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Physical, Thermal and Spectral Properties of Biofield Energy Treated 2,4-Dihydroxybenzophenone

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Abstract

Study background: 2,4-Dihydroxybenzophenone (DHBP) is an organic compound used for the synthesis of pharmaceutical agents. The objective of this study was to investigate the influence of biofield energy treatment on the physical, thermal and spectral properties of DHBP. The study was performed in two groups (control and treated). The control group remained as untreated, and the treated group received Mr. Trivedi’s biofield energy treatment.

Methods: The control and treated DHBP samples were further characterized by X-ray diffraction (XRD), differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), laser particle size analyser, surface area analyser, Fourier transform infrared (FT-IR) spectroscopy, and ultra violet-visible spectroscopy (UV-vis) analysis.

Results: The XRD study indicated a slight decrease in the volume of the unit cell and molecular weight of treated DHBP as compared to the control sample. However, XRD study revealed an increase in average crystallite size of the treated DHBP by 32.73% as compared to the control sample. The DSC characterization showed no significant change in the melting temperature of the treated sample. The latent heat of fusion of the treated DHBP was substantially increased by 11.67% as compared to the control. However, TGA analysis showed a decrease in the maximum thermal decomposition temperature (Tmax) of the treated DHBP (257.66°C) as compared to the control sample (260.93°C). The particle size analysis showed a substantial increase in particle size (d50 and d99) of the treated DHBP by 41% and 15.8% as compared to the control sample. Additionally, the surface area analysis showed a decrease in surface area by 9.5% in the treated DHBP, which was supported by the particle size results. Nevertheless, FT-IR analysis showed a downward shift of absorption peak 323→318 nm in the treated sample (T1) as compared to the control.

Conclusion: Altogether, the results showed significant changes in the physical, thermal and spectral properties of treated DHBP as compared to the control.

Keywords: 2,4-Dihydroxybenzophenone; X-ray diffraction; Thermal analysis; Laser particle size analyser; Surface area analyser; Fourier transform infrared spectroscopy; Ultra violet-visible spectroscopy.


Introduction

Benzophenone an aromatic ketone is an important class of organic compounds used in perfumes and photochemicals. Benzophenones are used as an intermediate for the synthesis of dyes, pesticides and drugs [1]. These compounds are widely used for the synthesis of various drugs having anxiolytic, hypnotic and antihistaminic activities [2]. 2,4-dihydroxybenzophenone (DHBP) is used as UV-light absorber in resins and polymer compositions such as polystyrene, acrylonitrile polymer and other copolymers [3]. Moreover, these UV light absorbers are also used in the preparation of sunscreen agents for cosmetic applications. DHBP has been used as promising sunscreen agent that reduces the skin damage by blocking the ultra violet light [2].

The chemical and physical stability of the pharmaceutical compounds are most desired quality attributes that directly affect its safety, efficacy, and shelf life [4]. Hence, it is required to explore some new alternate approaches that could alter the physical and chemical properties of the compounds such as DHBP. Recently biofield energy treatment has been used as a plausible approach for physicochemical modification of metals [5,6], ceramic [7], organic products [8] and pharmaceutical drugs [9]. Therefore, after considering the pharmaceutical applications of DHBP authors planned to investigate the influence of biofield energy treatment on physical, thermal and spectral properties of DHBP.

The National Centre for Complementary and Alternative Medicine (NCCAM), a part of the National Institute of Health (NIH), recommends the use of Complementary and Alternative Medicine (CAM) therapies as an alternative in the healthcare sector, and about 36% of Americans regularly use some form of CAM [10]. CAM includes numerous energy-healing therapies; biofield therapy is one of the energy medicine used worldwide to improve the health.

Fritz, has first proposed the law of mass-energy interconversion and after that Einstein derived the well-known equation E=mc² for light and mass [11,12]. Though, conversion of mass into energy is fully

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validated, but the inverse of this relation, *i.e.* energy into mass is not yet verified scientifically. Additionally, it was stated that energy exist in various forms such as kinetic, potential, electrical, magnetic, nuclear, etc. which have been generated from different sources. Similarly, neurons that are present in the human central nervous system have the ability to transmit the information in the form of electrical signals [13-16]. Hence, biofield is defined as a bioenergetic field that permeates and surrounds living organisms. Recently Prakash et al. reported that this inherent biomagnetic field around the human body can be measured by few medical techniques such as Kirlian photography, polychromat interference photography and resonance field imaging [17].

Therefore, it is envisaged that human beings have the ability to harness the energy from the environment/Universe and can transmit into any object (living or non-living) around the Globe. The object(s) will always receive the energy and responding in a useful manner that is called biofield energy. Mr. Trivedi’s unique biofield treatment is also known as ‘The Trivedi Effect’. It is known to transform the characteristics of various living and non-living things. Moreover, the biofield treatment has caused significant affect in different fields such as agriculture [18-20] and microbiology [21-22].

The present work is focused to study the impact of Mr. Trivedi biofield energy treatment on physical, thermal and spectral properties of DHBP and characterized by XRD, DSC, TGA, particle size, surface area, FT-IR and UV-visible spectroscopic analysis.

**Materials and Methods**

2,4-Dihydroxybenzophenone (DHBP) was procured from S D Fine Chemicals Ltd, India. The sample was divided into two parts; one was kept as a control sample while the other was subjected to Mr. Trivedi’s unique biofield treatment and coded as treated sample. The treated group was in sealed pack and handed over to Mr. Trivedi for biofield energy treatment under standard laboratory conditions. Mr. Trivedi provided the energy treatment through his energy transmission process to the treated group without touching the sample. The control and treated samples were characterized by XRD, DSC, TGA, particle size, surface area, FT-IR, and UV-visible analysis.

**Characterization**

**X-ray diffraction (XRD) study**

The XRD analysis of control and treated DHBP was carried out on Phillips, Holland PW 1710 X-ray diffractometer system, which had a copper anode with nickel filter. The radiation of wavelength used by the XRD system was 1.54056 Å. The data obtained from this XRD were in the form of a chart of 2θ vs. intensity and a detailed table containing peak intensity counts, d value (Å), peak width (θ°), relative intensity (%) etc. The average crystallite size (G) was calculated by using formula:

\[
G = kλ/(b\cosθ)
\]

Here, λ is the wavelength of radiation used, b is full width half-maximum (FWHM) of peaks and k is the equipment constant (=0.94).

Percent change in unit cell volume = \[(V_t - V_c)/V_c]\] x 100

The molecular weight of atom was calculated using following equation:

Molecular weight = number of protons x weight of a proton + number of neutrons x weight of a neutron + number of electrons x weight of an electron.

Molecular weight in g/Mol was calculated from the weights of all atoms in a molecule multiplied by the Avogadro number (6.023 \times 10^{23}). The percent change in molecular weight was calculated using the following equation:

\[
\text{Percent change in molecular weight} = \left(\frac{M_t - M_c}{M_c}\right) \times 100
\]

Where, \(M_c\) and \(M_t\) are molecular weight of control and treated powder sample respectively.

Percentage change in average crystallite size was calculated using following formula:

\[
\text{Percent change in average crystallite size} = \left(\frac{(G_t - G_c)/G_c}\right) \times 100
\]

Where, \(G_c\) and \(G_t\) are the average crystallite size of control and treated powder samples respectively.

**Differential scanning calorimetry (DSC)**

DSC was used to investigate the melting temperature and latent heat of fusion (\(\Delta H\)) of samples. The control and treated DHBP samples were analysed using a Pyris-6 Perkin Elmer DSC at a heating rate of 10°C/min under air atmosphere and the air was flushed at a flow rate of 5 mL/min. Predetermined amount of sample was kept in an aluminum pan and closed with a lid. A blank aluminum pan was used as a reference. The percentage change in latent heat of fusion was calculated using following equations:

\[
\% \text{ change in Latent heat of fusion} = \left(\frac{\Delta H_{\text{Treated}} - \Delta H_{\text{Control}}}{\Delta H_{\text{Control}}}\right) \times 100
\]

Where, \(\Delta H_{\text{Control}}\) and \(\Delta H_{\text{Treated}}\) are the latent heat of fusion of control and treated samples, respectively.

**Thermogravimetric analysis-differential thermal analysis (TGA-DTA)**

The thermal stability of control and treated DHBP were analyzed by using Mettler Toledo simultaneous TGA and Differential thermal analyzer (DTA). The samples were heated from room temperature to 400°C with a heating rate of 5°C/min under air atmosphere.

**Particle size analysis**

The average particle size and particle size distribution were analyzed by using Sympetac Helos-BF Laser Particle Size Analyser with a detection range of 0.1 to 875 micrometer. Average particle size \(d_{50}\) and \(d_{99}\) (size exhibited by 99% of powder particles) were computed from laser diffraction data table. The percentage changes in \(d_{50}\) and \(d_{99}\) values were calculated by the following formula:

\[
\% \text{ change in } d_{50} \text{ size} = \left(\frac{d_{50,\text{Treated}} - d_{50,\text{Control}}}{d_{50,\text{Control}}}\right) \times 100
\]

\[
\% \text{ change in } d_{99} \text{ size} = \left(\frac{d_{99,\text{Treated}} - d_{99,\text{Control}}}{d_{99,\text{Control}}}\right) \times 100
\]

**Surface area analysis**

The surface area of control and treated DHBP were characterized by surface area analyser, SMART SORB 90 Brunauer-Emmett-Teller (BET) using ASTM D 5604 method that had a detection range of 0.2-1000 m²/g. Percent change in surface area was calculated using following equation:

\[
\% \text{ change in surface area} = \left(\frac{S_{\text{Treated}} - S_{\text{Control}}}{S_{\text{Control}}}\right) \times 100
\]

Where, \(S_{\text{Control}}\) and \(S_{\text{Treated}}\) are the surface area of control and treated samples respectively.
FT-IR spectroscopy

The FT-IR spectra were recorded on Shimadzu’s Fourier transform infrared spectrometer (Japan) with the frequency range of 4000-500 cm\(^{-1}\). The analysis was accomplished to evaluate the effect of biofield treatment at an atomic level like dipole moment, force constant and bond strength in chemical structure [23]. The treated sample was divided into two parts T1 and T2 for FT-IR analysis.

UV-Vis spectroscopic analysis

UV spectra of the control and treated DHBP samples were recorded on Shimadzu UV-2400 PC series spectrophotometer with 1 cm quartz cell and a slit width of 2.0 nm. The analysis was carried out using wavelength in the range of 200-400 nm and methanol was used as a solvent. The UV spectra was analysed to determine the effect of biofield treatment on the energy gap of highest occupied molecular orbital and lowest unoccupied molecular orbital (HOMO–LUMO gap) [23]. The treatment on the energy gap of highest occupied molecular orbital and solvent. The UV spectra was analysed to determine the effect of biofield treatment on the energy gap of highest occupied molecular orbital and lowest unoccupied molecular orbital (HOMO–LUMO gap) [23]. The treated sample was divided in two parts T1 and T2 for the analysis.

Results and Discussion

X-ray diffraction

XRD was used to investigate the crystalline nature of the control and treated DHBP. Figure 1 shows the XRD diffractogram of the control and treated DHBP. XRD diffractogram of the control DHBP showed intense crystalline peaks at Bragg angle equal to 12.98°, 14.83°, 15.24°, 18.13°, 18.52°, 25.64°, 27.93°, 34.85°, 37.57° and 44.34°. However, the treated DHBP showed XRD peaks at Bragg angle equal to 12.97°, 14.85°, 15.23°, 18.13°, 18.50°, 25.63°, 27.94°, 34.75°, 34.85°, 37.56°, and 44.34°. The intensity of XRD peaks present at Bragg angle 20 equal to 18.13°, 18.50°, 34.85°, 37.56° and 44.34° were increased in the treated sample as compared to the control. This showed an increase in crystallinity of the treated DHBP with respect to the control sample. It is proposed that biofield energy treatment might increase the long-range order of the DHBP molecules that lead to the formation of the symmetrical crystalline pattern as compared to the untreated sample [24]. Based on XRD peaks, control and treated samples were indexed with the monoclinic crystal structure.

The unit cell volume, crystallite size and change in molecular weight were computed from the XRD diffractogram, and results are presented in Table 1. The unit cell volume of control DHBP was 1063.70 \(10^{-24} \times \text{cm}^3\) and it was minimally decreased to 1063.20 \(10^{-24} \times \text{cm}^3\) in the treated sample. The treated DHBP showed a decrease in unit cell volume by 0.05% as compared to the control sample. The molecular weight (number of proton and neutrons) in control DHBP was 214.95 g/mol and it was minimally decreased up to 214.84 g/mol in the treated sample. The treated sample showed 0.048 % change in molecular weight with respect to control. It is hypothesized that biofield energy may be acted on the treated DHBP crystals at nuclear level and altered the number of proton and neutrons as compared to the control, which may lead to change in its molecular weight [25].

The crystallite size is known as a group of molecules or atoms having the same orientation in one plane. Moreover, the crystallite size is one of the crystallographic factors associated with the formation of dislocations and point defects in the crystalline structure, which directly influences the material properties [26]. The crystallite size of the control sample on the plane corresponding to most intense XRD peak (i.e. 2θ = 27.9) was 78.08 nm, and it was remained unchanged in treated DHBP sample (78.08 nm). Nevertheless, the average crystallite size was also calculated from the XRD diffractograms and data are presented in Table 1. The average crystallite size of control DHBP was 62.19 nm, and it was significantly increased to 82.55 nm, in the treated sample. The result showed an increase in average crystallite size by 32.73% in treated sample as compared to the control. Caruntu et al. reported that dielectric properties of barium powder could be varied by modulating the crystallite size through an annealing process [27]. Vucinic-Vasic et al. during their studies on zinc ferrite nanoparticles revealed that crystallite size increases with elevation in annealing temperature [28]. Additionally, recently it was showed that introduction of ultrasound to materials leads to substantial increase in crystallite size [29]. Hence, it is assumed that biofield treatment may provide waves similar like ultrasound or thermal energy to treated DHBP atoms that led to a decrease in dislocation densities and increase in crystallite size with respect to control.

Thermal analysis

DSC study: DSC was used to investigate the melting point and latent heat of fusion of control and treated DHBP. DSC thermogram of the control and treated DHBP are presented in Figure 2. DSC thermogram of the control DHBP showed a sharp melting endothermic peak at 146.39°C, and it indicated the crystalline nature of the control DHBP. However, the treated DHBP showed a minimal decrease in melting endothermic peak and it was observed at 146.21°C.

The latent heat of fusion of control and treated samples were obtained from respective thermograms and data are presented in...
Table 1: XRD data (unit cell volume, molecular weight and crystallite size) of control and treated 2,4-dihydroxybenzophenone.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>Treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit cell volume (10^-24 cm^3)</td>
<td>1063.70</td>
<td>1063.20</td>
</tr>
<tr>
<td>Molecular Weight (g/mol)</td>
<td>214.95</td>
<td>214.84</td>
</tr>
<tr>
<td>Crystallite size (G' × 10^9)</td>
<td>62.19</td>
<td>82.55</td>
</tr>
</tbody>
</table>

Table 2. The control DHBP showed a latent heat of fusion of 109.99 J/g; however it was increased to 122.83 J/g in the treated DHBP. The latent heat of fusion of DHBP was substantially increased by 11.67% as compared to control. It was suggested that biofield treatment may provide some thermal energy that caused aggregation of particles leading to increase in particle size.

The surface area of control and treated DHBP was measured using BET method and data are presented in Figure 5. The surface area of control DHBP was 0.9497 m^2/g and it was decreased to 0.8667 m^2/g, in treated sample. The result indicated the decrease in surface area by 8.64% in treated DHBP as compared to the control sample. It was reported that particle size is inversely proportional to surface area. Thus, increase in particle size causes a decrease in surface area and vice versa [35]. This was also supported by the XRD data where average crystallite size of treated sample was increased that causes decrease in the surface area.

FT-IR spectroscopy

FT-IR spectra of control and treated DHBP are shown in Figure 6. The FT-IR spectrum of control DHBP showed –OH stretching vibration peak at 3178 cm^-1. However, in the treated DHBP (T1 and T2) the –OH stretching were observed at 3185 and 3180 cm^-1, respectively. The aromatic –C=C– vibration peak was observed at 1604 cm^-1 in the control and treated samples (T1 and T2). Whereas, the C-H stretch was assigned at 2930 cm^-1 in the control DHBP and 2928 cm^-1 in treated DHBP.

\[
\text{Parameter} \quad \text{Control} \quad \text{Treated}
\]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>Treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latent heat of fusion ΔH (J/g)</td>
<td>109.99</td>
<td>122.83</td>
</tr>
<tr>
<td>Melting temperature (°C)</td>
<td>146.39</td>
<td>146.21</td>
</tr>
<tr>
<td>T_max (°C)</td>
<td>260.93</td>
<td>257.66</td>
</tr>
<tr>
<td>Weight loss (%)</td>
<td>55.51</td>
<td>54.89</td>
</tr>
</tbody>
</table>

T_max: maximum thermal decomposition temperature

Table 2: Thermal analysis data of control and treated 2,4-dihydroxybenzophenone.
Figure 3: TGA thermogram of control and treated 2,4-dihydroxybenzophenone.

Overall, the FT-IR spectra of treated sample showed the downward shift in methyl (C-H) stretch of the treated sample 2885→2835 cm⁻¹ as compared to control sample. It was previously suggested that increase in the frequency of any bond causes a possible enhancement in force constant of the respective bond [23]. Hence, it is assumed that biofield energy treatment might alter the dipole moment or force constant of the methyl stretch bond in treated DHBP sample as compared to the control.

**UV-visible spectroscopy**

UV-visible spectra of control and treated DHBP are shown in Figure 7. The UV spectrum of the control DHBP showed absorption peaks at 204, 242, 289, and 323 nm. The UV spectrum of treated DHBP (T1) showed absorption peaks at 203, 242, 290 and 318 nm. Whereas,
Figure 4: Particle size (d_{50} and d_{99}) of control and treated 2,4-dihydroxybenzophenone.

Figure 5: Surface area of control and treated 2,4-dihydroxybenzophenone.

Figure 6: FTIR spectra of control and treated (T1 and T2) 2,4-dihydroxybenzophenone.
the UV spectrum of DHBP (T2) showed absorption peaks at 203, 242, 289 and 322 nm. The result showed a blue shift of absorption peak at 323 nm in the control sample to 318 nm in DHBP sample (T1). It is speculated that the biofield energy treatment may cause changes in the energy gap of highest occupied molecular orbital and lowest unoccupied molecular orbital (HOMO–LUMO gap) of the treated DHBP with respect to the control [23,36].

Conclusions

In summary, the XRD study showed a decrease in the volume of the unit cell and molecular weight of treated DHBP as compared to the control. However, average crystallite size was increased by 32.73% in treated DHBP as compared to the control sample. It is assumed that biofield energy treatment might cause a reduction in dislocation density that lead to an increase in crystallite size in treated sample. The DSC analysis showed an increase in the latent heat of fusion of treated DHBP by 11.67% as compared to the control sample. TGA analysis indicated the decrease in thermal stability of the treated compound as compared to the control. A significant increase by 41% and 15.8% was observed in $d_{50}$ and $d_{99}$, respectively of the treated DHBP as compared to control sample. Additionally, the BET analysis showed a reduction in surface area (8.64%) of the treated DHBP that was due to increase in particle size of the sample. The UV spectral analysis showed alterations in absorption peak at 323→318 nm in treated sample as compared to the control. Thus, the biofield energy treatment has caused substantial changes in physical, thermal and spectral properties of DHBP.
Acknowledgement

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