

# SAFEGUARDING HERB AND SPICE AUTHENTICITY





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# SAFEGUARDING HERB AND SPICE AUTHENTICITY

Infrared (IR) and near-infrared (NIR) spectroscopy are fast, easy-to-use techniques with applications in a wide variety of industries. The technique also has a history of being used for food applications such as those for measuring protein, moisture, and fat content. Food fraud and adulteration has become of particular concern to the industry over the past few years following reports of incidents in the media, with herbs and spices identified as one of the key problem areas. NIR spectroscopy used with the method outlined here can provide a rapid screening technique for detecting adulteration in herbs and spices.

This technique is non-destructive and does not affect the integrity of the sample. NIR absorbances are derived from the fundamental IR absorptions and appear at multiples of the fundamental bands (overtones) and at combinations of the fundamental bands (combination bands).

There are two main different ranges of IR radiation:

- Near-Infrared (NIR): 15000 – 4000  $\text{cm}^{-1}$
- Mid-Infrared (MIR): 4000 – 400  $\text{cm}^{-1}$

The range used is selected based on the material being studied and the area of interest. In some cases, the same substance can be studied using different ranges, yielding complementary results.

Once the spectra have been collected, multivariate data analysis techniques, known as chemometric techniques, can be used. Principal components analysis (PCA) is one such technique, and allows new samples to be compared to a model built from a large database of existing samples of a particular material. In this way, authenticity can be determined and adulteration detected.

NIR spectroscopy is an inexpensive, non-destructive technique, and can be used as a screening method for food fraud and adulteration and as a precursor to further testing, should it be required.

## Spectrum Two N FT-NIR

The PerkinElmer Spectrum Two N™ is a robust and portable FT-NIR spectrometer, capable of easy and reliable IR analysis. The NIR Reflectance Module (NIRM) enables near-infrared diffuse reflectance analysis of a wide range of samples.



Figure 1. Spectrum Two N FT-NIR with a NIR Reflectance Module (NIRM).

## Advantages of Near Infrared Spectroscopy for Herb and Spice Analysis

Though both MIR and NIR have their place in food analysis, for herb and spice analysis, NIR has generally been proven to be superior. While a MIR spectrum will mostly show large primary vibration bands of basic functional groups, a NIR spectrum will display more complex overtones, giving a better representation of what is a naturally varied sample group. The sampling techniques commonly used for each are attenuated total reflectance (ATR) for MIR and diffuse reflectance for NIR. ATR is only capable of measuring a small area of the sample in one scan; this may be a piece of leaf or stem and there is no way of guaranteeing that the adulterant is evenly distributed through the product. Blending the sample can help, but the results are still poor and inconsistent. This makes it difficult not just to detect adulteration, especially at low levels, but also to build up a representative database of pure material in the first place. Diffuse reflectance, however, measures a much larger area of the sample and penetrates further into the sample, generating a longer effective pathlength. This, together with spinning the sample as it is scanned, yields not only stronger spectra that are better for detecting adulteration, but more repeatable and reliable results.

Figures 2a and 2c show two sets of spectra, one produced using MIR (2a) and one using NIR (2c). The mean and standard deviation of 10 different sage sample scans are shown. It is clear that across different samples of the same type, NIR gives much less variation in results. Grinding the sage into a powdered form to measure using MIR-ATR was also tested (Figure 2b), but still did not yield results that were as consistent as NIR. The other drawback of this type of sample preparation is that the product cannot be used after testing.

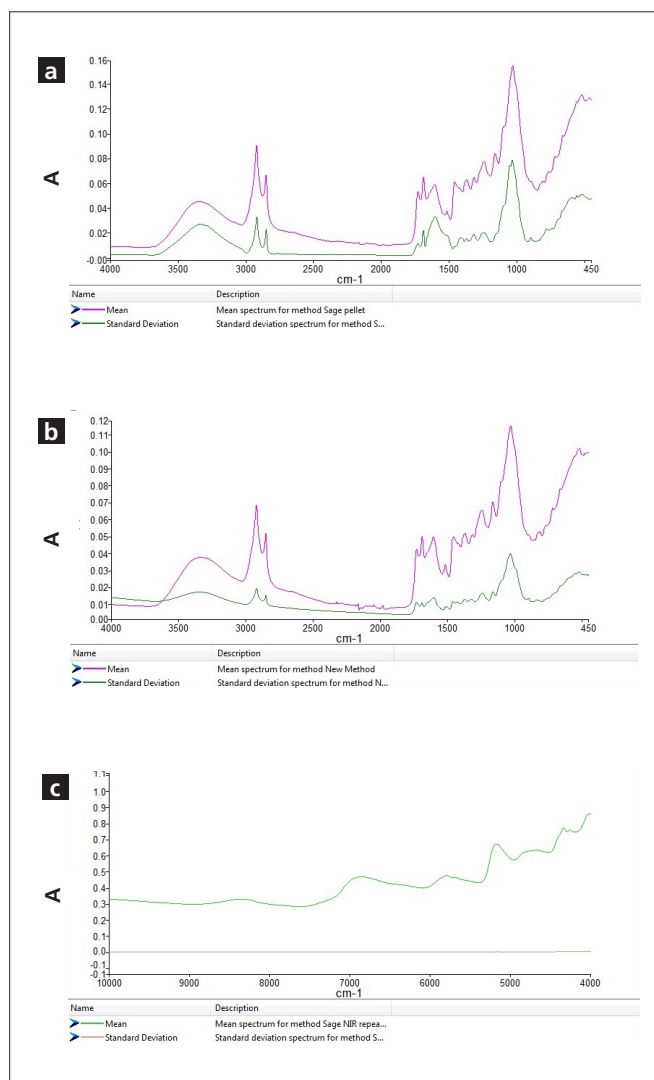




Figure 2. Mean and Standard Deviation of: (a) Mid-IR spectra of unhomogenized sage; (b) Mid-IR spectra of powdered sage; (c) Near-IR spectra of unhomogenized sage.

The MIR and NIR methods are compared in Table 1 below:

Table 1. Comparison of mid- and near-IR methods.

	Near-IR	Mid-IR
Sampling Type	Diffuse reflectance (non-destructive)	Attenuated total reflectance (non-destructive)
Sampling Size	 Large (60-100 mm across)	 Small (2 mm across)
Sample Quantity	Several grams (generally not an issue as plenty of sample is usually available)	Milligrams
Sample Requirements	Inhomogeneous/homogeneous liquids and powders/solids	Homogeneous liquids and powders/solids
Sampling Reproducibility	High	Poor for inhomogeneous materials but high for liquids
Sampling Consumables	Glass Petri dishes – transmit Near-IR radiation, are relatively low-cost, and no accessory cleaning is required	Cleaning with solvent and tissue
Sample Pathlength	~100 $\mu\text{m}$ to several millimetres	A few microns ( $\mu\text{m}$ )

Using the new NIR Reflectance Module with Spectrum 10 and Adulterant Screen software, food fraud can be screened for in a fast, simple, and efficient way.

## Assure ID

Principal components analysis (PCA) is an important technique for this kind of analysis, as it allows sample types, rather than one specific sample, to be modelled and studied. Assure ID software employs PCA to build Soft Independent Modeling Class Analogies (SIMCA) models of different materials. A model can be generated for sage, for example, including many spectral scans of different sage samples.

Each individual sample scan is assigned a score for each principal component (essentially a key feature of the spectrum.) These scores are then plotted in multiple dimensions to build up a region of acceptable variation of that sample type. When a new sample is tested against the model, it will either fall inside or outside this region, depending on whether it complies with the model samples or not. A range of pre-processing tools are easily accessed and available to optimize the response of the models. In addition to this, there is the option to add in validation samples which can be tested against the model.

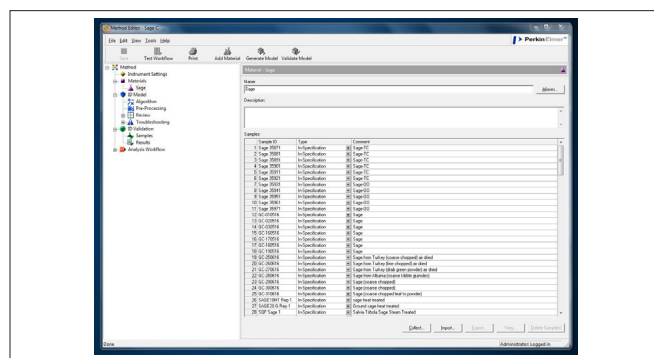


Figure 3. Sample scans can easily be added into the model, after which a variety of options are available to refine and optimize the model.

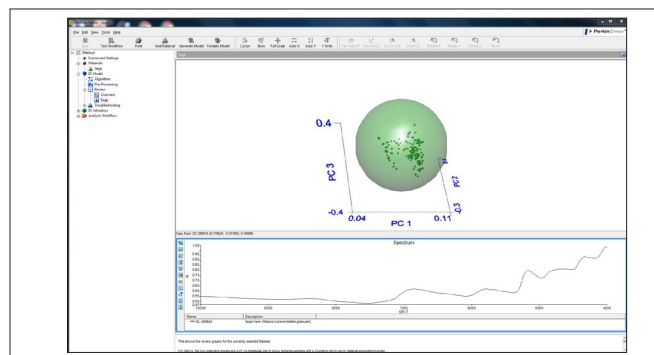


Figure 4. The SIMCA model along with the spectra can be reviewed here.



## Spectrum 10, Spectrum Touch and Adulterant Screen

Spectrum 10™, the IR software platform used for all PerkinElmer IR spectrometers, performs the data collection and processing options for the analysis. These functions and also Adulterant Screen can be incorporated into Spectrum Touch methods, allowing a workflow approach to methods and simple routine operation. Adulterant Screen is able to detect the presence of adulterants within samples and estimate the level of adulteration. To provide a more user-friendly interface, Spectrum Touch™ software enables users to access methods from a menu and run them with detailed step-by-step instructions. This eliminates the need for costly and time-consuming training. The results page shows an easy-to-read pass/fail result, color-coded red or green accordingly, with action instructions based on the result. More detailed results are also accessible from the drop-down menu, providing in-depth information, should it be required.

When compiling the databases, it is important to include as much natural variation as possible. This can include different geographical origins, plant species, pre-treatments and batches. This ensures that all variation is accounted for in the model and that samples do not fail simply because they have been grown or treated in a certain way. If there is an insufficient number of samples in the model, the detection limits for adulterants may also be too high, leading to misclassification of a sample.

With minimal sample preparation, scanning samples is straightforward; in the case of many of the herbs and spices studied here, the products are already in a suitable granular or powdered form. The sample is simply placed in a Petri dish, with two sizes available depending on the quantity at hand and sample type (60 or 100 mm diameter), and the Petri dish placed on the spinner. The scan conditions used are shown below.

## Methodology

The first step in creating databases to which new samples can be compared is collecting reliably authentic samples. To do this, PerkinElmer has sourced herb and spice samples from The Bart Ingredients Company, Sleaford Quality Foods, and Campden BRI. The portability of the Spectrum Two N allowed samples to be scanned on site at each of these locations with minimal set-up time. The non-destructive nature of this method also meant that samples could be scanned and then returned to their original containers.

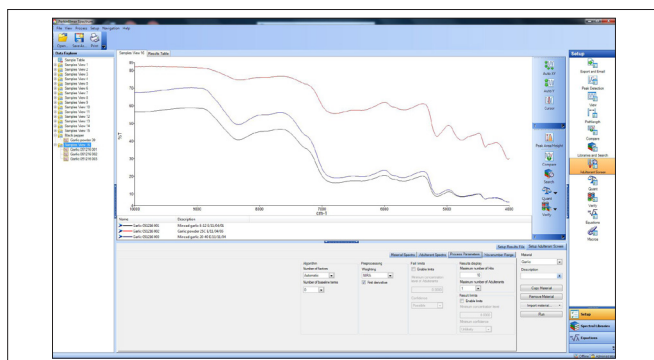


Figure 5. Adulterant Screen and Spectrum 10 software.



Figure 6. Spectrum Touch method for garlic.

Table 2. Comparison of mid- and near-IR methods.

<b>Spectral Range</b>	10000 – 4000 $\text{cm}^{-1}$
<b>Time</b>	~60 seconds
<b>Accumulations</b>	32
<b>Resolution</b>	8 $\text{cm}^{-1}$

In order to test the differences between the small and large Petri dishes, ten portions of the same sample were scanned in large and small Petri dishes and the standard deviation of the results calculated. This was done for both chopped sage, which is an inhomogenous mixture of leaf and stem, and paprika, which is a homogenous powder.

The results show that there is little to no meaningful difference between the spectra obtained using different size Petri dishes. This means samples can be scanned in smaller quantities, if necessary, without compromising the results.

Principal components analysis (PCA) is carried out using Assure ID software. In this way, models of the pure material can be built. The model, an example of which is shown in Figure 8, is effectively a region of acceptable principal component composition: the boundary of the model defines the limit of acceptable variation in these principal components. Similar samples sharing a characteristic, such as origin or processing, are likely to have similar PC scores, leading them to 'cluster'. Samples can be tested against this model alone to give a pass/fail result, depending on whether they lie in or outside the boundary. However, this gives the user no information about the reason the samples have failed: the result is only qualitative.

For this reason, Spectrum Adulterant Screen software can also be applied. It provides a semi-quantitative method that gives the user more information without the time-consuming process of preparing calibration standards as in a traditional quantitative methodology. It works by taking the SIMCA model, and one spectrum of each potential adulterant and comparing those to the spectrum of an unknown sample.

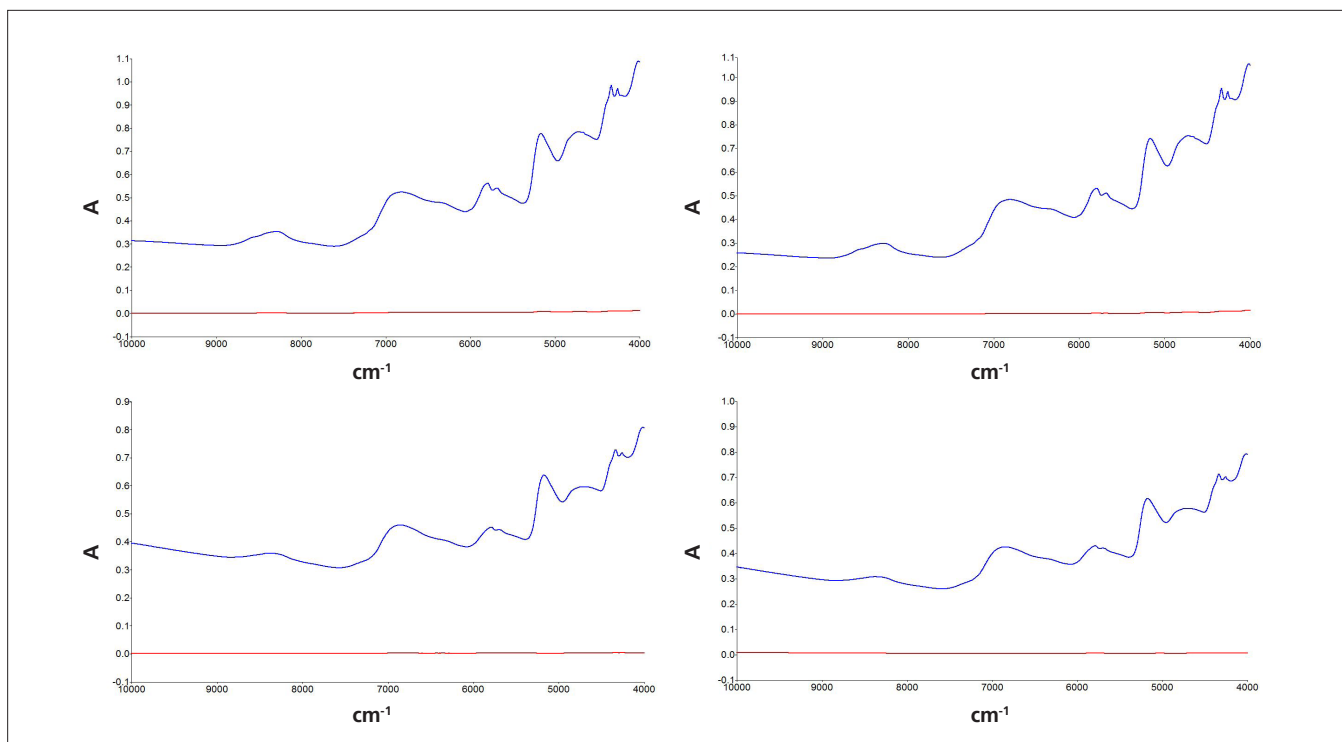


Figure 7. Top-left: Paprika in large Petri dish; Top-right: Paprika in small Petri dish; Bottom-left: Sage in large Petri dish; Bottom-right: Sage in small Petri dish.

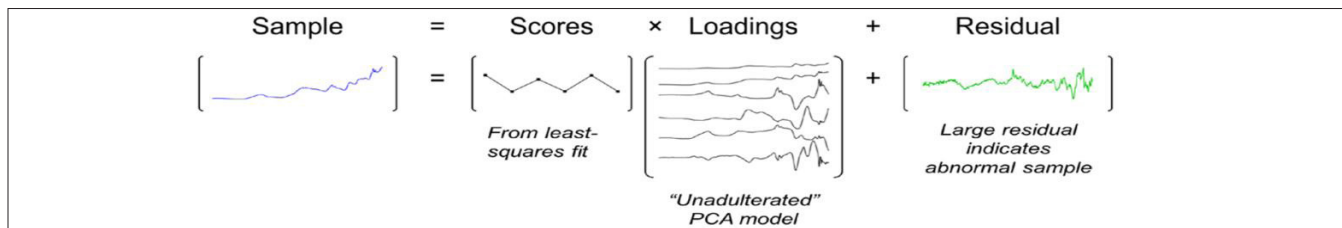


Figure 8. Residual calculated by comparing new sample scan to PCA model.

The spectra in the model are converted into a set of scores for each loading of the PCA model, and the part of the spectrum that cannot be described by the model is the residual. A large residual indicates an abnormal sample. By including adulterant spectra in the model and repeating the process, the software can determine whether a sample is likely to contain an adulterant; if the residual is reduced and the sample spectrum fits the model better when an adulterant is included, this is an indication that the adulterant is present in the sample.

The algorithm can also account for different combinations of up to three adulterants. Adulterant Screen software provides estimates for the concentrations of adulterants based on the relative intensities of the adulterant and sample spectra, detection limits for adulterants, and a confidence indicator. If the software cannot find an exact match in the database of adulterant spectra, but the sample shows noticeable differences from the model, the sample will fail and the identity of the adulterant will appear in the results as “unknown”. In this way, Adulterant Screen can still detect abnormalities, even if it cannot work out exactly what the adulterant is. With new ways of adulterating food appearing all the time, this method has a huge benefit over quantitative methods, since it is not necessary to know what adulterants are present in order to detect them.

To test this method, a number of adulteration studies were carried out with samples of different herbs and spices spiked with known potential adulterants, defined as being of higher risk by herb and spice companies. Further details regarding the types of adulterants used are provided in the following sections.

The detection limits achieved by this study are in the region of 0.1 – 5 %, depending on the material and the adulterant. Those with noticeable spectral differences, such as talc and garlic powder, are easier to distinguish than, for example, sage and oregano. Although these detection limits are not comparable to those attainable by other, more expensive, analytical methods this method is intended only as a quick screening test and many instances of adulteration will occur at higher percentages than the detection limits given here.

The results of both the PCA analysis and Adulterant Screen can be brought together in the Spectrum Touch platform. The easy-to-use interface has drop-down menus that allow the user to view more detailed results from each part of the analysis, in addition to the initial pass/fail results shown.

## Herbs and Spices Analyzed

Cayenne Pepper and Chili Powder

Cinnamon and Cassia

Coriander

Cumin

Garlic

Oregano

Paprika

Saffron

Sage

Turmeric

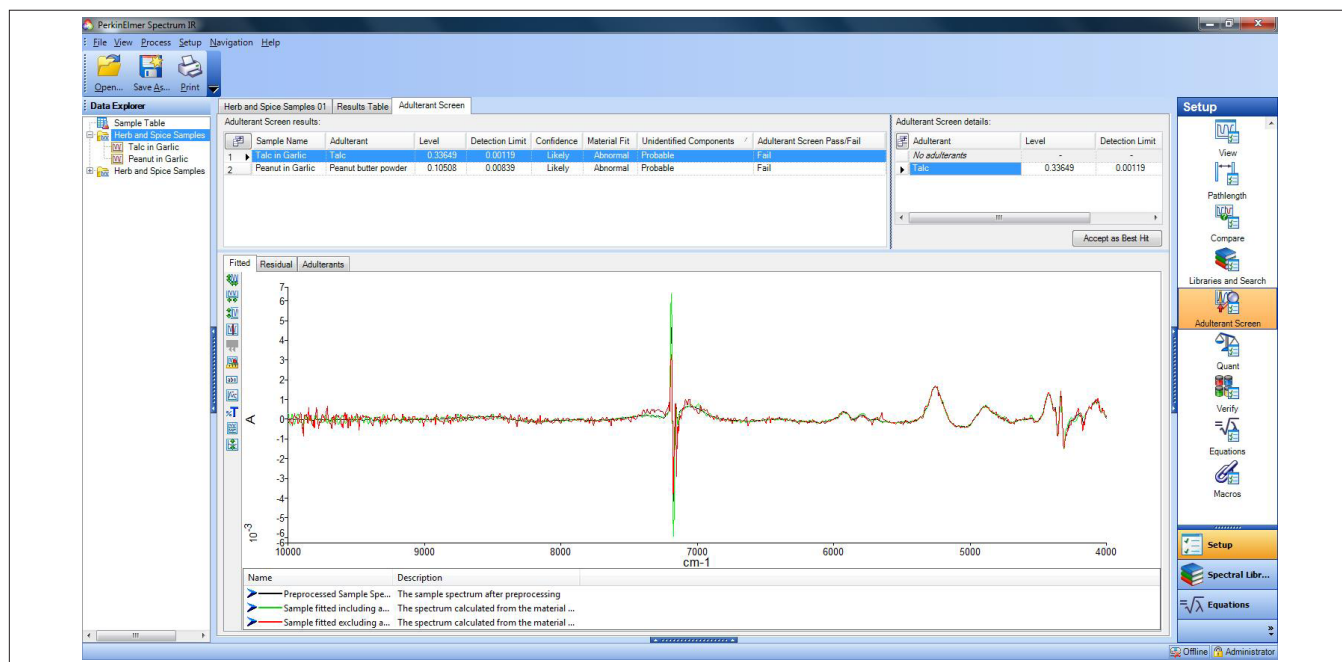


Figure 9. Adulterant Screen results in Spectrum 10 software.

## Cayenne Pepper and Chili Powder

Cayenne pepper has a particularly long history of adulteration incidents, dating back to the mid-19<sup>th</sup> century, where red lead ( $Pb_3O_4$ ), vermillion ( $HgS$ ), and venetian red ( $Fe_2O_3$ ) were added to color fillers such as ground rice, mustard seed husks, sawdust, and salt<sup>1</sup>. More recently, Sudan I dye has been found in chili powder and chili products; in 2005, Sudan I was found in chili powder in China and Worcestershire sauce in the UK, and two years later, it was also found in supermarket spices in South Africa<sup>2, 3</sup>. Other fillers such as rice husk and rice flour, and even brick dust, are also being identified in Indian chili supplies as well as  $Fe_2O_3$  and Rhodamine B in Pakistan<sup>4, 5, 6</sup>.

Since cayenne pepper and chili powder are both of the genus capsicum, we have chosen to group them here together. Different analytical techniques, such as LC, would be required to distinguish between capsicum species.

One of the many benefits of this method of analysis is that it requires minimal sample preparation. Included in this model (Figure 10) are samples of chili powders, though whole chilies can also be tested in a separate model to ensure the chilies are not coated with anything to increase the weight or improve the color.

Results of the adulteration studies for cayenne pepper and chili powder are shown in Table 3.

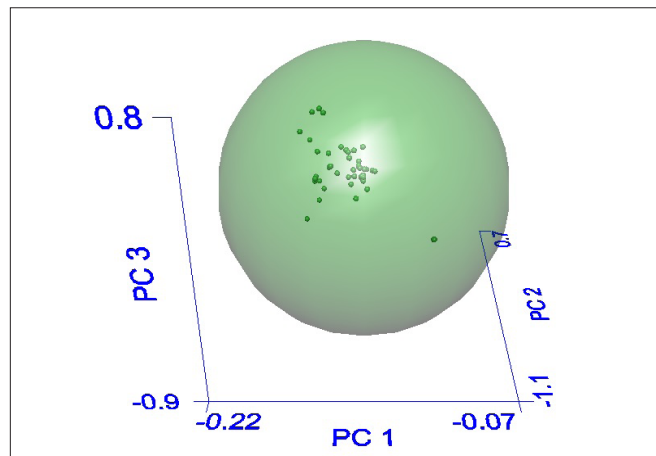


Figure 10. SIMCA model of Cayenne Pepper and Chili Powder.

### Summary

Adulterant Screen software has correctly identified the adulterants present in these samples with slight overestimates of some of the levels of adulterants. However, the current model is incapable of distinguishing between cayenne pepper and chili pepper powders.

Table 3. Adulteration study results for spiked samples of Cayenne Pepper and Chili Powder.

Spiked Cayenne Pepper and Chili Powder Samples	Material Detected	Amount Detected	LOD
10 % rice flour in cayenne pepper	Rice flour	12.7 %	1.2 %
10 % red food coloring in cayenne pepper	Red food coloring	13.7 %	1.6 %
10 % sawdust in cayenne pepper	Sawdust	10.2 %	1.9 %
10 % rice flour in chili powder	Rice flour	15.3 %	1.2 %
5 % Sudan I dye in chili powder	Sudan I dye	15.5 %	0.4 %



## Cinnamon and Cassia

Ground cinnamon, as with all other finely ground products, has been found to contain common adulterants, such as flours and other bulking agents. This is reflected in the adulterants studied. Coffee husks have also been identified in cinnamon in the past<sup>7</sup>. However, the main issue with cinnamon authentication reported in news articles is adulteration with the similar, but cheaper, cassia<sup>8,9</sup>. After several tests, we acknowledge that this method of herb and spice screening does not give sufficiently accurate results for the detection of cassia in cinnamon. Other analytical techniques may be used. Alternatively, a quick test using iodine may be done; adding a drop of iodine to a small amount of powder will reveal a blue color if it is cassia, but no color change if it is cinnamon<sup>10</sup>. If, on the other hand, cassia adulteration is not a concern, this method may be used to study both cinnamon and cassia as they are indistinguishable by NIR (based on current database samples).

In yet another case where two types of one sample can be studied, this model includes both ground cinnamon and cinnamon sticks. The cinnamon sticks can be prepared simply by breaking them into smaller pieces by hand. The model (Figure 11) shows little difference between the two sample types, suggesting either sample type can be studied using this model.

Results of the adulteration studies for cinnamon are shown in Table 4.

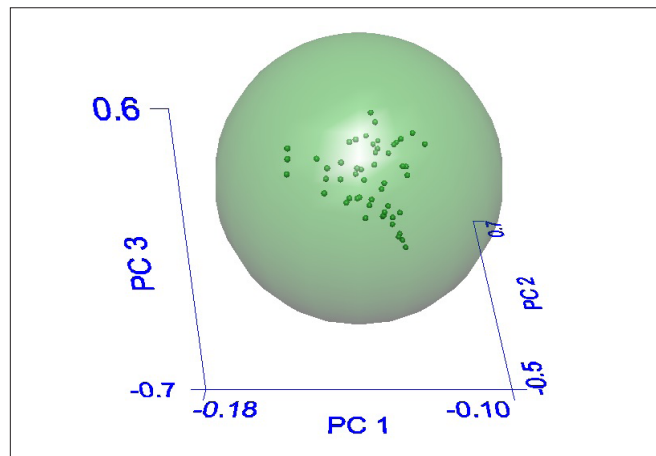


Figure 11. SIMCA model of Cinnamon.

### Summary

Adulterant Screen software has correctly identified the adulterant present in a spiked sample with an accurate estimate of the level of adulterant. However, the current model is incapable of distinguishing between cinnamon and cassia. A quick iodine test would reveal the presence of cassia, if suspected.

Table 4. Adulteration study results for spiked sample of Cinnamon.

Spiked Cinnamon Sample	Material Detected	Amount Detected	LOD
10 % corn flour in cinnamon	Corn flour	10.6 %	2.7 %

## Coriander

As with many spices, fillers can be used to bulk out the weight of ground coriander. In the last few years, instances of ground rice husk, sawdust, and starch as fillers have all been reported<sup>5, 11</sup>. This adulteration was reportedly carried out at around 5 %. Therefore, when carrying out tests with spiked studies, a sample of 5 % w/w rice flour in coriander was prepared.

As with the chilies, both whole and ground coriander seeds can be tested using this method, however, only ground coriander seeds are shown in this model (Figure 12). Since the two sample types scatter light differently, each type is best analyzed using its own model.

Results of the adulteration studies for coriander are shown in Table 5.

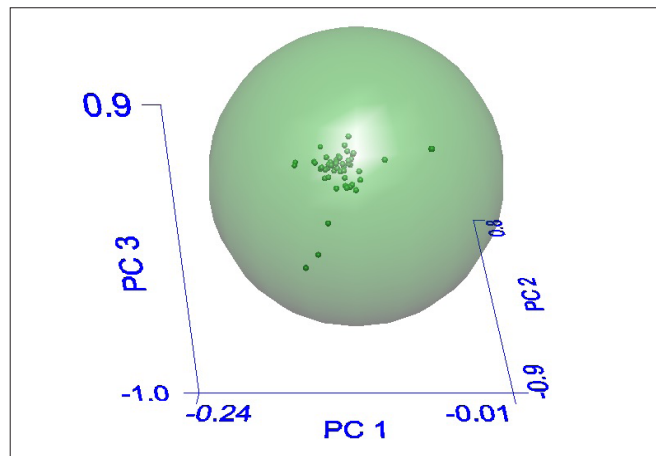


Figure 12. SIMCA model of Coriander.

## Summary

The model correctly identifies ground coriander seed samples. Adulterant Screen software has correctly identified the adulterants present in these samples with overestimates of the levels of adulterants.

Table 5. Adulteration study results for spiked samples of ground Coriander seed.

Spiked Coriander Samples	Material Detected	Amount Detected	LOD
5 % sawdust in coriander	Sawdust	10.6 %	2.1 %
5 % rice flour in coriander	Rice flour	12.0 %	1.0 %

## Cumin

In 2015, a poor cumin crop in India, caused by bad weather, led to prolific and widely reported adulteration with peanut and almond material<sup>12, 13</sup>. This, in turn, led to a withdrawal of some supermarket spice blend products and was a source of much concern for those who suffer from nut allergies<sup>14</sup>. Based on a scaled calculation, 10 % adulteration in 10 tons of cumin can result in a profit of \$4000<sup>15</sup>. Seeds of a similar shape and size to cumin have been passed off as cumin by coating them in marble dust and charcoal<sup>16</sup>. A similar technique has also been employed to make small, low-grade cumin seeds appear larger<sup>17</sup>.

Cumin is another case where there are both whole and ground products readily available. Both types are modelled here (Figure 13), with the larger cluster belonging to cumin powders. More samples of ground cumin were collected as these are more easily adulterated and more commonly used in domestic cooking.

Results of the adulteration studies for cumin are shown in Table 6.

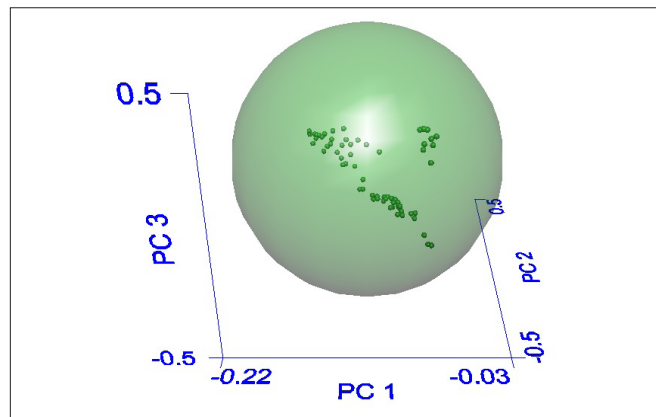


Figure 13. SIMCA model of Cumin.

### Summary

The model correctly identifies cumin samples. Adulterant Screen software has correctly identified the adulterants present in these samples with underestimates of some of the levels of adulterants, close to the estimated detection limits.

Table 6. Adulteration study results for spiked samples of Cumin.

Spiked Cumin Samples	Material Detected	Amount Detected	LOD
5 % peanut butter powder in cumin	Peanut butter powder	2.4 %	1.9 %
5 % almond in cumin	Almond	1.9 %	1.8 %
10 % grass seeds in cumin	Grass seeds	11.6 %	1.6 %

## Garlic

Of the dried garlic products, garlic powders are more likely to be adulterated than garlic granules or flakes, as they are easier to imitate. Any number of white or cream powders could be used in place of garlic powder, particularly starches, chalk, and talc<sup>18, 19</sup>. Although powders are the most likely to be adulterated, the method developed here can also be used with garlic granules, chips, and flakes.

The PCA model of garlic (Figure 14) shows a distinct difference between garlic chips, flakes, and granules; and garlic powders. This is due to the different-sized sample particles interacting with and scattering the light in different ways, with the cluster at the top-right containing garlic powders. The larger group on the left contains granules in the upper-right section and chips and flakes in the lower-left section. While it may be possible to separate these two groups into two separate models and methods, the definition of a powder will vary from user to user. Therefore, for the sake of clarity and ease of use, all sample types are accommodated in this model.

Results of the adulteration studies for garlic are shown in Table 7.

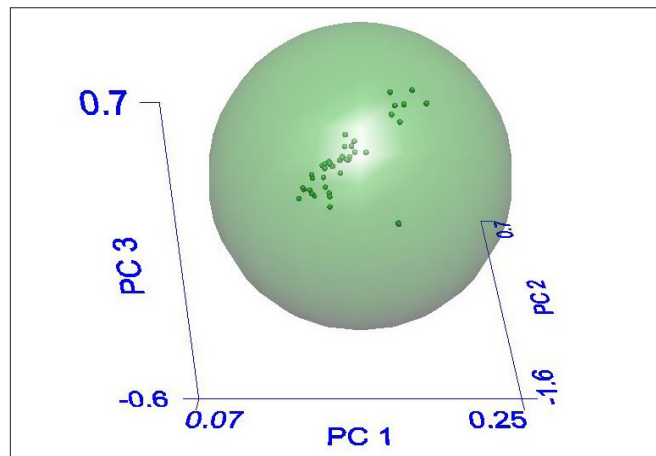


Figure 14. SIMCA model of Garlic.

### Summary

The model correctly identifies garlic samples in different physical forms. Adulterant Screen software has correctly identified the adulterants present in these samples with overestimates and underestimates of some of the levels of adulterants.

Table 7. Adulteration study results for spiked samples of Garlic.

Spiked Garlic Samples	Material Detected	Amount Detected	LOD
10 % talc in garlic powder	Talc	23.2 %	0.2 %
10 % peanut butter powder in garlic powder	Peanut butter powder	10.1 %	0.9 %
10 % wheat flour in garlic powder	Wheat flour	8.2 %	1.7 %
10 % rice flour in garlic powder	Rice flour	4.9 %	1.3 %
10 % corn flour in garlic powder	Corn flour	10.4 %	1.5 %



## Oregano

Many dried plants can be used to imitate oregano, including the leaves of cistus, blackberry, and sumac, as well as olive, myrtle, and hazelnut leaves<sup>20, 21</sup>. A study of oregano sold in UK and Ireland supermarkets revealed in 2015 that 25 % of products were adulterated at levels ranging from 30-70 %<sup>22</sup>. Thyme, marjoram, and 'Mexican oregano' lippia graveolens are also sometimes sold as oregano<sup>23</sup>.

The oregano model (Figure 15) does not display any obvious regions where certain sample types are more prevalent. Although some samples included were more finely ground rather than chopped, the difference in the spectra produced is not as visible as in other sample groups.

Results of the adulteration studies for oregano are shown in Table 8.

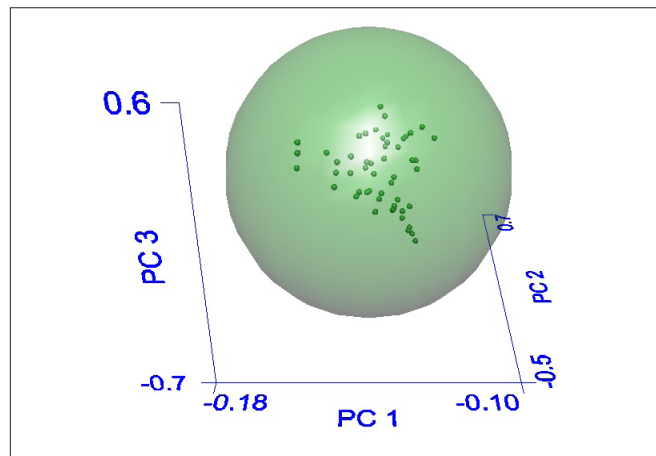


Figure 15. SIMCA model of Oregano.

### Summary

The model correctly identifies oregano samples. Adulterant Screen software has correctly identified the adulterants present in these samples with overestimates of the levels of adulterants.

Table 8. Adulteration study results for spiked samples of Oregano.

Spiked Oregano Samples	Material Detected	Amount Detected	LOD
10 % olive leaves in oregano	Olive leaves	20.8 %	4.2 %
10 % thyme in oregano	Thyme	12.2 %	5.3 %
10 % marjoram in oregano	Marjoram	16.2 %	2.9 %
10 % cistus leaves in oregano	Cistus leaves	11.5 %	4.4 %

## Paprika

Paprika has many purported health benefits, including lowering high blood pressure and improving eyesight<sup>24, 25, 26</sup>.

As with turmeric, paprika can be bulked out using other materials and then dyed; reported instances of such adulteration include the addition of white pepper and barium sulphate<sup>27</sup>. In 2015, small amounts of almond were found in paprika, leading to product recalls and fears for allergy sufferers<sup>12</sup>.

The model of paprika (Figure 16) shows a good continuity between all paprika samples collected, despite these being subject to different treatments in order to produce smoked, or sweet smoked as well as ordinary paprika.

Table 9 shows the results of adulteration studies with three different adulterants in paprika.

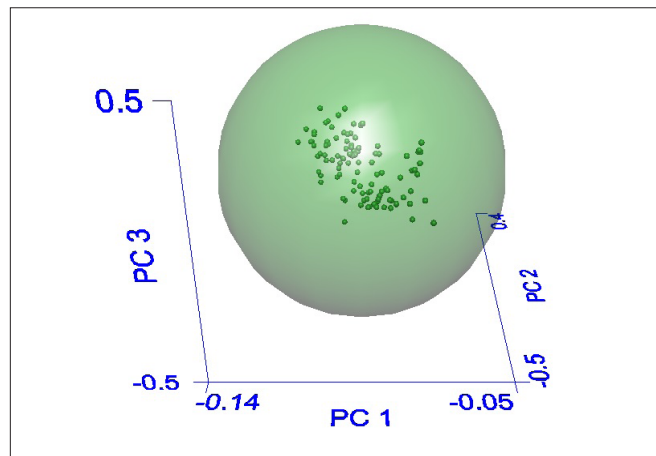


Figure 16. SIMCA model of Paprika.

## Summary

The model correctly identifies paprika samples. Adulterant Screen software has correctly identified the adulterants present in these samples with overestimates of the levels of adulterants.

Table 9. Adulteration study results for spiked samples of Paprika.

Spiked Paprika Samples	Material Detected	Amount Detected	LOD
10 % white pepper in paprika	White pepper	16.4 %	0.7 %
5 % Sudan I dye in paprika	Sudan I dye	15.4 %	0.3 %

## Saffron

As one of the most expensive spices in the world, saffron is highly susceptible to adulteration. Materials used to adulterate, imitate, and increase the weight of saffron include other parts of the *crocus sativus* flower, different species of plant, natural and synthetic dyes, and minerals. These range from relatively harmless, such as coating the fibers in honey or oil to increase the weight, to extremely harmful, as in the use of picric acid dye<sup>28, 29</sup>. An investigation in conjunction with a lab owned by the Ministry of Industry, Tourism, and Commerce in Spain in 2011 found that commercial saffron products were as much as 90 % adulterated with other floral matter<sup>30</sup>. In the same year, three people were arrested in Dubai after selling dyed corn hair as saffron<sup>31</sup>.

Samples of saffron with different geographical origins produce almost imperceptibly different spectra, and this phenomenon is reflected in the model. This highlights the importance of including as wide a range of samples as possible so as to accurately represent the material and account for all variation, therefore avoiding as much as possible the possibility of false negatives. The model reflects cultural differences in the form in which saffron is purchased, namely, filament or powder. In the saffron model (Figure 17), samples of Greek saffron appear in the top left of the cluster, while the rest are of Iranian origin.

Results of the adulteration studies for saffron are shown in Table 10.

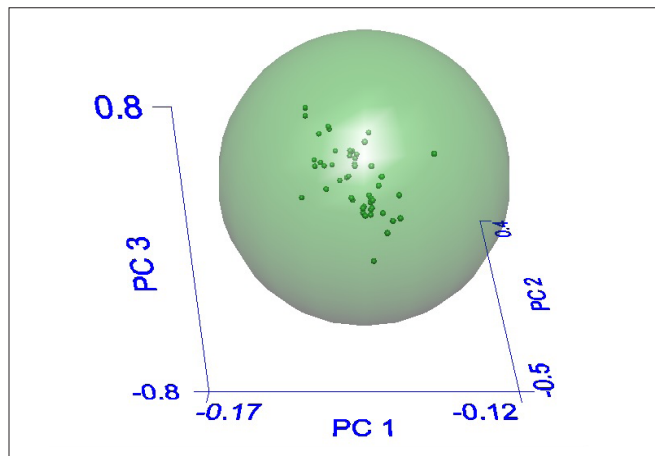


Figure 17. SIMCA model of Saffron.

### Summary

The model correctly identifies saffron samples. Adulterant Screen software has correctly identified the adulterants present in these samples with reasonable estimates of the levels of adulterants present. Additionally, the non-destructive nature of NIR spectroscopy allows this expensive material to be retained, as opposed to current destructive routine testing methods.

Table 10. Adulteration study results for spiked samples of Saffron.

Spiked Saffron Powder Samples	Material Detected	Amount Detected	LOD
10 % tartrazine in saffron powder	Tartrazine	9.2 %	1.0 %
2 % talc in saffron powder	Talc	2.5 %	0.3 %

## Sage

Many of the plants used to adulterate oregano can also be used to adulterate sage, including oregano itself<sup>32</sup>. These products are also primarily grown in similar regions, so for this reason, many of the same adulterants have been studied, along with a few others that bear resemblance to sage and could be substituted.

For sage, the model (Figure 18) appears much the same as that for oregano: there is little visible difference between the samples studied. There are, however, two samples, slightly away from the main cluster at the top right, which are a Jerusalem sage and a granulated sage from Albania, the latter appearing further left of the main cluster.

Results of the adulteration studies for sage are shown in Table 11.

### Summary

The model correctly identifies sage samples. Adulterant Screen software has correctly identified the adulterants present in these samples, but the estimates of the levels of adulterants are inaccurate.

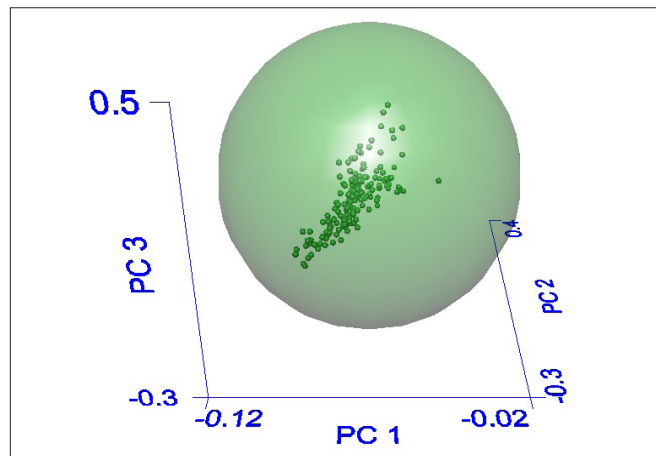


Figure 18. SIMCA model of Sage.

Table 11. Adulteration study results for spiked samples of Sage.

Spiked Sage Samples	Material Detected	Amount Detected	LOD
10 % oregano in sage	Oregano	11.9 %	4.8 %
10 % thyme in sage	Thyme	18.0 %	4.6 %
10 % basil in sage	Basil	25.7 %	3.8 %
10 % chives in sage	Chives	21.3 %	2.6 %
10 % cistus leaf in sage	Cistus leaf	14.1 %	3.7 %
10 % myrtle leaf in sage	Myrtle leaf	15.8 %	4.7 %
10 % strawberry tree leaf in sage	Strawberry tree leaf	4.6 %	1.8 %
10 % olive leaf in sage	Olive leaf	4.4 %	4.2 %



## Turmeric

Turmeric has been widely publicized recently as a 'miracle cure' for everything from depression to diabetes<sup>33</sup>. The anti-inflammatory properties of curcumin also make it a popular anti-aging solution and treatment for skin conditions<sup>34</sup>. With the growing popularity of this product, it's likely that it will be under even closer scrutiny, as suppliers hoping to capitalize on the trend may turn to adulteration in order to boost profits.

Sudan I dyes are well known as adulterants in a number of spices<sup>35</sup>. Materials such as flours or chalk dust, added to bulk out the product and maximize profits, can be dyed to give the same appearance as the spice. Dyes can also be used to improve the appearance and color of the spice itself as this can suggest better quality and higher curcumin content.

The model for turmeric (Figure 19) shows consistency in the samples collected, as seen by the lack of separate clusters and the limits on the PC axes.

Table 12 shows six different adulterants tested in turmeric, along with the amounts detected in each spiked sample.

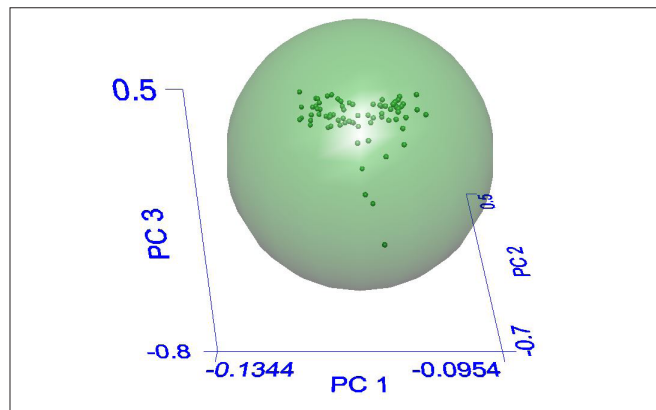


Figure 19. SIMCA model of Turmeric.

### Summary

The model correctly identifies turmeric samples. Adulterant Screen software has correctly identified the adulterants present in these samples, but the estimates of the levels of adulterants are inaccurate.

Table 12. Adulteration study results for spiked samples of Turmeric.

Spiked Turmeric Samples	Material Detected	Amount Detected	LOD
5 % Sudan I dye in turmeric	Sudan I dye	8.4 %	0.3 %
10 % sawdust in turmeric	Sawdust	3.0 %	0.9 %
10 % rice flour in turmeric	Rice flour	13.0 %	1.6 %
10 % corn flour in turmeric	Corn flour	17.5 %	2.2 %
10 % wheat flour in turmeric	Wheat flour	15.8 %	2.1 %

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