An iterative procedure for detecting foreign products in powder foods in NIR hyperspectral imaging spectroscopy: frauds and contaminations

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Abstract

Food adulteration is an issue of growing concern, specially delicate throughout early stages of food processing, regarding the control of the original ingredients included in the process and crossed contaminations. The use of Hyperspectral Imaging (HSI) to detect nuts contamination in powder food products is explored in this work. This study deals with two specific problems of using HSI for the detection of food adulterants: the low dose at which they need to be detected and a high similarity between the spectral NIR signatures of adulterating substances. A chemometric method, issued from a pharmaceutical context, is adapted and tested to detect and identify the presence of different species of oily seeds and nuts in a specific type of commercial wheat flour. The proposed approach was able to detect the presence of 5 kinds of contaminants in percentages from 1 to 5%, but not to identify the contaminant species.

Introduction

Food adulteration is an issue of growing concern that can lead to relevant medical, legal and religious issues. This is especially delicate throughout food processing, particularly in early stages, regarding the control of the original ingredients included in the process and crossed contaminations.

In food industry the composition of a powder pure substance can be compromised by two main causes: a) casual contaminations with traces of potentially allergenic products, as peanuts or other nuts and oily seeds, or b) intentional inclusion of adulterants or not declared ingredients. In this context, there is a requirement for non-destructive accurate, sensitive and rapid detection methods to deal with these threats at regulatory and industrial level.

Hyperspectral imaging (HSI) can accomplish the exposed requirements. Previous works show the applicability of HSI on the examination of powder food: detecting of traces of peanut in flour (Mishra *et al.*, 2015), identifying melamine and cyanuric acid in feed (J.A. Fernández Pierna et al., 2014), or quantifying of adulterants in milk powder (Forchetti *et al.*, 2016).

Nevertheless, two important challenges must be addressed in the detection of foreign contaminations in powder food products through HSI. Firstly, and particularly in the case of contamination by allergens, foreign contaminants need to be detected at a very low dose. As a consequence, spatial and spectral information of the contaminant in the image may be scarce, with only a few pixels of the image referring to the product of interest, and/or with the spectral fingerprint of the contaminant being mixed with the main compound(s). Secondly, in the food industry, contaminants and adulterating substances show, in many cases, highly similar spectral NIR signatures among the different species, making them difficult to identify when only a few pixels of the product are present in the image. This is the case when trying to differentiate particular species of allergens that are found as low dose contaminants in powder foods. Similar constraints, are addressed in the context of the pharmaceutical industry, for analyzing the composition and distribution of the different compounds present in a tablet. Boiret *et al.*, (2015), propose a procedure to highlight the presence of low dose compounds in drug products.

The objective of the present work is the detection of trace contaminations with different species of nuts and oily seeds, by combining the use of hyperspectral imaging spectroscopy and chemometric analysis.

Materials and Methods

Twenty five samples were analyzed: wheat flour type 45 (pastry flour), mixed with 5 types of nuts and oily seeds (hazelnut, brazil nut, pine nut, peanut and almond) in concentrations from 1% to 5%. Additionally, a spectral library of pure products, constituted of 25 flours and 10 grinded oily seeds and nuts (further on referred generically as "nuts"), was generated and used as an initial reference spectral database. Hyperspectral images of each sample and pure product were taken with a HySpex SWIR-320m-e spectral camera (950 - 2250 nm). SNV pre-treatment was applied to all spectra prior to further analysis.

The procedure presented by Boiret *et al.*, (2015) is adapted and tested in the present work for

authentication and detection of adulterants in powder food. For every sample, spectral distances were computed between each pixel of the image and each of the substances in the library. The main substance in the sample is identified as the one to which the image pixels present the lowest median of distances. Further on, orthogonal projection is iteratively applied both to the sample image and the spectral library in order to remove the main spectral signatures in the image, allowing minor components to be detected. Low dose contaminants are expected to be detected at this step as outliers with distinct low distance values to a particular pure product spectra. Finally, spectral distances of each pixel to the products identified in the images are computed in order to visualize the distribution map of adulterants in the sample.

Results and discussion

As shown in Figure 1 (5% almond adulteration sample, pure product number 35), in the first iteration, boxplots of distances showed a clear differentiation between flours (products 1 to 25) and nuts (26 to 35). Wheat flour type 45 (product 1) was correctly identified as the main substance for all 25 samples.

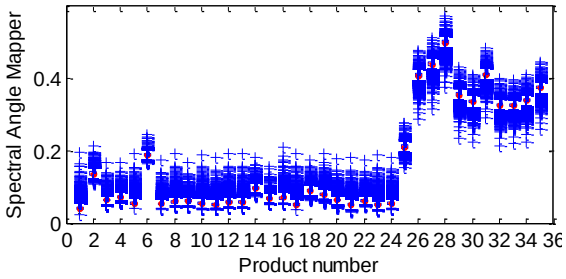

Fig. 1. Boxplot of Spectral distances to pure products (first iteration).

On a second iteration, when removing the spectral space of wheat flour, all distances to flour products increased, reducing the gap between flours and nuts (Figure 2). Outliers with a wide range of low distance values were observed regarding nuts pure spectra. Nevertheless, no distinct low distance values are shown for any particular nut product. Lowest distances had a value of 0.29 (SAM) and were shown by five different nuts: 26,27,29,34 and 35 (almond).

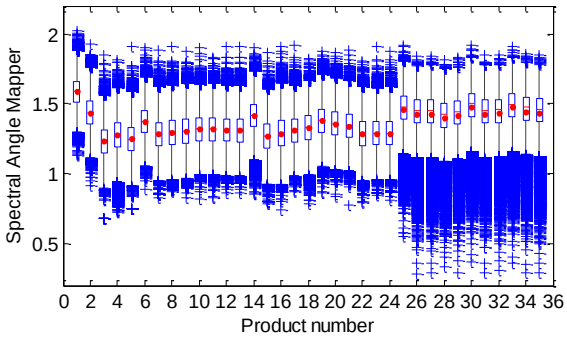

Fig. 2. Boxplot of Spectral distances to pure products (second iteration).

Hence, it was not possible to identify the kind of nut present in the sample. One possible explanation of this result lies in the close similarities between the Near Infrarred Spectral profiles of the considered nuts (Figure 3). When considering all nuts as a single type of product, the method allowed to recognize the presence of nuts contamination for all five kinds of contaminants from 1% to 5% adulteration (Figure 4).

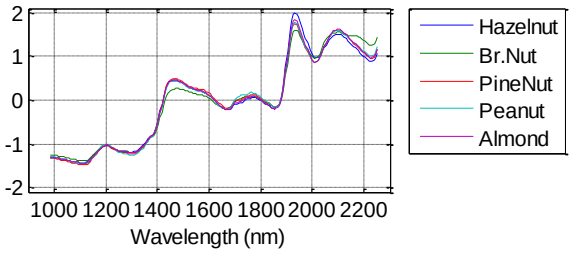

Fig. 3. Reference mean spectra of 5 nut contaminants. SNV pre-treated.

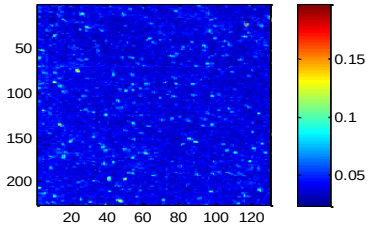

Fig. 4. Distribution map of distances to mean spectra of wheat flour . 5% almond adulterated sample.

Conclusions

The proposed method was able to detect the presence of trace concentrations (up to 1%) of nuts within wheat flour samples but not to differentiate between kinds of nuts. A wider spectral range or further spectral treatment to differentiate the spectral signature between nuts would be necessary to address this challenge in further works.

References

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