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NEAR-INFRARED SPECTROSCOPY IN FOOD SCIENCE AND TECHNOLOGY

ted by
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NEAR-INFRARED SPECTROSCOPY IN FOOD SCIENCE AND TECHNOLOGY

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PREFACE

Near-infrared (NIR) spectroscopy has recently become increasingly important in food science and technology as a non-destructive analytical technique. An enormous number of articles and research papers are published every year that deal with applications of NIR spectroscopy in this important field. Search for a comprehensive book describing both basic principles and modern application of NIR spectroscopy food science and technology proved fruitless. This book, *Near Infrared Spectroscopy in Food Science and Technology*, fills the void. It covers principles of molecular vibrations, spectral analysis, and instrumentation for NIR spectroscopy as well as its novel applications within food science and technology. It is written to be appreciated by food and agricultural scientists and engineers as well as molecular spectroscopists. The aim of this book is to provide a basic understanding of techniques and applications that demonstrate the potential of NIR spectroscopy for researchers and users in food science and technology.

The book is suitable for students at graduate level as well as researchers and engineers in academic and industry. It may be used as a textbook for a graduate course in food science and technology or agricultural science and technology and for short courses. We hope you enjoy this book and that it will inspire you and other readers to adapt the principles and techniques discussed herein to your particular area and interests.

Yukihiro Ozaki
W. Fred McClure
Alfred Christy

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CONTENTS

CHAPTER 1

Introduction

W. FRED MCCLURE

WORLD FOOD PRODUCTION

The industrialized world consists of about 59 countries, all with a total populations of about 0.9 billion people, about one-sixth of the total world population. In contrast, about 5 billion people live in approximately 125 low- and middle-income countries. The remaining 0.4 billion live in countries in transition, which include the Baltic states, eastern Europe and the Commonwealth of Independent States (1). Today, our world produces food for 6.39 billion people (Fig. 1.1). Yet statistics show that many people go to bed hungry every night. Each year the food crisis intensifies and more and more people go hungry.

Shockingly, the push to produce more and more food is thwarted by diminishing arable land suitable for food production. Plant yields have been maximized for many crops, leaving few options for increasing food production. In the face of these seemingly insurmountable problems, scientists are beginning develop technology for maximizing *food potential*, a philosophy that calls on any means that will reduce waste.

The philosophy for maximizing food for fresh foods potential goes something like this.[1] Time of harvest for plant-based foods must be optimized in order to maximize food potential. If harvested too early, both yield and quality are reduced: Again, if crops left too long in the field, both yield and quality fall. Furthermore, between the time of harvest and the time of consumption fresh foods undergo a decaying process called senescence. Senescence can reduce food potential by 7–12%, depending on how

[1] "Maximizing food potential" was first introduced by W. Fred McClure at the International Conference on Planning for the Future, Newcastle University, Newcastle, UK in W. F. McClure. 1995. Biological measurements for the 21st Century. In *New Horizons, New Beginnings*, ed. Staff, 1:34–40. Newcastle University, Newcastle, UK: Newcastle University.

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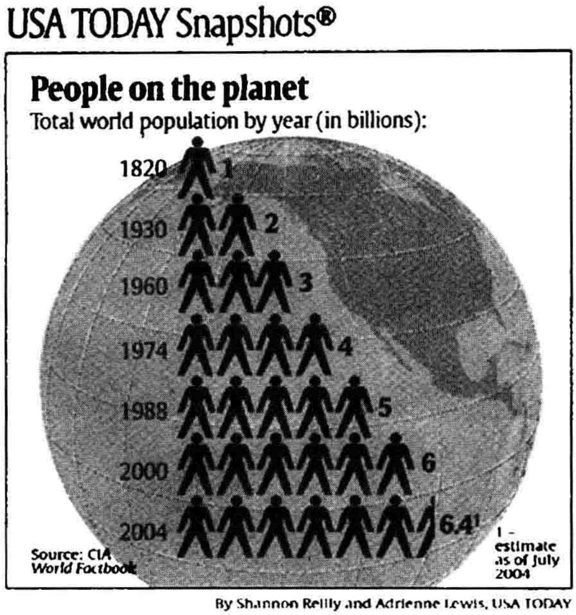

Figure 1.1. World population statistics for the USA, 1820–2004 published in CIA World Fact Book (USA Today Snapshots, July 2004).

quickly the food is made ready for consumption.[2] The potential exists for reducing losses if appropriate tools are made available for measuring the quality of fresh food.

Quality measurements made early in the production cycle, when fresh products are still edible, can determine whether the product goes to fresh market or to processing. The fresh market fraction with optimized quality factors is sent to fresh market; the remaining fraction is sent to facilities for further processing to make pop-tarts, jams, cooked meals and/or soups. Thus the food potential is maximized by minimizing waste.

NEAR-INFRARED SPECTROSCOPY

Near-infrared (NIR) spectroscopy has taken its place among other proven spectroscopic tools, especially for determining chemical and physical properties of foods and food products. Covering the small region of the electromagnetic spectrum from 780 to 2500 (nm) (Sheppard, 1985 #354), producing spectra with only 860 data points spaced 2 nm apart, NIR spectroscopy has experienced phenomenal growth over its short history from 1905 (the year Coblentz produced the first official NIR publication) to the

[2] Based on a survey taken of six major grocery chains in the USA in Ibid.; reported at the conference in Newcastle, UK.

TABLE 1.1. Major Constituents/Properties in Foods Determined with Near-Infrared Spectroscopy

Number	Constituent	Comment	References
1	Water	Water was the first constituent to be studied with near-infrared spectroscopy.	49
2	Protein	Williams, Norris and Kays studied of protein, oil, water and starch in pulverized wheat and foods.	10–15
3	Fats (Oils)	Fats (or oils) were in foods has become a routine NIR measurement today.	16–19
4	Cereals: Dietary Fiber	Dietary and health issues have been studied extensively.	20–23
5	Scattering Properties	Any solid material demands an understanding of the scattering properties in order to obtain robust calibrations.	24, 25
6	Sucrose	Sucrose is a critical constituent in health issues.	26
7	Carbohydrates	Dietary matters call for NIR analyses of carbohydrates.	10
8	Energy	Energy content of food determined by NIR spectroscopy	27
9	Homogeneity	Homogeneity is critical to robust calibrations.	28
10	Condiments Sucrose, Starch, Flour	Osborne has studied the combination of these constituents in processed cereals.	29
11	Meats: Beef, Poultry, Fish	Beef, poultry and fish are analyzed using NIR by a number of researchers.	30–39
12	Fresh Foods: Fruit, Nuts	Once thought to be a very difficult determination, Kawano, Saranwong and others have demonstrated that NIR is useful for the analyses of high-moisture products.	40–50
13	Honey, Corn Syrup, Molasses	Even amorphous sugars in honey and other products can be measured.	51–57
14	Candy, Chocolate, Caramel	The same is true for candies, plus the nicotine related components in chocolates.	54, 58–60

(*Continued*)

TABLE 1.1. ***(Continued)***

Number	Constituent	Comment	References
15	Sweets: Sucrose, Saccharin, Honey, Corn Syrup, Molasses	The spectra of sucrose and saccharin are strikingly similar.	54, 61–65
16	Beverages: Milk, Soft and Hard	In particular, ethanol in beer, wines and spirits is easily determined with near-infrared spectroscopy.	66–78
17	Bread	Osborne has been the leader in the analysis of bread using NIR spectroscopy.	79–81

present. Its sensitivity to the CH, NH, and OH absorptions related to food components, its speedy response time, the simplicity of sample preparation involved, the fact that the measurement is nondestructive, and its low instrumentation cost have fixed its position along side other spectroscopies, including ultraviolet, visible, mid-infrared, Raman and others. Its expansion into the field of food production and processing is undeniable. (2–11)

NIR technology cuts across many fields (agriculture, textiles, pharmaceuticals, cosmetics, medicine, and others), with demonstrated success in all areas published in the literature. This book is not intended to address all the above areas. Rather, this book is intended to provide the reader an opportunity to understand something of the impact NIR spectroscopy has had on food science and technology. Expectedly, it does include basic principles of NIR spectroscopy (Chapter 2), characteristics of the NIR spectra (Chapter 3), instrumentation (Chapter 4), sampling techniques (Chapter 5), and chemometrics (Chapter 6). The remainder of the book discusses numerous applications of NIR technology in the food science field [agricultural and Marine (Chapter 7), food and food products (Chapter 8)] and some specialized applications (Chapter 9). The Editors and Authors all hope you will find this book to be helpful in your work.

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