



# Identification of Commercial Sweetener (süssina) Components and Investigation of Aspartame and Saccharin Using Raman Spectroscopy

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## To cite this article:

Abdelmoneim Mohammed Awadelgied, Ahmed Abubaker Mohamed, Sohad Saad Elwakeel, Sufyan Sharafedin. Identification of Commercial Sweetener (süssina) Components and Investigation of Aspartame and Saccharin Using Raman Spectroscopy. *American Journal of Quantum Chemistry and Molecular Spectroscopy*. Vol. 3, No. 2, 2019, pp. 31-36. doi: 10.11648/j.ajqcms.20190302.11

Received: March 31, 2019; Accepted: May 5, 2019; Published: October 23, 2019

**Abstract:** Artificial sweeteners are being used extensively especially by diabetes and obesity and have entered most of the food industries, some of them contain natural compounds, but they are low in sweetness. Others are classified as high in sweetness, which are dangerous and harmful to health because they contain chemical additives, which are still under study, also in markets there are pure sweeteners or sweeteners mixed with these industrial chemical additives. A selection of one common and commercially available table-top artificial Sweetener in Sudanese Markets (süssina) was considered. The study was conducted by using Raman spectroscopy Model Horiba LabRAM HR 3D to examine the components of these industrial chemicals additives in the normal situation and after heating at boiling point of water. The study showed the presence of sorbitol ( $C_6H_{14}O_6$ ), a natural component of corn, Aspartame ( $C_{14}H_{18}N_2O_3$ ) and saccharin ( $C_7H_4NNaO_3S$ ) which are artificial chemical additives.

**Keywords:** Artificial Sweeteners, Natural Sweeteners, Laser Raman Spectroscopy

## 1. Motivation

Artificial sweeteners are functional food additives that impart sweetness in food. Also they are known as sugar substitutes, which contain zero-calorie or low-calorie. Uses of sweeteners, have largely increased in the past 20 years. Nowadays sweeteners occupy a large portion of commercial space on supermarkets worldwide. The use of these (zero calorie) sweeteners has increased dramatically these days particularly for diabetics, weight maintenance in food and drinks. The sweetening capacity of these artificial sweeteners ranging from hundreds to thousands of times more than that of the natural sugar [1-2].

Some of them contain natural compounds that include the monosaccharide polyols such as (sorbitol, sucrose, fructose...), but they are low in sweetness. Others are classified as high in sweetness that are actually artificial chemical additives include aspartame, acesulfame-K, neotame, saccharin, sucralose,

cyclamate, and alitame, which are dangerous and harmful to health, which are still under study [3].

Most artificial sweeteners are not metabolized by the body and are therefore considered safe. However, scientists disagree about safety because the metabolites of the "nonmetabolized" compounds have been shown to produce deleterious effects in mice, rats, and dogs [4].

The objective of this study is to investigate whether these sweeteners contain industrial chemical additives or just natural ingredients or mixture of these components, which is important for food quality.

Because the most common use of these materials is in the daily tea, so the sample (süssina) was added to mineral water in the boiling point and after cooling to the room temperature HCl acid (pH 3.1) was added to detect the change that occurs in the composition of this substance when it enters intervention inside the stomach. (pH of HCl inside the stomach range from 2 to 3.5) [5].

Several previous studies have been conducted to study the artificial sweeteners using another techniques such as FT-IR spectroscopy, surface enhanced Raman spectroscopy (SERS) to investigate saccharin, Aspartame, sorbitol accesulfame-k, xylitol, sodium cyclamate, Dextrose, Sucrose and Maltodextrin. [1, 2, 7-9, 12].

The obtained results from these previous studies have been also obtained in this study by using Raman spectroscopy.

Raman technique has proven that it is a precision technique with high efficiency and accuracy in Artificial sweeteners analysis and easy to use. Raman technique does not require any previous preparation; the analysis can be done on a small amount of sample (parts of the milligrams) whether the sample is liquid or dry, the analysis lasts short time within seconds Whereas the other techniques needs pre preparation to be processed also samples are needed in large quantities And longer time for analysis.

## 2. Raman Spectroscopy

Raman Effect or Raman phenomenon is defined as an inelastic scattering of Light by matter (Molecule). When a monochromatic wave (Laser light) is scattered by a matter, two types of interaction happens and result into two distinctive types of scattered light. One type of interaction does not involve energy transfer or exchange between the incident light and the matter (molecules), or atoms; of matter In This case the type of scattered light is elastic and referred to as Rayleigh scattering. This type of scattering is elastic in nature and referred to as Rayleigh scattering. The second type of interaction involves energy exchange between the incidents Light and the material (molecules) The scattered light will have a New frequency which is simply equal to the sum or the difference between the frequencies of the incident light and the natural frequency vibration of the material (molecules), in this case the scattering light is known as an inelastic, and is called Raman Effect [6].

### Basic Consideration

Raman Effect is explained using the classical theory of scattering as follows; let us assume a monochromatic light wave Propagating with an oscillating electric field in the x direction, with amplitude  $E_x$  of an electric field at a time (t) can be expressed as follows;

$$E_x = E_x^0 \cos(2\pi\nu_0 t) \quad (1)$$

$E_x^0$  is the amplitude of the electric field component,  $\nu_0$  is the electromagnetic wave frequency (laser light). as an explanation we can consider a diatomic molecule (in this case it is a material) with a Vibration frequency  $\nu_V$  it is called natural frequency with a normal vibration vector  $q_V$  can be expressed as a function of time as;

$$q_V = q_V^0 \cos 2\pi\nu_V t \quad (2)$$

When the electromagnetic wave (Laser light) interacts with the Molecule, electrons of the molecule will be polarized by the laser light to induce a dipole moment ( $\mu$ )

where  $\alpha$  is known as the polarizability in bellow equation;

$$\mu = \alpha E \quad (3)$$

The induced dipole will oscillate at three different frequencies as a result it will emit light (scattered light). These different frequencies can be identified by

Expanding the polarizability tensor ( $\alpha$ ) by the mathematical Taylor's series form for the component of ( $q_V$ ) as;

$$\alpha = \alpha^0 + \left(\frac{d\alpha}{dq_V}\right) q_V + \dots \quad (4)$$

By substituting the above equations the dipole moment can be expressed as;

$$\mu = E_x^0 \alpha^0 \cos(2\pi\nu_0 t) + E_x^0 \left(\frac{d\alpha}{dq_V}\right)_0 q_V^0 \{ \cos[2\pi(\nu_0 - \nu_V)t] + [2\pi(\nu_0 + \nu_V)t] \} \quad (5)$$

The frequencies that, the scattered light will have are ( $\nu_0$ ), ( $\nu_0 - \nu_V$ ), ( $\nu_0 + \nu_V$ ) the scattered light at the same frequency ( $\nu_0$ ), there is no energy loss or gain due to interaction with the molecule and it is known as elastic scattering or Rayleigh scattering. The other two components would have experienced a gain or loss of energy equal to the energy of the molecular vibration; this is known as inelastic scattering or Raman scattering represented ( $\nu_0 - \nu_V$ ), ( $\nu_0 + \nu_V$ ) which are known as Stokes and anti-Stokes lines respectively and they are fundamentally important as a finger print for molecular vibrations frequencies figure 1 illustrates stokes and anti-stokes Raman scattering [6].

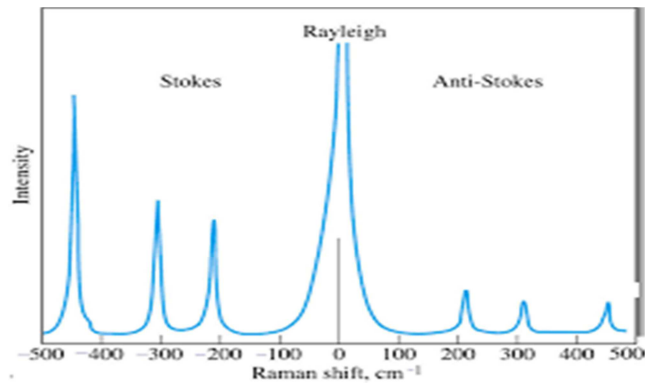


Figure 1. Stokes and anti-Stokes Raman scattering.

## 3. Materials & Methods

Two samples of commercial sweetener, (Süssina) were investigated in this work by laser Raman spectrometer in the Range from  $50 \text{ cm}^{-1}$  to  $4000 \text{ cm}^{-1}$  for both powder and solution.

### 3.1. Equipment

In this work laser Raman Microscope spectrometer Model Horiba Lab RAMHR 3D shown in the Figure 2 was used. The laser wavelength is 532 nm and output power of 6 mW. The Raman shift in wave number, and the change in intensities of the scattered light were compared with data in the references and previous studies.

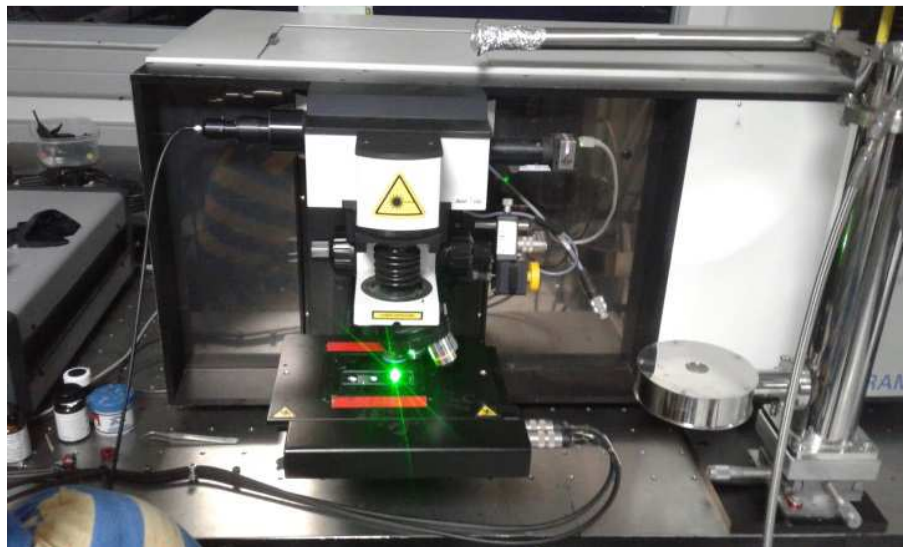


Figure 2. Schematic diagram of laser Raman microscope spectrometer.

### 3.2. Samples Preparation

Samples were prepared as follows:

Sample:

(a) (süssina) powder.

(b) 5g of (süssina) powder dissolved in a boiling mineral water (25 mL) 100C<sup>0</sup> with HCl acid 5mL (PH 3.1)

## 4. Results & Discussion

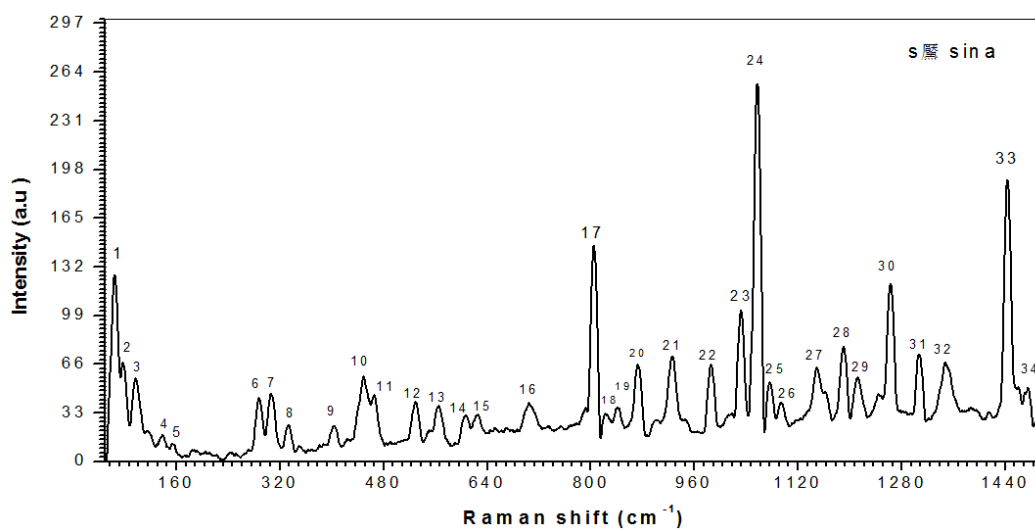


Figure 3. Raman spectrum of (süssina) powder in the range from 50 to 1500cm<sup>-1</sup>.

Figure 3 illustrates Raman spectrum of the sample (süssina) in the range from 50 to 1500cm<sup>-1</sup>.

Table 1 lists the main frequencies of the Raman spectra and the vibrational assignment.

Table 1. The analyzed data of Raman spectrum of (süssina) from 50 to 1500cm<sup>-1</sup>.

| Peak NO | Raman shift (cm <sup>-1</sup> ) | Assignment                  | Reference |
|---------|---------------------------------|-----------------------------|-----------|
| 1       | 67                              | Skeldef                     | [7]       |
| 2       | 78.2                            | -                           | -         |
| 3       | 97.3                            | -                           | -         |
| 4       | 140                             | Stretching (O-Ag-O)         | [7]       |
| 5       | 153.7                           | -                           | -         |
| 6       | 288                             | C-CH <sub>3</sub> sci       | [11]      |
| 7       | 306                             | Torsion (N <sub>2</sub> OH) | [12, 17]  |
| 8       | 334                             | -                           | -         |

| Peak NO | Raman shift (cm <sup>-1</sup> ) | Assignment   | Reference   |
|---------|---------------------------------|--|-------------|
| 9       | 405                             | --   | -           |
| 10      | 451.4                           | $\beta$ OCC + $\gamma$ NCCC  | [9]         |
| 11      | 467.3                           | -  | -           |
| 12      | 530                             | C – CL   | [13]        |
| 13      | 566                             | Amide VI   | [14]        |
| 14      | 608.5                           | -  | -           |
| 15      | 622.4                           | Aryl ring deformation and C–H bending                              | [2]         |
| 16      | 711                             | Skeleton deformation   | [2]         |
| 17      | 805                             | O-P-O  | [15]        |
| 18      | 843                             | C – O – C  | [13]        |
| 19      | 818                             | Aryl C–H wagging   | [2]         |
| 20      | 876                             | Skeletal vibration and C–H twisting                                | [2, 8]      |
| 21      | 919.5                           | C–H bending and C–C stretching                                     | [1]         |
| 22      | 982                             | melamine   | [10]        |
| 23      | 1034                            | mannitol   | [2, 8]      |
| 24      | 1054                            | Ring Stretching sodium saccharin                                   | [16]        |
| 25      | 1093.3                          | C–C stretching and O–H bending                                     | [2, 8]      |
| 26      | 1154                            | Aryl ring deformation and C–H bending C–C stretching               | [2, 10]     |
| 27      | 1196                            | $\nu$ OC + $\beta$ HOC+ $\beta$ HNC+ $\beta$ HCC                   |             |
| 28      | 1210                            | amide III  | [10]        |
| 29      | 1267.4                          | C–H symmetric rock   | [10]        |
| 30      | 1300                            | C–N stretching and C–H bending                                     | [10, 2]     |
| 31      | 1360                            | C3H, C2H2  | [7, 17, 18] |
| 32      | 1445                            | C–C stretching   | [14]        |
| 33      | 1475                            | $\nu$ (CC) stretching vibrations<br>$\nu$ (CN) in-plane vibrations | [8]         |

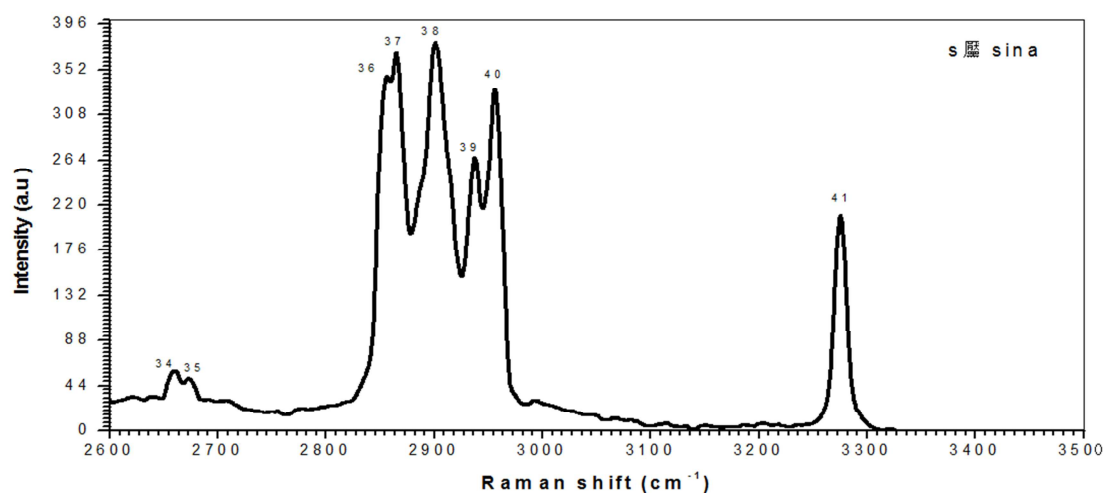


Figure 4. Raman spectrum of (süssina) powder in the range from 2600 to 3500 cm<sup>-1</sup>.

Figure 4 illustrates Raman spectrum of the sample the main frequencies of the Raman spectra and the (süssina) in the range from 2600 to 3500cm<sup>-1</sup>. Table 2 lists vibrational assignments.

Table 2. The analyzed data of Raman spectrum of (süssina) from 2600 to 3500cm<sup>-1</sup>.

| Peak NO | Raman shift (cm <sup>-1</sup> ) | Intensity (au) | Assignment    | Reference |
|---------|---------------------------------|----------------|---------------|-----------|
| 34      | 2677                            | 60.8           | H-bonds       | [17]      |
| 35      | 2673.1                          | 52.3           | H-bonds       | [7, 17]   |
| 36      | 2852                            | 347.4          | $\nu$ CH      | [9]       |
| 37      | 2864                            | 370.4          | -             | -         |
| 38      | 2885                            | 380            | (O–H stretch) | [12, 19]  |
| 39      | 2936                            | 267            | -             | -         |
| 40      | 2952                            | 333.1          | $\nu$ CH      | [9]       |
| 41      | 3276.1                          | 210.8          | Alkyne        | [13]      |

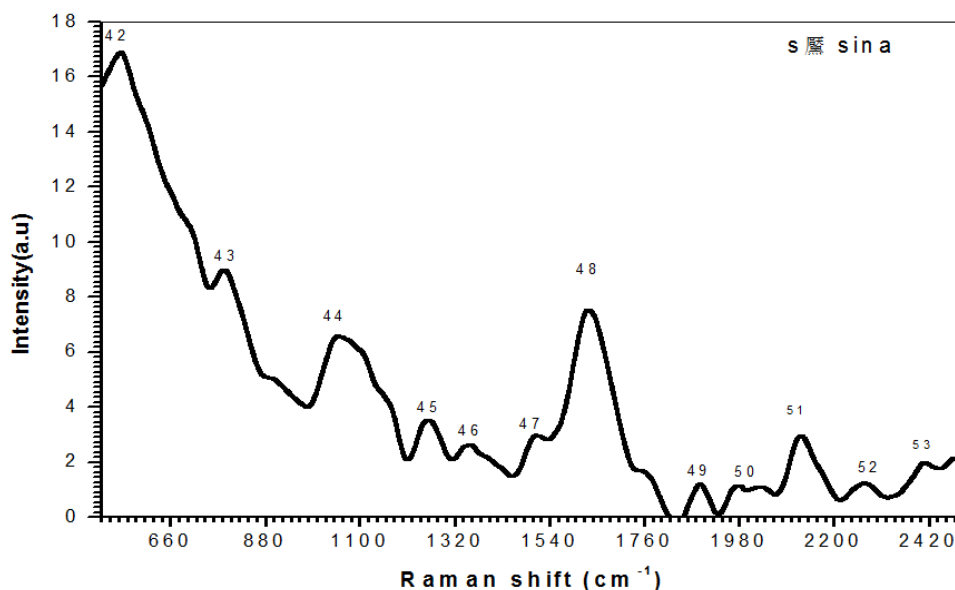


Figure 5. Raman spectrum of dissolved (süssina) in boiling mineral water and HCl acid (PH 3.1) in the range from 500 to 2500  $\text{cm}^{-1}$ .

Figure 5 illustrates Raman spectrum of the dissolved (süssina) in the range from 500 to 2500  $\text{cm}^{-1}$ . Table 3 lists the main frequencies of the Raman spectra and the vibrational assignments.

Table 3. The analyzed data of Raman spectrum of the dissolved (süssina) from 500 to 2500  $\text{cm}^{-1}$ .

| Peak NO | Raman shift ( $\text{cm}^{-1}$ ) | Intensity (a.u) | Assignment                           | Reference |
|---------|----------------------------------|-----------------|--------------------------------------|-----------|
| 42      | 540                              | 16              | disulphide bridges                   | [10]      |
| 43      | 785                              | 9               | twist $\text{CH}_3$                  | [11]      |
| 44      | 1056                             | 6               | C–O stretching and O–H bending       | [2]       |
| 45      | 1271                             | 3               | Torsion HCCN + torsion HCCO          | [9, 7]    |
| 46      | 1350                             | 2.6             | -                                    | -         |
| 47      | 1513                             | 3               | lycopene                             | [10]      |
| 48      | 1632                             | 7               | Asymmetric $\text{NH}_2$ deformation | [14]      |
| 49      | 1899                             | 1.1             | C = C                                | [13]      |
| 50      | 2121                             | 1.2             | sothiocyanate                        | [13]      |
| 51      | 2275                             | 2.9             | -                                    | -         |
| 52      | 2413                             | 1.3             | -                                    | -         |
| 53      | 2408                             | 2               | -                                    | -         |

## 5. Discussion

Through the analysis of the two samples it was found that some of the vibration modes of the sweetener s appeared as follows:

- 1 Vibrations modes of (süssina powder) at (876.0 very strong, 1056.0, 1093.0, 1134.0)  $\text{cm}^{-1}$ , which were attributed to the Sorbitol ( $\text{C}_6\text{H}_{14}\text{O}_6$ ).
- 2 Vibrational modes of the powder (süssina) at (622.4, 818.0)  $\text{cm}^{-1}$  are attributed to the Aspartame ( $\text{C}_{14}\text{H}_{18}\text{N}_2\text{O}_3$ ).  
Vibrational modes at (711.0, 1032, 1154.0, 1300.0)  $\text{cm}^{-1}$  are attributed to Saccharin ( $\text{C}_7\text{H}_4\text{NNaO}_3\text{S}$ ).
- 3 In the dissolved sample vibrational modes at (540, 1513, 2121)  $\text{cm}^{-1}$  are attributed to disulphide bridges, lycopene and sothiocyanate respectively.

## 6. Conclusion

The results presented in this work show that

Ramanspectroscopy technique is an efficient method to identify the compositions of the artificialsweeteners. It provides precise information about components found in the two samples of the commercial sweeteners.

## Acknowledgements

The authors would like to thank the Institute of Laser university of Sudan and the Indian Institute of Science (iisc) Bangalore INDIA for supporting this research and for technical facilitate in recording the Raman spectra.

## References

- [1] JohnR. Ferro, Kauzo Nakamoto and chrisWBrown, (2006)" Introductory Raman Spectroscopy" Fourth edition Elsevier.
- [2] Arpita Das and Runu Chakraborty, An Introduction to Sweeteners, Kolkata, India (2016).
- [3] Dills WL, (1989) Sugar alcohols as bulk sweeteners. Annu Rev Nutr 9: 161–186.

- [4] Bray GA1, Nielsen SJ, Popkin BM, (2004), Consumption of high-fructose corn syrup in beverages may play a role in the epidemic of obesity, *Am J Clin Nutr.*
- [5] Christina R. Whitehouse, BSN, et al, (2008), The Potential Toxicity of Artificial Sweeteners, Continuing education.
- [6] Niculina Peica, (2009), Identification and characterization of the E951 artificial food sweetener by vibrational spectroscopy and theoretical modelling, *Journal of Raman Spectroscopy.*
- [7] Marleen de Veij, a Peter Vandenabeele, et al, (2008), Reference database of Raman spectra of pharmaceutical excipients, *Journal of Raman Spectroscopy.*
- [8] P. Ramesh, S. Gunasekaran, (2018), Structural, Spectroscopic Investigation and Quantum Chemical Calculation studies on Methyl L- $\alpha$  aspartyl -Lphenylalaninate (Aspartame) for pharmaceutical Application, *International Journal of ChemTech Research.*
- [9] Ismail Hakki Boyaci, abHavvaTumayTemiz, et al (2015), Dispersive and FT-Raman spectroscopic methods in food analysis, *Royal society of chemistry.*
- [10] G. Mahalakshmi1, R. Suganya2, et al, (2016), Determination of Structural and Vibrational Spectroscopic Properties of 4-Amino-2, 2, 6, 6- tetramethylpiperidine using FT-IR and FT-Raman Experimental Techniques and Quantum Chemical Calculations, *International Journal of Science and Research (IJSR).*
- [11] Alicia Beatriz Brizuela a, Ana Beatriz Raschiet al, (2012), Theoretical structural and vibrational properties of the artificial sweetener sucralose, Elsevier B. V.
- [12] Nafie A. Almuslet1 and Mohammed A. Yousif, (2016), Identification Of Groundwater Components In Western Part Of Saudi Arabia Using Raman Spectroscopy, *Journal of Multidisciplinary Engineering Science and Technology (JMEST).*
- [13] Yuan Xiaojuan, Gu Huaimin, Wu Jiwei, (2010), Surface-enhanced Raman spectrum of Gly-Gly adsorbed on the silver colloidal surface, *Journal of Molecular Structure, ELSEVIR.*
- [14] Evelin Witkowska1 & Dorota Korsak, et al, (2016), Surface-enhanced Raman spectroscopy introduced into the International Standard Organization (ISO) regulations as an alternative method for detection and identification of pathogens in the food industry, DOI 10.1007/s00216-016-0090-z, *Anal Bioanal Chem.*
- [15] Anna G. Mignani a, Leonardo Ciaccheri, et al, (2014), Raman spectroscopy for distinguishing the composition of table-top artificial sweeteners, ELSEVIR.
- [16] Suzanne S. Leung†Brian E. Padden, et al, (1998), Solid-State Characterization of Two Polymorphs of Aspartame Hemihydrate, ELSEVIR.
- [17] Vaclav Ranc, Zdenka Markova, et al, (2014), Magnetically Assisted Surface-Enhanced Raman Scattering Selective Determination of Dopamine in an Artificial Cerebrospinal Fluid and a Mouse Striatum Using Fe<sub>3</sub>O<sub>4</sub>/Ag Nanocomposite, *American Chemical Society.*