Targeted detection of allergen foods in quinoa flour using VNIR hyperspectral imaging and machine learning

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Introduction

Food allergens are extremely dangerous to certain groups of people; they may cause severe illnesses or even deaths to people regardless of gender or age. Currently, there are over 15 million people in the US suffering from various allergies, and the number is still increasing (Wen & Kwon, 2017). At the same time, approximately 1,015,000 hospital visits are made related to food allergies across the US each year, and among them, 203,000 emergency department visits happened due to acute food allergies (Clark et al., 2011). Cross-contamination between grains/grain flours during processing is a major issue for the food industry. Due to cross-contact with allergen foods/gluten-rich grains, an allergen can get into the food that is free from allergen and may be unconsciously ingested by people who are allergic to the component. According to the Food Allergy Safety, Treatment, Education, and Research (FASTER) Act 2021 signed by President Joe Biden in the recent year, sesame is declared to be the ninth major food allergen in the United States (Center for Food Safety and Applied Nutrition, 2022). All products that use sesame seeds or items derived from sesame will have to be explicitly labeled after January 1, 2023 (Center for Food Safety and Applied Nutrition, 2022). The conventional method for allergen detection in food is time-consuming, complicated, laborious, and expensive, and they require technical skills when interpreting the data. Therefore, there is a need for rapid, accurate, non-destructive, and real-time analytical techniques for allergen detection in food. Recently, hyperspectral imaging has emerged

as a powerful analytical technique to solve many agricultural and food-related issues. Therefore, the primary objective of this research is to use hyperspectral imaging in tandem with some machine learning techniques such as partial least square regression (PLSR) and wavelength selection techniques to accurately detect food allergens (i.e., sesame, peanut, and wheat) in quinoa flour in real-time.

Methods

Quinoa seeds and wheat seeds were collected from different local supermarkets and mixed to enhance the universality of the samples. Due to the relatively high fat content, sesame and peanut powder were purchased directly from different local supermarkets. The authenticity of these powders will be verified in future experiments. Quinoa seeds and wheat seeds were dried at 60˚C for 4 hours and then ground using a laboratory grinder. All four kinds of flour were filtered with a 250-micrometer sieve (standard Tyler equivalent #60 mesh) for uniform particle size. All food samples are stored in a refrigerator at 5˚C to prevent potential spoilage due to oxidation. To prepare the samples for the experiment, the total amount of the mixture was kept uniform at 15g per sample. Two types of samples were prepared, calibration samples and validation samples. For calibration samples, sesame flour, peanut flour, and wheat flour were mixed in quinoa flour respectively in the range of 2-100% at 2% intervals (150 samples in total, 3 samples with different adulterants at each adulteration level); while for validation samples, the three adulterant flour were mixed in quinoa flour respectively in the range of 4-97% at 3% intervals (96 samples in total, 3 samples with different adulterants at each adulteration level). All samples were completely mixed with a vortex mixer. During image acquisition, the prepared samples were put in black cylindrical containers approximately 4 cm in diameter and 1 cm in depth. The containers were then placed onto a blackboard to ensure maximum contrast between the samples and the background. Three

samples with the same adulteration rate were scanned at the same time. The original pure samples for quinoa flour and the three adulterants were scanned as well for future references. All the data analyses in this study were done using MATLAB R2021b coupled with PLS-toolbox_90.

Summary of findings so far

The main goal of this study was to explore the potential of a visible near-infrared (VNIR) hyperspectral imaging system (400-1000 nm) for allergen (sesame, peanut, and wheat) detection in quinoa flour. Quinoa samples were adulterated with sesame, peanut, and wheat in the range of 2-100% at 2% intervals. Their spectral data were extracted, and initial calibration models were developed using PLSR. The effect of different machine learning calibrations, important variable selection, and spectral pre-treatment will be applied to improve the model accuracy. The final calibration model will be transferred to each pixel in the images for visualization. A manuscript will be prepared from this research and will be submitted to Food Control.

Impact of the grant on the research project

It was not possible to design and conduct the experiment without support from RSG. All primary sample materials, including seeds, flour, and sample preparation accessories (such as laboratory grinder and vortex mixer), were purchased with this support. An additional project will be prepared from this research findings if the project is successful.

Reference:

Center for Food Safety and Applied Nutrition. (2022). *Food allergies*. U.S. Food and Drug Administration. Retrieved May 15, 2022, from https://www.fda.gov/food/food-labeling-nutrition/food-allergies

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