Evaluation of Na and K in anti-diabetic ayurvedic medicine using LIBS

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Abstract

Diabetes mellitus, known as diabetes, is a challenging issue, and to control diabetes, a large population is lining toward ayurvedic medicine. In the present study, four brands of anti-diabetic ayurvedic medicines, along with a home remedy, are analyzed using the laser-induced breakdown spectroscopic (LIBS) technique. The study is carried out to know the elements responsible for glycemic potential. The laser-induced breakdown (LIB) spectra elucidate the presence of organic and inorganic elements like Al, Ba, C, Ca, Cu, Fe, H, K, Mg, N, Na, O, Si, Sr, Zn, and the molecular band of CN molecule in medicines. LIBS result also reveals Na and K's distinct concentration, which plays a vital role in diabetes management. The presence of the CN band and organic elements indicate the presence of organic molecular compositions in medicines. For confirmation of organic composition in the drugs, Fourier transform infrared spectroscopy (FT-IR) has been performed. Principal component analysis (PCA) on the LIBS data of the medicines has been used for instant discrimination based on their elemental/molecular compositions.

Keywords Diabetes mellitus · Ayurvedic medicine · LIBS · PCA · FT-IR

Introduction

Diabetes mellitus, generally called diabetes, is a chronic condition that occurs when there is an increase in glucose level in the bloodstream of a person due to inadequate production of insulin or when produced insulin is not effectively used. According to the International Diabetes Federation (IDF) Diabetes Atlas report, 463 million adults of the age group from 20 to 79 years had diabetes in 2019 worldwide, and this number attained to 578 million by 2030 and 700 million by 2045. India is the second country consisting of larger adults having diabetes [1]. Diabetes has been categorized as type 1 diabetes, type 2 diabetes, and gestational diabetes mellitus (GDM) or diabetes in pregnancy (DIP). In type 1 diabetes, insulin production is very less due to the autoimmune destruction of insulin-producing beta cells (β -cells) of the pancreas. Consequently, glucose levels in the bloodstream are raised [2].

Type 2 diabetes, which initially results in hyperglycemia, refers to the serious chronic condition in which the body produces an inadequate amount of insulin or creates a state of insulin resistance due to which hormone is not effective and the body's cell or target tissue is unable to respond fully to insulin. This condition often leads to life-threatening health complications such as cardiovascular diseases, nephropathy, neuropathy, and retinopathy [1]. One may also be affected by coronavirus diseases (COVID-19) due to lack of immunity [3]. Any woman may get affected with GDM, which may occur anytime during pregnancy, including their first trimester. This is because of insufficient insulin secretory capacity to overcome the diminished insulin action as the result of hormone produced by the placenta. Globally, approximately 90% of people, even children and young people aged 0–19 years, have been suffering from type 2 diabetes due to increased obesity, physical inactivity, inappropriate diet, and ethnicity and family history [1].

There are various recommended oral medicines/drugs such as metformin, sulphonylureas, dipeptidyl peptidase 4 (DPP-4) inhibitors, and glucagon-like peptide1 (GLP-1) for diabetic treatment [1]. When these recommended drugs are unable to control hyperglycemia to the recommended level, insulin injection may be necessary. These oral medicines and insulin therapy are chemically synthesized. Thus, they are not preferred for the treatment of diabetes because they have various side effects, such as insulin allergy, lipodystrophy and

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lipoatrophy, altered metabolic control, insulin antibodies, autoimmunity, morphological changes in kidneys, and severe vascular complications. Therefore, most of the world's population is shifted toward the usage of herbal medicine due to its fewer side effects than chemical drugs.

In the Indian traditional system of medicine, ayurvedic/herbal medicines have been used by people for the prevention and treatment of various ailments. Ayurveda has drawn its source from many medicinal plants and herbs having medicinal properties such as anticancer, anthelmintic, antimutagenic, antifertility, and anti-diabetics. A wide range of medicinal plants, such as *Gymnema sylvestre* [4], *Mangifera indica* [5], *Momordica charantia* [6], *Moringa oleifera* [7], *Pterocarpus marsupium* [8], *Salacia reticulata* [9], and *Syzygium cumini* [10] having bioactive phytochemical constituents, has shown to possess anti-diabetic and hypoglycemic activities.

The presence of minerals in medicine can be investigated with the help of elemental analysis. There are various conventional analytical techniques such as X-ray fluorescence (XRF) [11], inductively coupled plasma-optical emission spectroscopy (ICP-OES) [12], atomic absorption spectroscopy (AAS) [13], and inductively coupled plasma mass spectroscopy (ICP-MS) [14] which can be used for the same. Laser-induced breakdown spectroscopy (LIBS) has emerged as an effective emission spectroscopic tool for determining the elemental compositions as well as the presence of molecular bands in any form of materials. Recently, in order to explore out the relevant information about the biomaterial such as medicinal plants/herbs [15], drugs/medicines [16], edible plants/food [17], and plantation crop [18], Nisar et al. [19] reported the qualitative and semi-quantitative analysis of pharmaceutical products using the LIBS technique, which is suitable for distinguishing between genuine and counterfeit medicine. Aldakheel et al. [20] have shown the spectral analysis of Miracle Moringa tree leaves using the LIBS technique, which has been very suitable for the development of traditional herbal medicine. A comparison of LIB spectra of Chinese traditional medicine has been studied by Wang et al. using two excitation sources [21]. Therefore, LIBS has been an effective analytical technique for qualitative, semi-quantitative, and quantitative analytical purposes.

In the present study, anti-diabetic ayurvedic medicines accompanied by home remedy have been taken to know the composition (organic and inorganic elements) using the LIBS technique. Further, to confirm the presence of organic molecules, Fourier transform infrared spectroscopy (FT-IR) technique is used to reveal the interatomic bonds associated with functional groups of molecules. FT-IR spectra represent the signature of the absorption peak corresponding to the vibration of the group of atoms present in these medicines/samples.

Since the recorded LIB spectra composed of a lot of spectral emission lines corresponding to the various wavelengths, that is complex, thus, principal component analysis (PCA) [22], a data reduction technique, is used to demonstrate its application in evaluating the relationship between numerous variables simultaneously. It is also used to interpret clusters as well as to identify the responsible elements for the differentiation of clusters observed in these ayurvedic medicines.

Materials and methods

Medicines collection

Four anti-diabetic ayurvedic medicines of different brands were collected from Nikhil Aushadhalya, located in Prayagraj, U.P, India. Besides, an anti-diabetic herbal home remedy was also collected used by local people in the locality of Prayagraj. The herbal home remedy was in powdered form, and 0.8-g powder was compressed to form a pellet using a pellet press machine (H-Br Press MODEL M-15). Since other anti-diabetic ayurvedic medicines were originally in tablet form, thus, they were used directly in the experiment. The anti-diabetic ayurvedic medicine consists of different medicinal herbs, detail of which is given in Table 1. Various medicines were designated as samples A, B, C, D, and E.

Experimental setup

The LIB spectra of medicines were recorded using LIBS experimental set up described elsewhere [23]. The spectra were analyzed using Andor SOLIS acquisition and analysis software. To get a good quality of LIB spectra, i.e., to get optimum condition for signal-to-noise and signal-to-background ratios, the experimental parameters like laser energy, gate delay, gate width, and repetition rate were observed at 15 mJ, 1 μ s, 1 μ s, and 2 Hz, respectively. Consequently, a better quality of the LIB spectra of the medicines was recorded in the spectral range 200–980 nm. FT-IR spectra of medicines were measured using PerkinElmer FT-IR/FIR frontier spectrometer in spectral range 400–4000 cm^{-1} .

Results and discussions

Qualitative analysis

We have recorded ten spectra of each sample, and each spectrum is the average of fifty laser shots spectra. LIB spectra of medicines have been shown in Fig. 1a–c. The elemental and molecular signatures in LIB spectra were recognized using the National Institute of Standards and Technology (NIST) atomic spectral database and the book entitled *The identification of*

Table 1 Compositions of anti-diabetic ayurvedic medicines

S.N.	Anti-diabetic ayurvedic medicines (medicine sample)	Compositions: medicinal plants/herbs and minerals
1.	A	Saptrangi (<i>Salacia oblonga</i>)
2.	B	Jammun Giri (<i>Syzygium cumini</i>), Gudmar Buti (<i>Gymnema sylvestre</i>), Tribang Bhasma, Yashad Bhasma, Shilajit (<i>Asphaltum punjabinum</i>), Mamejava (<i>Enicostema littorale</i>), Billpatra (<i>Aegle marmelos</i>), Karela (<i>Momordica charantia</i>), Neem Patra (<i>Azadirachta indica</i>), Amalaki (<i>Phyllanthus emblica</i>), Methi (<i>Trigonella foenum-graecum</i>), Haridra (<i>Curcuma longa</i>)
3.	C	Karavallaka (<i>Momordica charantia</i>), Jambu (<i>Syzygium cumini</i>), Amra (<i>Mangifera indica</i>), Meshashringi (<i>Gymnema sylvestre</i>)
4.	D	Daruharidra (<i>Berberis aristata</i>), Vijaysar (<i>Pterocarpus marsupium</i>), Gudmar (<i>Gymnema sylvestre</i>), Majeeth, Methika (<i>Trigonella foenum-graecum</i>), Giloy (<i>Tinospora cordifolia</i>)
5.	Home remedy E	Karela (<i>Momordica charantia</i>), Methika (<i>Trigonella foenum-graecum</i>), Neem (<i>Azadirachta indica</i>), Gudmar (<i>Gymnema sylvestre</i>), Jambu (<i>Syzygium cumini</i>), Cinnamon (<i>Cinnamomum verum</i>), Tezapatta (<i>Cinnamomum tamala</i>), Saptrangi (<i>Salacia oblonga</i>), Shilajit, Gokhru (<i>Tribulus terrestris</i>)

Molecular spectra authored by Pearse and Gaydon, respectively [24, 25]. The LIB spectra of medicines demonstrate the presence of organic elements (C, H, N, and O) and inorganic elements (Al, Ba, Ca, Cu, Fe, K, Mg, Na, Si, Sr, and Zn) along with a molecular band of CN molecule. Elements present in the LIB spectra of the medicines with their corresponding wavelength have been shown in Table 2.

The maximum and similar spectral lines of element Ca are identified in samples B, D, and E. The spectral lines of element Fe are absent in samples A and C. The presence of element Ba is identified in samples D (Fig. 1c) and E. The spectral lines of Sr are absent only in sample C. The presence of elements Cu and Zn is observed only in LIB spectra of sample B, as shown in Fig. 1a, b. The organic elements C, H, N, and O have been observed in all medicines along with the presence of CN molecular band. It has been observed that samples A and C have similar elemental compositions except the absence of Sr in sample C. Based on observation, it has also been found that the elemental compositions of samples B, D, and E are similar. Further, Cu and Zn are present in sample B and absent in D and E, whereas Ba is present in samples D and E but absent in sample B. Thus, sample B is quite different from samples D and E.

Since ayurvedic medicines mostly contained herbal/medicinal plants in their natural form that exhibits anti-diabetic properties, these medicinal plants have different compositions that are required for their development and growth on the ground of their requirement. The compositions (organic and inorganic) of medicinal plants depend on biotic and abiotic factors, but sometimes, its absorption capacity of nutrients is influenced by some other factors such as drip irrigation, atmospheric dusts, rainfalls,

fertilizers, and soil contamination [26, 27]. Thus, non-essential elements like Ba and Sr are also present in medicinal plants, and ultimately, these are intake by the patient in the form of medicines. Research indicates that Sr may have therapeutic potential in the treatment of osteopenic disorders due to its anabolic and antiresorptive properties [28]. The role of some inorganic elements like Ca, K, Mg, Na, and Zn for the improvement of impaired glucose tolerance and their indirect role in the management of diabetes mellitus are being recognized. Cu and Zn are one of the key components of enzymatic in the human body. Zn plays a crucial role in the synthesis and storage of insulin in β -cell of the islets of Langerhans. The deficiency of Zn causes prediabetic conditions. The release of insulin from β -cell is improved with the help of Ca. K requires to optimize insulin secretion and also plays an active role in glycogen and glucose metabolism [29]. Mg acts as an activator for all enzymes which transfer a phosphate from adenosine triphosphate to adenosine diphosphate that influences the glycolytic cycle. It also plays an important role in cell duplication. Fe is an essential element in the human body, present as a component of hemoglobin. Si is absorbed through the gastrointestinal tract and enters the bloodstream. An excess amount of Si level in blood is excreted through urine, but sometimes, it deposited in the kidney, bladder, or urethra to form small calculi, which block the passage of urine. Generally, people with diabetes show a low level of Mg due to excess urinary as they losses Mg content from the body. Thus, in insulin resistance as well as secretion and binding activity of insulin, Mg supplementation may play an important role [15].

Fig. 1 A representative LIB spectra of **a** medicine sample B in the wavelength range from 230 to 440 nm, **b** medicine sample B in the wavelength range from 440 to 853 nm, and **c** medicine sample D in the wavelength range from 440 to 853 nm

Semi-quantitative analysis

LIBS analysis of medicine samples shows the presence of some relevant elements such as Mg, K, and Na, which play a significant role in diabetes management [15, 29, 30]. To check the correlation of elements having a potential role in

diabetes management, the relative concentration of the elements was calculated. Since in LIB spectra, the intensity of the spectral lines of the elements is directly proportional to the concentration of those elements in the sample/medicine [15].

Thus, to determine an element's absolute concentration, a standard reference having its known concentration is required

Table 2 Identified elements with their respective wavelength in LIB spectra of medicines

S.N.	Elements	Wavelengths (nm)
1.	Aluminum (Al)	308.1, 309.2, 394.3, 396.1
2.	Barium (Ba)	493.3, 455.3, 614.1, 649.6, 649.8, 705.9
3.	Calcium (Ca)	315.8, 317.9, 370.5, 373.6, 393.2, 396.7, 422.6, 428.2, 428.8, 429.8, 430.1, 430.7, 431.8, 445.4, 530.8, 531.9, 558.8, 585.6, 849.6, 442.4, 443.4, 447.9, 485.5, 487.7, 492.7, 518.8, 526.1, 526.4, 526.9, 534.8, 534.9, 558.1, 559.3, 559.7, 560.0, 560.2, 585.7, 610.1, 612.1, 616.1, 616.8, 643.7, 644.8, 646.1, 647.0, 649.2, 649.8, 671.6, 714.6, 720.0, 732.4
4.	Carbon (C)	247.8, 606.8, 607.4, 833.4
5.	Copper (Cu)	324.7, 327.3
6.	Hydrogen (H)	656.2
7.	Iron (Fe)	232.9, 234.5, 235.3, 275.5, 259.9, 240.4, 238.1, 239.5, 371.9, 373.4, 474.5, 574.8, 667.7, 800.6, 808.6
8.	Magnesium (Mg)	277.6, 277.7, 277.9, 278.0, 278.2, 279.0, 279.5, 279.7, 280.2, 285.1, 292.8, 293.6, 382.8, 383.1, 383.7, 516.6, 517.2, 518.2, 678.2, 794.9
9.	Nitrogen (N)	742.2, 744.1, 746.7, 818.7, 821.5, 824.1
10.	Oxygen (O)	777.1, 777.33, 844.5
11.	Potassium (K)	401.2, 404.7, 766.3, 769.7
12.	Silicon (Si)	250.6, 251.3, 251.5, 251.8, 252.4, 252.8, 288.1, 390.5
13.	Sodium (Na)	588.8, 589.5, 818.3, 819.3
14.	Strontium (Sr)	407.7, 421.5, 460.6
15.	Zinc (Zn)	328.1, 330.2, 334.4, 467.9, 472.1, 480.9

to construct a calibration curve. Since these samples are ayurvedic medicine, so, there are no standard references available. Therefore, we cannot use the calibration curve method to determine the elemental concentration in these medicines. Thus, in the present work, the relative concentration of the constituents of the medicines is evaluated. The intensity of the spectral lines present in the LIB spectra of the medicine sample is normalized by taking the ratio of intensities of detected elements Na, K, Mg, H, N, and O to the spectral reference line of C having a wavelength of 247.8 nm. The intensity of the spectral line of carbon in all the samples is almost constant.

After normalizing the intensity of the spectral lines to the spectral line of C (247.8 nm), we have calculated the intensity ratios Mg (285.2 nm)/Na (588.9 nm), K (766.4 nm)/Na (588.9 nm), and Mg (285.2 nm)/K (766.4 nm), and the results are shown in Fig. 2. Since the relative intensity of elements indicates the relative concentration, thus, Fig. 2 reveals that the relative concentration of K (766.4 nm) w.r.t Na (588.9 nm) is nearly equal in all anti-diabetic ayurvedic medicines except home remedy, suggesting that these two elements could be playing a vital role in diabetes management. K and Na are very significant blood minerals called the electrolyte, which carries a small electrical charge (potential). The specific concentration of K takes part in carbohydrate metabolism. It is also active in glycogen and glucose metabolism that helps in converting glucose to glycogen that can be stored in the liver for energy. Mg plays an important role in maintaining the specific amount of K in the cells, but the K and Na balance is finely tuned, which is also revealed from the result that a specific concentration ratio of K and Na is present in all anti-diabetic medicines except home remedy. This result indicates that if a diabetic patient uses medicinal herbs/plants or a mixture of different herbs as a home remedy without knowing its elemental information, then it might be properly ineffective in the management and regulation of blood glucose level. So, one must focus their attention on the elemental compositions of medicinal herbs as well as ayurvedic medicines.

Fig. 2 Bar diagram showing the variation in relative intensity of Mg (285.2 nm), Na (588.9 nm), and K (766.4 nm)

Analysis of molecular band present in the LIB spectrum of the medicines

LIB spectra of medicines show the presence of organic constituents C, H, N, and O (Fig. 1a, b) and CN violet degraded band of CN molecule (Fig. 3a–c). Generally, the presence of C and N are required to form CN molecule during the laser ablation of material. Thus, there might be two possibilities for the occurrence of CN band:

- (1) Recombination of C species of the organic compound of the medicine in the plasma with N species of the atmosphere;
- (2) Due to a combination of C and N species present in the plasma of organic compounds of the medicine themselves [16, 31].

The CN band of the ($B^2 \Sigma^+ \rightarrow X^2 \Sigma^+$) system has been observed in all medicine samples. The LIB spectra of the medicines consist of $\Delta v = +1, 0$, and -1 sequences of the CN violet degraded molecular band. The sequence of $\Delta v = +1$ contained the vibrational bands (1–0), (2–1), and (3–2); $\Delta v = 0$ contained (0–0), (1–1), (2–2), (3–3), and (4–4); and $\Delta v = -1$ contained (0–1), (1–2), (2–3), (3–4), (4–5), and (5–6). The observed CN molecular band is shown in Fig. 3a–c, and their corresponding wavelengths are tabulated in Table 3. Since medicine samples consist of medicinal herbs/plant that exhibits organic compound, thus, CN band in LIB spectra of the medicine might be present through the fragmentation of CN bonding from the parent molecule present in the medicines.

Our aim is to correlate the concentration of C and N in different medicines. Therefore, the variation in the intensity of CN ((0–0); 388.3 nm) is calculated and shown in Fig. 3d. The intensity of CN (0–0) band is maximum in sample A and minimum in sample C (Fig. 3d). Further, the intensity of the spectral line of N at 746.7 nm shown in Fig. 3e is maximum in sample A and minimum in sample C. The trend in variation in the intensity of CN band is the same as in the variation in the intensity of the spectral line of N (746.7 nm) (Fig. 3f). It indicates that the variation in the intensity of CN molecular band might be occurred due to variation in concentration of N in the medicines as the intensity of C is nearly the same in all medicines.

The intensity variation of the spectral line H at 656.1 nm and O at 777.1 nm in different medicines is also calculated, and the results are shown in Fig. 3e, which shows the different concentration of H and O in medicines. The concentration of H and O is maximum in sample D in comparison to others. The presence of organic elements C, H, N, and O, along with CN molecular band, confirms the presence of the organic compound in the samples. Further, the confirmation of the

Fig. 3 LIBS spectra of medicine sample “A” depicting CN band in the wavelength ranges **a** 357–360 nm, **b** 384–389 nm, and **c** 414–422 nm; bar diagram showing **d** the variation in the intensity of CN (0–0), **e** the

variation of intensity of N, H, and O, and **f** the variation of concentration of CN ((0–0); 388.3 nm) with respect to N (746.8 nm)

organic molecules/compound is also validated by FT-IR analysis.

FTIR analysis

The FT-IR spectra of medicines are recorded in 400–4000 cm^{-1} , as shown in Fig. 4. To evaluate the structure of the matrix of medicines, the functional groups are analyzed with the help of literature [32–38]. FT-IR absorption peaks associated with the corresponding bands are given in Table 4.

The strong band occurs at 1017 cm^{-1} , 1018 cm^{-1} , 1019 cm^{-1} , 1024 cm^{-1} , and 1030 cm^{-1} due to the C–O stretching vibrations in samples B, D, C, E, and A, respectively. The intensity of the absorption band due to C–O vibration is

strongest in sample B and weakest in sample D. This indicates that the sample exhibits strong C–O vibrations that have more concentrations of CO molecules. This means that the concentration of CO molecules is more in sample B and less in sample D. The C≡C stretching vibration occurs at 2137 cm^{-1} and 2206 cm^{-1} only in sample B. The N–C=O group stretching occurs at 2283 cm^{-1} , observed only in sample B [33]. The vibrational band, seen at 3289 cm^{-1} , 3290 cm^{-1} , 3298 cm^{-1} , 3299 cm^{-1} , and 3317 cm^{-1} corresponds to a broad stretching vibration band due to the hydroxyl group [36]. The observed C–H, C–O, C=O, C–N, N–O, CH₃, C≡C, N–C=O, and O–H functional group is associated with the organic molecules in medicine samples. The presence of C–N and N–C=O functional groups indicate that the CN band in LIBS spectra is

Table 3 CN molecular band with their corresponding wavelength observed in LIB spectra of medicine samples

S.N.	Sequence of CN violet ($B^2 \Sigma^+ \rightarrow X^2 \Sigma^+$) transition system					
	$\Delta v = +1$		$\Delta v = 0$		$\Delta v = -1$	
	Transitional vibration	Wavelength (nm)	Transitional vibration	Wavelength (nm)	Transitional vibration	Wavelength (nm)
1.	1–0	358.8	0–0	388.2	0–1	421.5
2.	2–1	358.4	1–1	387.0	1–2	419.6
3.	3–2	358.2	2–2	386.1	2–3	418.0
4.	—	—	3–3	385.3	3–4	416.5
5.	—	—	4–4	385.0	4–5	415.7
6.	—	—	—	—	5–6	415.1

Fig. 4 FT-IR spectra of medicine samples in the range 600–4000 cm^{-1}

observed due to the fragmentation of CN bond from molecules in medicines. In addition to that, the organic elements such as C, H, N, and O in LIB spectra are observed only due to the presence of organic molecules in anti-diabetic ayurvedic medicines. The results obtained from the combined analytical tools such as LIBS and FT-IR techniques reveal the elemental and molecular compositions of the matrix in medicines.

Principal component analysis

Principal component analysis [22, 39] was performed using unscrambler software. A set of 50 LIB spectra of five different anti-diabetic ayurvedic medicine having ten replicates of each

have been taken for PCA analysis. Figure 5a–c shows the 2-D score plot, explained variance, and PC-1 loading plot of PCA.

The PCA plot reflects the two principal components (PCs), PC-1 (79%) and PC-2 (3%), which explain the total 82% of the variance in the data matrix. It shows that PC-1 and PC-2 are sufficient to give relevant information about the clustering of the sample rather than higher-order PCs. The PCA plot depicts three different clusters associated with the sample matrix. PC-2 discriminates the LIBS spectra of samples B, D, and E with positive scores from spectra of samples A and C with negative scores. The positive score region of PC-1 depicts two clusters, which show that samples D and E lie with each other, and sample B clustered alone in this region. The negative score region of PC-1 depicts the clusters of samples A and C. This verifies the observed fact that the compositional structures of samples A and C are similar, which differ from the elemental compositions of samples B, D, and E. Although the elemental constituents present in samples B, D, and E are almost similar at some instant, yet we see that they form two different clusters. This is only due to the presence of elements Cu and Zn in sample B and the presence of element Ba in samples D and E.

The loading plot of PC-1 (Fig. 5c) shows which spectral lines contribute to the calculation of PC1. It is also observed from the loading plot of PCA that PC1 is composed of a positive correlation of emission lines corresponding to Al, Ca, Cu, Mg, Sr, and Zn and negatively correlated with Na. It indicated that concentrations of Al, Ca, Cu, Mg, Sr, and Zn in samples B, D, and E are higher than in samples A and C. This also indicates that samples A and C have a higher concentration of Na than samples B, D, and E. Thus, PCA result is in close agreement with the qualitative analysis of medicines presented in this paper.

Table 4 Vibrational band assignment of medicines

S.N.	Assignments	FT-IR wavenumber (cm^{-1})				
		Sample A	Sample B	Sample C	Sample D	Sample E
1.	C–H out of plane deformation	666	671	766	665	660
2.	C–H in plane deformation	902	881	926	875	781
3.	C–O stretching	1030, 1103, 1160	1017, 1075, 1100	1019, 1072, 1103, 1150	1018, 1092	1024, 1074, 1101, 1149
4.	C–N stretching	1206	1207	1217	1217	1217
5.	N–O stretching	1315	—	—	—	1317
6.	CH_3 deformation	—	1365	1366	1366	1365
7.	C–H bending	1428	1423	1420	1438	1438
8.	C=O asymmetry stretching	1611	1601	1601	1611	1614
9.	C=O stretching	—	1739	1737	1738	1737
10.	C=C stretching	—	2137, 2206	—	—	—
11.	N–C=O stretching	—	2283	—	—	—
12.	C–H stretching	2918	2917	2971, 2659	2971, 2993	2918, 2851
13.	O–H stretching	3299	3289	3298	3317	3290

Fig. 5 PCA result of medicine samples **a** 2-D score plot of PCA, **b** explained variance, and **c** PC-1 loading plot

Conclusion

Specific proportions of Na and K were determined in medicines that play a significant role in glycemic activity in diabetes management. The results of the present study show that elemental information is more useful before using any medicine. PCA coupled with LIBS suggests the potential of application as a rapid and selective technique for the classification of selected ayurvedic medicine. It also demonstrates that LIBS can be used as a powerful tool for determining the presence of glycemic elements as well as the quality control of phytomedicines and ayurvedic medicines. The presence of CN band and the organic elements (C, N, H, and O) in the LIB spectra reveal the presence of organic compound/molecule having a functional group of CN molecule in the medicines investigated in the present study. The results obtained by the LIBS technique are validated by the FT-IR spectroscopic technique, which confirms the presence of organic

molecules in anti-diabetic ayurvedic medicines. Thus, LIBS can be an effective technique for the investigation of compositions (organic and inorganic elements) in the form of trace elements, active and inactive ingredients, and molecules contained in ayurvedic medicine.

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