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## Characteristic fingerprints of adulterated tomato: alternative tools of rapid authentication

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### ABSTRACT

As an indispensable ingredient to cuisines around the world, tomato powder is amongst susceptible targets of profit-driven fraud. Our present study attempted at pinpointing characteristic spectral fingerprints of Annatto-adulterated tomato powders. Multivariate assessment with Principal component analysis (PCA), Linear discriminant analysis (LDA) and Partial Least Squares Regression (PLSR) showed that near infrared (NIR)-based evaluation of the samples could detect differences of authenticity as well as quantify the varying levels of adulteration (0.5%, 1%, 2%, 5%, 10%, 15% and 20%). With LDA prediction rate of 92.68% and PLSR coefficient of cross-validation ( $R^2_{CV}$ ) of 0.98 and Root Mean Square Error of cross-validation (RMSECV) of 0.81 (g/100 g), we can attest to the adequacy of the applied method for rapid authentication purposes.

**Keywords:** NIR spectroscopy, tomato powder, Annatto powder, adulteration

### 1. INTRODUCTION

The food industry has a long history of well-documented fraud scandals with effects that transcend borders and complications that can sometimes be life threatening [1,2]. To alleviate food insecurity, researchers are constantly looking up for novel techniques to keep pace with those perpetrating these deleterious acts. Standard techniques, despite their demonstrated efficiency, are known to be invasive, costly and require higher levels of technicality. Rapid analytical tools, on the other hand, can resolve such limitations and be instilled across the food production chain [3].

Near Infrared Spectroscopy, has been adopted as an alternative tool for the rapid authentication of a panoply of food products [4]. Powdery food ingredients, including spices have been particularly subjected to qualitative NIR analysis [5–8]. More recently,

in a study by Vitalis et al. [9], multi-component adulteration of tomato paste was investigated and adulterant concentrations even as low as 0.5% were accurately detected. Studied adulterants comprised paprika seed, corn starch, sucrose, and salt. Alongside these components, other potential inferior products can be deliberately added to tomato derived products to enhance their apparent organoleptic attributes. Annatto powder, which will be the subject of this particular study, has also been reportedly added as an adulterant [10,11].

## **2. AIMS**

Through conducting the present study, we seek to extend the research done on tomato derived products by determining the applicability of NIR Spectroscopy to detect and quantify the adulteration of Tomato powders with Annatto powder.

## **3. MATERIALS AND METHODS**

In this study, we place an emphasis on the application of near infrared spectroscopy for fingerprinting the adulteration of tomato powders. To do so, authentic powders extracted from three different tomato varieties (Navrongo, Tytanium and Tuobodom ) were intentionally tampered with Annatto powder in concentrations of 0.5%, 1%, 2%, 5%, 10%, 15% and 20% resulting in a total of 63 samples made up of three repeats of each mixture. Controls for each pure tomato variety and for Annatto powder were equally prepared in triplicates. The spectra of the powders were recorded on MetriNIR (MetriNIR Research, Development and Service Co., Budapest, Hungary) benchtop spectrometer in the wavelength range of 740-1700 nm. Rstudio software, particularly aquap2 package was applied to process the generated data and to build multivariate models such as Principal Component Analysis (PCA) to visualize the distribution pattern and understand more about the spectral variation of the samples, Linear Discriminant Analysis (LDA) with three-fold cross validation (CV) to classify the samples into groups depending on the levels of adulteration and Partial Least Squares Regression (PLSR) with ten-fold (CV) to quantify the added adulterant. Different spectral pretreatments (Savitzky-Golay (SG) smoothing, Multiplicative Scatter Correction (MSC) and Standard Normal Variate (SNV)) were applied for reduced noise and optimized data analysis.

## **4. RESULTS AND DISCUSSION**

#### 4.1. Linear Discriminant analysis of Annatto-adulterated tomato powders

The LDA models built to regroup the samples according to their corresponding varieties (Navrongo, Tytanium and Tuobodom) enabled a clear discrimination of three different groups with recognition and prediction rates amounting to 99.67% and 92.68% respectively. Likewise, LDA was proven effective when applied to classify the Annatto-adulterated tomato powders depending on their adulteration levels. This translated into 100% recognition and 91.0 % prediction accuracies, irrespective of the varieties. This is depicted in Figure 1 where a pattern of separation could be identified. Misclassifications were observed only between the 0.5%, 1% and 2% Annatto-containing powders.

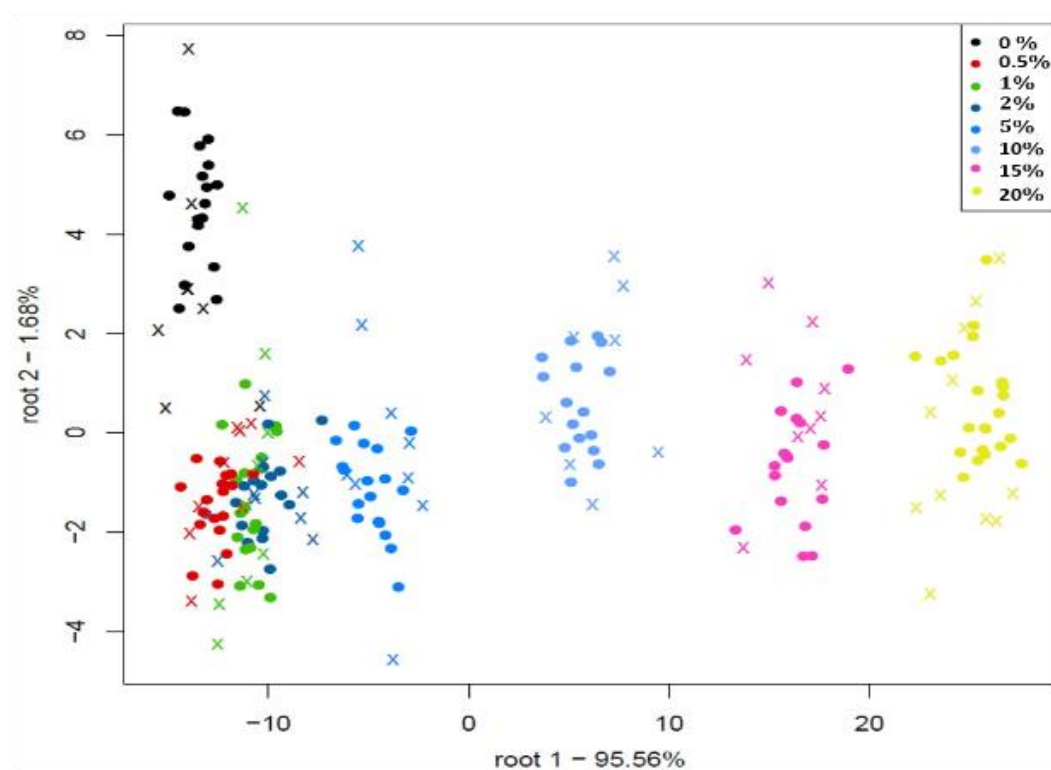


Figure 1: Classification plot of Annatto-adulterated tomato powders by adulteration levels, Spectral pre-processing: SNV (Standard Normal Variate)

#### 4.2. PLSR prediction of tomato powder adulteration

In quantifying the added Annatto powder by means of PLSR, the cross-validated models enabled an accurate determination of the different levels of adulteration with  $R^2_{CV}$  and RMSECV values of 0.98 and 0.81 g/100 g, respectively (Figure 2).

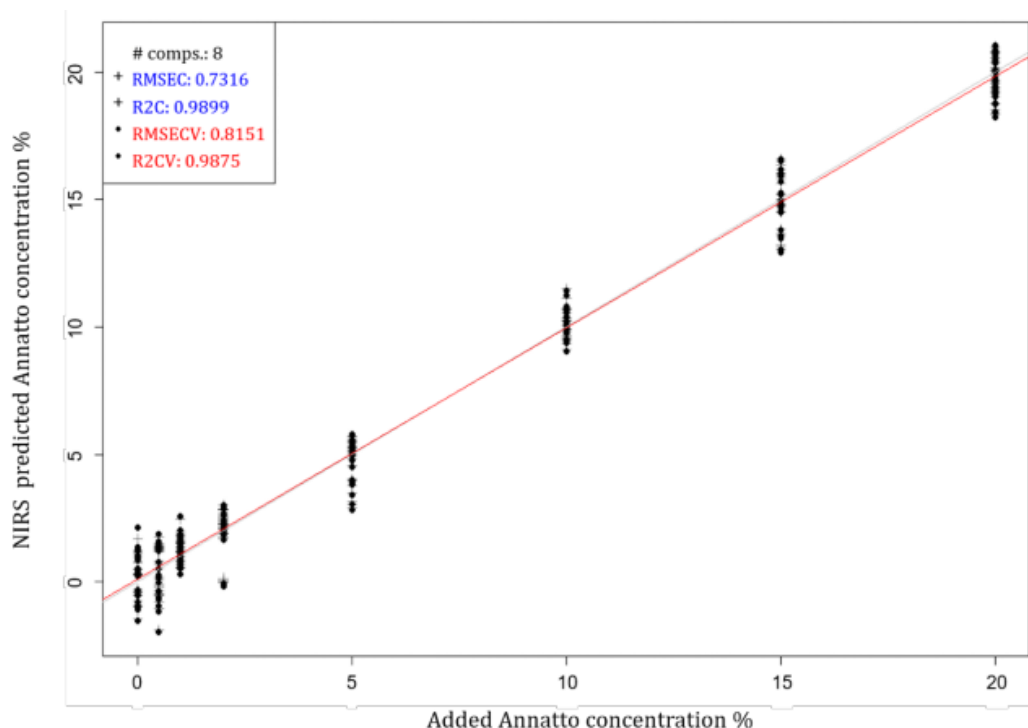


Figure 2: Y-fit graph of the prediction of Annatto concentration in adulterated tomato powder samples. Spectral pre-processing: SNV (Standard Normal Variate)

## 5. CONCLUSION

NIR spectroscopy was found to give typical spectral fingerprints to the tomato samples adulterated with Annatto powder. While LDA could distinguish between authentic and non-authentic samples through a distinctive separation pattern depending on the adulteration level, PLSR enabled a successful prediction of concentrations below 1%. These findings corroborate the suitability of the aforementioned method as an alternative tool of rapid authentication.

## 6. ACKNOWLEDGMENTS

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