Application of near Infrared Reflectance Spectroscopy On Determination of Moisture, Total Oil and Protein Contents of in-Shell Peanuts

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Abstract

Moisture, total oil and protein content of peanuts are important factors in peanut grading. A method that could rapidly and nondestructively measure these parameters for in-shell peanuts would be very useful. In this work, NIR reflectance spectroscopy was used to analyze the moisture, total oil and protein content of Virginia type in-shell peanuts. NIR absorbance spectra were collected in the region from 400 nm to 2500 nm using a Foss NIR instrument. Average values of moisture and total oil contents of all samples were determined by standard air-oven and Soxtec methods, respectively. Protein was measured using a Leco Nitrogen analyser. Partial Least Squares (PLS) analysis was done on the spectral data to develop empirical models to be used for prediction. The best model was selected based on the coefficient of determination (R2), Standard Error of Prediction (SEP) and the Residual Percent Deviation (RPD) values.

Keywords: NIR reflectance spectroscopy, Partial Least Square, In-shell peanut, Total oil, Moisture content, Protein.

Introduction

Moisture content (MC), total oil and protein are important grading factors in the sale and purchase of peanuts (Arachis hypogaea L.). Typically, peanuts are marketed with moisture content below 10.5% wet basis [1]. Storing the peanuts with excessive moisture content increases the risk of microbial growth and aflatoxin contamination during storage. Therefore, measurement of peanut MC is important for storage and processing. Total oil and protein contents are also important in processing industry where the peanuts are processed into different products, such as roasted peanuts, peanut butter, and peanuts for candy and cereal bars.

In instruments currently used to measure MC of peanuts, peanuts are shelled and kernels placed in the sample holder to measures moisture content as a function of certain dielectric properties of the kernels. Similarly, total oil and protein contents are presently measured, using methods that are laborious and time consuming. The samples used for these tests are usually discarded and result in considerable cumulative loss of edible peanuts. In-shell measurement of the kernel moisture, oil and protein would result in considerable savings in both time and money during the grading and drying processes.

Techniques using near infrared (NIR) spectroscopy for food quality measurements are being applied in food processing and quality inspection. NIR is rapid, nondestructive, and provides

more information about the constituents present in the raw materials as well as in formulated food products. NIR spectroscopy can be applied with minimal sample preparation and had been successfully used in many other crops such as soybean [2], sunflower [3], rape seeds [4], canola [5] and flax seeds [6]. The primary objective of this research is to develop calibration models to predict the moisture, total oil and protein contents of the peanut kernels using NIR reflectance spectroscopy on in-shell peanuts.

Materials and Methods

Moisture Determination

The initial moisture content of whole peanut pods was determined by drying about 100 g samples of in-shell peanuts in small aluminum pans kept in an air oven at 130oC for 6 hours. The moisture content of the peanut samples was calculated and expressed as percentage wet weight basis (w.b).

Sample Preparation

The initial moisture content of the peanuts selected for this experiment was 6%. These peanuts were divided into 15 sub-lots and for each sub-lot appropriate quantities of water were added to raise their moisture levels in increments of 2%. The containers were sealed and allowed to equilibrate at 4°C for one week. The containers were periodically rotated during this period to allow uniform moisture distribution. Final moisture contents of the sub-lots ranged between 7% and 26%. After a week, the containers were removed from cold storage and allowed to equilibrate to room temperature before making the NIR spectroscopic measurements. The final moisture content value of each sub-lot was determined after equilibration, using the oven method described above.

Total Oil Determination

Soxtec automated solvent extractor (2050 SOXTEC, FOSS Tecator AB, Höganäs, Sweden)was used to measure total oil content of the peanut samples. In this method, petroleum ether was used to extract the oil from ground peanut samples. Good and intact peanut kernels were selected and frozen before grinding to minimize loss of oil. About one gram of homogeneously ground, fine peanut meal was weighed and used for oil extraction. The temperature was maintained at 135±2 oC for 45 minutes for extraction and another 45 minutes to evaporate the residual petroleum ether from the oil. The samples were cooled for 15 minutes. Cups with the collected oil were kept in an air oven at 40oC for 30 minutes to drive out any residual traces of petroleum ether. The total oil content was calculated as the weight of the oil collected and expressed as weight percent (wt%).

Protein Analysis

LECO® FP 2000 nitrogen analyzer (LECO® Corporation, St. Joseph, MI, USA) was used to measure protein percentage in the peanut sample. The sample size used was 0.12 grams of homogeneously ground fine peanut meal. Sample placed and weighed in a ceramic sample

holder was introduced into the combustion chamber. Combustion temperature was maintained at 1050 oC. The combustion process converted covalently bound nitrogen in protein molecules into nitrogen gas. This gas was quantified by passing it through the conductivity cell. A conversion factor of 6.3 was used to calculate the percentage of protein from the amount of nitrogen gas collected.

NIR Spectroscopy Measurements

The peanut pod samples, after conditioning, were separated into calibration and validation groups. NIR spectral measurements were made using a scanning monochromator (Model 6500, FOSS NIRSystems, Silver Springs, MD, USA). Spectral data were collected using Vision software (Version 1.0, FOSS NIRSystems, Silver Springs, MD, USA). The reflected energy, carrying absorption information was measured over the wavelength range, 400 nm -2500 nm.

Data Analysis

NIR spectral data were analyzed using multivariate data analysis software (Unscrambler Version 9.7 CAMO ASA, USA). Using the spectral data from the calibration dataset, partial least square (PLS) regression analysis was conducted to develop empirical equations to estimate the peanut moisture contents and their corresponding total oil and protein contents. The derivative of the absorption and reflection spectral data with respect to wavelength was also used for model development along with raw spectral data. PLS analysis was performed and the best calibration model was selected based on Standard Error of Calibration (SEC) and coefficient of multiple determinations (R2) values. Goodness of fit of the different models was evaluated based on Standard Error of Prediction (SEP) values, comparing measured and predicted values of moisture, oil and protein contents. The RPD values (ratio of the standard deviation of predicted values to the SEP) were also used to evaluate the goodness of fit.

Results

Moisture Content

All the calibration models generated applying different types of treatments on the calibration samples of in-shell peanuts gave an R2 of 0.99. The calibration model equations were then used to predict the moisture content of the validation sample sets. Based on the fitness measurements, the model, developed using reflectance spectral data with derivative treatment, produced the highest RPD value of 5.75 and the lowest SEP value of 0.771.

Total Oil

For in-shell peanuts, RPD values greater than 5.0 were obtained for both absorbance and reflectance derivative data. Also, both NIR absorption and reflection derivative data resulted in correlations of over 95%. However, considering the lowest SEP values of 2.77 for absorbance and 1.65 for reflectance, the model developed from the reflectance derivative data was considered as the best model for total oil prediction.

Protein Content

Calibration models of peanut samples for protein, gave an R2 of 0.99 for both absorbance and reflectance, and their respective derivative functions. An RPD value of 4.8 was obtained for the two absorption models, which is close to the recommended value of 5.0 for quality analysis.

Conclusions

NIR reflectance spectroscopy could be a useful tool for rapid and nondestructive analysis of moisture, total oil and protein content of in-shell peanuts with minimal requirements of sample preparation. Based on the RPD values, the calibration models developed using the derivative of the reflectance data was found most suitable for the determination of moisture and total oil contents. However, for the determination of protein content in the in-shell peanuts both the absorption and absorption derivative data yielded good results.

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