APPLICATION NOTE

FT-IR and NIR Spectroscopy

Author:

Ian Robertson

PerkinElmer, Inc.
Shelton, CT

Detection of Adulteration of Glycerol with Diethylene Glycol by Infrared Spectroscopy

Introduction

Glycerol is a popular alcohol used within the food, pharmaceutical, and personal care industry. Glycerol (or glycerine) is listed in over 2,000 products, such as toothpaste, mouthwash, and pain relief medication due to its desirable properties to act as a humectant, preservative, and lubricant. It is prepared from fats and oils and also as a by-product from biofuel production. Demand for glycerol is expected to increase by 6.3% to $2.1 billion within the next four years, with North America and Western Europe being the largest suppliers, accounting for 64% of the market.

There have been a significant number of glycerol adulteration cases found by various regulatory services around the world. Diethylene glycol (DEG) is the most common adulterant reported, as the physical properties are similar and it is three times cheaper than glycerol. This fraudulent activity has caused fatalities due to the toxic nature of DEG. In 2006, cough syrups in Panama were manufactured with DEG instead of glycerol, resulting in hundreds of reported deaths. Furthermore, cases of contaminated toothpastes (1% - 8% DEG) have been reported across Europe, America, and Australia. This resulted in the recall of the products and stricter regulations by various health organizations on the testing and use of glycerol. As a result, the FDA stipulates a safety limit of 0.1% DEG by weight in products and propose testing of the raw materials.

Traditionally, thin layer chromatography (TLC) and gas chromatography (GC) have been adopted to detect DEG, but this process can be time consuming. Infrared (IR) spectroscopy is a fast, reliable, and low-cost alternative with minimal volume of samples required. This application note describes the utilization of Compare and Adulterant Screen within Spectrum 10 (and Spectrum 10 ES for regulated environments) to enable a fast and accurate verification of samples or to confirm the presence and concentration of the adulterant DEG down to sub per cent levels.

PerkinElmer®
For the Better

Experiment

Before a raw material can be used in a process, tests must be performed to ensure that it is the correct material and of the desired grade or purity. Infrared (IR) and near-infrared (NIR) spectroscopy are often the first or only analytical technique adopted for this purpose. Companies will have collected reference spectra of standards (often Pharmacopoeia standards) for all of their raw materials and will compare the spectrum of the incoming material against those reference standard spectra. The Spectrum software uses the patented Compare algorithm for this purpose. A perfect match between the unknown and the reference spectra will yield a result of 1.00 with the Pass/Fail threshold normally set to 0.98. Data has been collected using a Spectrum Two FT-IR Spectrometer equipped with a UATR (diamond ATR) sampling accessory. Spectra were measured at 4 cm-1 resolution with a data collection time of about 30 seconds. The result shown in Figure 1 is for a test sample of glycerol where the sample passes the test with a correlation value greater than the Pass/Fail threshold.

A sample of a potential adulterant, diethylene glycol (DEG), yields the result shown in Figure 2 where the material correctly fails the Compare against the glycerol standard.

The infrared spectrum and the Compare result will prevent cases where the material has been incorrectly labelled as the wrong material or cases where gross contamination or adulteration has occurred.

In cases where a material fails the Compare test, the material would normally be subjected to further testing by additional instrumental techniques or wet chemistry. However, PerkinElmer has invented an algorithm for detection of adulterants available within the Spectrum software in cases where adulteration or contamination is suspected. The same spectrum collected for the Compare test can be used with the Adulterant Screen routine to test to see if the software can detect any adulterants.

To create an Adulterant Screen for the material, the Spectrum 10 software is used to collect your IR or NIR data representing "good examples" spectra for your material. This will consist of multiple spectra representing many sources of variation of your product, such as different batches, sources, grades of material, etc. These spectra define the boundaries of the acceptable product. You will then collect the spectra of all known adulterants as pure materials. These spectra define your Adulterant Spectra. In this example of the detection of diethylene glycol in glycerol, we have collected 10 spectra of glycerol to define our acceptable product and one spectrum of pure diethylene glycol as the adulterant.

Using the same spectrum that we used for our unknown sample with the Compare algorithm we could test the sample for adulteration. The results for the sample previously identified as glycerol are shown in Figure 3.

The plot shows the difference between the calculated model for glycerol and the unknown spectrum. The glycerol sample is reported as containing no adulterants, passing the test with very small spectral residual between the Adulterant Screen model and the unknown spectrum.

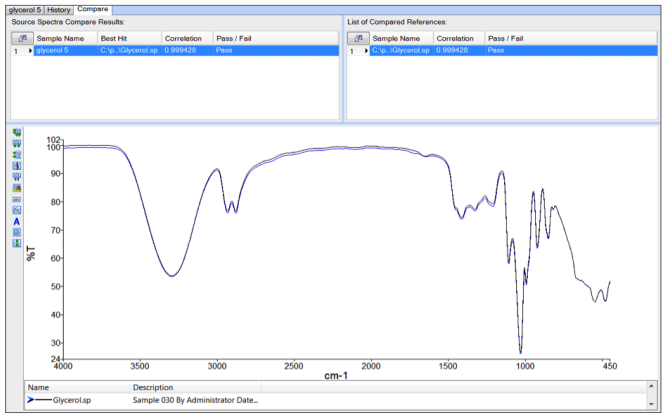

Figure 1. Compare result for a test sample of glycerol

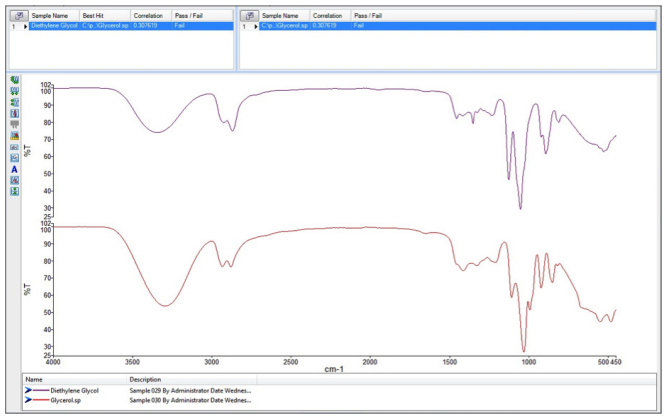

Figure 2. Compare result for a test sample of diethylene glycol (DEG) vs. glycerol standard

Table 1. Compare results against a glycerol standard

Sample Name	Best Hit	Correlation	Pass/Fail
Glycerol	C:\pel_data\spectra\ATR\Glycerol.sp	0.999428	Pass
Diethylene Glycol	C:\pel_data\spectra\ATR\Glycerol.sp	0.307619	Fail

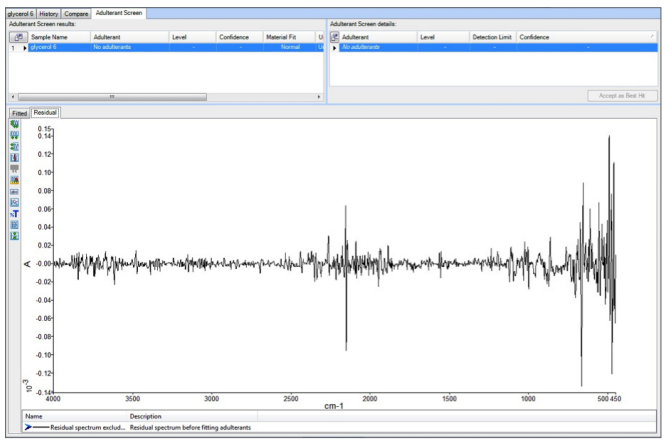

Figure 3. Adulterant Screen result for a test sample of glycerol

A series of mixtures were prepared by mixing the diethylene glycol and glycerol in order to test the Adulterant Screen method. Results are shown for these test samples in Table 2. An example for one of these test samples is shown in Figure 4.

Including the adulterant in the model greatly reduces the residual and clearly shows that the adulterant is present. Adulterant Screen has also given an estimated concentration level for this adulterant, without the requirement for preparing accurate standards and measuring their spectra. The software will also estimate the detection limit of the adulterant, in this case approximately 0.2%. This makes this mid-infrared measurement perfectly suited to screening glycerol samples for the presence of diethylene glycol. Further adulterants could be added to the method in the future by simply adding in the spectrum of the pure adulterant. If more accurate quantitative measurements are required then the Spectrum Quant software is capable of generating quantitative calibrations for the measurement of diethylene glycol in glycerol using infrared data. However, calibrations would need to be generated for all potential adulterants. Adulterant Screen removes this requirement, and, in this case, the Adulterant Screen quantitative estimate of the level of adulterant is accurate.

In an ideal scenario, these measurements would be performed close to the point where the raw materials are received or where they are to be used in the process. The measurement should be performed by a trained operator, not necessarily the skilled chemist. These Adulterant Screen methods can be deployed using the Spectrum 10 or Spectrum 10 macros with Adulterant Screen software, utilizing a simple user interface, following a prescribed method or SOP on the screen. In addition, results can be exported to the TIBCO Spotfire® for enhanced visualization and data analysis.

Summary

Deployment of the Spectrum Two with the UATR sampling module and the Spectrum 10 software enables fast and accurate testing of the glycerol raw material. The Compare algorithm achieves identification of the correct raw material. The Adulterant Screen method is very effective in cases when it is required to screen against suspected economic adulterants. This simple and effective method has the ability to detect the adulteration by DEG in glycerol raw ingredient, down to 0.2% (w/w). An additional advantage is that Adulterant Screen allows new adulterants to be added at any time, and, along with the implementation as a Spectrum macro, it enables easier, simplified use. Spectrum 10 ES provides all of the security features required for deployment in regulated environments.

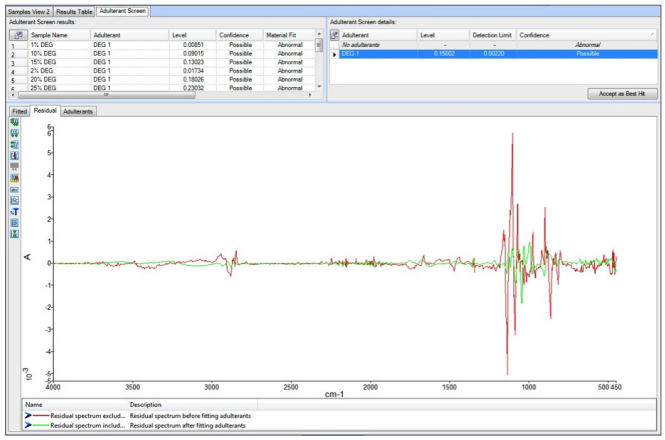

Figure 4. Adulterant Screen residuals for a test sample of glycerol spiked with 17% DEG (Red: excluding adulterant, Green: including adulterant)

Table 2. Calculated levels of DEG adulterant for a series of spiked samples

Concentration of Diethylene Glycol	Adulterant Screen Pass/Fail	Level of Adulterant Reported
1.08%	Fail	0.0101
2.20%	Fail	0.0203
5.31%	Fail	0.0519
10.29%	Fail	0.1031
14.96%	Fail	0.1488
20.36%	Fail	0.2043
25.56%	Fail	0.2606
30.17%	Fai	0.3040
40.19%	Fail	0.4028
50.25%	Fail	0.5143
0%	Pass	-

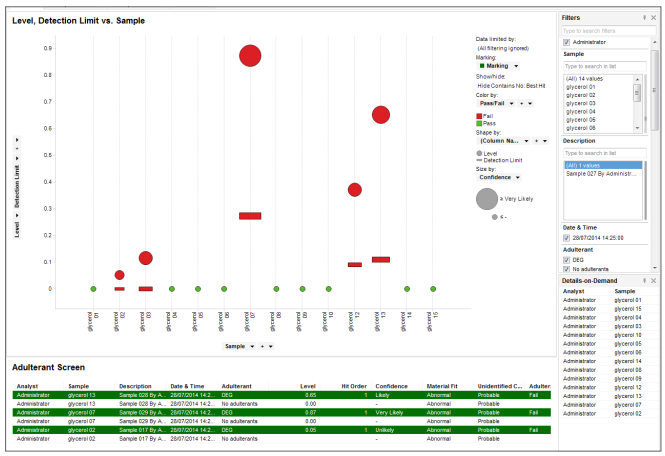

Figure 5. TIBCO Spotfire® software displaying multiple results for Adulterant Screen

PerkinElmer, Inc.
940 Winter Street
Waltham, MA 02451 USA
P: (800) 762-4000 or
(+1) 203-925-4602
www.perkinelmer.com

For a complete listing of our global offices, visit www.perkinelmer.com/ContactUs

011876_01