

Exploring Structural and Chemical Changes in Honey Caused by Photonic and Acoustic Effects Towards Detection of Adulterants

DR. S. SELVA NIDHYANANTHAN[1*], D. PREETHIKA[2], M. AISHWARYA[3]

[1]Associate Professor, [2,3]UG Scholars, Dept. of ECE,

Mepco Schlenk Engineering College, Sivakasi, TamilNadu, India

SUMMARY

Research background. This paper provides an alternate way to destructive testing methodologies to identify the presence adulterants in the honey. Honey is consumed worldwide for its known nutritional benefits. Nowadays, it is often adulterated by cheaper, commercially available sweetening agents with chemically identical properties. Adulterated honeys are commonly labelled as natural and valued similar to pure honeys, thus demanding the need for the development of quick, simple and precise analytical procedures for determining their features and authenticity.

Experimental approach. Naturally available fresh honey samples and commercially available honey samples were used and subjected to tests under a device called spectrophotometer and an instrumentation system using acoustics to detect the Structural and Chemical changes to it. The data of pure and adulterated honey samples such as absorbance and transmittance were recorded with the help of spectrophotometer. Similarly, the signals obtained from the sound vibrations of the acoustic setup traversing the honey samples was measured using Sound Level meter and Digital Storage Oscilloscope (DSO) which are then processed for classification.

Results and conclusions. Quality parameters of the honey sample is determined using its absorbance and transmitting nature with respect to light source and sound level. The natural honey shows high absorbance level and increases with increase in concentration when compared to the adulterated honey using spectrophotometer. Similarly, the sound level transmitted is low for natural honey. Both the results infer that the pure honey sample absorbs more sound and light than adulterated honey. Also, the spectrum obtained from the sound signal shows multiple peaks in adulterated honey when compared to pure honey which has only single significant peak.

Novelty and scientific contribution. This study produced notable results regarding the qualitative characteristics of honey as a food, as well as important information on its response to light and sound. Moreover, a novel methodology has been proposed to classify pure from adulterated by analysing the peaks in the spectrum of the honey sample . Finally, the outcomes of the research could be used as a promising way to identify whether the honey is adulterated or not.

Keywords: *Honey adulteration; absorbance; transmittance; acoustics; digital storage oscilloscope (dso)*

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INTRODUCTION

Honey is a naturally available sweet and highly viscous product made from flower nectar by bees (*1*). Sugars (about 40% fructose and 30% glucose) and water (17%) make up the majority of honey, with the rest consisting of various sugars, carbohydrates, and a minor quantity of vitamins and minerals (*20*). Sucrose, on the other hand, is a disaccharide made up of equal portions of two monosaccharides: 50% fructose and 50% glucose (*2, 14*). Honey has long been used as a significant energy source and as a raw element in many manufactured food products, especially in grain-based products such as sweeteners, colors, flavors, caramelizations and viscosities (3). Because of its high demand, honey is often adulterated by the direct addition of sucrose syrups derived from sugar beets, high-fructose corn syrup (HFCS), maltose syrup, or the addition of industrial sugar (glucose and fructose) (*7*). The methods available to detect adulteration in honey are Gas Chromatography, Liquid Chromatography analysis, Near Infrared spectroscopy, Raman Spectroscopy, FTIR spectroscopy, High-performance Anion Exchange Chromatography and various calorimetric and chemometric methods (*6, 18, 19, 21*). Modern mass spectrometry delivers direct qualitative and quantitative information on a molecule of interest from a very little amount of sample. To decrease the vast number of samples, genomics and transcriptomics, as well as affinity-based approaches, can be employed for pre screening (30). Various image processing techniques such as ANN provides a non-destructive and precise method of calculating and measuring the number of adulterants in a food product (*11, 22*). To detect the sugar content of honey, a fibre optic approach can be used. This can be accomplished by measuring the output signal of both pure and adulterated honey samples, with a Green laser of 535nm serving as the optical source (*27*). Proteomic approaches enable simultaneous investigation of several hundred to several thousand proteins in food of animal origin, such as meat, seafood, milk and milk products, which are very complex combinations containing proteins and other components (31).

Different spectroscopic techniques have been used for the recognition of adulteration in food particles like Spices, Natural Oil, Juice, Honey, Milk Products and Wines. Normal spectrochemical examination strategies incorporate Ultra Violet and Visible Infrared Spectroscopy, IR absorption Spectroscopy, molecular fluorescence, Spectroscopy, Raman Spectroscopy, NMR (Nuclear Magnetic resonance) spectroscopy and Fourier transform infrared Spectroscopy (*1, 5, 23, 25*). All of these methods rely on the fact that electromagnetic radiation's energy can be absorbed or released by matter when the energy associated with the

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radiation equals the energy difference for the sample's allowed transition. Spectroscopy is a powerful tool for detecting physicochemical changes caused by changes in a material's molecules (*19*). Using deionized water as a blank on the Pfund scale, the honey colour can be calculated by measuring the absorbance of a pure honey sample at 560 nm and multiplying by a factor of 3.15 (*4*). Sugar content quantifications using a single measurement have been said to be unaffordable due to the molecular similarities between sugar molecules in honey matrix. This problem was solved by combining Raman spectroscopy with chemometric methods (principal component analysis (PCA) and partial least squares (PLS)) and an artificial neural network (ANN) (*24*). Over a range of 10-100 rpm and 25 degree Celsius, the rheological characteristics of pure and adulterated honey can be examined using a Brookfield viscometer. When compared to the MFCC feature, the extracted DMFCC feature provides more accurate recognition. The DMFCC feature has a 13 percent higher recognition accuracy than the MFCC features (*28*). Different types of sensors namely biosensors and chemical sensors based on silver nanoparticles helps in ensuring food safety (32).

A new instrumentation method used for detecting and categorizing milk adulteration caused by industrial pollutants such as bicarbonate, urea, and hydrogen peroxide. Acoustic waves were propagated in bovine milk samples using a pair of pitch-catch piezoelectric transducers. Advanced signal processing analysis was used to determine the milk condition. The acoustic signals from raw and contaminated milk samples were separated using a measure such as root mean square deviation (RMSD), correlation coefficient deviation metric (CCDM), and cross correlation square difference (CCSD) (*8*). An Arduino controller-based system used to detect milk parameters such as CLR and SNF. The lactometer is used to calculate the CLR of the milk. The value of SNF is frequently computed and analysed qualitatively using the values of FAT and CLR (*12*). Discrimination of Monofloral and Multifloral Honey was performed using UV-Visible Spectroscopy in conjunction with Linear Discrimination Analysis by heating the sample in a water bath at 60°C for 30 minutes to melt the crystals of honey, then allowing it to cool at room temperature before diluting with distilled water in a ratio of 1:20 (ml). Spectral data in the wavelength range of 190-1100 nm was recorded for the prepared sample using UV-VIS Spectrophotometer (*10, 13*).

Spectrophotometer can be used determine the honey quality based on optical parameters using a spectrophotometer to measure absorbance. This absorbance was used to determine color at 560 nm, diastase count at 620 nm, sugar content at 500 nm, fructose content at 518 nm, invertase at 400 nm, and HMF at 284 nm (*15-17*).

This work is aimed to detect the presence of adulterants in the honey by studying and observing the absorbing and transmitting nature in response to sound and light energy. An additional approach was also adopted to classify pure from adulterated honey by recording and analyzing the spectrum of each honey sample and their variations with adulterants.

MATERIALS AND METHODS

Materials

Various samples of natural honey procured directly from the collection point and branded honey samples were purchased from the local market. Spectrophotometer169, Quartz Cuvette, Standard Measuring Flask of 100ml, Sound Sensor, Speaker and Sound Level Meter, Digital Storage Oscilloscope GDS-1000A-U Series were utilized from the laboratories of Mepco Schlenk Engineering College. The solutions used in the experiments were prepared using pure distilled water based on the datasheet specifications of the associated measurement setup used.

Preparation of the sample

Five different samples of honey are taken and labeled as 1, 2, 3, 4 and 5. Prior to the spectral measurement, each honey sample was diluted using distilled water with various concentrations as per standard measurement procedures. Then, various adulterants such sugar syrup, molasses and glucose were added to the pure honey sample in different concentrations (5%, 10%, 15%, 20% and 25%).

Two methods were adopted for testing the sample using spectrophotometer and using an acoustic setup.

Method using Spectrophotometer

The device used for testing the honey sample is spectrophotometer169. Two parameters can be observed namely absorbance and transmittance. Initially, the sample to be tested is placed in the Quartz Cuvette which has four faces, of which, two faces are transparent and other two faces are opaque. The spectrophotometer utilizes monochromatic light that falls on the prism and scatters into 7 colors in the visible region. Each color has certain range of wavelength composing of Violet in the range of 380-430, Blue in the range of 430-500, Cyan in the range of 500-520, Green in the range of 520-565, Yellow in the range of 565-580, Orange in the range of 580-625, Red in the range of 625-740 (*25*). The wavelength required for the sample can be fixed using the wavelength selector available with a knob. The quartz Cuvette containing the sample must be placed in the sample holder in such a way that

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the transparent face must be on the path of light so that the light emerging from the prism will be converged to get accurate results.

Measurement of Absorbance and Transmittance

Before taking the reading for the honey samples, we need to calibrate the device by zero correction taking distilled water as reference. After calibration, the parameters such as absorbance and transmittance will be set as Abs=0.000 and %T= 1.000.Then each prepared honey samples were taken and these were noted for both pure and adulterated samples.

Method using Acoustics

In this method, an experimental set up is built by assembling several components in such a way that the sound produced at one end must be captured in the other end. For this, we have used a 8 ohm speaker which produces maximum sound. This speaker is placed in the bottom of the setup. The entire setup must be enclosed within a plastic amplifier so that the sound waves produced from the speaker will not be reflected and scattered. The sound produced must be recorded by capturing the sound using a condenser microphone which is sensitive to sounds (8, 9). The spectrum can be recorded from the microphone using an apparatus called DSO. In between the speaker and the microphone, the sample must be placed in a paper cup in a plastic amplifier which has less interference in response to sound. The sound is generated with different frequencies using a software called Online Tone Generator. Several samples were placed in the cup for analyzing its reponse with and without adulterants one by one. For this method, no sample preparation is required. We can directly place the sample in the cup enclosed within the plastic amplifier.

Similarly, instead of recording the spectrum, the reflected sound level obtained after passing through the honey sample can be easily retrieved using the sound level meter. This sound level meter gives the sound level in the units of decibel. Initially, the sound level is recorded without placing the cup and the sample. Then this procedure is repeated for each sample with and without adulterants. The sound level meter can be operated in two modes namely analog and in digital. The sound level shows the relationship with absorbance and reflectance.

Fast Fourier Transform

The Fourier transform has been used to define linear systems and to extract the frequency components of a continuous waveform from a time domain input. However, during

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sampling the waveform or analyzing the system on a digital computer, the finite, discrete version of the Fourier transform (DFT) must be understood and used. Although the DFT retains the majority of the properties of the continuous Fourier transform (CFT), there are a few differences due to the requirement that it operate on sampled waveforms defined over finite intervals. The fast Fourier transform (FFT) is a faster way to compute the DFT. The FFT can only be used in place of the continuous Fourier transform in a manner similar to the DFT, but at a significant decrease in computer time. The Fourier transform for continuous signals can be written in the below equations

$$X(j)=\frac{1}{N}\sum_{k=0}^{N-1}x(k)e^{\frac{-j2\pi k}{N}}$$

$$x(k)=\frac{1}{N}\sum_{k=0}^{N-1}X(j)e^{\frac{j2\pi k}{N}}$$

for *j = 0,1, . . ., N-1; k=0,1, . . ., N-1* (*26*).

Power spectral density

$$S(f)=\frac{1}{N}\left|\sum_{n=1}^{N}x_n(t=n\Delta t)e^{-j2\pi fn\Delta t}\Delta t\right|$$

In our work, we have used FFT which converts the time domain signal obtained from the DSO in acoustics to frequency domain to analyze the peak variations of the pure and adulterated honey samples. This process was done using a software called MATLAB.

RESULTS AND DISCUSSION

The response of various honey samples with light and sound waves were studied and observed and it is correlated by the factors such as absorbance and transmittance.

Response of honey to light

The honey samples which when placed in the path of light, some of the light energy gets absorbed and some get transmitted or reflected. The absorbance values increases linearly with increase in concentration (Table 1).

Table 1. Absorbance Vs Concentration for Pure honey samples

Concentration	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
1g	0.015	0.026	0.032	0.002	0.032
2g	0.033	0.031	0.039	0.012	0.043
3g	0.046	0.058	0.045	0.019	0.051
4g	0.062	0.076	0.05	0.025	0.076
5g	0.088	0.09	0.053	0.045	0.091

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For all the samples, the absorbance values increases but when taking on comparison between natural and adulterated honey, it is evident that the natural honey has more absorbance than other samples. The natural sample in the table is Sample 5 and Sample 1 to sample 4 are branded honey samples. All the branded honey samples have absorbance nearly equal to the natural honey and are more or less same in their absorbance with minor variations. The bar chart for easy understanding is shown in the Fig. 1.

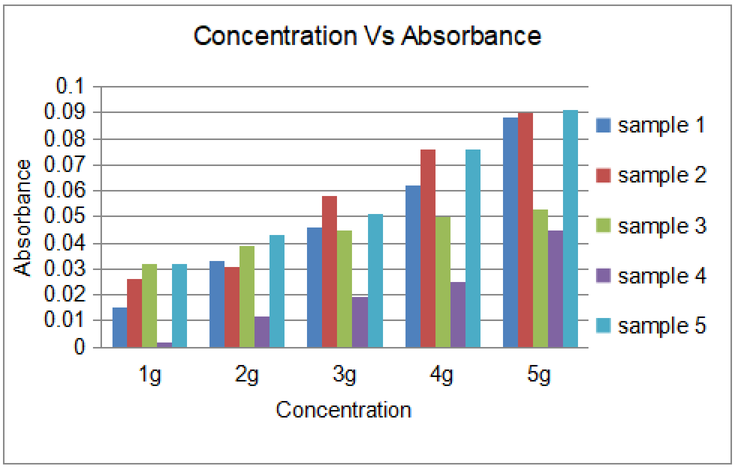

Fig 1. Bar chart for Absorbance Vs Concentration from the table 1.

Transmittance of light after passing the sample will not be 100%. Some of the light gets reflected and refracted. The transmittance values obtained for honey samples are inversely proportional to absorbance (Table 2). Its graphical illustration is given in Fig.2.

Table 2. Transmittance Vs Concentration for pure honey samples

Concentration	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
1g	96.2	93.6	98.4	98.5	92.6
2g	92.6	92.9	96.9	96.2	90.8
3g	89.5	87.3	95.4	93.3	89.1
4g	86.1	83.8	94.6	92.5	84
5g	81.7	81.3	93.4	88.5	81

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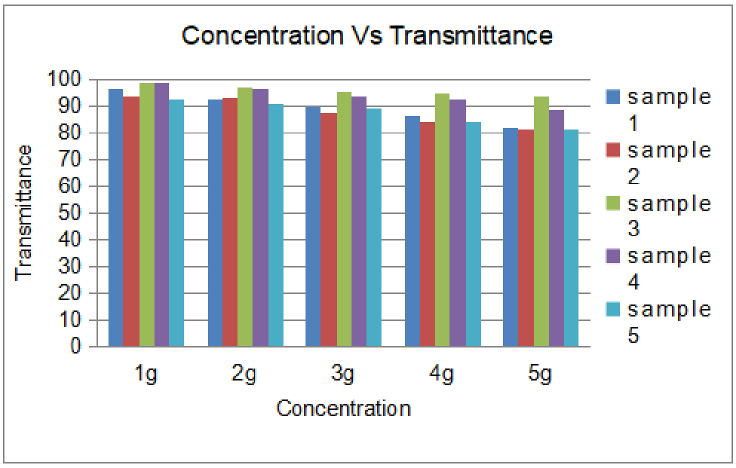

Fig 2. Bar chart for Concentration Vs Transmittance from the table 2.

The transmittance value of natural honey sample (sample 5) is very low when compared to all the other samples. This means that the pure honey offers less transmittance since the atoms and molecules present within it will be absorbed.

Additionally, the effect of absorbance further decreases gradually when compared to samples without adulterants (Table 3). Its graphical illustration is given in Fig.3.

Table 3. Absorbance Vs Concentration for Adulterated honey samples

Concentration	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
1g	0.057	0.058	0.054	0.059	0.067
2g	0.130	0.136	0.132	0.134	0.143
3g	0.134	0.136	0.132	0.138	0.148
4g	0.152	0.155	0.144	0.159	0.170
5g	0.196	0.199	0.190	0.192	0.219

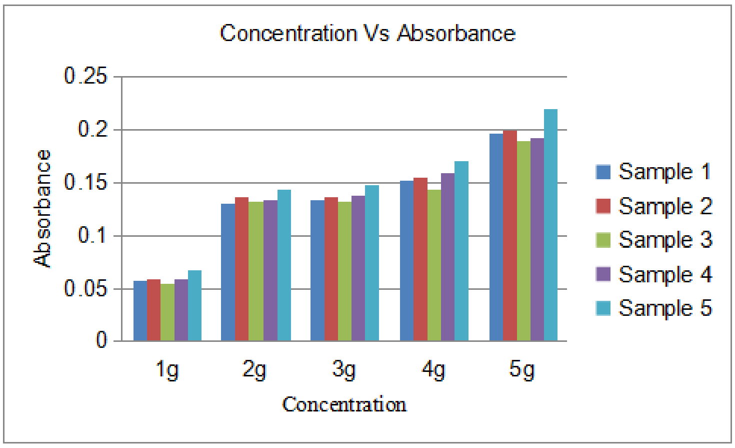

Fig 3. Bar chart for Concentration Vs Absorbance from the table 3.

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With this information, the honey having more absorbance is pure than the sample with less absorbance value whereas while focussing on transmittance, it is high for adulterated than the samples without the addition of adulterants (Table 4).

Table 4. Concentration Vs Transmission for adulterated honey samples.

Concentrations	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
1g	81.1	83.5	79.6	80.1	84.6
2g	66.5	70.6	64.9	68.6	72.0
3g	64.0	68.8	63.4	65.0	70.9
4g	62.7	64.2	59.1	61.5	67.4
5g	55.3	58.0	55.3	56.3	60.2

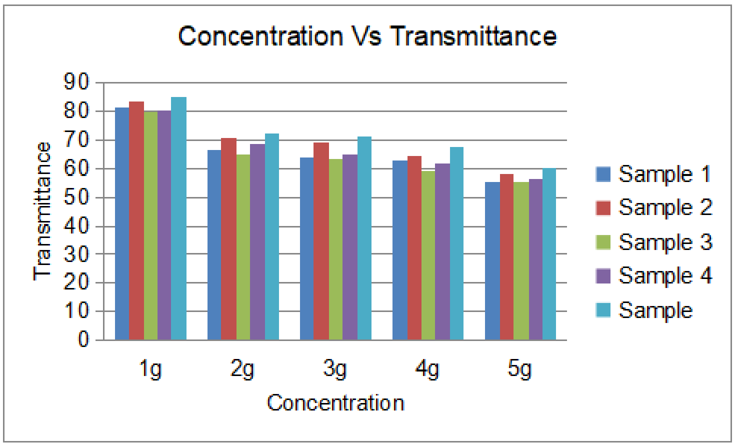

Fig 4. Bar chart for Concentration Vs Transmittance from the table 4.

Response of honey to Sound

Any source of output sound wave will not be same as the input when it passes through a sample. Interference plays a major role in scattering the sound. The sound level obtained without placing samples are depicted in the (Table 5).

Table 5. Sound level obtained without samples

Contents / Label	Sound level without samples (in dB)
At room temperature (Open Space)	40
Without sample holder	55
With sample holder	50

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It shows the original level of sound at a given frequency. Then, with the presence of honey sample the sound level decreases because the honey sample absorbs some energy (Table 6).

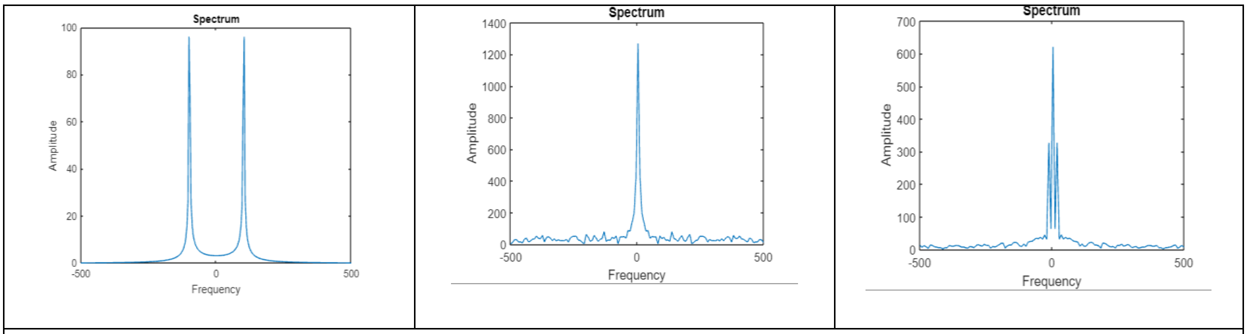
Table 6. Sound level obtained with pure and adulterated samples

Contents/ Label	Pure (in dB)	Adulterated (in dB)
Sample 1	43	30
Sample 2	41.5	31
Sample 3	42	30
Sample 4	42	29

In this experimental method, the natural honey sample (Sample 4) showed greater absorbance since little level of sound is transmitted than other branded samples which has high sound level. When various adulterants are added to the unadulterated honey samples, the sound level further decreases and showed values more or less equal to the branded honey samples (Table 5). With this, we can say if an unknown honey sample having sound level in the range close to the honey with adulterants, then that unknown sample can be treated as adulterated honey.

Determination of Peaks using Acoustics

The recorded Frequency domain signals after applying FFT to both pure and adulterated honey samples obtained shows (*Fig. 5*) that the spectrum of the pure honey has a single peak and adulterated honey has multiple peak for each frequency tone generated. In the frequency of 100Hz, the variation in the peak is clearly seen as pure has single peak and adulterated has three peaks at different magnitudes (*Fig. 5*).



(a)

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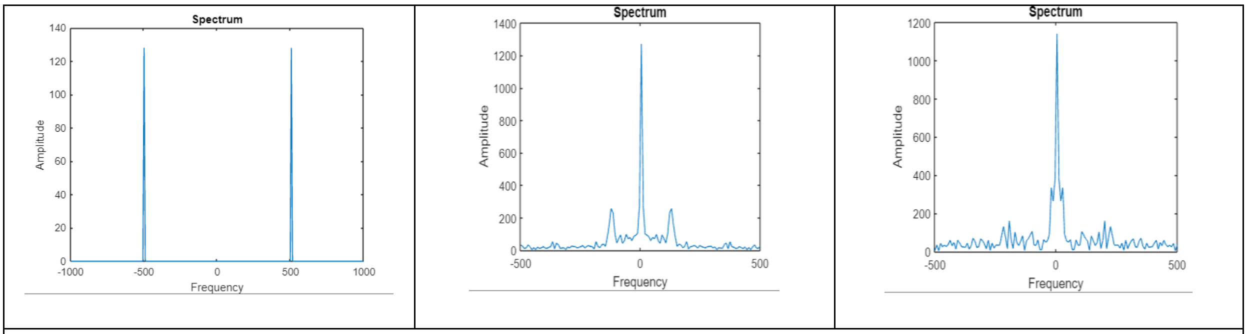

(b)

Fig. 5. FFT of the original tone, Pure and adulterated honey sample at (a) 100Hz (b) 500Hz

Similarly, there are major variations which are easily distinguishable with peaks at each frequency tones. The presence of adulterants in honey can be predicted with the maximum number of peaks in the spectrum of the sample. The Power spectral density measure also clearly distinguishes adulterated honey from pure honey. Moreover, if these data are collected in large quantity and fed as an input to deep learning neural network, this method can serve as an efficient tool in detecting the presence of adulterants in honey.

CONCLUSIONS

This research provides the qualitative characteristics to detect the presence of adulterants in honey in a simple, cost-effective and an easy to test approach. It is the first time in finding the correlation between light and sound source in detecting the adulterants which employs non-destructive testing mechanisms. From all of these approaches adopted, it is evident that the parameters such as absorbance and transmittance of light and sound varies when it interacts with a viscous liquid. The frequency peaks of each sample clearly shows the difference in pure and adulterated honey samples. From the proposed method, we can order the honey samples based on quality. The order goes by Natural honey (sample 5) which stands first in the list, followed by sample 2 at second, sample 1 at third, sample 3 at fourth and sample 4 stands at last position since it has least absorbance to both light and sound energy. This methodology can also be extended for other liquid food items. Hence, liquid food adulteration can be tested using Spectroscopy and acoustics.

 https://doi.org/10.37896/pd91.3/91336

REFERENCES

1. A. Ravindran, F. P. Nesamani and N. D., "A Study on the use of Spectroscopic Techniques to Identify Food Adulteration," 2018 International Conference on Circuits and Systems in Digital Enterprise Technology (ICCSDET), 2018, pp. 1-6, doi: 10.1109/ICCSDET.2018.8821197.
2. N. M. El-Bialee and M. A. Sorour, “Effect of adulteration on honey properties,” Int. J. Appl. Sci. Technol., vol. 1, no. 6, pp. 122–133, 2011.
3. NoriahBidin, NurulHdiaZainuddMohYasinShumaila Islam, Mundzir Abdullah, FaridahMohdMarsin., “Sugar Detection in Adulterated Honey via Fiber Optic Displacement Sensor for Food Industrial Applications”, IEEE SENSORS JOURNAL, VOL. 16, NO. 2.
4. Daniel Frasco, Thermo Fisher Scientific, Madison, WI, USA, “Analysis of Honey Color and HMF Content using a GENESYS UV-Visible Spectrophotometer”,
5. Birgit LICHTENBERG-KRAAG*, Christoph HEDTKE†, Kaspar BIENEFELD, “Infrared spectroscopy in routine quality analysis of honey”, Apidologie 33 (2002) 327–337 © INRA/DIB-AGIB/EDP Sciences, 2002 doi: 10.1051/apido:2002010.
6. Kuan Wei Se, Roswanira Abdul Wahab, Syariffah Nuratiqah Syed Yaacob, Sib Krishna Ghoshal, “Detection Techniques for Adulterants in Honey: Challenges and Recent Trends”, Journal of Food Composition and Analysis (2019), https://doi.org/10.1016/j.jfca.2019.04.001.
7. Alemu Girma Tura, Dechasa Bersissa Seboka. Review on Honey Adulteration and Detection of Adulterants in Honey. International Journal of Gastroenterology. Vol 4, No. 1, 2019, pp, 1-6. Doi: 10.11648/j.ijg.20200401.11
8. Marcos Messias dos Santos Junior et.al., “A New Acoustic-Based Approach for Assessing Ind,k ced Adulteration in Bovine Milk”, Mdpi, Sensors 2021, 21, 2101. https://doi.org/ 10.3390/s21062101.
9. Gokce Iymen et.al., “Artificial intelligence-based identification of butter variations as a model study for detecting food adulteration”, journal on Innovative Food Science and Emerging Technologies, https://doi.org/10.1016/j.ifset.2020.102527 .
10. Diding Suhandy, Meinilwita Yulia,” Using UV-Visible Spectroscopy Coupled with Linear Discrimination Analysis to Discriminate between Monofloral and Multifloral Honey from Indonesia”, The International Conference on Chemical Science and Technology (ICCST – 2020) AIP Conf. Proc. 2342, 100004-1–100004-7; https://doi.org/10.1063/5.0045325 Published by AIP Publishing. 978-0-7354-4085-2/$30.00.

11. Ruth Moly Benjamin, D. Abraham Chandy," Survey on Adulteration in Food Products and Image Processing Techniques used for its Detection", International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 10 Issue 02, February-2021.

12. Dr. S. MaryJoans et.al.," ADULTERATION DETECTION IN MILK USING EMBEDDED SYSTEM", International Research Journal of Engineering and Technology (IRJET), Volume: 07 Issue: 08 | Aug 2020.

13. Stefas, D.; Gyftokostas, N.; Kourelias, P.; Nanou, E.; Kokkinos, V.; Bouras, C.; Couris, S. A Laser-Based Method for the Detection of Honey Adulteration. Appl. Sci. 2021, 11, 6435. https://doi.org/10.3390/ app11146435

14. M. F. N. Akhmazillah, M. M. Farid, and F. V. M. Silva, "High pressure processing (HPP) of honey for the improvement of nutritional value," Innovative Food Science & Emerging Technologies, vol. 20, 2013.

15. Davor Valinger, Lucija Longin, Franjo Grbeˇs, Maja Benkovi´c, Tamara Jurina, Jasenka Gajdoˇs Kljusuri´c, Ana Jurinjak Tuˇsek ; "Detection of honey adulteration – The potential of UV-VIS and NIR spectroscopy coupled with multivariate analysis", LWT 145 (2021) 111316, https://doi.org/10.1016/j.lwt.2021.111316

16. Almaleeh, A. A., Adom, A. H., & Fathinul-Syahir, A. S. (2017). Classification of the botanical origin for Malaysian honey using UV-Vis spectroscopy. AIP Conference Proceedings, 1808, Article 020008. https://doi.org/10.1063/1.4975241

17. Li, Y., & Yang, H. (2012). Honey discrimination using visible and near-infrared spectroscopy. International Scholarly Research Notices, 487040. https://doi.org/ 10.5402/2012/487040, 2012.

18. Ozbalci, ¨ B., Boyaci, I. H., Topcu, A., Kadilar, C., & Tamer, U. (2013). Rapid analysis of sugars in honey by processing Raman spectrum using chemometric methods and artificial neural networks. Food Chemistry, 136, 1444–1452. https://doi.org/ 10.1016/j.foodchem.2012.09.064

19. Guelpa, A., Marini, F., du Plessis, A., Slabbert, R., & Manley, M. (2017). Verification of authenticity and fraud detection in South African honey using NIR spectroscopy. Food Control, 73, 1388–1396.https://doi.org/10.1016/j.foodcont.2016.11.002

20. Czipa, N., Philips, C. J. C., & Kovacs, ´ B. (2019). Composition of acacia honeys following processing, storage and adulteration. Journal of Food Science & Technology, 56, 1245–1255. https://doi.org/10.1007/s13197-019-03587-y.

21. Cen, H., He, Y. and Huang, M. (2006) "Measurement of soluble solids con- tents and pH in orange juice using chemometrics and VIS-NIRS"; J. Agric. Food Chem. 54(20):7437–7443.

22. Ruth Moly Benjamin, D. Abraham Chandy," Survey on Adulteration in Food Products and Image Processing Techniques used for its Detection", International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 10 Issue 02, February-2021.

23. Guelpa, A., Marini, F., du Plessis, A., Slabbert, R., & Manley, M. (2017). Verification of authenticity and fraud detection in South African honey using NIR spectroscopy. Food Control, 73, 1388–1396. https://doi.org/10.1016/j.foodcont.2016.11.002

24. Ozbalci, ¨ B., Boyaci, I. H., Topcu, A., Kadilar, C., & Tamer, U. (2013). Rapid analysis of sugars in honey by processing Raman spectrum using chemometric methods and artificial neural networks. Food Chemistry, 136, 1444–1452. https://doi.org/ 10.1016/j.foodchem.2012.09.064

25. D. Malacara, *Color Vision and Colorimetry: Theory and Applications*, *Second Edition*, SPIE Press, Bellingham, WA (2011).

26. G. D. Bergland, "A guided tour of the fast Fourier transform," in *IEEE Spectrum*, vol. 6, no. 7, pp. 41-52, July 1969, doi: 10.1109/MSPEC.1969.5213896.

27. Ms.R.Mercy Kingsta, Miss. M.Shamilee, Miss.S.Sarumathi, "Detection of Adulteration
in Honey using Optical Sensor",International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering; Volume No: 7, Issue No: 3; pp: 1234-1241; 2017-18
DOI:10.15662/IJAREEIE.2018.0703032 2017-18

28. Dr.S.Selva Nidhyananthan, Miss.A. Joe Virgin, "FPGA Based Speech Recognition using Dynamic MFCC", Journal Advances in Natural and Applied Sciences; Volume No: 11, Issue No: 8; pp: 476-484

29. Dr.S.Selva Nidhyananthan, Miss.M. Pandi Muneeswari, Miss.A.J. Ashmi Grace, "Handling Impulsive Disturbances in Speech Recordings using Filtering Techniques", International Journal of Control Theory and Application; Volume No: 9, Issue No: 8; pp: 3497-3504.

30. Uroš Andjelković, Martina Šrajer Gajdošik, Dajana Gašo-Sokač, Tamara Martinović and Djuro Josić, "Foodomics and Food Safety: Where We Are", Food Technology and biotechnology, 2017

doi: 10.17113/ftb.55.03.17.5044

31. Dajana Gašo-Sokač, Spomenka Kovač and Djuro Josić", Use of Proteomic Methodology in Optimization of Processing and Quality Control of Food of Animal Origin" , Food Technology and biotechnology, vol No.49, (4) pp-397–412 (2011).

32. Hesham M. A. El-Komy, "Coimmobilization of Azospirillum lipoferum and Bacillus megaterium for Successful Phosphorus and Nitrogen Nutrition of Wheat Plants", Food Technology and biotechnology, vol.No: 43, pp: 19–27 (2005)

BIBILIOGRAPHY

Dr.S.Selva Nidhyananthan received his B.E degree in Electronics and Communication Engineering from Manonmanium Sundaranar University, Tirunelveli, in 1999, M.E. degree in Communication Systems from Anna University, Chennai, in 2005 and Ph.D degree in Speech Processing from Anna University, Chennai, in 2014. He has 20 years of teaching experience and he is currently working as Associate Professor in the department of Electronics and Communication Engineering at Mepco Schlenk Engineering College, Sivakasi, Tamil Nadu. He has published more than 90 papers in refereed International Journals and Conferences. He has also published 8 book chapters in speech processing. His current research interest includes Signal Processing and Image Processing. He has completed one DST Sponsored R& D Project worth Rs. 12 lakhs in the field of Texture analysis. He has been bestowed with several awards from different societies across the country. Now, he serves various editorial positions for reputed international journals across the globe. He is a member of IETE,IAENGandISTE.

Preethika Dhanaram pursuing his Bachelor of Engineering (B.E) - Electronics and Communication Engineering (2018-2022) in Mepco Schlenk Engineering College (Autonomous), Sivakasi, Tamilnadu. Field of Interest –Digital Signal Processing.

Aishwarya Murugan pursuing his Bachelor of Engineering (B.E) - Electronics and Communication Engineering (2018-2022) in Mepco Schlenk Engineering College (Autonomous), Sivakasi, Tamilnadu. Field of Interest – Digital Signal Processing.