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APPLICATION OF NIRS AND AQUAPHOTOMICS FOR THE DETECTION OF ADULTERATION OF HONEY, PAPRIKA AND TOMATO PASTE

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ABSTRACT

Over the course of the years, food adulteration has taken many shapes and forms, with the main motive of making profit often regardless of its detrimental effects. The complex nature of some adulterants can outmaneuver detection with conventional methods. The cost, high technicality and sensitivity of some conventional methods is a challenge in detecting new trends of adulteration. Near infrared spectroscopy (NIRS) and aquaphotomics provides an approach for rapid monitoring of food quality. Our research aimed to apply NIRS to detect and predict the concentrations of added starch, salt (NaCl) and sugar (sucrose) in tomato concentrates, corn flour in paprika powders and rice or beet syrup in honey. In total, 81 honey samples, 90 aqueous paprika powder solutions and 141 tomato paste samples, both authentic and adulterated, were used for the experiments. NIR spectra of the samples were recorded with MetriNIR in the range of the 740-1700 nm. Multivariate models such as Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA) and Partial Least Squares Regression (PLSR) were used for the discrimination of adulterated samples and the determination of the concentration of the different adulterants, respectively. Results of all the experiments provided high accuracy of prediction of the adulterating agents and also accurate classification results to classify the adulterants and control samples.

Keywords: NIRS, Aquaphotomics, Honey, Tomato paste, Paprika

INTRODUCTION

Food fraud is a global issue that challenges both the authorities and scientists. More and more fraudulent techniques are applied for several types of foods and beverages. Adulteration aims to gain financial advantage with the intentional fraud of food products however it also influences the perception of consumers by misleading them and undermining the trust for the food sector. Adulteration of food is not only an economical problem, but it can be harmful for health and cause varying degrees of illnesses⁽¹⁾. Fraudulent techniques include mislabeling, substitution, tampering, simulation, misleading statements and counterfeiting. In the past years numerous types of food have been adulterated. The most commonly manipulated foods are olive oil, honey, meat and fish, protein powders, wine, juices and spices^(2,3).

Honey is a widely used natural product made by honeybees. Different types of nutritious components can be found in honeys such as minerals, polyphenols, vitamins and other antioxidants⁽⁴⁾. Honey is usually adulterated in two ways, directly and indirectly but overheating, mislabeling, fermentation and coloring also, can be considered as a technique for honey fraud⁽⁵⁾. Direct adulteration means the blending of honeys with sugar syrups produced from C4 and C3 plants such as beet, rice and corn, while indirect adulteration is the feeding of bees with these syrups during the collecting period. As a result of this manipulations more honey can be produced but with lower quality⁽⁶⁾.

Tomato paste or concentrated tomato is produced from matured red tomatoes, without peels, seeds and other hard substances and also preserved physically. The concentrated tomato can be labelled as “tomato puree” or “tomato paste” when the product meets with the requirements. Puree should contain at least 7% but not more than 24% natural soluble solids, while concentrate should contain of these solids at least 24%⁽⁷⁾. When making the concentrates, only few ingredients can be added such as salt, spices, or aromatic herbs, lemon juice, and water, under strict regulations⁽⁸⁾ (EU, 2001). Tomato juices and purees can usually be adulterated by the addition of water, sugars, cheaper filler materials or non-acceptable colorants⁽⁹⁾. In some cases, starch is also added to achieve a more stabilized product.

Paprika powder is the powder of the milled *Capsicum annuum* berry. Capsicum fruits are present in different forms and they are well-known spices around the world⁽¹⁰⁾. Chemical composition of paprika mainly consist of water, fixed (fatty) oils, steam volatile oils, carotenoids, mineral elements, capsaicinoids, resin, protein and fiber. Color is one of the most important quality indicators of paprika and chili powders, but usually during the processing and storage, the redness of the powder can decrease, thereby, reducing consumer interest in the product. This fact, has led to the

adulteration of these product to keep the bright red color. Spices also have higher price in the market therefore inferior products are sometimes added to the spices to increase the volume⁽¹¹⁾ or boost other marketable sensory attributes. Paprika powder is sometimes preferred by consumers because, it is easy to use, affordable and has a good shelf-life. All over the world there have been reports about fraudulent activities in connection with paprika and chili powder, such as addition of colorants (Sudan-dyes) or oils⁽¹²⁾. In a Hungarian thesis several types of paprika adulteration were mentioned. These included mixing it with flour or bran, adding sunflower or pumpkin seed oil to reach a more vivid color⁽¹³⁾ or in Ghana paprika was suspected to be adulterated with avocado-seed powder, corn flour and food colorants.

Detecting food adulteration is a challenging task due to several creative trends of adulteration for numerous types of foods. As per the techniques used to detect such practices, they range from conventional tools to more sophisticated ones⁽¹⁴⁾. The most promising methods are the application of high performance liquid chromatography (HPLC), mass spectrometry(MS), nuclear magnetic resonance (NMR) and other instrumental analysis, however most of these techniques are time consuming or acquire chemicals and destructive sample preparation methods⁽¹⁵⁾. A non-destructive and rapid method, commonly known as the near infrared spectroscopy (NIRS) is also often applied for qualitative and quantitative food authentication. Aquaphotomics is a novel discipline studying the effect of substances dissolved in water with NIRS. The method relies on the monitoring of water spectral pattern changes caused by the dissolved molecules, with the expectation that, water can behave as a molecular mirror to indirectly measure other molecules that might not have absorbance within the NIR range. In aqueous systems the structure of water can change according to the surrounding components, resulting from the formation of water bond molecules in the matrix. This novel technique has been successfully used in the detection of honey adulteration with corn syrup⁽¹⁶⁾, discrimination of mineral waters⁽¹⁷⁾ and other food and non-food related studies^(18,19). In this paper we are introducing some adulteration techniques used in the manipulation of honey, paprika and tomato paste and advanced methods used in detecting them.

Our aim was to check the applicability of aquaphotomics technique for the detection of honey adulteration with syrups, paprika powder with corn flour and tomato paste with multiple adulterants: starch and paprika seed, salt and salt.

MATERIALS AND METHODS

Experimental design

Honey study

Linden honey (*Tilia spp.*) was adulterated with rice (RI) or beet syrup (BE) to contain 0.5%, 1%, 2%, 2.5%, 5%, 7.5%, 10%, 15%, 20%, 30%, 40% and 50% of the syrup. Each sample was prepared in three replicates including control (non-adulterated honey) and adulterants (RI and BE) resulting in 81 samples.

Paprika powder study

Authentic paprika powder samples were mixed with corn flour at ten increasing concentration levels: 0%, 1%, 3%, 5%, 10%, 15%, 20%, 25%, 30% and 40%. The mixtures were then diluted 10^1 , 10^2 and 10^3 times with distilled water and filtered after homogenization. This resulted in a total of 90 aqueous paprika powder solutions.

Tomato paste study

Authentic tomato concentrates (T) were acquired from a tomato processing plant in Kecskemét, Hungary and adulterated with ground paprika seed (P), corn starch (K), sugar (sucrose, C) and salt (sodium chloride, S). Tomato concentrates were falsified according to a matrix encompassing all the potential (suspected) combinations of the adulterants: paprika seed powder and starch (0.5%, 1%, 2%, 5%, 10%), sugar and salt (0.5%, 1%, 2%, 5%). There was a total of eleven combinations: T, C, S, WK, CS, WKC, WKS, WKCS, WP, WPC, WPS, WPCS with some samples containing multiple adulterants. Distilled water (W) was added to the samples containing starch to maintain predetermined consistencies. In all, 141 adulterated samples made up of three repeats each and one control, were prepared.

NIRS measurements.

The transreflectance spectra of the samples were recorded with MetriNIR spectrometer in the wavelength range of 740 to 1700 nm, for all the sample sets. The layer thickness of the cuvette was 0.4 mm, and in the case of the honey and tomato paste experiment the cuvette was equipped with a cape allowing temperature control with the usage of water circulation at 25 °C. In the case of the honey study five consecutive scans were recorded per sample, water was measured after every 5 samples resulting in 495 spectra in total. For aqueous paprika powder and tomato paste study, three consecutive scans were recorded for each triplicate sample and pure water was scanned after every

10 samples resulting in a total of and 336 spectra for aqueous paprika adulteration study and 468 spectra for the tomato paste adulteration study.

Statistical analysis

Before the statistical analysis pretreatments were applied on the absorbance spectra of all the sample sets. In the case of the honey and tomato paste experiments Savitzky-Golay smoothing filter (2nd order polynomial and 21 number of points) and multiplicative scatter correction (MSC) pretreatments were applied in the spectral ranges of 950-1650 nm and 1300-1600 nm, respectively. In the case of paprika powder evaluation, besides the aforementioned pretreatments, a detrending and an averaging of the spectra were performed in the 1300-1600 nm range

The aquap2 package in R-project was applied to build multivariate models such as Principal Component Analysis (PCA), Soft independent modeling of class analogies (SIMCA), Linear Discriminant Analysis (LDA) and Partial Least Squares Regression (PLSR) for the discrimination of adulterated samples and the quantification of adulterants, respectively. Three-fold cross validation was used in the LDA for tomato paste and aqueous paprika study. The spectral range from 1300 to 1600 nm has been reported to contain the 12 main water matrix absorbance coordinates (WAMACs), so it was adopted for our aquaphotomics analysis⁽²⁰⁾ (Pollner & Kovacs, 2016).

RESULTS AND DISCUSSION

Results of the honey experiment

Results of NIRS provided an increasing absorbance in the range of 1300-1450 nm region with the increasing addition of the syrup for both types of adulterants. Principal component analysis of the spectra showed a separation tendency through PC1 (Figure 1). In the case of the rice syrup adulterated honeys the 1274 nm, 1348 nm, 1422 nm, and 1580 nm wavelengths had the highest role in the formation of PC 1 which describes the 97.59% of the total variance.

In the case of beet syrup adulterated honey 1290 nm, 1426 nm and 1588 nm showed the highest contribution, where PC 1 covered 94.53% of the total variance. The peaks of 1274 nm and 1290 nm belonging to the second overtone region CH stretches. 1348, 1422 and 1426 are in the first overtone region and can be related to the OH stretches and water content of the samples.

Wavelengths of 1580-1590 nm can be assigned to specific sugar peaks of glucose, fructose and sucrose in solutions that are the sugars mainly present in honeys^(16,21).

In both types of adulteration, PLSR models showed high correlation between the originally added and predicted concentration of the syrup with higher than 0.99 R^2 value for calibration and validation, respectively. The error of prediction in both cases were under 1% but better results were obtained for the honeys adulterated with the beet syrup. The detailed parameters and contributing wavelengths can be seen in

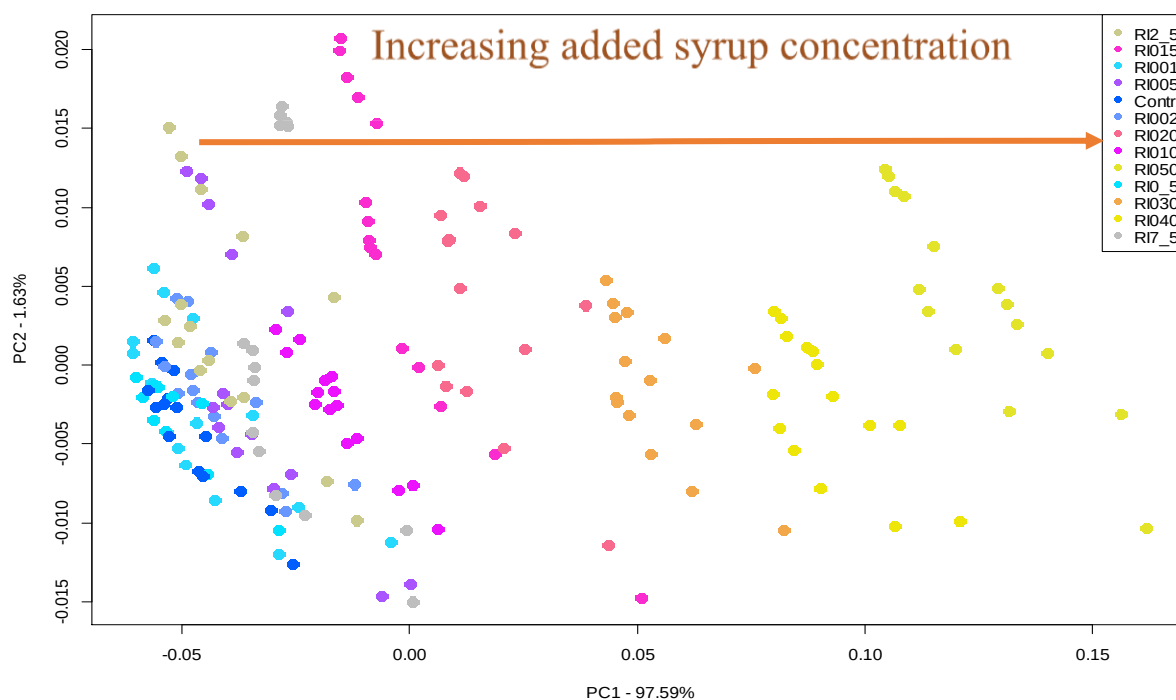


Figure 1: PCA results of rice syrup adulterated honeys after Savitzky-Golay Smoothing and multiplicative scatter correction at NIR spectral range of 950-1630 nm. N=190

Table 1: Results of the PLRS model for rice syrup and beet syrup adulterated honeys using the spectral range of 950-1630 nm after smoothing and scatter correction.

Model parameter	Latent variables	R^2	RMSEC %	R^2_{CV}	RMSECV %	Contributing Wavelengths in the first overtone region 1300-1600 nm
Rice syrup adulterated	8	0.9985	0.61	0.9961	0.98	1320, 1372, 1410, 1438, 1468, 1528, 1566
Beet syrup adulterated	11	0.9987	0.57	0.9963	0.95	1346, 1368, 1406, 1424, 1460, 1490, 1502, 1552, 1566, 1594

SIMCA models also provided better results for beet syrup adulterated honeys. In the confusion matrix, overlapping between control and adulterated honeys were found only in the case of 0.5% adulterated sample during training and validation. While in the case of the rice syrup adulterated honeys, control was misclassified to 2.5% adulterated honey. Aquagram of the spectra was drawn using the most frequently used wavelengths (Figure 2) in aquaphotomics. The aquagram of the two types of adulteration look different due to the different adulteration agent.

In the case of the rice syrup adulterated honeys an increasing absorbance can be seen in the range of 1342-1488 nm with the elevation of the concentration of added syrup, while at 1512 nm the absorbance has decreased. The beet syrup adulterated honey did not show this clear trend, but in the case of the 1512 and range of 1384-1488 nm the trend was similar to the rice syrup adulterated honey.

The wavelengths in the range of 1398 – 1418 nm can be assigned to the free water content of the samples and free OH⁻, the range of 1421-1444 nm are assigned to the water molecules with one on no H bonds^(16, 19), showing that with the elevation of the added sugar concentration the free water content of the samples increased, that could be a problem because samples can be fermented more easy and exposed to contamination much easier due to the higher water activity.

The wavelength of 1512 nm is connected to the highly structured water, where the absorbance spectra of adulterated honeys was lower showing that the highly bonded water is decreased with the addition of the syrup^(16, 19).

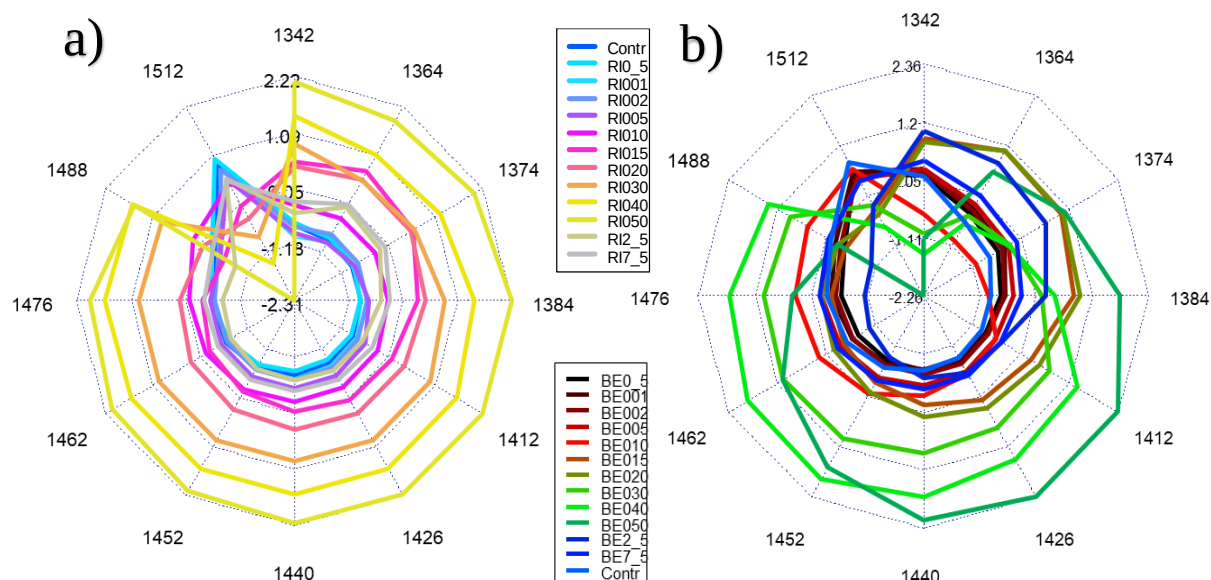


Figure 2: Aquagram of the adulterated honeys a) rice syrup adulterated honeys b) beet syrup adulterated honeys

Results of the paprika study

Principal Component Analysis (PCA) showed clear separation among the groups of different dilution levels where samples with the highest concentration of corn flour (C1) were clearly distinguished from the rest (Figure 3). The corresponding loading vectors revealed the importance of the wavelengths 1460 nm and 1494 nm implying more hydrogen bonded water structure in samples with lower dilutions. Authentic paprika samples were 100% correctly classified by LDA as opposed to misclassifications among adulterated ones.

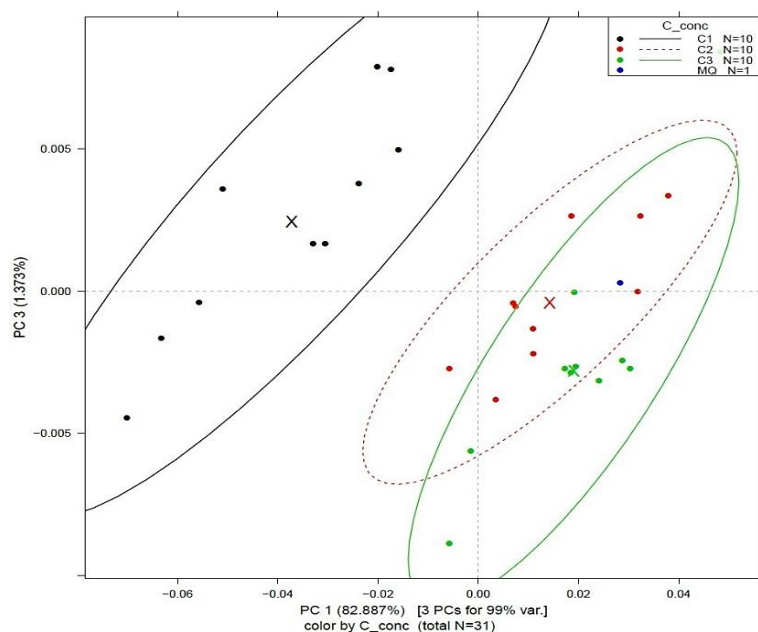


Figure 3 PCA results of averaged NIR spectra (1300-1630 nm) of the corn adulterated and diluted paprika powder solutions after Savitzky-Golay Smoothing and multiplicative scatter correction and Detrend n=31; (C1,C2 and C3 are the 10^1 , 10^2 and 10^3 times dilutions respectively)

Using the averaged spectra of adulterated paprika powders, PLSR models built for the quantification of added corn flour in the 10 times diluted solutions resulted in R^2CV and RMSECV values of 0.85 and 5.02% w/w, respectively (Figure 4).

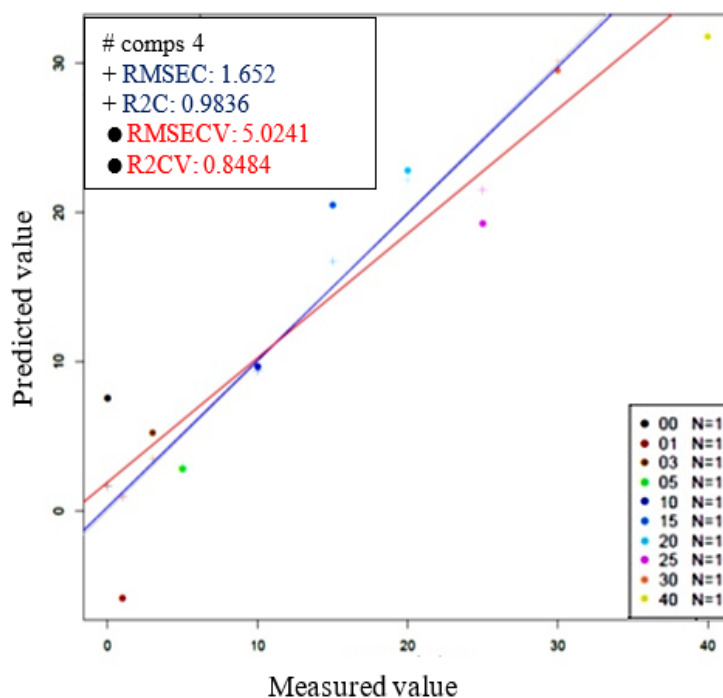
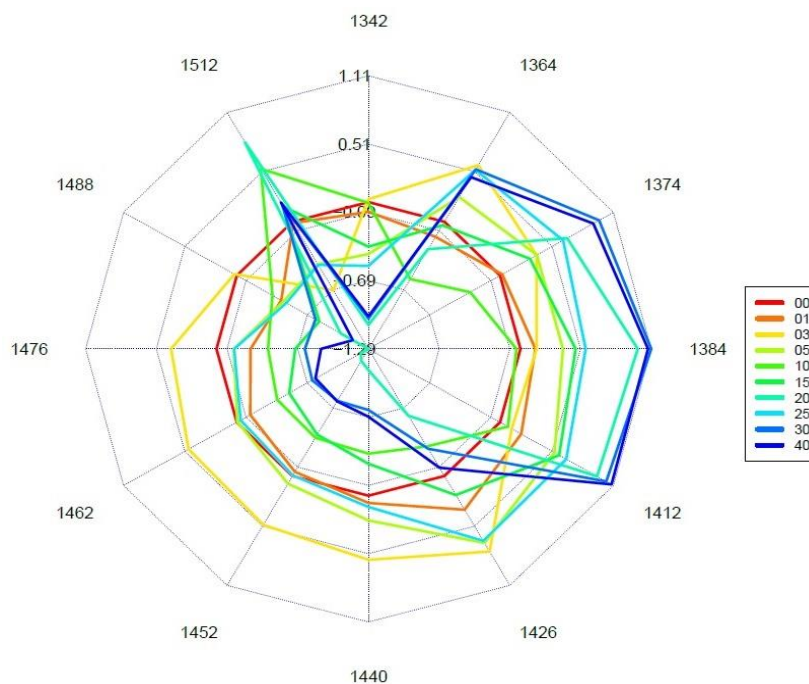


Figure 4 Y-fit graph of the prediction of corn flour concentration in aqueous solution of adulterated Paprika Powder samples using 1300-1600 nm after averaging

The obtained aquagrams showed higher absorbance values in the less hydrogen bonded region for samples with higher adulteration levels (Figure 5), those with lower adulteration levels had higher absorbance in the region of highly bonded hydrogen. These findings accentuate the efficiency of monitoring the adulteration of paprika powder by corn flour with near infrared spectroscopy and aquaphotomics.



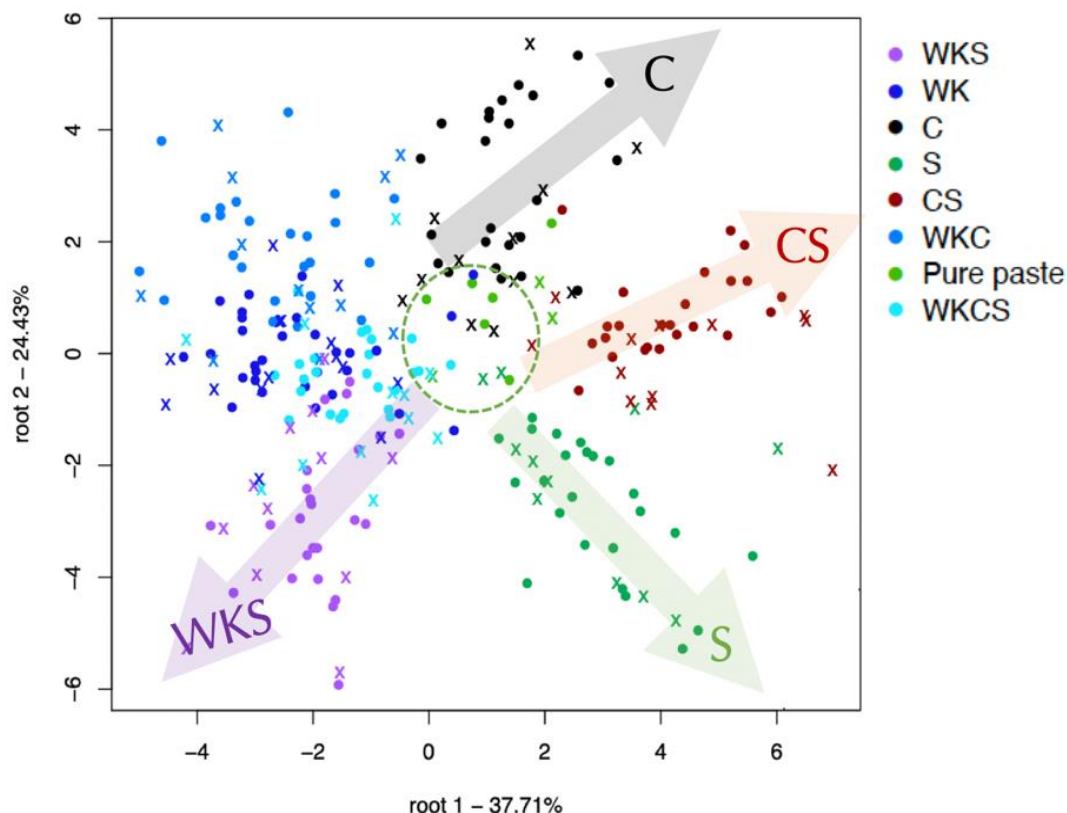


Figure 6: LDA plot of tomato paste concentrates containing single and multiple mixtures of adulterants at five different concentration levels.

LDA classification of the different corn starch and paprika seed powder concentrations in tomato paste

Examining each counterfeiting material by the different adulteration levels, Figure 7 shows a plot of the different concentration levels of corn starch and paprika seed powder in tomato paste concentrate. Clear separation patterns could be seen for all the different concentration levels of corn starch (Figure 7A) and paprika seed powder (Figure 7B). There was an increasing pattern of adulterant concentration from left to right in both plots. Classification after three-fold cross validation showed 100% average recognition accuracy for all the different concentration levels corn starch and 95.4% prediction accuracy in the 950-1650 nm spectral range. In the 1300-1600 nm spectral range, the average recognition and prediction of corn starch was 87.43% and 71.33% respectively. In the case of paprika seed powders, the average recognition and prediction was 83.61% and 68.52%.

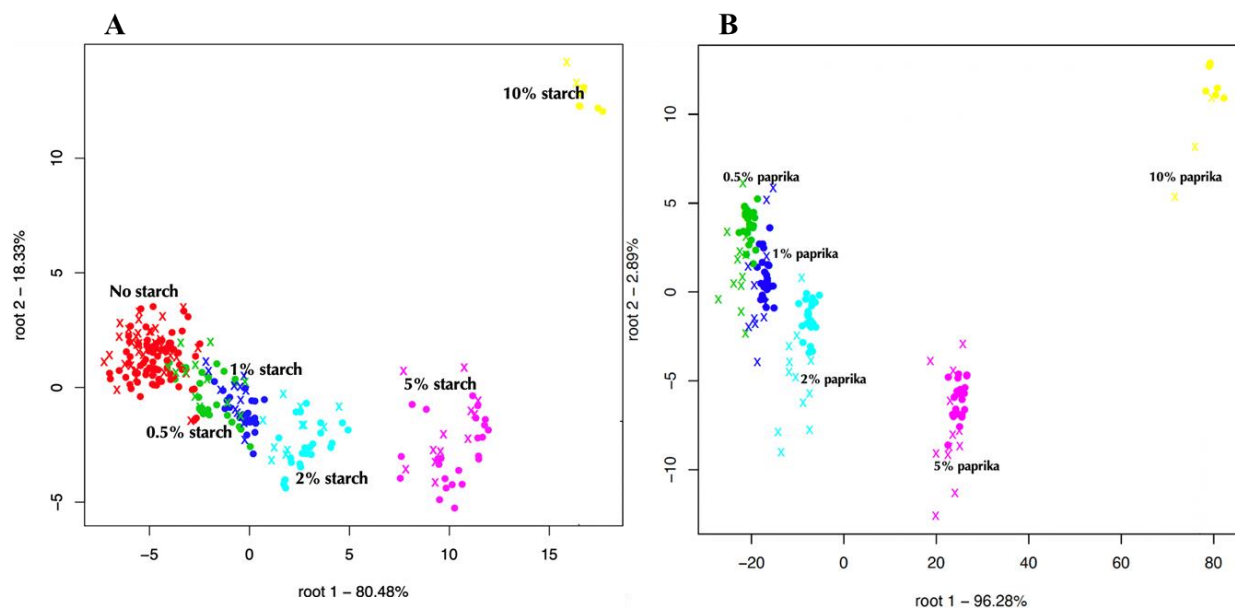


Figure 7: LDA plot of tomato paste concentrates containing five different concentrations of corn starch (A) and paprika seed (B) at the spectral range of 950-1650 nm

LDA classification of four different concentrations of salt and sugar in tomato paste

Figure 8A shows a plot of the four different concentrations levels of salt in tomato paste concentrate and Figure 8B shows the different concentrations of sugar in tomato paste concentrate. All the different salt concentrations were distinctively separated from each other in Figure 8A. The concentrations of sugar in tomato paste were also separated in in Figure 8B. There was an increasing pattern of adulterant concentration from left to right in both Figure 8A and Figure 8B.

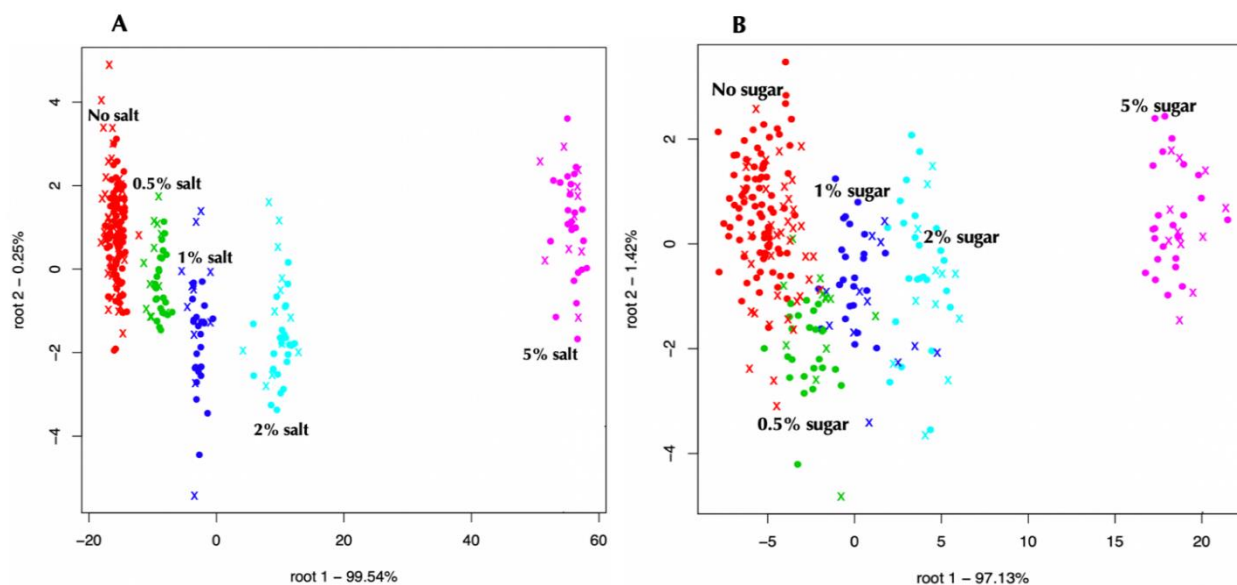


Figure 8: LDA plot of tomato paste concentrates containing four different concentrations of salt (A) and sugar (B) at the spectral range of 950-1650 nm

In the spectral range of 950-1650 nm, the classification after three-fold cross validation could recognize the different salt concentrations in tomato paste concentrate with an average accuracy of 100% and predict them with 99.5% average accuracy. Average recognition of sugar in tomato paste concentrate was 99% and prediction was 80.8%. In the 1300-1600 nm wavelength range, salt was still discriminated with a good accuracy of 99.39% for recognition and 89.58% for prediction. The average recognition and prediction of sugar was 84.03% and 63.11%.

PLSR prediction of paprika seed, starch, salt and sugar in tomato paste concentrates

Table 2 shows the regression models in the 950-1650 nm spectral range for the different adulterants in tomato paste concentrate. In PLSR, samples with starch, paprika seed, salt, sugar and water were predicted with R^2_{CV} 's in the range of 0.90-0.98 and a very low error after cross validation (RMSECV) less than 1% w/w. Salt in tomato had the best prediction accuracy in PLSR.

Table 2: PLSR prediction of paprika seed, starch, salt and sugar in tomato paste concentrates in the 950-1650 nm spectral range

Adulterants	Latent variables	R^2	RMSEC (%w/w)	R^2_{CV}	RMSECV (%w/w)
Paprika seed	6	0.95	0.44	0.94	0.46
Corn starch	6	0.97	0.43	0.96	0.44
Salt (NaCl)	5	0.98	0.23	0.98	0.24
Sugar	5	0.91	0.51	0.90	0.53

The models built in the 1300-1600 nm wavelength range (Table 3) estimated the paprika seed concentration with the highest RMSE values for model building (1.17% w/w) and validation (1.27%w/w) respectively.

Table 3: PLSR prediction of paprika seed, starch, salt and sugar in tomato paste concentrates in the 1300-1600 nm spectral range

Adulterants	Latent variables	R ²	RMSEC (%w/w)	R ² CV	RMSECV (%w/w)
Paprika seed	6	0.64	1.17	0.58	1.27
Corn starch	6	0.81	0.86	0.76	0.95
Salt (NaCl)	5	0.98	0.24	0.97	0.26
Sugar	5	0.85	0.64	0.83	0.67

In the other cases, the error of prediction was below 1%w/w. The method predicted the salt concentration most accurately ($R^2 > 0.97$) and with the least error (0.24-0.26%w/w). The aquagram WAMACs, created both in the wavelength range of 950-1650 nm and 1300-1600 nm showed trends that correlated to adulteration patterns.

CONCLUSION

This study aimed at evaluating the applicability of Near infrared spectroscopy and aquaphotomics to detect adulteration in honey, paprika powder, and tomato paste adulterated with commonly used adulterants. Honey experiments provided good results for the detection of adulteration of honey with sugar syrup using the range of 950-1650 nm, SIMCA models showed the complete separation above 5%. Aquagram showed that aquaphotomics is a promising method for the detection of changes of the water structure in the honey as a result of syrup addition.

The quantification of corn flour in 10¹ diluted paprika powder solutions by PLSR regression was also accurate with R²CV and RMSECV values of 0.85 and 5.02%, respectively. Obtained aquagram showed a distinctive pattern depending mostly on the added corn flour concentrations.

Good prediction performances were equally obtained by PLSR regression ($R^2\text{CV} > 0.9$ and $\text{RMSECV} < 1\%\text{w/w}$) for the adulteration of tomato paste concentrate with paprika seed power, Starch, salt and sugar and could be classified with high recognition (100%) and prediction (80%-100%) accuracies in LDA in the case of the tomato paste data set. Multiple adulterant combinations could also be discriminated in LDA with high accuracies. The adulterants were predicted with high accuracies in PLSR and low error (less than 1 % w/w). Generally, salt had the best prediction models both in LDA and PLSR but NIRS presents viable options of rapid determination and quantification of all the investigated adulterants. In the examined 1300 – 1600 nm wavelength range corn starch and salt could be classified with the highest recognition and prediction. Based on the results of the

three experiments aquapotomics and NIRS could be promising methods for uncovering adulteration of different food matrices and quantification of the added adulterant.

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REFERENCES

- [1] Codex Alimentarius Commission. CODEX STANDARD FOR PROCESSED TOMATO CONCENTRATES, Pub. L. No. (CODEX STAN 57-1981), 1 (1981). Retrieved from http://www.fao.org/input/download/standards/237/CXS_057e.pdf
- [2] Johnson, R. (2014). Food fraud and “Economically motivated adulteration” of food and food ingredients. *Food Fraud and Adulterated Ingredients: Background, Issues, and Federal Action*, 1–56.
- [3] Ryan, J. M. (2016). Chapter 2 - Some Food Fraud Laws. In J. M. B. T.-F. F. Ryan (Ed.), *Food Fraud* (1st ed., pp. 9–20). San Diego: Academic Press. <https://doi.org/https://doi.org/10.1016/B978-0-12-803393-7.00002-0>
- [4] Da Silva, P. M., Gauche, C., Gonzaga, L. V., Costa, A. C. O., & Fett, R. (2016). Honey: Chemical composition, stability and authenticity. *Food Chemistry*, 196, 309–323. <https://doi.org/10.1016/j.foodchem.2015.09.051>
- [5] Trello (2019b). Honey-Food Fraud Risk Information. Retrieved November 11, 2019, from <https://trello.com/c/UpKMShl0/623-honey>
- [6] Záborská, B., & Vorlová, L. (2014). Adulteration of honey and available methods for detection – a review. *Acta Veterinaria Brno*, 83(10), S85–S102. <https://doi.org/10.2754/avb201483S10S85>
- [7] Codex Alimentarius Commission. (2017). *CODEX COMMITTEE ON FOOD IMPORT AND EXPORT INSPECTION AND CERTIFICATION SYSTEMS*. Mexico. Retrieved from http://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FMeetings%252FCX-733-23%252FWD%252Ffc23_05e.pdf
- [8] EU. (2001). COMMISSION REGULATION (EEC) No 1764/86 - Laying down minimum quality requirements for products processed from tomatoes under the production aid scheme, (1764), 1–23. Retrieved from <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:01986R1764-20010526&from=EN>

- [9] Trello (2019c). Tomatoes and tomato paste-Food Fraud Risk Information. Retrieved November 11, 2019, from <https://trello.com/c/0BBkItvu/410-tomatoes-and-tomato-paste>
- [10] Zachairas, T. J., & Gobinath, P. (1979). Paprika and chilli. In V. A. Parthasarathy, B. Chempakam, & T. J. Zachariah (Eds.), *Chemistry of Spices* (First, Vol. 32, pp. 260–284). <https://doi.org/10.4327/jsnfs1949.32.267>
- [11] Horn, B., Esslinger, S., Pfister, M., Fahl-Hassek, C., & Riedl, J. (2018). Non-targeted detection of paprika adulteration using mid-infrared spectroscopy and one-class classification – Is it data preprocessing that makes the performance? *Food Chemistry*, 257, 112–119. <https://doi.org/10.1016/J.FOODCHEM.2018.03.007>
- [12] Trello (2019a). Chilli powder and flakes - Food Fraud Risk Information. Retrieved November 11, 2019, from <https://trello.com/c/MSRJbc4z/310-chilli-powder-and-flakes>
- [13] Csóka, M. (2014). *INVESTIGATION OF COLOUR AND AROMA PROPERTIES OF RED PEPPER POWDERS*. Corvinus University of Budapest. Retrieved from http://phd.lib.uni-corvinus.hu/794/6/Csoka_Mariann_ten.pdf
- [14] Feng, Y. Z., & Sun, D. W. (2012, November). Application of Hyperspectral Imaging in Food Safety Inspection and Control: A Review. *Critical Reviews in Food Science and Nutrition*. <https://doi.org/10.1080/10408398.2011.651542>
- [15] Hong, E., Lee, S. Y., Jeong, J. Y., Park, J. M., Kim, B. H., Kwon, K., & Chun, H. S. (2017). Modern analytical methods for the detection of food fraud and adulteration by food category. *Journal of the Science of Food and Agriculture*, 97(12), 3877–3896. <https://doi.org/10.1002/jsfa.8364>
- [16] Bázár, G., Romvári, R., Szabó, A., Somogyi, T., Éles, V., & Tsenkova, R. (2016). NIR detection of honey adulteration reveals differences in water spectral pattern. *Food Chemistry*, 194, 873–880. <https://doi.org/10.1016/j.foodchem.2015.08.092>
- [17] Munćan, J. S., Matija, L., Simić-Krstić, J. B., Nijemčević, S. S., & Djuro, L. (2014). Discrimination of mineral waters using near-infrared spectroscopy and aquaphotomics. *Hemijaska Industrija*, 68(2), 257–264. <https://doi.org/10.2298/HEMIND130412049M>
- [18] Muncan, J., & Tsenkova, R. (2019). Aquaphotomics—From Innovative Knowledge to Integrative Platform in Science and Technology. *Molecules*, 24(15), 2742. <https://doi.org/10.3390/molecules24152742>
- [19] Tsenkova, R. (2018). Aquaphotomics: A new science for understanding the role of water. Retrieved November 13, 2018, from <http://www.aquaphotomics.com/about/>
- [20] Pollner, B., & Kovacs, Z. (2016). *Understanding Water in Biology at the 2nd International Aquaphotomics Symposium* 26.-29.
- [21] Bázár, G., Kovacs, Z., Tanaka, M., Furukawa, A., Nagai, A., Osawa, M., ... Tsenkova, R. (2015). Water revealed as molecular mirror when measuring low concentrations of sugar with near infrared light. *Analytica Chimica Acta*, 896, 52–62. <https://doi.org/10.1016/j.aca.2015.09.014>