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Research Article

Efficiency Enhancement of Banana Peel for Waste Water Treatment through Chemical Adsorption

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Abstract: Many types of agricultural wastes are now being studied for waste water treatment because of their adsorbing properties. For instance, banana peels are capable of adsorbing various metals and other pollutants present in industrial waste waters, provided the peels are pretreated with proper surface-active agents. This manuscript reports an investigation regarding activation of banana peels for this purpose. Banana peels were treated with dilute solutions of oxalic acid, sulfuric acid and sodium hydroxide at room temperature for 24 hours followed by drying at 90˚C. The adsorbing properties of banana peels were studied by using Fourier's transform infrared spectroscopy (FT-IR). It was observed that FT-IR is a quick and simple technique to verify the surface activation of banana peels.

Keywords: Banana peels, surface activation, chemical adsorption, concentration, Fourier transform infrared spectroscopy (FT-IR)

1. INTRODUCTION

Treatment of contaminated water from various sources is a challenge for engineers and scientists [1, 2]. Different technologies were introduced for waste water treatment like membrane separation, chemical and physical treatment but further research is required to overcome the problem of waste water treatment for proper disposal [3, 4]. Among various methodologies of treating waste water the sorption is the quite effective technique. Reasons of gaining attention towards this technique are its availability, low cost and versatility [5]. Researches have shown that various adsorbents can be used for the waste water treatment but the banana peels are the most popular adsorbent because of its availability and simple processing and satisfactory results [6]. Banana peels can remove wide variety of contaminants from waste water like oil spills, biological waste, carcinogenic elements, heavy metals and various dyes in water from textile and other sources [7].

`The adsorption involves a surface adhesion phenomenon. In adsorption process if some biological material is used as an adsorbent then process is known as bio-sorption. This process involves solid and liquid phase interaction [8]. Due to this interaction of sorbent and sorbate exchange the ions and remove unwanted dissolved species. Higher affinity of sorbent to sorbate species, unwanted ions in sorbate are attracted to sorbent ions. Solid and liquid phase distribution in sorption process is very important for determining the effectiveness of the process and degree of sorbent affinity plays a key role in this aspect [9, 10]. The

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sorption process is preferred over conventional treatment methods because of its low cost, easy sorbent availability and regeneration and minimum biological sludge production. Many researchers have reported the use of different adsorbents for waste water treatment, waste oil treatment, etc. [11, 12] investigated the sorbent properties of walnut shell and Naqvi et al. [13, 14] investigated the sorption properties of bentonite clay for waste lube oil treatment.

In this study banana peels were studied by analyzing its sorbent properties through simple testing technique. Chemical treatment enhanced properties of banana peels. The main objective in this research is to activate the surface of banana peels for enhancing the sorption properties by various chemicals like sodium hydroxide, sulfuric acid and oxalic acid [15, 16]. These chemicals modified the properties of banana peel in such a way that its sorption properties were increased and can be used in sorbent applications. Testing technique for sorption properties of banana peels were analyzed by Fourier's transform infrared spectroscopy (FT-IR) [17, 18].

2. MATERIALS AND METHODS

Banana peels samples were collected from kitchen waste. These peels were first washed with distilled water and then were dried at room temperature for 24 hours. Preparation of bio-sorbent is a critical step for enhancing the properties of banana peels. To this end, the banana peels were dried in a dryer for 24 hours at 90 ^{0}C. After drying, the banana peels were ground to average 200 mesh size in a coffee grinder. After grinding, banana peels' powder was once again dried in a tray dryer for 24 hours to ensure the removal of moisture [19, 20]. After drying, samples of banana peel were treated with sodium hydroxide, sulfuric acid and oxalic acid separately. The main parameters taken into consideration for sorbent preparation were concentration and residence time. According to the literature, the concentration varies from 0.5 *N* to 2 *N* solution of sodium hydroxide, 1 *N* to 3 *N* solution of sulfuric acid and 0.5 *N* to 1.5 *N* for solution of oxalic acid [21]. In this work, 1 *N* solution for each chemical was prepared for experimentation for comparison. Approximately 100 g of banana peels were dipped in these three solutions separately for 24 hours. According to the literature, the suggested soaking time for banana peels varies from 6 to 72 hours [16, 19]. After this experimentation, the sorbents were filtered and washed three times with distilled water and filtered by ordinary filter paper. The samples of banana peels powder were dried again in a tray drier for 24 hours at 90 $^{\circ}$C to remove the moisture contents and finally were stored in air tight bags. These sorbents are known as activated sorbents, and can be applied to sorbent applications [22].

Method of Characterization: Characterization technique used for analyzing adsorbent properties before and after activation was Fourier Transform Infrared Spectroscopy (FT-IR). This is a proven technique for investigating various functional groups and structural variations in biomass [23]. In this research, this technique is used and given preference over other techniques because it can detect a wide variety of functional groups which are present in banana peels structure though long range of wavelengths [24]. These wavelength variations provide accurate and many information about porous structure of banana peel and helps in concluding the adsorption properties of the adsorbent. Each wavelength in a structure associated to specific functional group which can be found through catalogue of FT-IR equipment or by using the library of functional group already present in some machines. Maximum range of electromagnetic waves in FT-IR is 500 cm^{-1} to 5000 cm^{-1} [25]. FT-IR analysis involves study of a sorbent with respect to specific functional group frequency which helps in developing the criteria for removal of impurities when applied to any material. These functional groups are linked with group frequency which in turn linked with fundamental modes of vibration. At the end the spectral data obtained is used to determine the development of simple or complex structure produced in sorbent [26].

3. RESULTS AND DISCUSSION

FT-IR spectra show better identifications of functional group and the surface changes of the banana peels. The modified porous surface of banana peels and reformed chemical bonding within the structure, addition and removal of any functional group were identified by FT-IR technique.

3.1 Banana Peel Structure before Treatment

The spectrum of raw banana peels shown in Fig. 1 generated by FT-IR. Starting right hand side from 500 cm^{-1}, the weak peeks are formed initially with very small gaps indicating inside structure. As wave number increases and reaches around 1000 cm^{-1}, the declining in the spectrum become high but peaks strength remains the same. If analyzed further the spectrum become narrow and near wave number 1500 cm^{-1} the peaks become sharper and the number of peaks within this range become high. This increase in number of peaks in spectrum continues up to 2200 cm-1. After this the peaks strength again start getting weaker and number of peaks start decreasing and the spectrum start declining up to 3300 cm^{-1}. As wavenumber further approaches to 3400 cm^{-1} and onwards spectrum pattern shows ascending behavior. Number of peaks becomes sharper and increased in numbers near the end of spectrum.

In Fig. 1 ascending and descending pattern of spectrum and number of peaks and their sharpness shows the adsorption properties of the sample under consideration. The portion of the spectrum where number of peaks are less sharp and decrease in number shows that the rays couldn't get enough space to penetrate inside the surface and reflect and finally the fewer peaks are formed. While sharper portion of the peaks are greater in number shows the penetration behavior of ray inside the surface. Penetration of rays inside the structure shows porous surface and hence greater the penetration of peaks more will be the porosity factor. In untreated

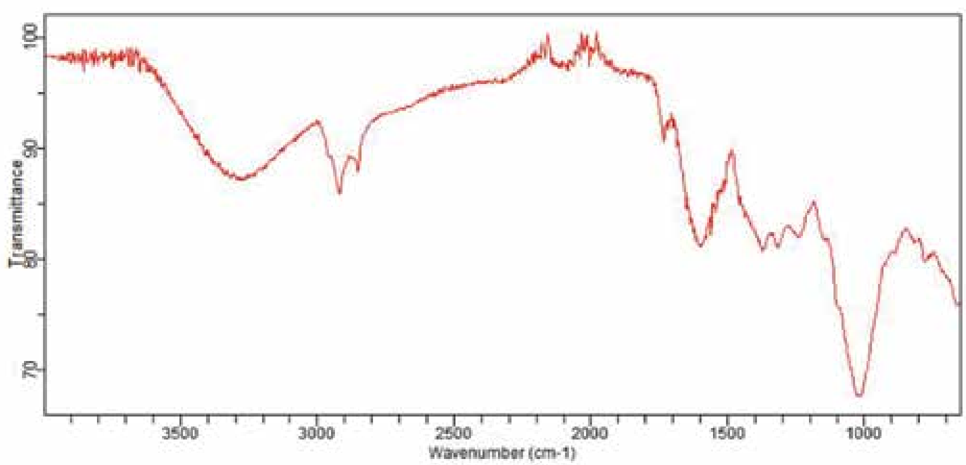

Fig. 1. Raw banana peel's spectrum.

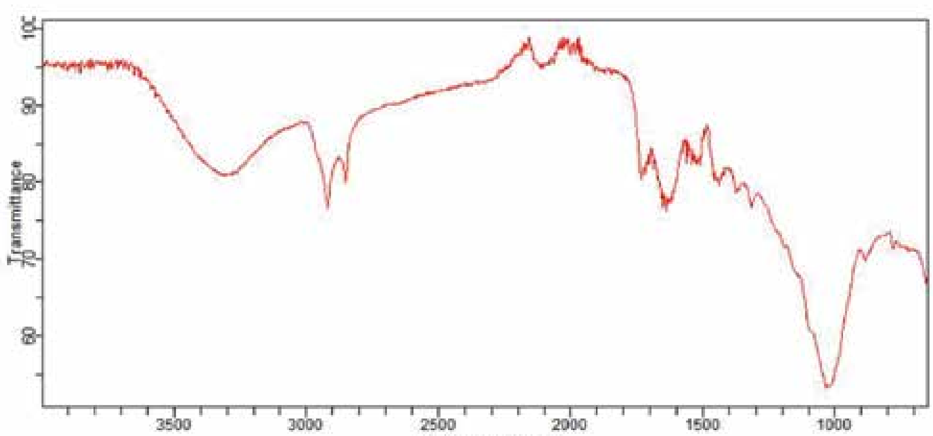

Fig. 2. Spectrum of banana peel treated with sulfuric acid.

banana peels majority of sharp peaks were found in the range of 1600 cm^{-1} to 2100 cm^{-1}. According to FT-IR wavenumber table in this range alkenyl C=C stretch, aryl substituted C=C and terminal alkyne C≡C functional groups are present [27]. Similarly, sharp peeks in raw banana peel are also formed from 3600 cm^{-1} and onwards. This range of wavenumber contains hydroxyl groups -OH with bond stretch. Stretch in bonds shows weak attractive forces between the bonds. So overall raw banana peel shows some tendency of adsorption process because of unsaturated double and triple bonded functional groups.

3.2 Banana Peel Structure after Treatment

Fig. 2 is the spectra generated by FT-IR for banana peels powder treated with 1N solution of sulfuric acid. Comparing the results with untreated banana peels, little difference in peak pattern is observed. Spectrum declining pattern at the beginning of spectrum from right hand side varies showing less depression points while up to 1000 cm^{-1} declining pattern is same. As the spectra proceed further the pattern remains the same as in Fig.1 up to 1200 cm^{-1}. However, after 1200 cm^{-1} rays strikes at different depression points and after 1400 cm^{-1} sharpness in peaks increase along with the depression points and this pattern continues up to 1700 cm^{-1}. This ascending spectrum with increase in number of peaks in spectrum continues up to 2000 cm^{-1}. A depression point again starts between 2100 cm^{-1} to 2200 cm^{-1} and after this declining pattern of spectrum with decrease in number of peaks start up to 3300 cm^{-1}. The spectrum pattern from 2200 cm^{-1} remains the same as in Fig.1 till the end of spectrum, but sharpness of peaks is decreased in this range. Peak sharpness increases within range 1400 cm^{-1} to 1700 cm^{-1} showing more porous behavior and enhanced adsorption capacity and in this range along with multiple bonds, some aromatic groups are also present which shows more tendency of unsaturation and adsorption process [28]. After 3500 cm^{-1} peaks sharpness are reduced as compared to raw banana peels showing less porosity factor in this particular portion of the spectrum. Therefore, it can be concluded that adsorption capacity of banana peels is not improved effectively when treated with sulfuric acid.

Fig. 3 shows the spectra generated by FT-IR for banana peels treated by 1N solution of oxalic acid. This spectrum is different than previous two patterns indicating the effect of oxalic acid is better than the sulfuric acid. Up to 1000 cm^{-1} peak depressions occurs which shows some narrow gaps within the structure of treated banana peels powder indicating porous behavior. Between 1000 cm^{-1} and 1700 cm^{-1} peak pattern is entirely different than the previous one. Some depression points can be seen in the spectrum at 1150 cm^{-1}, 1350 cm^{-1} and 1450 cm^{-1}. Sharpness in peaks increases between range 1300 cm^{-1} to 1500 cm^{-1}. After 1600 cm^{-1} peak pattern up to end of spectrum remains same as in fig.1. However, from 1800 cm^{-1} to 3200 cm^{-1} peak sharpness is greater at different points as compared to raw banana peels sample, which shows the enhanced porous behavior of the sample. In oxalic acid treatment, majority of sharp peeks are produced within the range 1700 cm^{-1} to 2300 cm^{-1}. In this range, C-C double bond and triple stretch bonds are present along with some stretch aromatic group. Which shows more porous behavior and hence more tendency of adsorption process [29]. However, after 3500 cm^{-1} and onwards peaks sharpness and their number is decreased as compared to raw banana peels sample but shows better result than sulfuric acid treatment. Similarly, depression points in oxalic acid treatment are more than previous two samples. So, by oxalic acid treatment it is concluded that adsorption capacity of banana peel is enhanced.

The FT-IR spectrum of banana peel sample treated with 1N solution of sodium hydroxide solution is shown in Fig. 4. This pattern is quite different than first two but relatively close to pattern 3. At starting point some depressions in spectrum occurred and after 700 cm^{-1} long peak depression is observed. After 1000 cm^{-1} and onward ascending pattern of spectrum is observed this is same as in previous samples except for absence of depressions up to 1200 cm^{-1}. After 1300 $cm^{-1}$the peak sharpness start increasing with increasing number of peaks within spectrum pattern up to 1500 cm^{-1}. As the spectrum proceeds further the peak sharpness and number of peaks are increasing constantly up to 2300 cm^{-1}. Maximum numbers of sharper peak are produced within range 1800 cm^{-1} to 2100

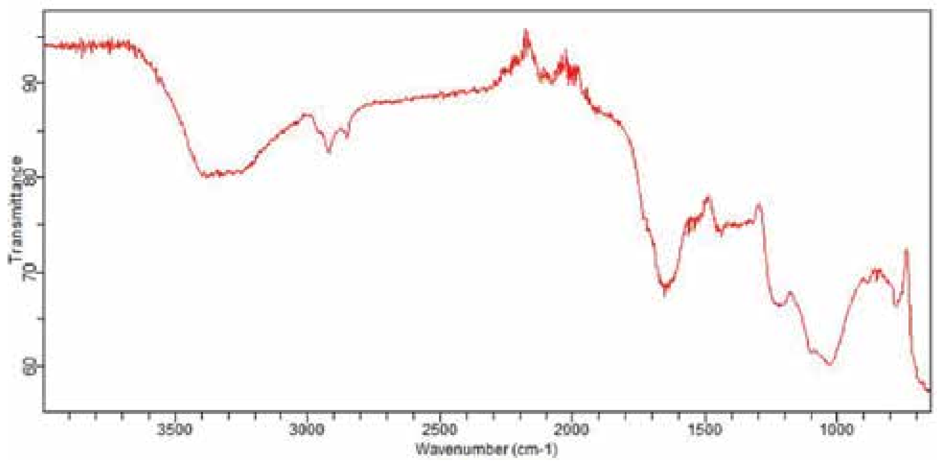

Fig. 3. Spectrum of banana after treatment with oxalic acid.

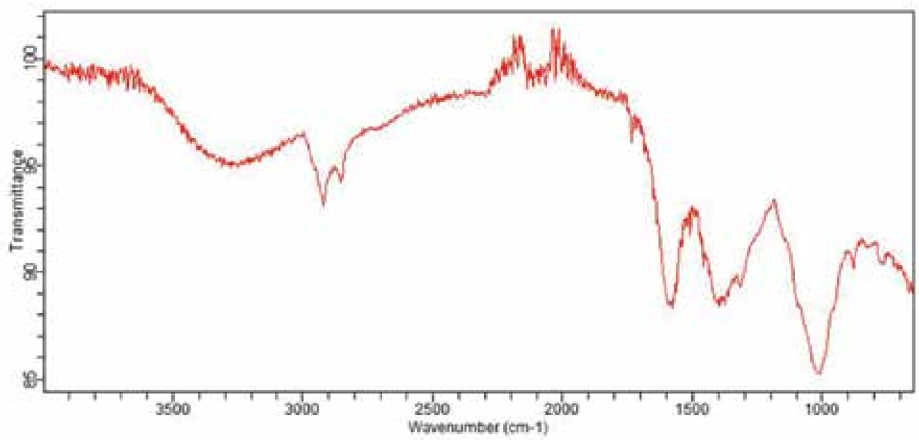

Fig. 4. Spectrum of banana peels after treatment with sodium hydroxide.

cm^{-1}. After 2300 cm^{-1} peak sharpness and spectrum pattern shows descending pattern up to 2800 cm^{-1} with some depressions. After 3000 cm^{-1}spectra shows again ascending pattern. Peak sharpness and number again start increasing up to end of the spectrum. Comparing the results of sodium hydroxide treated banana peels with other samples then it can easily be observed that depression points in the spectrum and overall sharp peaks are greater in numbers throughout the spectrum. Sharpness in peaks and depression points inside the spectrum shows that infrared rays of equipment (FT-IR) strikes more in depth of the sample which shows gaps are produced inside the structure. Sodium hydroxide treatment clearly reveals that very sharp, long, and better peaks are formed in the range 1800 cm^{-1} to 2200 cm^{-1} and in this range greater aromatic stretch functional groups are present as compared to double and triple bonded alkenes and alkynes. From 3500 cm^{-1} and onwards, more sharp and better peaks are formed and in this range phenolic groups with C-H stretch bond are present along some hydroxyl or alcoholic groups [30]. Peak depressions and gaps are greater than previous samples. Hence sodium hydroxide modified and improved the adsorption characteristics of the banana peel effectively.

4. CONCLUSIONS

The banana peels were treated with different chemicals for enhancing the adsorption properties. The banana peels were treated with 1 *N* solution each of sulfuric acid, oxalic acid and sodium hydroxide for 24 hours. The samples were dried and then identified by FT-IR technique. It was observed that sulfuric acid partially enhanced the adsorbing qualities of banana peels. Oxalic acid under same conditions also enhanced partially the adsorbing qualities of banana peels. The results of oxalic acid were found better than sulfuric acid. The results of banana peels treated with sodium hydroxide were found better than other two. Everything treated and untreated samples of banana peels were analyzed by FT-IR. It was observed that FT-IR is simple and rapid technique for identification of adsorbing properties of banana peels.

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6. REFERENCES

1. Achak, M., A. Hafidi, N. Ouazzani, S. Sayadi, & L. Mandi. Low cost biosorbent "banana peel" for the removal of phenolic compounds from olive mill wastewater: Kinetic and equilibrium studies. *Journal of Hazardous Materials* 166: 117-125 (2009).
2. Annadurai, G., R.-S. Juang, & D.-J. Lee. Use of cellulose-based wastes for adsorption of dyes from aqueous solutions. *Journal of Hazardous Materials* 92: 263-274 (2002).
3. Hossain, M., H.H. Ngo, W. Guo, & T. Nguyen. Removal of copper from water by adsorption onto banana peel as bioadsorbent. *Int. J. Geomate 2*: 227-234 (2012).
4. Annadurai, G., R. Juang, & D. Lee. Adsorption of heavy metals from water using banana and orange peels. *Water Science and Technology 47*: 185-190 (2003).
5. Hossain, M., H. Ngo, W. Guo, & T. Nguyen. Biosorption of Cu (II) from water by banana peel based biosorbent: experiments and models of adsorption and desorption. *Journal of Water Sustainability* 2: 87-104 (2012).
6. Memon, J.R., S.Q. Memon, M.I. Bhanger, A. El-Turki, K.R. Hallam, & G.C. Allen. Banana peel: a green and economical sorbent for the selective removal of Cr (VI) from industrial wastewater. *Colloids and Surfaces B: Biointerfaces 70*: 232-237 (2009).
7. Memon, J.R., S.Q. Memon, M. Bhanger, G.Z. Memon, A. El-Turki, & G.C. Allen. Characterization of banana peel by scanning electron microscopy and FT-IR spectroscopy and its use for cadmium removal. *Colloids and Surfaces B: Biointerfaces* 66: 260-265, (2008).
8. Anwar, J., U. Shafique, M. Salman, A. Dar, & S. Anwar. Removal of Pb (II) and Cd (II) from water by adsorption on peels of banana. *Bioresource Technology* 101: 1752-1755 (2010).
9. Amela, K., M.A. Hassen, & D. Kerroum. Isotherm and kinetics study of biosorption of cationic dye onto banana peel. *Energy Procedia* 19: 286-295 (2012).
10. Sivaraj, R., C. Namasivayam, & K. Kadirvelu. Orange peel as an adsorbent in the removal of acid violet 17 (acid dye) from aqueous solutions. *Waste Management* 21: 105-110 (2001).
11. Khalid, A., M.A. Kazmi, M. Habib, & K. Shahzad. Kinetic & Equilibrium modelling of copper biosorption. *Journal of Faculty of Engineering & Technology* 22: xx-xx (2015).
12. Ngah W.W., & M.A.K.M. Hanafiah. Removal of heavy metal ions from wastewater by chemically modified plant wastes as adsorbents: a review. *Bioresource Technology* 99: 3935-3948 (2008).
13 Shamaila, S., N. Zafar, S. Riaz, R. Sharif, & J. Nazir. Gold nanoparticles: an efficient antibacterial agent against enteric bacterial human pathogen. *Journal of Engineering and Technology* 43: 456-463 (2012).
14. Mansha, M., A.R. Saleemi, & J.H. Naqvi. Status and spatial visualization of toxic pollutants (BTEX) in urban atmosphere. *Advances in Chemical Engineering and Science* 1: 231-237 (2011).
15. Griffiths P.R. & J.A. De Haseth. *Fourier Transform Infrared Spectrometry*. John Wiley & Sons, USA (2007).
16. Khan, A., S. H.J. Naqvi, M.A. Kazmi, & Z. Ashraf. Surface Activation of fuller's earth (Bentonite Clay) using organic acids. *Science International* 27: 2252-2258 (2015).
17. Faix, O. Fourier transform infrared spectroscopy. *Methods in Lignin Chemistry* 1992: 83-109 (2014).
18. Griffiths P.R. & J. A. de Haseth. Fourier transform infrared spectroscopy. *Science* 222: 297-302 (1983).
19. Khan, A. Bleaching of Vegetable Oil using Organic Acid Activated Fuller's Earth (Bentonite Clay). *Global Journal of Research In Engineering* 15: 234-238 (2015).
20. AjayKumar, A.V., N. A. Darwish, & N. Hilal. Study of various parameters in the biosorption of heavy metals on activated sludge. *World Applied Sciences Journal* 5: 556-563 (2009).
21. Arunachalam, R. & G. Annadurai. Nano-porous adsorbent from fruit peel waste for Decolorization studies. *Research Journal of Environmental Sciences* 5: 366-373 (2011).
22. Banerjee, S.S., M. V. Joshi, & R. V. Jayaram. Treatment of oil spill by sorption technique using fatty acid grafted sawdust. *Chemosphere* 64: 1026-1031 (2006).
23. Surewicz, W.K., H.H. Mantsch, & D. Chapman. Determination of protein secondary structure by

Fourier transform infrared spectroscopy: a critical assessment. *Biochemistry* 32: 389-394 (1993).
24. Susi H., & D.M. Byler Resolution-enhanced fourier transform infrared spectroscopy of enzymes. *Methods in Enzymology* 130: 290-311 (1986).
25. Goormaghtigh, E., V. Cabiaux, & J.-M. Ruysschaert. Determination of soluble and membrane protein structure by Fourier transform infrared spectroscopy. In: *Physicochemical Methods in the Study of Biomembranes*, p. 405-450 (1994).
26. Rey, C., B. Collins, T. Goehl, I. Dickson, & M. Glimcher. The carbonate environment in bone mineral: a resolution-enhanced Fourier transform infrared spectroscopy study. *Calcified Tissue International* 45: 157-164 (1989).
27. Siesler, H.W., Y. Ozaki, S. Kawata, & H.M. Heise, *Near-infrared Spectroscopy: Principles, Instruments, Applications*. John Wiley & Sons (2008).
28. Nichols, P.D., J.M. Henson, J.B. Guckert, D.E. Nivens, & D.C. White. Fourier transform-infrared spectroscopic methods for microbial ecology: analysis of bacteria, bacteri-polymer mixtures and biofilms. *Journal of Microbiological Methods* 4: 79-94 (1985).
29. Al-Qadiri, H.M., M. Lin, A.G. Cavinato, & B.A. Rasco. Fourier transform infrared spectroscopy, detection and identification of Escherichia coli O157: H7 and Alicyclobacillus strains in apple juice. *International Journal of Food Microbiology* 111: 73-80 (2006).
30. Håkansson, K., M.J. Chalmers, J.P. Quinn, M.A. McFarland, C.L. Hendrickson, & A.G. Marshall. Combined electron capture and infrared multiphoton dissociation for multistage MS/MS in a Fourier transform ion cyclotron resonance mass spectrometer. *Analytical Chemistry* 75: 3256-3262 (2003).