

Detecting Spice Adulteration with the Agilent 8700 LDIR Chemical Imaging System

Accelerating adulterant detection in turmeric with IR spectroscopy and imaging



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Introduction

Spices are essential components of culinary practices worldwide, valued for their flavor, aroma, and health benefits. However, the intentional or accidental adulteration of spices with cheaper or foreign substances poses significant risks to both food quality and consumer safety. Adulteration practices often aim to increase product volume, enhance visual appeal, or mimic authentic flavors, compromising the integrity of the final product.¹

Common adulteration practices include substituting genuine plant materials with cheaper or visually similar ones, using inferior plant species or parts, and mixing with fillers such as corn starch, bran, or sawdust. Some products are also adulterated with chemicals to enhance flavor, inorganic substances such as sand, chalk, or red brick powder, or illegal dyes such as Sudan dyes and rhodamine B to intensify color.¹⁻⁴

Current tools for detecting adulteration in herbs and spices face several challenges. Sampling across complex supply chains often lacks consistency, making it difficult to obtain representative samples.⁵ The chemical and physical complexity of sample matrices, combined with natural variation among species and origins, complicates data interpretation.⁵

In ground or powdered spices, the original plant structures are lost, making it difficult to visually or morphologically identify adulterants, particularly when they are fine or physically similar to the genuine material.⁶

An Agilent 8700 Laser Direct Infrared (LDIR) chemical imaging system (Figure 1) was used in this study to detect spice adulteration through the integration of infrared spectroscopy and microscopy.



Figure 1. The Agilent 8700 LDIR chemical imaging system with Agilent Clarity software allows the high-speed routine analysis of particles, including the number of particles present in powdered samples, their size, and their chemical composition.

Experimental

Agilent Clarity software: To evaluate the 8700 LDIR's capability in distinguishing genuine spices from common adulterants, a series of pure and adulterated samples were prepared and analyzed using the system's automated Particle Analysis (PA) workflow.

Pure substances: Five powders (turmeric, paprika, black pepper, corn starch, and sand) were selected to represent typical spices and common adulterants. Each sample was applied directly as a dry powder onto low emissivity (low-e) "Kevley" slides without any solvent addition or further sample preparation, preserving the native particulate morphology.

Workflow: The PA workflow was employed to analyze particles ranging from 20 to 500 μm in size. For each individual material, four or five representative infrared spectra were selected and compiled into a custom spectral reference library (named "Spices Internal Library"). To ensure spectral diversity within the library, spectra generated from particles of varying sizes (300, 200, 100, 50, and 20 μm) were selected.

Adulterated mixture: An adulterated spice sample was prepared by mixing 5 to 10 mg each of turmeric, corn starch, and sand (the same powders that were used for library generation). This mixture was similarly analyzed on a low-e slide using the 8700 LDIR's automated PA workflow and the Spices Internal Library for spectral matching and identification.

Results and discussion

Identification of pure spices (turmeric)

To verify the 8700 LDIR and the user generated library in identifying particles of varying sizes, shapes, and counts, the pure turmeric sample was analyzed as an "unknown".

Turmeric sample identification demonstrated high spectral matching accuracy. Within the selected analysis area, 74 particles were detected and 70 particles (94.6%) were matched to the turmeric reference spectra in the custom library. Notably, 64 particles achieved Hit Quality Index (HQI) values exceeding 0.8, indicating strong spectral correlation and high confidence in the identification data (Figure 2).

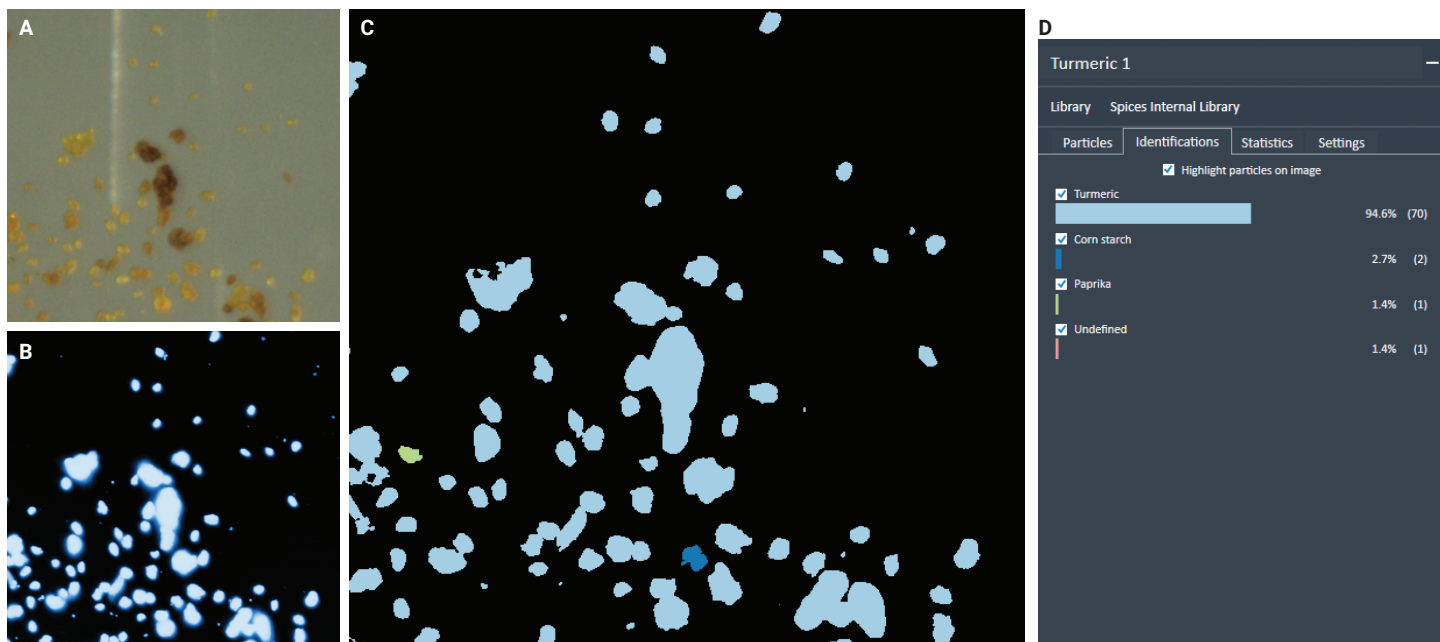


Figure 2. Turmeric sample analyzed on a low-e slide by an Agilent 8700 LDIR and the automated Particle Analysis workflow within Agilent Clarity software. (A) Visible image of the area selected. (B) IR image scanned at 1,442 cm^{-1} . (C) Highlights of particles found—the color of the particles relates to the type of particle on the slide. (D) Automatically generated statistical data based on the identification of particles in the sample.

Identification of pure adulterant (corn starch and sand)

Similar to the turmeric sample, the 8700 LDIR showed excellent performance in identifying organic and inorganic adulterants in their pure form. For corn starch (used as an organic adulterant), 203 particles were detected, with 201 particles (99%) matching the corn starch spectral signature. Of these particles, 198 particles achieved an HQI > 0.8, confirming robust identification (Figure 3).

Sand, representing an inorganic adulterant, was similarly well characterized: 24 out of 25 detected particles (96%) matched the sand reference spectra with an HQI > 0.8, and 23 particles exceeded HQI > 0.9. The distinct infrared spectral features of sand, primarily composed of silica and quartz, facilitated clear differentiation from organic matrices (Figure 4).

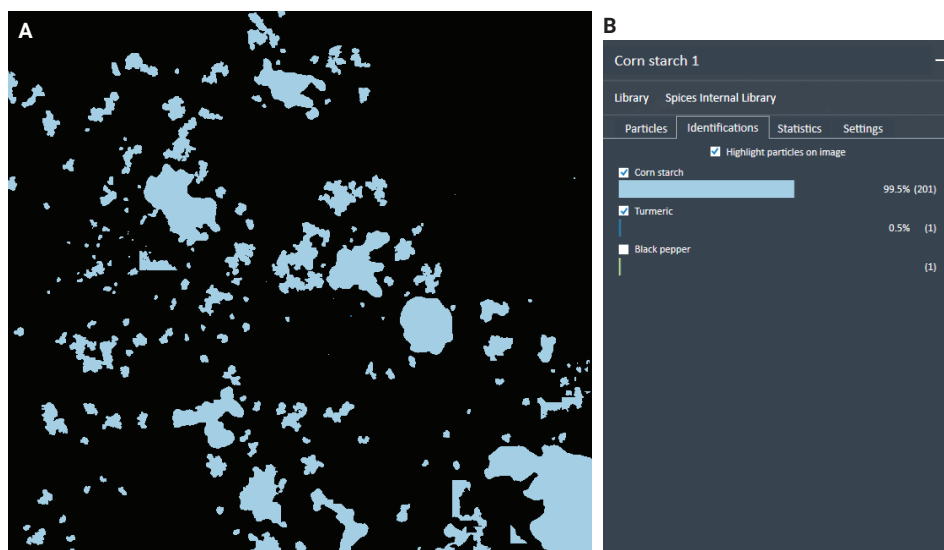


Figure 3. Corn starch powder analyzed on a low-e slide using an Agilent 8700 LDIR and the automated Particle Analysis workflow within Agilent Clarity software. (A) Detected particles—the color of the highlighted particles relates to the type of particle on the slide. (B) Automatically generated statistical data based on the identification of particles in the sample.

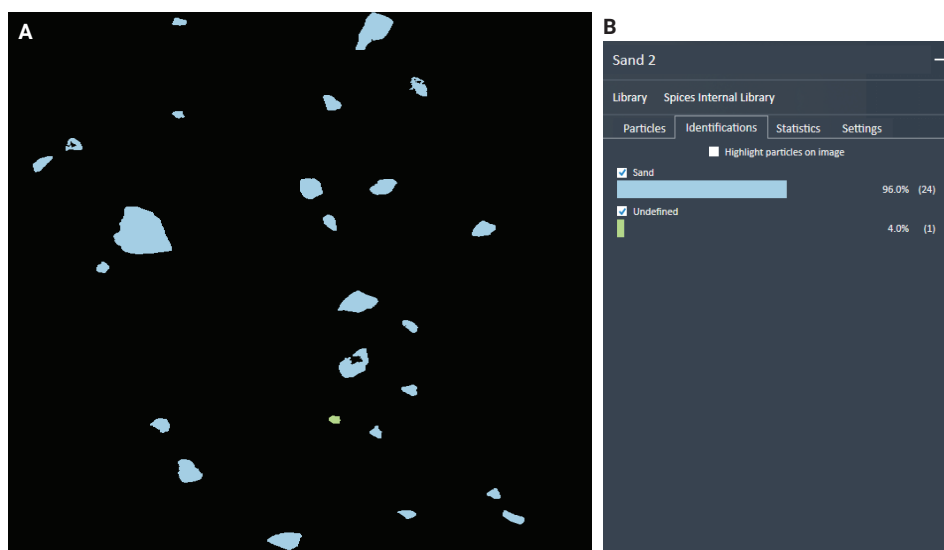


Figure 4. Sand sample analyzed on a low-e slide using an Agilent 8700 LDIR and the automated Particle Analysis workflow within Agilent Clarity software. (A) Highlights of particles found—the color of the particles relates to the type of particle on the slide. (B) Automatically generated statistical data based on the identification of particles in the sample.

Adulterated spice mixture

To evaluate the 8700 LDIR system's ability to detect adulterants in complex spice mixtures, a test sample was prepared by combining turmeric powder with corn starch and sand. Within a scanned area of 4.85×14.58 mm, the system detected 351 particles. Of these, 337 particles (96%) achieved high-confidence spectral matches (HQI > 0.8).

Specifically, 168 particles (47.9%) were identified as corn starch, 139 (39.6%) as turmeric, and 22 (6.3%) as sand. A small fraction (~6%) matched black pepper and paprika, which were not present in the sample. These results were likely due to spectral overlaps with turmeric.

The 8700 LDIR system's visible light imaging capability enabled manual verification of the sample's composition by providing clear visual distinction between yellow turmeric and the other particles present (Figure 5A). Overall, the 8700 LDIR effectively differentiated spice from adulterants in a complex and high-particle-count mixture (Figure 5).

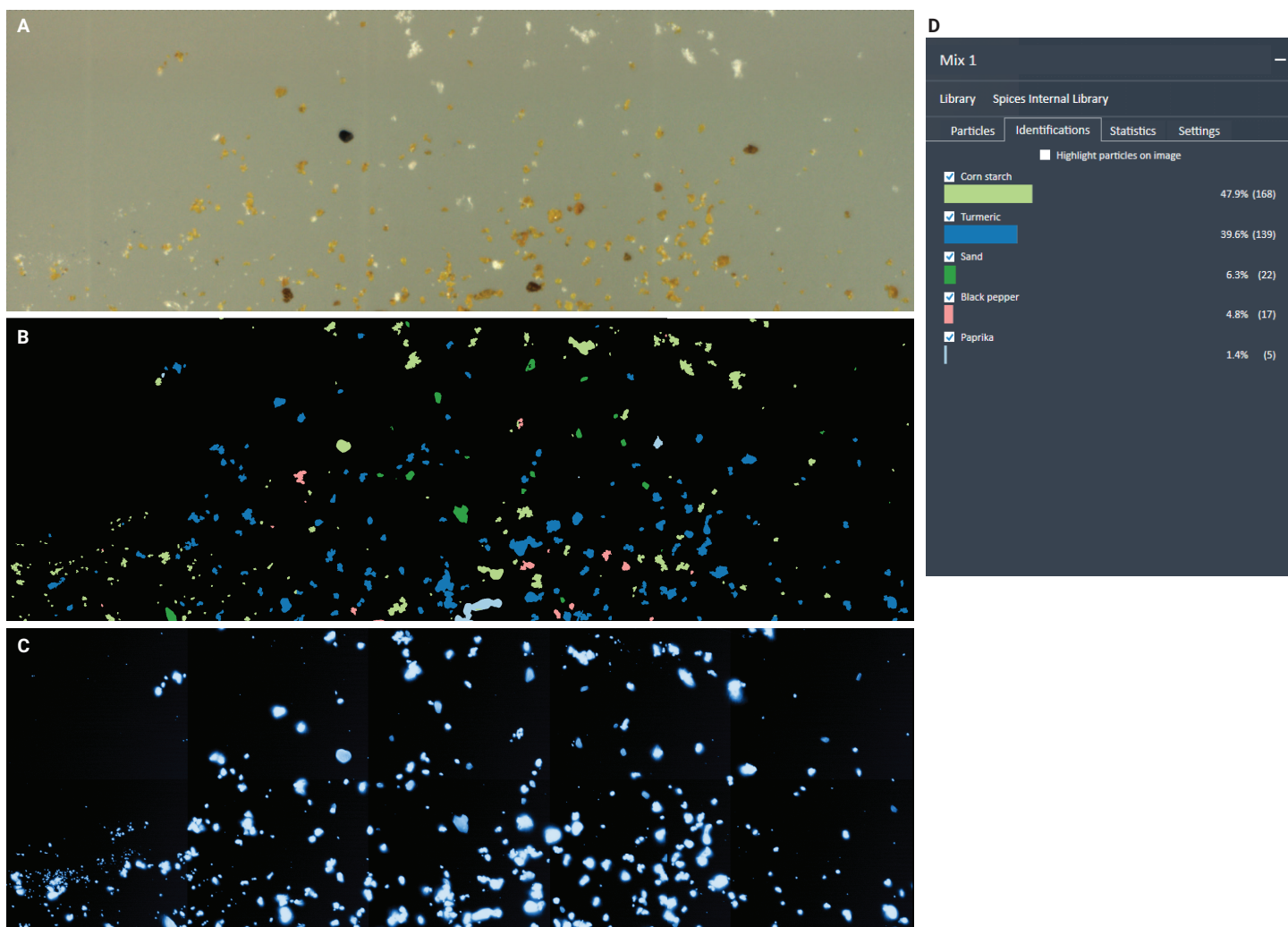


Figure 5. Adulterated spice mixture analyzed on a low-e slide using an Agilent 8700 LDIR and the automated Particle Analysis workflow within Agilent Clarity software. (A) Visible image of the area selected. (B) IR image scanned at $1,442\text{ cm}^{-1}$. (C) Highlights of particles found—the color of the particles relates to the type of particle on the slide. (D) Automatically generated statistical data based on the identification of particles in the sample.

As shown in Figure 6, both corn starch and sand exhibit distinct IR spectral profiles, enabling clear differentiation from turmeric. The use of first-derivative spectral matching in the Clarity software enhances spectral resolution and improves the discrimination of subtle infrared features, strengthening this approach for spice adulteration analysis.

Conclusion

This study demonstrates the suitability of the Agilent 8700 LDIR chemical imaging system with Agilent Clarity software as an effective tool for detecting adulteration in ground spices. Using the automated Particle Analysis (PA) workflow, the system quickly and reliably distinguished turmeric from both organic (corn starch) and inorganic (sand) adulterants based on their distinct IR spectral signatures.

Differentiating between chemically similar spices remains challenging due to overlapping IR profiles. However, the 8700 LDIR system's ability to build custom spectral libraries offers flexibility for targeted authentication, allowing laboratories to adapt the system to their evolving analytical needs.

A key advantage of the 8700 LDIR method is the speed and simplicity of sample preparation—dry powders can be analyzed directly on low-e slides without solvents or extraction. By combining the high-throughput automated PA workflow with integrated imaging, the 8700 LDIR provides a practical, time-saving solution for routine analysis in food testing laboratories.

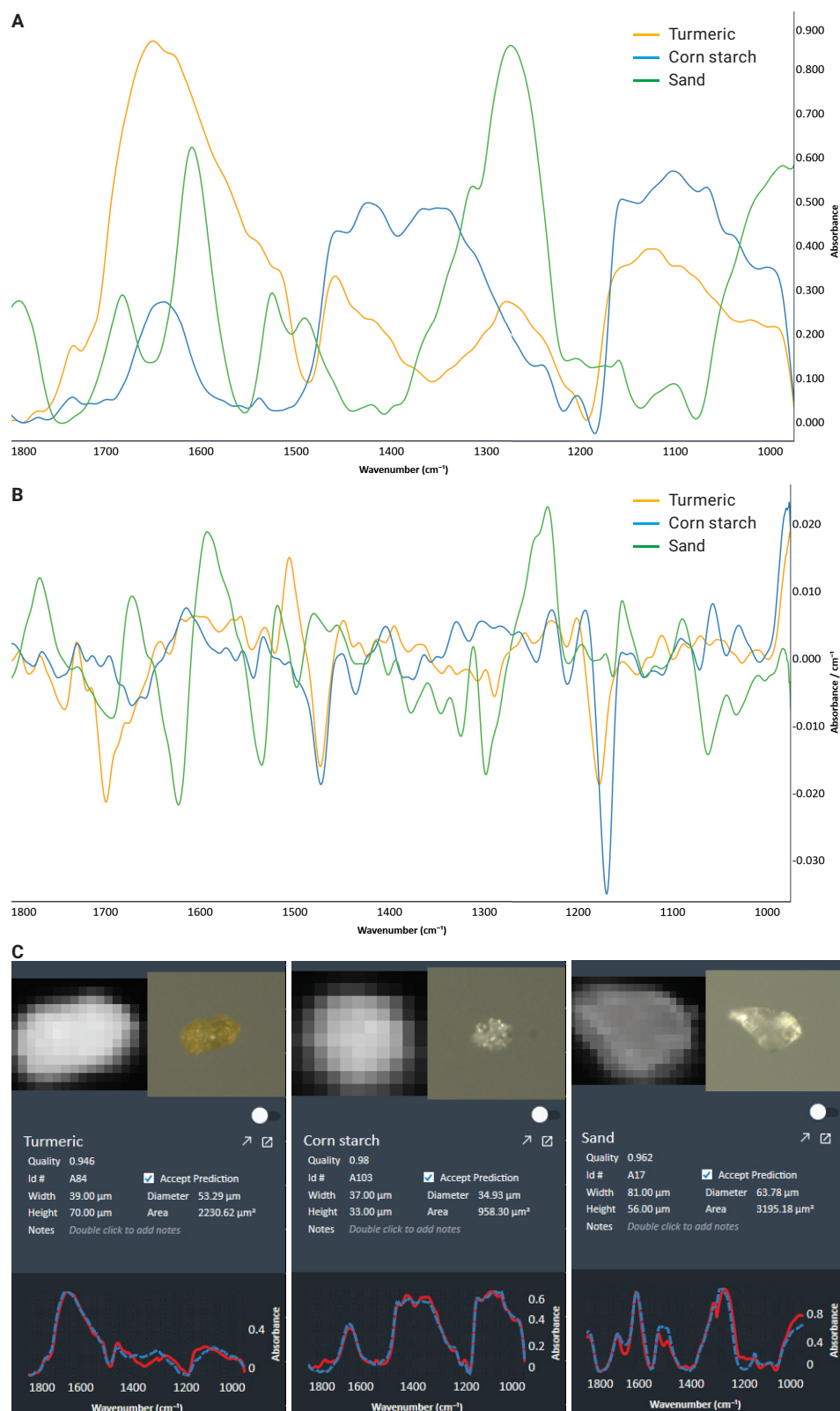


Figure 6. Overlay of IR spectra for turmeric (yellow), corn starch (blue), and sand (green). (A) Absorbance spectra. (B) First-derivative spectra used for matching. (C) Examples of particles (solid red line) identified in the adulterated spice mixture sample by matching to the library spectrum (dashed blue line).

References

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