have shown promising results in the detection of disintegrants in honey samples. These methods, together with chemometric analysis, can provide a rapid, non-destructive and accurate assessment of honey quality and authenticity.

The purpose of this study is to develop an optical characterization method using tunable laser source (TLS) to analyse stingless honey purity with different concentrations. The most important advantage of TLS is their flexibility. Most conventional laser systems operate at a single wavelength and hence find applications in only a few areas. TLS can, however, emit light over a large range of wavelengths. This feature is highly advantageous in spectroscopy, where substances absorb and emit light at specific wavelengths. By changing the laser output, researchers can detect and study various materials with much greater efficiency. For instance, a high-end tunable laser will allow for speedy identification of chemical substances in environmental monitoring, ensuring that specific pollutants are caught in time. This study will help establish a robust analytical framework for rapid, non-destructive and accurate assessment of the quality and authenticity of stingless bee honey, which will ultimately increase consumer confidence and support the growth of this valuable industry.

2. Methodology

2.1 Sample Preparation

The sample used in this study was composed of one type of stingless bee honey dissolved in glucose corn syrup at concentrations of 0%, 10%, 20%, 30%, 40% and 50 %.

Fig. 1 The samples of pure stingless bee honey and other concentrations (0%, 10%, 20%, 30%, 40% and 50%)

2.2 Tunable Laser Source

A TLS is a type of laser that allows the user to adjust the wavelength of the light emitted by the laser. This is in contrast to fixed wavelength lasers, which emit light at a single, specific wavelength. In this research, the wavelength of TLS was set in the range of 1515nm to 1550nm with an output power of 1mW to evaluate its performance without honey samples. Following this initial assessment, a specific wavelength of 1540nm was selected for analysis with the stingless bee honey sample. As the light passes through the honey, it interacts with the molecules present in the honey, causing absorption or emission of certain wavelengths.

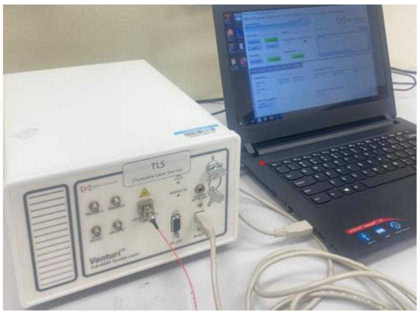

Fig. 2 The tunable laser source (TLS)

2.3 Optical Power Meter

An optical power meter is an important tool for measuring the output power of a fiber laser system. It is usually placed at the output of a laser system or at strategic points in the optical path to monitor power levels. An optical power meter accurately measures laser output power, which is an important parameter for understanding the overall performance and stability of a fiber laser. In this project, the optical power meter was utilized to measure the output power from the Tunable Laser Source (TLS) as the wavelength was adjusted. This configuration facilitated precise assessments of laser output power, which is essential for evaluating the overall functionality and stability of the fiber laser system. The triplet values in dBm were recorded on the optical power meter, yielding important data that supplemented the spectral analysis performed with the TLS. By associating these values with variations in wavelength, dependable results were achieved, improving the comprehension of how adulteration impacts the optical characteristics of stingless bee honey samples.

Fig. 3 The optical power meter

2.4 Refractometer

A refractometer is used to measure the refractive index of a substance. The refractive index is a measure of how much the speed of light is reduced when it passes through a material. This is an important property of materials, as it can be used to identify and characterize different substances. Refractometers work by shining a beam of light through a sample of the material being measured.

The light will bend, or refract, as it passes through the material, and the angle of refraction is directly related to the refractive index of the material. By measuring this angle, the refractometer can calculate the refractive index of the sample The refractometer works by measuring the refractive index of the honey, which is the way light bends as it passes through the honey. This refractive index can then be used to determine the concentration of the honey, which is an important factor in determining its quality and purity.

Fig. 4 The refractometer

2.5 Optical Spectrum Analyzer

An optical spectrum analyzer is a device used in the field of optics to analyse the spectral composition of light. The basic function of an optical spectrum analyzer is to separate a light signal into its component wavelengths and measure the intensity of each wavelength. This allows researcher to see a visual representation of how much light is present at each wavelength in a given signal.

By shining light through a honey sample and measuring the resulting spectra, researchers can identify the specific compounds and chemical properties that differentiate stingless honey from other types of honey. The optical spectrum analyzer can detect important characteristics of stingless honey, such as its sugar content, moisture level, and presence of antioxidants.

By analysing these properties, researchers can verify the authenticity of stingless honey samples and ensure that they meet the required quality standards. In addition to authenticity testing, the optical spectrum analyzer can also be used to detect any adulterants or contaminants in stingless honey

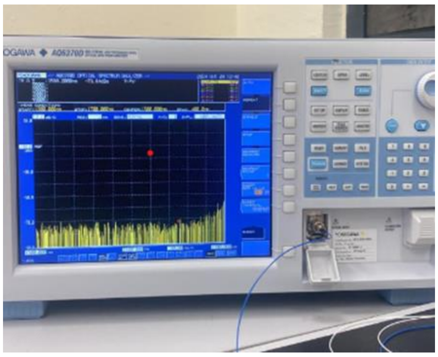

Fig. 5 The optical spectrum analyzer (OSA)

2.6 The Setup Design of Tunable Laser Source

First, the TLS is positioned to emit light in the range of 1515 nm to 1550 nm without any sample in order to investigate the performance of the TLS. This initial assessment can confirm the stability and functionality of TLS. Then, the TLS is adjusted to operate at a specific wavelength of 1540 nm, and the stingless honey sample is introduced. The stingless honey is mixed with glucose corn syrup at different concentrations of 0%, 10%, 20%, 30%, 40%, and 50%. Place the stingless honey in the sample holder. The light, as it passes through the honey, changes the refractive index and absorption characteristics, which results in measurable changes in the spectrum and power levels. The tunable laser will sweep through the specified wavelength range, recording the data by using an Optical Spectrum Analyzer and an optical power meter for capturing peak power levels.

The FBG is integrated into the setup to introduce precise filtering and reflection characteristics of wavelength. Light coming from the TLS propagates through the FBG into the sample holder, where it interacts with the optical properties of each sample. The evanescent field of the guided light penetrates into the samples, enabling the measurement of changes in refractive index and absorption characteristics. Extraction of the data is made from OSA and the optical power meter analyses would represent changes within the reflected wavelength of TLS or the variations within optical power.

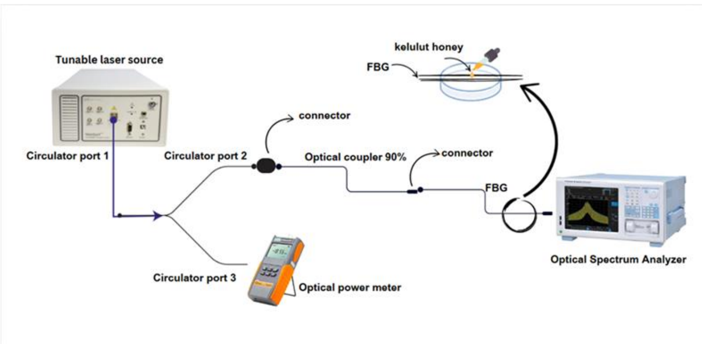

Fig. 6 The setup design of Tunable laser source (TLS)

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3. Results and Discussion

3.1 Detection of Tunable Laser Source

Before presenting the stingless bee honey samples for analysis, the TLS was evaluated to verify its functionality and set a dependable baseline response. In figure 7 below, the graph shows the variations in peak power over a spectrum of wavelengths, ranging from 1420 nm to 1550 nm, featuring sharp TLS wavelength peaks occurring at regular intervals. The upward trend in peak power at these particular wavelengths supports the sensor's responsiveness and affirms its ability to identify changes in optical properties. Each wavelength, from 1515 nm to 1550 nm, exhibits consistent and distinct responses, demonstrating the sensor's stability and capacity to deliver repeatable results under comparable conditions.

This preliminary testing is essential to verify the sensor's sensitivity to slight variations in refractive index or strain, which underpin the principles for identifying adulteration in stingless bee honey. The noticeable sharp peaks indicate the accurate alignment of the TLS structure, signifying that the sensor is functioning optimally. In addition, the consistent behaviour across various wavelengths confirms that the sensor's capability to measure the optical responses accurately before analysing the stingless bee honey samples.

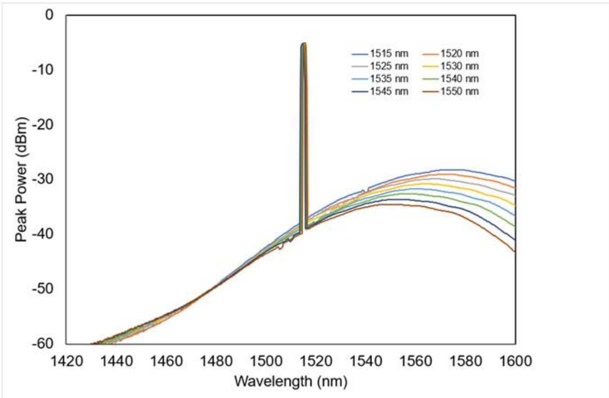

Fig. 7 The characterization of TLS

3.2 Detection of Adulteration in Stingless Bee Honey Utilizing TLS as a Sensing Element

After adding the stingless bee honey samples with different levels of glucose corn syrup adulteration (0%, 10%, 20%, 30%, 40%, and 50%), the outcomes illustrate a relationship between the level of the adulterant and the TLS sensor's reaction. Fig. 8 shows the peak power (dBm) versus wavelength for each sample, uncovering clear patterns. The unadulterated stingless bee honey (0% corn syrup), depicted by the green curve, displays the lowest peak power response in comparison to the adulterated samples.

As the level of corn syrup increases, the peak power progressively increases. For samples with 10% and 20% glucose corn syrup, the rise in peak power is moderate, suggesting that the sensor responds to minor variations in the refractive index of the sample. At 30% and 40% glucose corn syrup levels, the upward trend becomes more defined, indicating a more considerable shift relative to the pure honey baseline. The sample containing 50% glucose corn syrup shows the highest peak power, reflecting a significant alteration in optical properties due to the large adulterant content.

This rising trend highlights the sensitivity of the TLS sensor to variations in the refractive index of the samples, which correlates directly with the quantity of corn syrup added. The refractive index of glucose corn syrup exceeds that of pure honey, resulting in the noted increase in the intensity of the reflected TLS wavelength and peak power. The sensor's capability to differentiate between pure honey and adulterated samples, even when adulteration levels are low, highlights its accuracy and dependability.

The steady upward trend observed across all evaluated concentrations (0%, 10%, 20%, 30%, 40%, and 50%) confirms the TLS sensor as a useful tool for identifying adulteration in stingless bee honey. These findings illustrate the potential of TLS sensors for real-time, non-invasive quality evaluation, offering a strong approach for monitoring the authenticity of honey samples.

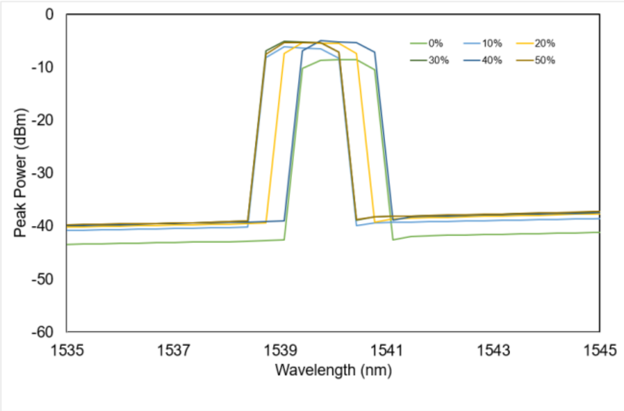

Fig. 8 The data shifts in the TLS at different concentrations of adulteration in stingless bee honey samples

3.3 Refractive Index

The refractive index is used in this study as a key parameter in determining the quality and purity of honey. The refractive index was measured using a refractometer after adding stingless bee honey samples with varying levels of glucose corn syrup adulteration (0%, 10%, 20%, 30%, 40%, and 50%). Fig. 9 shows the increasing trends of the refractive index values with increasing concentrations of glucose corn syrup in stingless bee honey samples. The graph shows that the results of refractive indices range from 0.684533, 0.6936, 0.7004, 0.705533, 0.712033 and 0.717533 for the concentrations of honey in stingless bee honey samples of 0% - 50%. The differences in refractive indices may be due to the alterations in the structure of stingless bee honey caused by the addition in glucose corn syrup. Moreover, the addition of contaminations in stingless bee honey changes the natural characteristics of stingless bee honey. The addition of glucose corn syrup alters the natural characteristics of stingless bee honey by introducing a new composition. Pure honey has a unique mixture of sugars, water, and other chemicals that contribute to its flavours, fragrance, and nutritional value. When corn syrup is added, it can dilute the inherent characteristics of honey and affect its overall quality. Furthermore, because corn syrup often has a higher sugar content than pure honey, the combination becomes denser. The greater density results in a higher refractive index, which means that light bends more when it passes through the mixture. This change in optical characteristics can be identified with techniques such as refractometry and TLS analysis.

In the sample of pure honey (0% corn syrup), the refractive index is the lowest, signifying its natural composition, which consists of a higher water content and lower sugar density compared to corn syrup. As the proportion of corn syrup increases in the honey samples (10%, 20%, 30%, 40%, and 50%), the refractive index increases linearly. This is the result of the growing influence of the corn syrup's optical characteristics, which lead to the mixture becoming optically denser.

The linear relationship seen in Fig. 9, indicated by the high coefficient of determination (R^2 = 0. 9915), shows that the refractive index is a dependable parameter for identifying and measuring adulteration in stingless bee honey. The high R^2 value suggests that about 99. 15% of the variation in refractive index can be explained by alterations in glucose corn syrup content. Knowing the amount of glucose corn syrup added to honey may accurately predict its refractive index, as seen by the high R^2 value. Such a strong association implies that precise predictions can be made about how the refractive index will change with different amounts of adulteration, making it a viable tool for assessing honey purity.

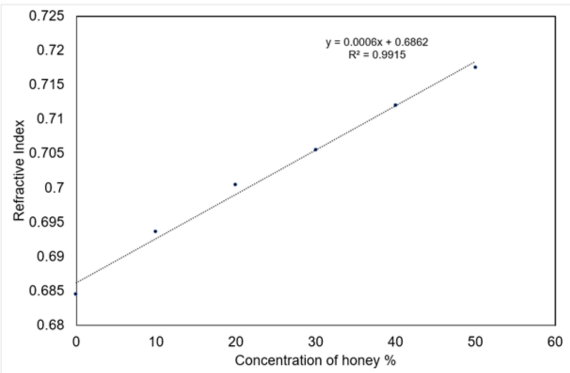

Fig. 9 The concentration of honey (%) vs refractive index

The relationship between the refractive index and the peak power (dBm) is shown in Fig. 10 for the adulteration levels of 0% - 50% in stingless bee honey. The refractive index was measured using a TLS after adding stingless bee honey samples with varying levels of glucose corn syrup adulteration (0%, 10%, 20%, 30%, 40%, and 50%). Fig. 10 shows that the refractive indices in all six samples increases linearly with increasing the amount of dilution. This trend is anticipated as glucose corn syrup is more optically dense than pure honey, attributable to its elevated sugar concentration and reduced water content. The results indicate the values of the peak power of 0.24, 0.593333, 0.766667, 0.796667, 1.133333, and 1.31 were observed for adulterations in six samples (0% - 50%).

In pure honey (0% glucose corn syrup), the refractive index is minimal. As additional glucose corn syrup is introduced (10%, 20%, 30%, 40%, 50%), the refractive index rises in a linear manner, mirroring the increasing impact of the properties of corn syrup. The high R^2 value (0. 961) denotes a strong linear correlation, reinforcing the credibility of the refractive index as a measure for detecting and quantifying adulteration in honey samples. Both graphs show that a linear relationship between peak power and refractive index in stingless bee honey, highlighting their usefulness in detecting adulteration. The TLS sensor effectively differentiates between pure and adulterated honey, making it a valuable tool for food quality assessment.

Both graphs demonstrate a robust linear relationship between peak power and refractive index in stingless bee honey, underscoring their effectiveness in detecting adulteration. The refractive index determined via a refractometer presents a high coefficient of determination (R^2 = 0. 9915), establishing it as a reliable reference for assessing the accuracy of the results derived from the TLS, which exhibits a slightly lower, yet still significant, R^2 value of 0. 961. This relationship emerges because the refractive index signifies changes in the composition of the honey, particularly as glucose corn syrup is introduced, thereby elevating the overall sugar concentration. As the refractive index increases, the optical properties of the honey are altered, influencing how light interacts with the sample and leading to measurable variations in peak power. The strong linear correlation implies that both parameters can consistently indicate levels of adulteration, with the refractometer acting as a standard for confirming the accuracy of TLS measurements. Collectively, these findings bolster the potential of both measurement techniques as effective tools for evaluating honey purity and authenticity based on their optical properties, while also validating that TLS results are in close alignment with those obtained from conventional refractometric methods.

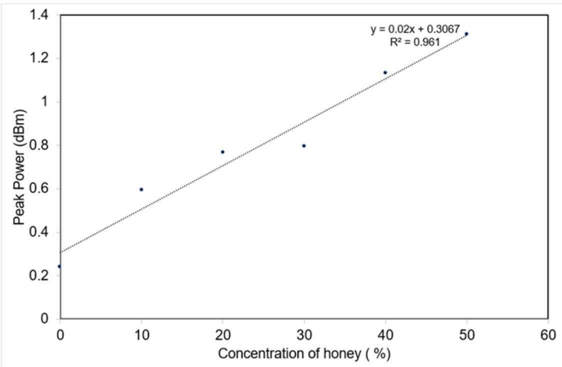

Fig. 10 The concentration of honey (%) vs the peak power (dBm)

4. Conclusions

The results of this study demonstrated that the TLS is effective in detecting and quantifying adulterants in stingless bee honey samples. The study successfully identified both the types and concentrations of adulterants, providing valuable information for consumers and producers. The TLS system operated at a central wavelength of 1540 nm and showed precision, stability, and sensitivity, making it well-suited for detecting honey adulteration. Key parameters such as output power, repetition rate, and peak power spectrum were characterized, confirming the system's reliability. The performance of the TLS was further evaluated using honey samples with varying concentrations of glucose corn syrup (0%, 10%, 20%, 30%, 40% and 50%). The sensor effectively identified adulteration by measuring changes in optical parameters, particularly peak power and refractive index. A linear relationship was observed between peak power and glucose corn syrup concentration, with higher concentrations resulting in greater power. Similarly, the refractive index increased linearly with glucose corn syrup concentration, confirming its effectiveness as an indicator of honey purity. In summary, the project objectives were successfully achieved. The TLS was designed, characterized, and utilized effectively to analyse adulteration in stingless bee honey samples. The findings validate the system’s capability as a reliable and non-invasive technique for ensuring food quality and detecting adulteration in honey.

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Conflict of Interest

The authors confirm that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Sharifah Nur Diani Sayed Mohd Azman;* ***data collection:*** *Sharifah Nur Diani Sayed Mohd Azman;* ***analysis and interpretation of results:*** *Sharifah Nur Diani Sayed Mohd Azman, Noor Azura Awang;* ***draft manuscript preparation:*** *Sharifah Nur Diani Sayed Mohd Azman, Noor Azura Awang. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] Matea, C., Mocan, T., Tabaran, F., Pop, T., Mosteanu, O., Puia, C., Iancu, C., & Mocan, L. (2017). Quantum dots in imaging, drug delivery and sensor applications. International Journal of Nanomedicine, Volume 12, 5421–5431. https://doi.org/10.2147/ijn.s138624

[2] Padovan, G. (2003). Detection of adulteration of commercial honey samples by the 13C/12C isotopic ratio. Food Chemistry, 82(4), 633–636. https://doi.org/10.1016/s0308-8146(02)00504-6

[3] Lohumi, S., Lee, S., Lee, H., & Cho, B.-K. (2015). A review of vibrational spectroscopic techniques for the detection of food authenticity and adulteration. Trends in Food Science & Technology, 46(1), 85–98. https://doi.org/10.1016/j.tifs.2015.08.003

[4] Cárdenas-Escudero, J., Galán-Madruga, D., & Cáceres, J. O. (2023). Rapid, reliable and easy-to-perform chemometric-less method for rice syrup adulterated honey detection using FTIR-ATR. Talanta, 253, 123961. https://doi.org/10.1016/j.talanta.2022.123961

[5] Shamsudin, S., Selamat, J., Abdul Shomad, M., Ab Aziz, M. F., & Haque Akanda, Md. J. (2022). Antioxidant Properties and Characterization of Heterotrigona itama Honey from Various Botanical Origins according to Their Polyphenol Compounds. Journal of Food Quality, 2022, 1–14. https://doi.org/10.1155/2022/2893401

[6] Ferreiro-González, M., Espada-Bellido, E., Guillén-Cueto, L., Palma, M., Barroso, C. G., & Barbero, G. F. (2018). Rapid quantification of honey adulteration by visible-near infrared spectroscopy combined with chemometrics. Talanta, 188, 288–292. https://doi.org/10.1016/j.talanta.2018.05.095

[7] Azmi, M. F. J., Jamaludin, D., Abd. Aziz, S., Yusof, Y. A., & Mustafah, A. M. (2021). Adulterated stingless bee honey identification using VIS-NIR spectroscopy technique. Supplementary 1, 5(S1), 85–93. https://doi.org/10.26656/fr.2017.5(s1).035

[8] Kumar, N., Ranjan, R., Kumar, Y., Surendra Kumar Patel, V. Sai Krishna, Anu Appaiah, Gupta, K. L., & Panchariya, P. C. (2021). Discrimination of Various pure Honey samples and its Adulterants using FTIR Spectroscopy Coupled with Chemometrics. International Conference on Advanced Computing. https://doi.org/10.1109/icaccs51430.2021.9441971

[9] Lohumi, S., Lee, S., Lee, H., & Cho, B.-K. (2015). A review of vibrational spectroscopic techniques for the detection of food authenticity and adulteration. Trends in Food Science & Technology, 46(1), 85–98. https://doi.org/10.1016/j.tifs.2015.08.003