Determination of Moisture Content of Milk Powder by Using NIR Spectroscopy

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ABSTRACT

Ensuring the quality of milk powder is crucial due to its nutritional importance. This study investigates the use of Near-Infrared (NIR) spectroscopy as a nondestructive, rapid alternative for the classification of milk powders under various relative humidity conditions and different variations. Samples, including whole, skim milk, and lactose-free milk powders, were analyzed using both a desktop (NIRFlex N-500) and a portable (NIR-S-G1) NIR spectrometer. Advanced chemometric methods, such as mean centering, baseline correction, Gaussian smoothing, and derivative processing, were applied to the raw NIR spectra using Orange data analysis software (Demšar et al., 2013). The study revealed that skim milk powder samples with different relative humidity rates showed distinct NIR spectra at 1455 nm and 1927 nm, corresponding to water absorption. High relative humidity samples exhibited higher absorbance values. Principal Component Analysis (PCA) was employed to explore sample differences, with k-Nearest Neighbors (kNN) and Support Vector Machine (SVM) models achieving 100% classification accuracy based on relative humidity. The portable NIR device demonstrated high efficiency for the project due to its fast data collection, ease of transportation, cost-effectiveness, and robust classification ability. Our findings affirm that NIR spectroscopy combined with robust chemometric techniques provides a reliable, efficient method for nondestructive moisture content determination and classification in milk powder, enhancing real-time quality control and product standardization.

INTRODUCTION

Milk powder is a widely consumed dairy product, valued for its nutritional content, long shelf life, and convenience. Ensuring quality attributes like protein content, fat levels, moisture, and absence of adulterants is crucial for consumer safety and product standardization. Near-Infrared (NIR) spectroscopy has emerged as a powerful tool for the rapid, non-destructive analysis of milk product components Zhang et al. (2023). This technique leverages the absorption of NIR light by molecular bonds, offering valuable information about the chemical composition without extensive sample preparation. NIR spectroscopy is advantageous due to its real-time, in-line monitoring capability during manufacturing, facilitating immediate quality control and decision-making. This enhances efficiency and reduces waste. Furthermore, NIR spectroscopy can analyze multiple components simultaneously, making it a cost-effective solution for comprehensive quality assessment (Manley, 2014). Several studies have demonstrated the efficacy of NIR spectroscopy in evaluating various properties of milk powder. NIR spectroscopy utilized to quantify protein and fat content in milk powder.

The objective of this study is to establish a robust classification model for the determination of milk powder using NIR spectroscopy, complemented by advanced chemometric methods to enhance prediction accuracy and reliability. k-Nearest Neighbors (kNN), Support Vector Machines and Artificial Neural Network algorithms were used to obtain classification models (Otto, 2017).

MATERIALS AND METHODS

Whole milk powder, skim milk powder and lactose-free milk powder were prepared and kept in the desiccators to have a relative humidity of 0, 25, 43, 60, 75%, 90% for measurements. In total 54 samples were examined. Two devices, desktop (Figure 1) and portable type (Figure 2), NIR instruments were used for analyses. Bencthop type NIR spectrometer device (NIRFlex N-500, Buchi, Switzerland) is equipped with an InGaAs detector that can measure in the spectral range of 1000nm – 2500nm with a sensitivity of 2.5 nm.

Portable type NIR spectrometer device (NIR-S-G1, InnoSpectra, Taiwan) can take measurements in the 900nm-1700 nm spectral range, with 3 nm spectral sensitivity, has an InGaAs detector and uses two 0.7 W tungsten filament lamps as light sources.

Orange (Demšar et al., 2013) application was used for chemometric analysis. NIR raw spectra were processed to account for the scattering effect of the obtained absorbance data, inhomogeneities in the samples, and to avoid environmental factors. This was done using mean centering, baseline correction, Gaussian smoothing, standard normal variate (SNV) transformation, and/or Savitszky-Golay first (1st Der) and second (2nd Der) derivative preprocessing methods. An exploratory approach was taken to evaluate and demonstrate the differences between samples in multivariate space using Principal Component Analysis (PCA). Subsequently, the data set was examined with K-Nearest Neighbors (kNN), Support Vector Machine (SVM), and Artificial Neural Networks (ANN) prediction algorithms.

Figure 1. Benchtop NIR.

Figure 2. Portable NIR.

Samples were prepared by homogenizing and evenly distributing them on the sample tray of the infrared moisture analyzer to have a reference data. The infrared moisture analyzer operates by emitting infrared radiation, which heats the sample, causing the moisture to evaporate.

RESULTS AND DISCUSSION

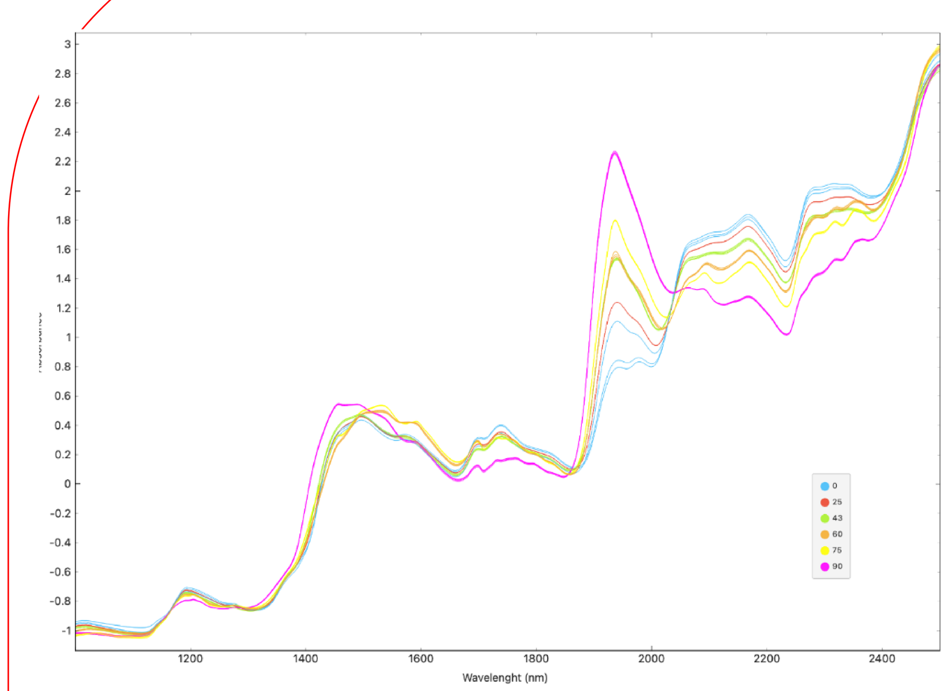

Figure 3: Buchi NIR, fat-free milk powder spectra after Savitsky-Golay (15-2) and SNV preprocessing.

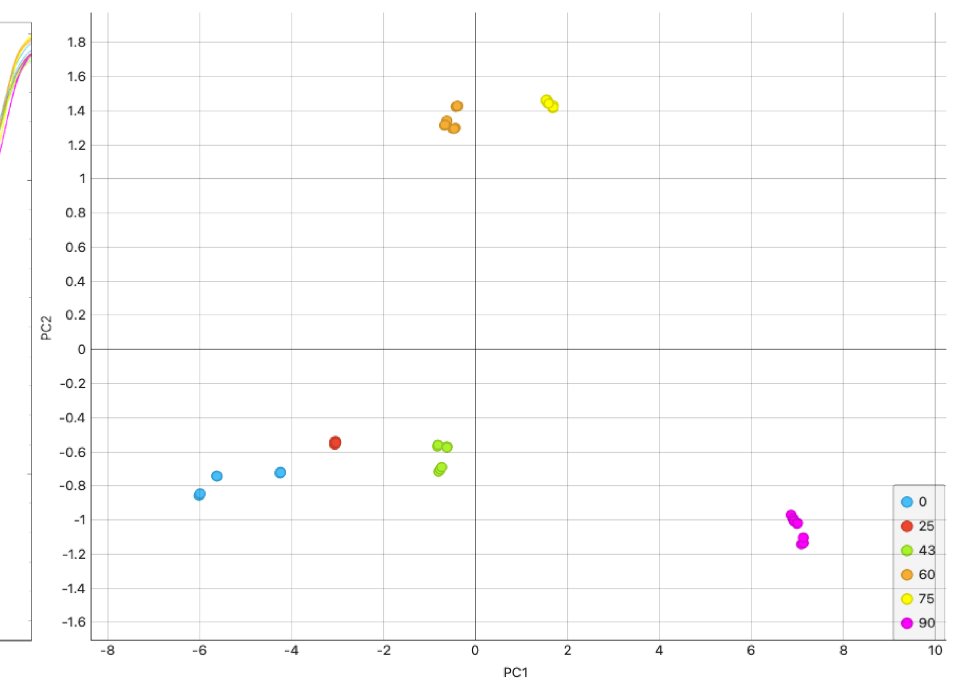

Figure 4: Buchi NIR - Fat-free milk powder PCA results - After preprocessing.

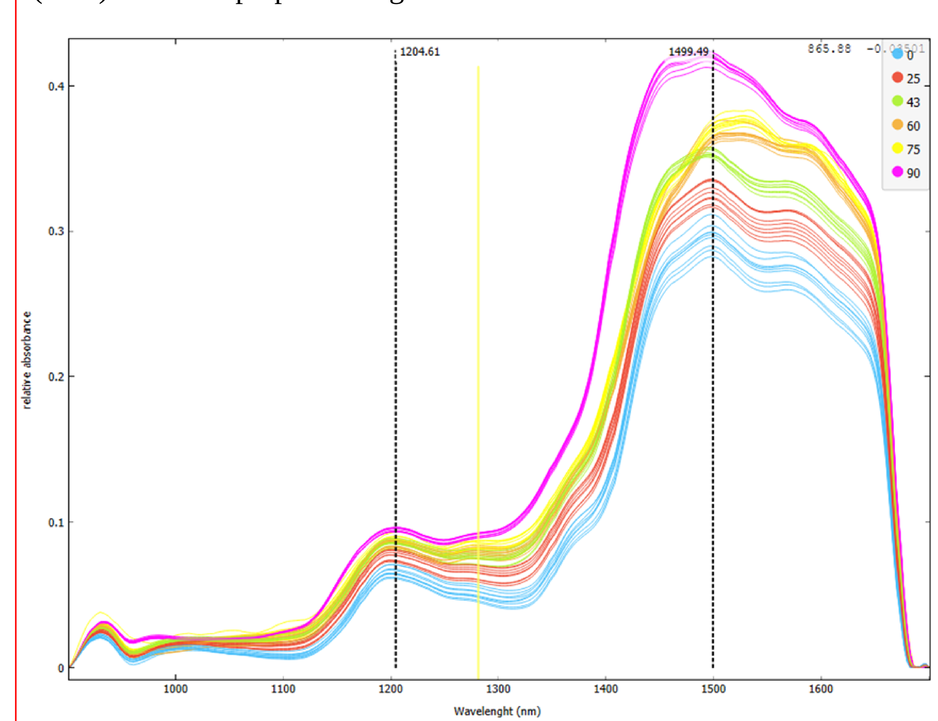

Figure 5: NIR-S-G1 portable spectrometer obtained fat-free milk powder spectra after Savitsky-Golay (15-2) and baseline correction preprocessing.

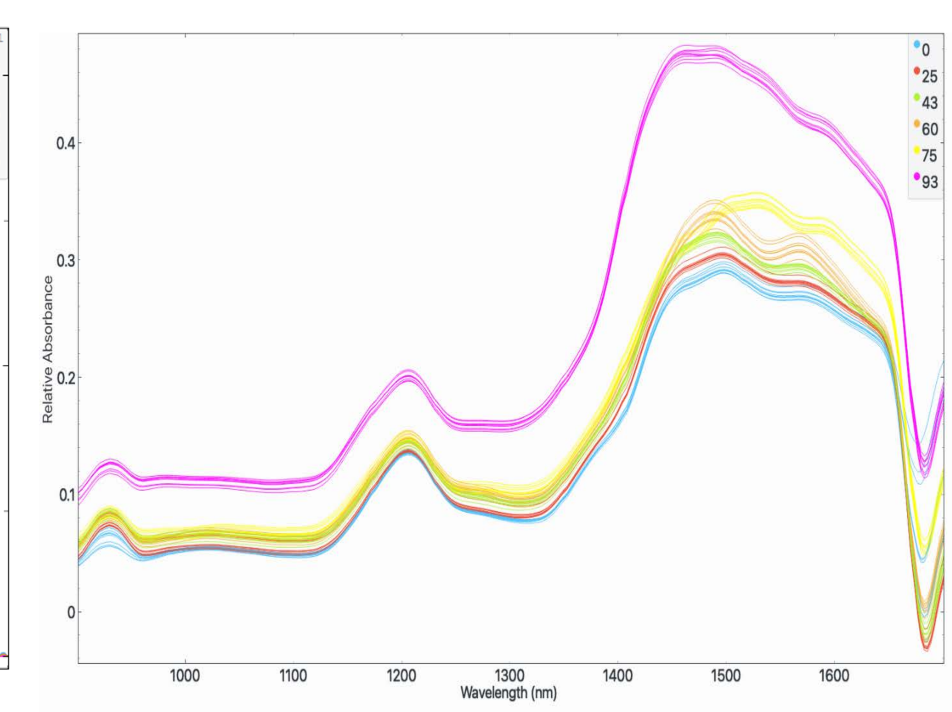

Figure 6: NIR-S-G1 portable spectrometer result after whole milk powder, Savitsky Golay (15-2) and base correction preprocessing obtained with.

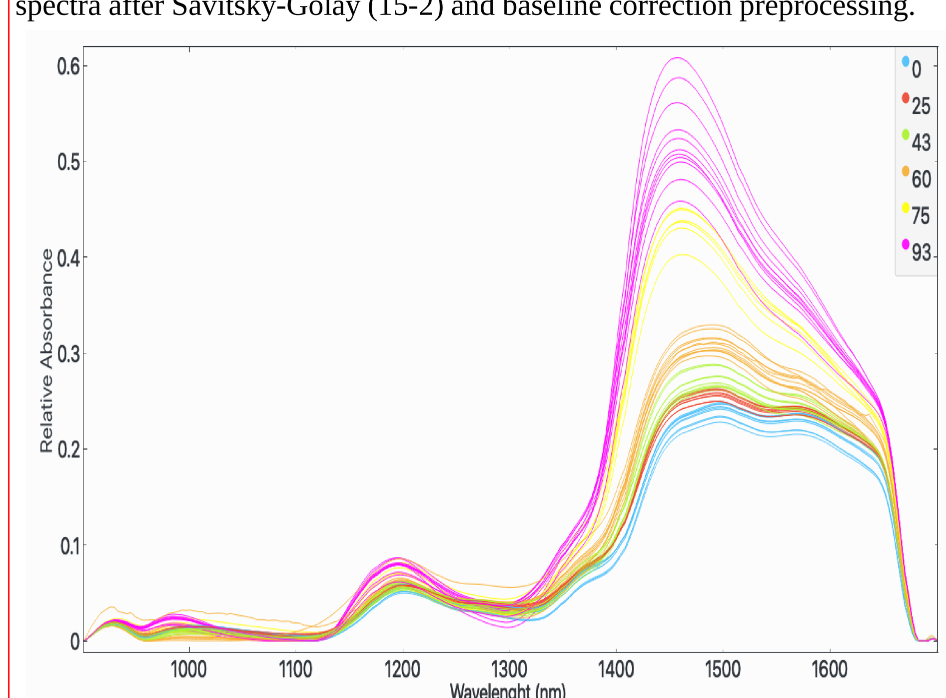

Figure 7: Spectrum after lactose-free milk powder, Savitsky Golay (15-2) and base correction preprocessing obtained with NIR-S-G1 portable spectrometer

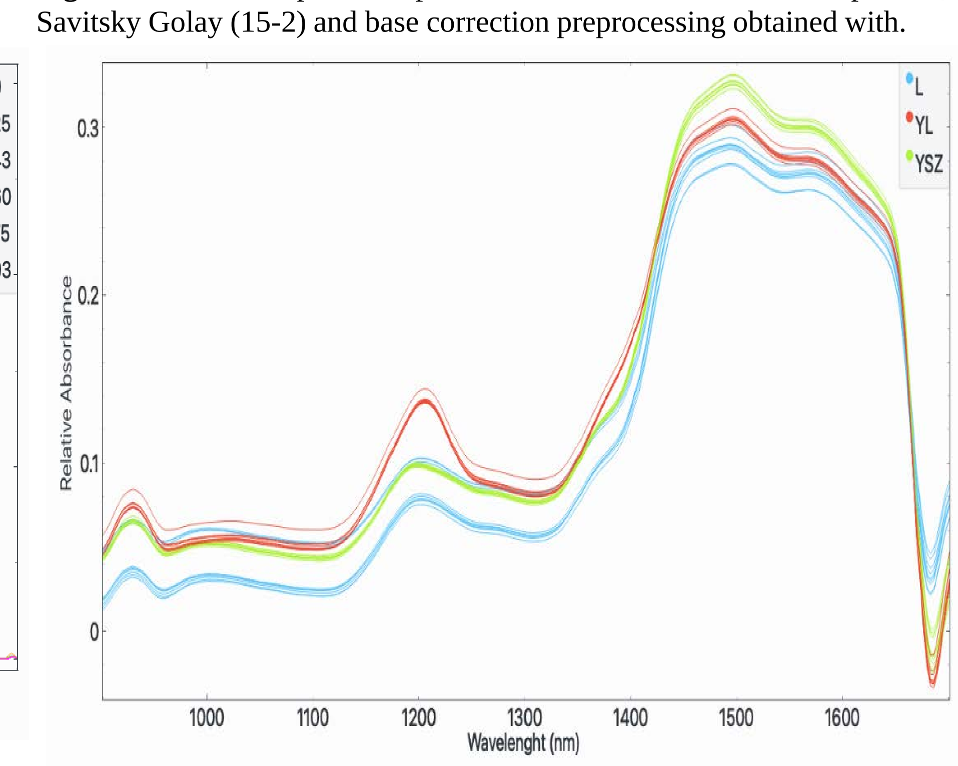

Figure 8: Spectrum after L=Lactose-Free, YL=Fat Milk Powder, YSZ=Skimmed Milk Powder, Savitsky Golay (15-2) pretreatment at 25% relative humidity obtained with NIR-S-G1 portable spectrometer.

Model	AUC	CA	F1	Prec	Recall	MCC
kNN	0.988	0.964	0.964	0.964	0.964	0.956
Tree	0.859	0.764	0.767	0.775	0.764	0.716
SVM	0.994	0.964	0.963	0.967	0.964	0.957
Neural Network	0.982	0.927	0.924	0.937	0.927	0.915

Figure 9: Lactose-free milk powder classification results (Ca-Classification Accuracy, Prec-Precision).

100%

CONCLUSION

Both handheld and benchtop devices were able to successfully classify the moisture content. However portable NIR device, being more cost effective and easy to implement gave 100% classification for most of the cases.

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