Application of a handheld infrared sensor for monitoring the distribution of vitamins and minerals in fortified corn-based snacks

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ABSTRACT

Fortification of snack foods is growing due to increasing consumer demand for healthier products. According to the Snack Food Association, total sales of snack foods in the U.S. grossed 26 billion dollars a year and corn based snacks accounted for 21.8% of total sales. Many snack foods produced in the U.S. are fortified with vitamins and minerals to improve their nutritional quality. A fortification blend of zinc, iron, vitamin E, and calcium was added to whole grain corn meal at different levels (0.65% to 5.65%) and mixed for 30 minutes to obtain a homogeneous matrix. For real-time infrared analysis, aliquots (0.1g) were placed onto an ATR diamond crystal of a handheld spectrometer with pressure being applied to obtain good contact between the sample and the crystal. Spectra were collected in the 4000-700 cm-1 range. Distribution uniformity of the supplements was verified by high pressure liquid chromatography (HPLC). Partial least squares regression (PLSR) analysis was used to correlate the concentration of supplemented vitamins and minerals in the whole grain corn meal with the infrared spectra. The model predicted the level of fortification in corn meal using the infrared region between 885 to 1225 cm-1 (r=0.98, 5 factors). The standard error of cross-validation was <0.35% which gives potential to be used as a new tool in the industry. By using a simple, handheld FT-IR instrument, a methodology for real time monitoring of corn meal fortification was developed for the snack food industry to monitor corn-based extruded snack products. This could provide the snack food industry with a simple, real-time method to ensure the homogenous fortification of snack foods.

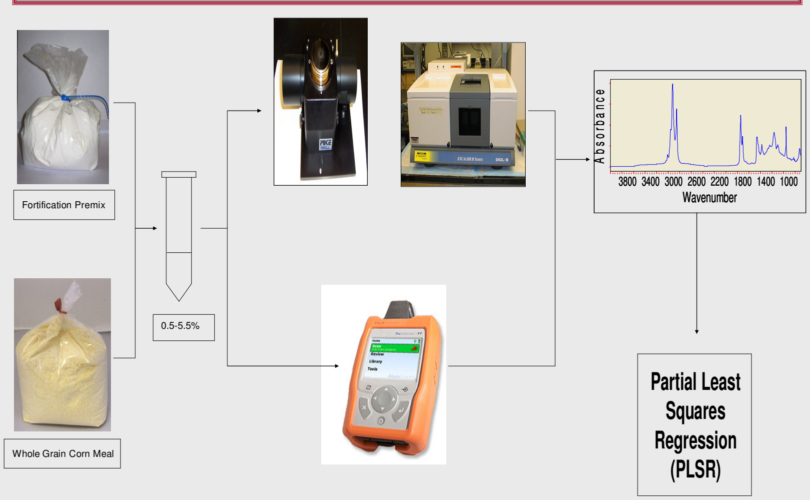
INTRODUCTION

Fortification is the supplementation of nutrients such as vitamin E, calcium, iron, and zinc, at levels beyond those that are naturally occurring in food (1). Many populations suffer from vitamin and mineral deficiencies, and the fortification of common processed foods can protect large populations using sustainable market channels (4). Sales of the total fortified foods market in the U.S. reached almost $18 billion in 2001, tripling the sales achieved by the market in 1997. The requirements for labeling and safe control of dosage during the production of fortified products in complex matrices require reliable, precise and accurate concentration analysis. The industry currently relies on the use of high performance liquid chromatography (HPLC) and inductively coupled plasma mass spectrometry (ICP-MS) analysis to measure levels of vitamins and minerals in fortified foods (5,3). Often these methods are time-consuming, expensive, the precision is strongly dependent on the operation of skilled personnel, and they are not easily adapted into a quality assurance setting (2). In addition, unwanted interference from the sample matrix often requires the use of extensive sample preparation and clean-up. Cutting edge sensor technologies are directed at improving efficiency, throughput and reliability of critical processes. On-line or real-time spectroscopic methods can provide a valuable window into in-process food manufacturing to permit optimization of production rate, quality and safety of many food products. Field-based devices for rapid determination of fortification levels in foods will streamline quality assurance, protecting consumers against the risk of purchasing and consuming nutritionally inadequate, deceptively mislabeled or misbranded, impure, or unsafe foods. Advances in Fourier transform infrared (FT-IR) spectroscopic instrumentation combined with multivariate data analysis have made this technology ideal for large volume, rapid screening and identification of various analytes. Infrared spectroscopy provides valuable information of the biochemical composition of the samples, especially in the fingerprint region, which can be used to monitor the fortification of food samples.

OBJECTIVE

The objective was to develop a real-time methodology for monitoring the uniformity of vitamins and minerals during fortification in corn-based extruded snack products.

MATERIALS & METHODS



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RESULTS

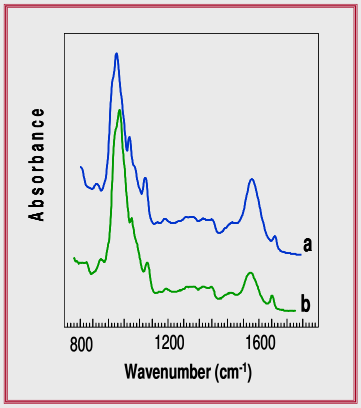

Figure 1. Bench-top[a] and handheld[b] ATR-IR spectrum of fortified whole grain corn meal.

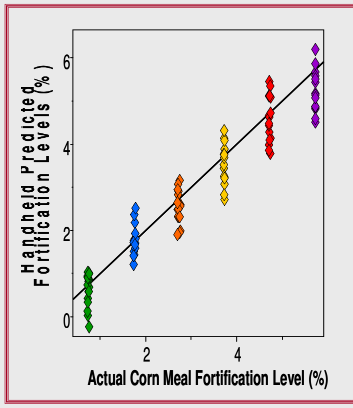

Figure 2. PLSR model using handheld infrared spectra for corn meal fortification from 0.5 – 5.5%.

Table 1. Comparison of techniques used for quantifying whole grain corn meal fortification

Technique	# of samples	# of factors	SECV[a]	rVal[b]	SEC[c]	rCal[d]
Benchtop ATR-IR	36	5	0.3557	0.9772	0.3256	0.9821
Handheld ATR-IR	36	4	0.4400	0.9662	0.4107	0.9722

[a]standard error of cross validation. [b]coefficient of correlation for validation model.
[c]standard error of calibration. [d]coefficient of correlation for calibration model.

DISCUSSION

- Comparison of the ATR-IR spectrum of fortified corn meal samples by using the benchtop and handheld spectrometers (Figure 1) showed similarities with respect to spectral profile and response for both instruments generating high-quality and reproducible spectra for fortified whole grain corn meal samples.
- Second derivative (5 pt window) transformation of the spectral measurements improved the quantitative analysis by resolving overlapped bands and limiting variations in spectral baselines.
- The regression (PLSR) model based on specific infrared spectral information (1800-800 cm^{-1}) showed strong correlation (r >0.96) between the IR predicted and actual levels of fortification for both infrared methods (Figure 2).
- PLSR models based on mid-infrared spectra collected by the handheld technique (rVal=0.97 and SECV=0.41%) gave similar performance statistics as models generated from spectra collected by the benchtop system (rVal=0.98 and SECV=0.32%).
- Both mid-infrared techniques were accurate for the determination of fortification levels in corn meal, based on the predictions of an independent validation set of samples with an estimated error of validation of 0.34%.

CONCLUSION

- A portable battery operated handheld ATR-IR spectrometer allowed for the sensitive and reliable determination of fortification levels in whole grain corn meal.
- A fast, simple and accurate method for determination of homogeneity in whole grain corn meal was developed with ATR-IR spectroscopy.
- This technique provides for the fast analysis of food components with minimal personnel training, simple data acquisition, and immediate predictions.
- Given the greater simplicity, speed, versatility, ruggedness, and portability of the handheld system over the laboratory bench-top instrument it can provide the food industry with real-time sensor tools for the reliable assessment of quality, enabling the food manufacturer to rapidly asses the quality of their food, and for timely correction measures during manufacture.

REFERENCES

1. Berner, L. A., Clydesdale, F. M., Douglass, J. S. 2001. Fortification Contributed Greatly to Vitamin and Mineral Intakes in the United States, 1989-1991. The Journal of Nutrition 131(8):2177-2183.
2. Caselunghe, M. B., Lindeberg, J. 2000. Biosensory-based determination of folic acid in fortified food. Journal of Food Chemistry 70(4):523-532.
3. Chen, K., Jiang, S. 2002. Determination of calcium, iron and zinc in milk powder by reaction cell inductively coupled plasma mass spectrometry. Anlytica Chimica Acta 470(2):223-228.
4. Governments of Indonesia, Pakistan, People's Republic of China, Thailand, Viet Nam, and the Asian Development Bank and The Keystone Center. 2004. Food Fortification in Asia: Improving Health and Building Economies. Manila Philippines: Asian Development Bank. 11p.
5. Haughey, S. A., O'Kane, A. A., Baxter, G. A., Kalman, A., Trisconi, M., Indyk, H. E., Watene, G. A. Determination of Pantothenic Acid in Foods by Optical Biosensor Immunoassay. Journal of AOAC International 88(4):1008-1014.

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