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Applications and Perceptions of Date Labeling of Food

Rosetta Newsome, Chris G. Balestrini, Mitzi D. Baum, Joseph Corby, William Fisher, Kaarin Goodburn, Theodore P. Labuza, Gale Prince, Hilary S. Thesmar, and Frank Yiannas

Abstract: Open dating of food products has been practiced for decades, and has been key to achieving stock rotation at retail and providing information to consumers. The open date provides a simple communication tool, which may be based on product quality and/or food safety as determined by the manufacturer or retailer. Date marking is generally open but it can be closed (code intended for managing product at retail, and for recall and traceability), and the terminology and applications vary widely around the world. The variation in date labeling terms and uses contributes to substantial misunderstanding by industry and consumers and leads to significant unnecessary food loss and waste, misapplication of limited resources, unnecessary financial burden for the consumer and the food industry, and may also lead to potential food safety risk in regards to perishable foods. A "use by" or similar date cannot be relied on to indicate or guarantee food safety because absolute temperature control of food products throughout the food supply chain cannot be assured. This paper provides an introduction to the issue of food product date labeling and addresses its history in the United States, different terms used and various practices, U.S. and international frameworks, quality compared with safety, adverse impacts of misconceptions about date labeling, and advantages of technological innovations. Collaboration to develop a simple workable solution to address the challenges faced by stakeholders would have tremendous benefit. Conclusions include a call to action to move toward uniformity in date labeling, thereby decreasing confusion among stakeholders and reducing food waste.

Keywords: code dating, date labeling, date marking, open dating

Introduction

Date labeling of foods has been practiced and studied in countries around the world for decades, and many activities and developments have occurred since the 1970s (OTA 1979; IFT 1981; Labuza and Szybist 1999a; NACMCF 2002, 2005; ERG 2003; NRDC 2013). Despite the extent to which the topic of date labeling of packaged food products has been addressed, its use and understanding vary substantially among stakeholders around the world. The variation in date labeling terms and applications contributes to substantial misunderstanding in the marketplace with regard to how the dates relate to food quality or safety. This misunderstanding leads to unnecessary food loss and waste, misapplication of limited resources, and unnecessary financial burden on the food industry and consumers alike. The misunderstanding can also result in storage of food for longer than it has been designed to be stored, presenting food safety risks for perishable foods (Evans and Redmond 2014).

This paper addresses the different terms used in date labeling; various date-labeling practices; legal, regulatory, and other frameworks in several countries; misconceptions about date labeling; and the extent of adverse impacts of those misconceptions. The purpose of this paper is to provide science-based information to help bring clarity to the issue of date labeling of food products to allow for more informed risk-based decision making by all stakeholders, including government officials, food manufacturers, retailers, and consumers—worldwide.

History of Food Product Date Labeling in the United States

Date labeling of food products has a long history, as is demonstrated by its beginning in the United States and the numerous activities that have since taken place. Dates first appeared on food packages approximately 100 y ago. As populations became further removed from food production and the source of their food, their

MS 20140640 Submitted 16/4/2014, Accepted 25/4/2014. *Author Newsome is with Institute of Food Technologists, 525 West Van Buren St., Chicago, IL 60607-3830, U.S.A. Author Balestrini is with Grocery Manufacturers Assn., 1350 I St., NW, Suite 300, Washington, DC 20005, U.S.A. Author Baum is with Feeding America, 35 East Wacker Drive, Suite 2000, Chicago, IL, 60601, U.S.A. Author Corby is with Assn. of Food & Drug Officials, 2550 Kingston Rd., Suite 311, York, PA, 17402, U.S.A. Author Fisher is with Institute of Food Technologists, 1025 Connecticut Ave., N.W., Suite 503, Washington, DC 20036-5422, U.S.A. Author Goodburn is with Chilled Food Assn, P.O. Box 6434, Kettering NN 15 5XT, United Kingdom. Author Labuza is with Dept. of Food Science and Nutrition, Univ. of Minnesota, Andrew Boss Lab, Room 136A, 1354 Eckles Ave, St. Paul, MN, 55108, U.S.A. Author Prince is with SAGE Food Safety, LLC, P.O. Box 54491, Cincinnati, OH 45254, U.S.A. Author Thesmar is with Food Marketing Inst, 2345 Crystal Drive, Suite 800, Arlington, VA, 22202-4801, U.S.A. Author Yiannas is with Walmart, 508 Southwest 8th St, Bentonville, AR, 72716-0275, U.S.A. Direct inquiries to author Newsome (E-mail: rlnewsome@ift.org).*

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ability to determine product freshness decreased. People began purchasing their food from stores and were no longer privy to its history in the food system. Consumers had to rely on food manufacturers to supply them with food. Manufacturers applied dates on product packages to indicate freshness (Labuza and Szybist 2001). In the United States, dairy products are believed to have been the first to have dates on packages. By the late 1960s, the Kroger Co. (Cincinnati, Ohio, U.S.A.) became an industry leader through use of sell by dates on packages of pasteurized milk; the dates related primarily to the onset of sensory-based spoilage of the milk (Pal and others 2007).

Surveys of consumers in the United States have shown a desire for open date labeling (use of terms such as "best if used by" or "best before," described later). Books have been provided at some supermarkets to allow consumers to decipher the codes used in closed date labeling (use of product packing information by manufacturers, described later; Labuza and Szybist 1999a). By the 1970s, U.S. supermarkets implemented date labeling systems in response to consumer requests. In addition, by the early 1970s legislation was being introduced; more than 75 pieces of legislation were introduced that would require open date labeling of foods (USDA/ERS 1973). A study conducted between 1971 and 1972 by the U.S. Dept. of Agriculture (USDA)/Economic Research Service (ERS) indicated that 60 retail food chains had introduced some type of open date labeling system (USDA/ERS 1973).

State and local regulations were adopted, and a model open dating regulation for states was developed in 1973 (GAO 1975). The U.S. General Accounting Office (now the Government Accountability Office) suggested that the U.S. Congress consider amending the Fair Packaging and Labeling Act, Food Drug & Cosmetic Act (FD&C Act), and related food labeling laws to establish a uniform open-dating system for perishable and semiperishable foods (GAO 1975). A report was published in 1977 by the New York State Consumer Protection Board to help consumers understand manufacturer code dates. Joint labeling hearings were conducted in 1978 by the U.S. Food and Drug Administration (FDA), USDA, and the Federal Trade Commission, and more than 9000 written comments were received (OTA 1979; NRDC 2013). The U.S. Office of Technology Assessment (OTA) conducted an extensive assessment and analysis for a Senate committee (OTA 1979). Additional legislative activity occurred in the late 1990s and between 2001 and 2009, with members of the Congress introducing 2 acts and a number of bills (NRDC 2013).

Surveys of shoppers were conducted by government agencies and others (FDA 1975; GAO 1975; Market Facts 1978; OTA 1979; IFT 1981; Cates and others 2004; Kosa and others 2007). A 1971 study by Rutgers Univ. found that of the 628 consumers who were surveyed on open date labeling, 62% of them sort for the youngest date when shopping, causing the older product to remain on the shelf for a longer period of time and losing more quality (Anonymous 1971), a phenomenon referred to as the "sorting dilemma." During the 1980s and 1990s, consumer awareness and requests for open date labeling subsided, but continued to emphasize freshness as a key factor in grocery shopping (Labuza and Szybist 2001).

An extensive study was conducted under contract for the U.S. FDA (ERG 2003), and the U.S. Natl. Advisory Committee on Microbiological Criteria for Foods (NACMCF) considered aspects of the topic (NACMCF 2005). Additionally, in 2005 the U.S. FDA Food Code included date labeling as a requirement for ready-to-eat (RTE), potentially hazardous food (PHF) prepared at the retail establishment for which time and temperature control is important for food safety. This provision was not intended to require date marking on the labels of consumer packages but as a mechanism for active managerial control of time and temperature during cold holding within the retail establishment. The Food Code also contains date marking requirements for foods packaged at the retail establishment in reduced-oxygen packaging to control the growth of *Clostridium botulinum* and *Listeria monocytogenes* (FDA Food Code 2013; USDA 2013a), and date labeling-related specifications for receiving packaged raw shucked shellfish. The Food Code is for safeguarding public health and ensuring that food in the retail and foodservice sectors is unadulterated and honestly represented when offered for sale to consumers. As of 2012, all 50 states and 3 of 6 territories had retail codes patterned after the FDA model Food Code (FDA Food Code 2013).

Historical details on food product date labeling have been addressed by several individuals and organizations, and are available in publications by the Institute of Food Technologists (IFT 1981), Sherlock and Labuza (1992), Labuza and Szybist (1999a, 2001), the NACMCF (2005), and in a report produced in partnership between the Natural Resources Defense Council (NRDC) and Harvard Food Law and Policy Clinic (NRDC 2013). Current date labeling practices in the United States and elsewhere are addressed later in this article.

Inconsistent Nomenclature and Practices Foster Confusion

A variety of information and terminology is used on food packages to inform and allow date-related action by stakeholders (food manufacturers and consumers, for example). Additionally, regulatory frameworks and guidance for date labeling applications vary around the world.

Terminology and Applications

There is considerable variation in the terminology that manufacturers use on food product packages for different date-labeling purposes. This variation in terminology and inconsistency in date-labeling practices fosters confusion in the marketplace and the home.

Food product date labeling is generally classified as either "open" or "closed." Open date labeling—with terms such as sell by, best if used by, or best before, freeze by, use by, baked on, and packed on—is for indicating to retail personnel and consumers the shelf life of the product with respect to optimum quality and for stock rotation. Driven by a readable code for retail employees and by consumers, open date labeling has been a major benefit at retail in achieving effective stock rotation. Thus, open date labeling is intended to be understandable by consumers and individuals in the supply chain who are responsible for the product and for ensuring high product quality to consumers. Terms commonly used in open date labeling in the United States include the following (FMI and GMA 2007; NIST 2013):

- Sell by—The date, determined by food manufacturers, by which the food at retail should be sold unless it is frozen prior to or upon reaching the date. There is a period of time beyond this date that the product is usable before the quality is less than the manufacturer's standards for consumer acceptance. Typically one-third of the product's shelf life remains after the sell by date for consumer use in the home. Many manufacturers will credit the store for the past-date product, especially if it is donated to food banks or food salvage stores.
- Use by—The date, determined by the product manufacturer, by which the product should be consumed. In addition, retail

packaging of certain reduced-oxygen packaged foods requires labeling with use by dates in conjunction with time limits for refrigerated shelf life. The product should be discarded after the use by date.

- Best by, best if used by, best if used before, or best before—Dates by which the product should be consumed for ideal quality. These may be combined with a freeze-by statement (for example, best if used by X or "can be frozen but must be used within X days if taken from the freezer"), which is becoming commonly used with poultry and fish.

These and other terms, including "durable life date" (similar to best before) "minimum durability," "frozen on," and "best if purchased by" are used outside the United States. As described later, in some countries (for example, in the European Union [EU]) certain terms may be based on food safety (use by dates applied to highly perishable foods, for example) rather than food quality characteristics.

Closed (code) date labeling, on the other hand, is the information that manufacturers place on products, usually those having a long shelf life, to manage product stock at retail, from a quality-driven perspective, and for recall and product tracing purposes. Closed code dates may be comprised of letters, numbers, or symbols; may refer to the place of manufacture, time of manufacture, or product identity; and are generally not easily understandable by consumers (USDA/FSIS 2011). Closed date labeling aids in product identification and is useful for product recalls or tracing, particularly trace-backs and trace-forwards, because the production dates can be identified or obtained by the manufacturer. Information and resources on product tracing are available through the Global Food Traceability Center (2013).

Additionally, the terms "code" or "coding" may be used generally in a broad sense in referring to open as well as closed date labeling. For example, "out of code" is a phrase that may be used from a general perspective to refer to product that is past its use by date, and "close to code" may be used in food bank networks to refer to food product that is approaching its best if used by, sell by, and consume by dates.

The Codex Alimentarius Commission, the international food standards setting organization of the Food and Agriculture Organization of the United Nations and the World Health Organization, has available a "General Standard for the Labelling of Prepackaged Foods" (CAC 2007a) that describes application of date marking and use of date of minimum durability in the labeling of prepackaged food. The Codex standard defines several related terms including date of manufacture, date of packaging, sell by date, and use by date. New work began in 2014 in the Codex Committee on Food Labelling (CCFL) to review the date marking provisions portion of this standard.

The current Codex standard indicates that the date of minimum durability consists at least of the day and the month for products with a minimum durability of not more than 3 mo, and the month and the year for products with a minimum durability of more than 3 mo, unless the month is December in which case indicating the year is sufficient. The standard indicates that the date shall be declared by the words best before, where the day is indicated, or "best before end . . . ," in other cases, and accompanied by either the date itself or a reference to where the date is provided. The standard indicates that the day, month, and year shall be declared in uncoded numerical sequence except that the month may be indicated by letters in those countries where such use will not confuse the consumer. Further, if the validity of the date depends on any special storage conditions, they are to be declared on the label. The date of minimum durability described in the Codex standard does not apply to fresh fruits and vegetables, wines, beverages containing 10% or more by volume of alcohol, baked goods normally consumed within 24 h of manufacture, vinegar, food-grade salt, solid sugars, confectionery products consisting of flavored and/or colored sugars, or chewing gum.

U.S. and International Date Labeling Frameworks

Application and perception of food product date labeling is complicated by multiple regulatory jurisdictions in the United States and different perspectives and challenges around the world (developed markets versus emerging markets, for example). Although exact requirements vary among countries, most developed countries other than the United States require open date labeling of most food products, and generally the date represents the time after which product freshness is not guaranteed (ERG 2003). Open date labeling of food products is mandated in the EU, many South American countries, many of the Arabic States, the European Free Trade Assn. member countries, Israel, and Taiwan (Labuza and Szybist 1999a). The regulatory frameworks of a few countries, exemplifying varying frameworks, are addressed below and shown in Table 1.

Australia and New Zealand. The Australia New Zealand Food Standards Code outlines date marking provisions for these countries (Australian Government 2012). With some exceptions, date marking with a best before or use by date is required for most packaged foods for retail sale or catering purposes that have a shelf life of <2 y. Exceptions are individual servings of ice cream or ice confections, and foods in a small package, except where the food should be consumed before a certain date because of health or safety reasons. The label on a package of bread with a shelf life of <7 d may include instead of a best before date its baked on date (date on which the bread was baked) or its baked for date (date not later than 12 h after the time the bread was baked). The Australia New Zealand Food Standards Code indicates the prescribed wording and precise format of the date marking. Furthermore, the label on a package of food must include a statement of any specific storage conditions required to ensure that the food will keep for the period indicated by the use by or the best before date. Additionally, the requirements do not preclude the label on a package of food from including a packed on date or a manufacturer's or packer's code in addition to the required use by or best before date.

Paragraphs 2(1)(c) and (d) (regarding date marking with a best before date) of Standard 1.2.5 do not apply to the Standard for infant formula products (Standard 2.9.1), and a label on a package of infant formula product must contain storage instructions addressing the period after it is opened (Australian Government 2013a). The label on a package of formulated supplementary sports foods must include a statement of the recommended consumption in 1 d (Australian Government 2013b). Foods for special medical purposes must comply with Standard 1.2.5; however, the package label may use the words "Expiry Date" or similar words instead of the words "Use By" if the food is required to include a use by date under Standard 1.2.5 (Australian Government 2013c).

A Guide to the Code's "Standard 1.2.5 – Date Marking of Packaged Food" helps manufacturers determine whether food should be date marked with a best before, use by, baked on, or baked for date, and provides details on the use and form of date marking (FSANZ 2013). Date marking is described in the code as being based on either quality, health (for products having

Table 1–Examples of different regulatory frameworks for food date labeling.

Country	Framework	Focus	Additional information
Australia, New Zealand	Australia New Zealand Food Standards Code – Standard 1.2.5 – Date Marking of Packaged Food – F2012C00762 (Australian Government 2012a)	Use by date on foods that should be consumed before a certain date because of health or safety reasons or best before date for most packaged foods for retail sale or catering purposes; Any specific storage conditions required to ensure that the food will keep for the period indicated by the use by or best before date must be included on the label; Sale after required use by date prohibited	Best before date signifies end of period which the intact package of food, if stored according to any stated storage conditions, will be fully marketable and retain any specific expressed or implied qualities; Use by date signifies end of the estimated period, if stored according to any stated storage conditions, after which the intact package of food should not be consumed because of health or safety reasons. Requirements do not preclude the label on a package of food from including a packed on date or a manufacturer's or packer's code in addition to the required use by or best before date Bread with a shelf life of $<$7 d may include instead of a best before date a baked on or baked for date
	Australia New Zealand Food Standards Code – Standard 2.9.1 – Standard for Infant Formula Products	Storage instructions for period after package opening	
	Australia New Zealand Food Standards Code – Standard 2.9.4 – Formulated Supplementary Sports Foods	Statement of recommended consumption in 1 d	
	Australia New Zealand Food Standards Code – Standard 2.9.5 – Food for Special Medical Purposes	Expiry date or similar words is permitted instead of use by date on foods required to include a use by date	
Canada	Food and Drug Regulations C.R.C., c. 870	Durable life date with the terms best before and meilleur avant on prepackaged foods with a durable life of $\leq$90 d that are packaged at other than retail, unless an explanation of the significance of the durable life date appears elsewhere on the label; Packaging date with the terms packaged on and empaqueté le and the durable life on prepackaged foods with a durable life of $\leq$90 d that are packaged at retail, except when the durable life appears on a poster next to the food; with exceptions; Storage conditions if different from normal room temperature; Expiration date on formulated liquid diets, food represented for use in a very low-energy diet, meal replacements, nutritional supplements, and human milk substitutes	Durable life is the date on which the durable life of a prepackaged product ends; Packaging date is the date on which a food is placed for the first time in a package in which it will be offered for sale to a consumer or the date on which a prepackaged product is weighted by a retailer in a package in which it will be offered for sale for the first time to a consumer; Expiration date, regarding a formulated liquid diet, a food represented for use in a very low-energy diet, a meal replacement or a nutritional supplement, is the date after which the manufacturer does not recommend that it be consumed, and up to which it maintains its microbiological and physical stability and the nutrient content declared on the label
European Union (EU)	E.U. Regulation No. 1169/2011 of the European Parliament and the Council of the EU, and EC Regulation No. 178/2002	Date of minimum durability, preceded by best before, when the date indicates the day, or best before end, accompanied by the date or reference to location of date on the label; or a use by date, with some exceptions; Use by date for microbiologically highly perishable foods likely to be an immediate health danger after a short time period; Any special food storage conditions and/or conditions of use; Date of freezing or date of first freezing for frozen meat, frozen meat preparations, and frozen unprocessed fishery products, preceded by the words frozen on accompanied by the date or a reference to location of date on the label	
United States	21 U.S.C. § 350a and 21 CFR 107.20(c)	Use by date required for infant formula; Storage conditions required for before and after opening	
	21 CFR 113.60(c)	Code identifying packing establishment, product, year and day packed, and period during which packed, on each thermally processed low-acid food packaged in a hermetically-sealed container	

[a]

(Continued)

Table 1–Continued

Country	Framework	Focus	Additional information
	9 CFR 381.126(a) and (b)	Pack date in either closed or open format required on poultry products, relates to quality; sell by or use by date permitted in lieu of pack date; Lot number (indicating slaughter date) or a coded number required on dressed poultry Pack date, in a 3-digit code, required on egg cartons with USDA grade shield; if a sell by date is used, the code may not exceed 45 d from the pack date	
	2011 'Grade A' Pasteurized Milk Ordinance	Code or lot number on condensed or dry milk products, identifying contents, container quantity, and specific date, run, or product batch; "Keep refrigerated after opening" required on aseptically processed and packaged milk and milk products and condensed or dry milk products	
	Uniform Open Dating Regulation, Natl. Conference on Weights and Measures (2-option model for states and local jurisdictions to adopt)	(1) Mandatory uniform date labeling of prepackaged, perishable foods or (2) Optional uniform date labeling of non-perishable foods, with exceptions	For perishable food, the sell by date is based on allowance of a reasonable period after sale for consumption of the food without physical spoilage, loss of value, or loss of palatability; For semi-perishable and long-shelf-life food, sell by or best if used by dates relate to quality, characteristics, formulation, processing impact, packaging or container and protective wrapping or coating, customary transportation, and storage and display conditions
	2013 U.S. FDA Food Code (Voluntary model for states and local jurisdictions to adopt for managerial control at retail and in food service)	Date or day by which the food shall be consumed on the premises, sold, or discarded, being prepared on premises and held at $\leq$ 41 °F (5°C) for $>$ 24 h and $\leq$ 7 d; Date or day, which shall not exceed the manufacturer's use by date, if safety-based, by which the food shall be consumed on the premises, sold, or discarded, being held at $\leq$ 41 °F (5°C) for $>$ 24 h and $\leq$ 7 d upon opening original container of food that is commercially processed, except for deli salads, certain hard and semi-soft cheeses, cultured dairy products, preserved fish products, shelf stable dry fermented sausages, and shelf stable salt-cured products Retained date marking of earliest-prepared or 1st-prepared ingredient for refrigerated ready-to-eat (RTE) time/temperature control for food safety food ingredient or portion of a refrigerated RTE time/temperature control for safety food subsequently combined with additional ingredients or portions of food Limit refrigerated shelf life to $\leq$ 30 d of packaging, except for time maintained frozen, or the original manufacturer's sell by or use by date if earlier, and implement HACCP plan in conjunction with packaging time/temperature control for safety food using reduced oxygen packaging, unless a variance exists Sell by or best if used by date on $<$1.89 L (1/2 gallon)-capacity packages of received raw shucked shellfish and date shucked on $\geq$1.89 L (1/2) gallon-capacity packages	

nutrient profiles critical to consumer health, for example), or safety considerations (for foods that may become microbiologically unsafe before discernibly spoiling, for example), and as the length of time a food should "keep" before it begins to deteriorate or become less nutritious or unsafe (FSANZ 2013). A best before date is "the last date on which you can expect a food to retain all of its quality attributes, provided it has been stored according to any stated storage conditions and the package is unopened." A use by date is "the last date on which the food may be eaten safely, provided it has been stored according to any stated storage conditions and the package is unopened," after which the food should not be eaten for health and safety reasons (FSANZ 2013). Foods with an expired best before date may be sold provided the food is not spoiled and complies with other applicable legislation, whereas foods with an expired required use by date may not be sold, because consumption may pose a health risk (Australian Government 2012a; FSANZ 2013). The Guide also indicates, with reference to special purpose foods in Part 2.9 of the Code, that foods that

need to be eaten within a certain period to ensure that they provide the claimed amounts of nutrients, and thereby achieve their intended purpose, must be marked with a use by date, which will indicate the period that the unopened food is expected to retain all nutrients in the correct amounts provided it is stored according to any stated storage conditions (FSANZ 2013).

Recognizing the increased availability of an expanding range of RTE, short-shelf-life foods and need for use of measures to minimize the potential for microorganisms such as *L. monocytogenes* and *C. botulinum* to be present in foods in numbers potentially hazardous to health, the New Zealand Food Safety Authority (NZFSA) produced guidelines (NZFSA 2005) for determining the shelf life of foods capable of supporting growth of these microorganisms and to assist in meeting the requirements of legislation. The guidelines describe in some detail the procedures used in direct and indirect shelf-life studies. Direct shelf-life studies involve storing the product under preselected conditions for a period of time longer than the expected shelf life and checking the product at regular intervals to determine when it begins to spoil. The indirect approach uses accelerated storage and/or predictive microbiological modeling to determine an appropriate shelf life (NZFSA 2005).

Canada. In Canada, the Food and Drug Regulations require for prepackaged foods having a durable life of 90 d or less: (a) on prepackaged foods packaged at a place other than retail, a durable life date grouped with it the words "best before" and "meilleur avant," unless a clear explanation of the significance of the durable life date appears elsewhere on the label, and instructions for proper storage conditions if storage conditions different from normal room temperature are required; and (b) on prepackaged foods packaged at retail, the packaging date and the durable life of the food, except when the durable life appears on a poster next to the food, and the terms "packaged on" and "empaqueté le" (Minister of Justice 2014). Durable life means "the period, commencing on the day on which a prepackaged product is packaged for retail sale, during which the product, when it is stored under conditions appropriate to that product, will retain, without any appreciable deterioration, its normal wholesomeness, palatability, nutritional value, and any other qualities claimed for it by the manufacturer." Durable life date means "the date on which the durable life of a prepackaged product ends" (Minister of Justice 2014). Packaging date means "the date on which a food is placed for the first time in a package in which it will be offered for sale to a consumer" or "the date on which a prepackaged product is weighed by a retailer in a package in which it will be offered for sale for the first time to a consumer." The format (showing, for example, the month in words after the year, if the year is shown, with abbreviation allowed, and the day of the month after the month and expressed in numbers) for indicating the durable life date is specified in the Food and Drug Regulations. Foods with an anticipated shelf life >90 d are not required to be labeled with a best before date or storage information (CFIA 2014).

Expiration dates are required on: formulated liquid diets, foods represented for use in a very-low-energy diet, meal replacements, nutritional supplements, and human milk substitutes (CFIA 2014; Minister of Justice 2014). Expiration date means, regarding a formulated liquid diet, a food represented for use in a very-low-energy diet, a meal replacement, or a nutritional supplement, the date "after which the manufacturer does not recommend that it be consumed, and up to which it maintains its microbiological and physical stability and the nutrient content declared on the label."

Exceptions to this requirement are: prepackaged products consisting of fresh fruits or vegetables, prepackaged individual portions of food served by a restaurant or other commercial enterprise with meals or snacks; prepackaged individual servings of food prepared by a commissary and sold by automatic vending machines or mobile canteens; or prepackaged donuts.

Further, subsection 5(1) of the Food and Drugs Act states that "No person shall label, package, treat, process, sell or advertise any food in a manner that is false, misleading or deceptive or is likely to create an erroneous impression regarding its character, value, quantity, composition, merit or safety" (General Principles for Labelling and Advertising: Requirements 2014).

Canada has a retail guidance document addressing control of pathogens, including *L. monocytogenes*, in RTE refrigerated foods (Health Canada 2013). The guidance was produced by the Retail Council of Canada, Food Safety Committee, and Health Canada for labeling product at retail that has a durable life of ≤90 d. The guidance contains specifics pertaining to supplier code dates, relabeling, cooked/RTE/processed meat and hard cheeses being vacuum-packaged at retail, overwrapping of cheeses at the store level and other products, and PHFs. PHFs are defined in the guidance document as "foods capable of supporting the growth of pathogenic microorganisms and/or the production of toxin (for example, foods that have a pH level above 4.6, foods that have a water activity above 0.85). Such products might also be referred to as temperature controlled for safety (TCS)." The guidance recommends that PHFs should not be sold beyond their best before date. The guidance also recommends that the durable life applied to store-prepared or assembled multi-ingredient/multicomponent RTE PHFs (for example, sandwiches, cut produce, sushi, salads, fresh fruit flans, cream- or custard-filled bakery products, yogurt parfaits) that support the growth of pathogens and/or toxin production be limited to a maximum of 3 d unless at least one of the following items supports a longer, product-specific, or appropriate product category-specific durable life:

- reference to scientific literature or historical knowledge of the performance of the control measure,
- science-based valid experimental data that demonstrate the adequacy of the control measure,
- collection of data throughout operating conditions representative of food retail operations,
- mathematical modeling (Health Canada 2013).

European Union. As of December 13, 2014, Regulation No. 1169/2011 of the European Parliament and the Council of the European Union mandates, with some exceptions, a date of minimum durability or a use by date (EC 2011). The regulation requires that foods that are highly perishable from a microbiological point of view "and are therefore likely after a short period to constitute an immediate danger to human health," carry a use by date, after which date the "food shall be deemed unsafe" in accordance with Article 14(2) to (5) of Regulation (EC) No. 178/2002, rather than a date of minimum durability. Additionally, any special food storage conditions and/or conditions of use that may be required are to be indicated. The Regulation repeals EC Directive 2000/13/EC among other Directives and Regulation.

The date of minimum durability must be preceded by the words "best before" when the date includes an indication of the day (or "best before end . . . " in other cases), and accompanied by either the date itself or a reference to where the date appears on the label, and if necessary followed by a description of the storage conditions

that must be observed if the product is to keep for the specified period. The date is to consist of the day, the month, and possibly the year, in that order and in uncoded form, with the following exceptions:

- for foods which will not keep for more than 3 mo, an indication of the day and the month is sufficient;
- for foods which will keep more than 3 mo but not more than 18 mo, an indication of the month and year is sufficient; and
- for foods which will keep more than 18 mo, an indication of the year is sufficient.

A minimum-durability date is not required for: fresh fruit and vegetables including unpeeled potatoes; wines, liqueur wines, sparkling wines, aromatized wines, and similar products obtained from fruit other than grapes, and beverages falling within Combined Nomenclature code 2206 00 obtained from grapes or grape musts; beverages containing 10% or more by volume of alcohol; bakers' or pastry cooks' wares which, given the nature of the content, are normally consumed within 24 h of manufacture; vinegar; cooking salt; solid sugar; confectionery products consisting almost solely of flavored and/or colored sugars; chewing gums and similar chewing products.

The use by date, which is to be indicated on each individual prepacked portion, must be preceded by the words "use by," which shall be accompanied by either the date itself, or a reference to where the date is given on the labeling, and shall be followed by a description of the storage conditions that must be observed. The date shall consist of the day, month, and possibly the year, in that order and in uncoded form.

Frozen meat, frozen meat preparations, and frozen unprocessed fishery products must carry the date of freezing or the date of first freezing, preceded by the words "frozen on" and accompanied by the date itself or a reference to where the date is given on the label; the date must consist of the day, the month, and the year, in that order and in uncoded form.

United Kingdom. U.K. date-marking requirements are, as in other E.U. Member States, subject to E.U. legislation. The Dept. for Environment, Food and Rural Affairs (DEFRA) issued in 2012 a Guide to compliance with The Food Information Regulations 2013, which are intended to allow enforcement of E.U. No 1169/2011 of the European Parliament and of the Council (DEFRA 2012). The Guide indicates that "where a 'use by' date is exceeded, action should be taken under the General Food Regulations 2004 (S.I. 2004/3279) which enforce the food safety requirements of Regulations (EC) No 178/2002) . . . .However, a criminal offence will be committed and the enforcement officers may prosecute the FBO for the sale of 'unsafe' food." The DEFRA/Food Standards Agency (FSA) guidance on applying date labels to food that was issued in 2011 (FSA/DEFRA 2011) also applies. The 2011 guidance was issued after determining in 2009 at a joint event with the Waste and Resource Action Program (WRAP) on date marking and food waste that its guidance on use by date marks should be updated. WRAP is a U.K.-based organization that focuses on the benefits of reducing waste, developing sustainable products, and using resources in an efficient way. Additionally, the FSA conducted a consultation in 2010 (FSA 2010) to seek input for the update. The guidance was to help businesses comply with the legal requirements on date marks and decide whether to label food with either a best before or a use by date. The guidance mentions as key legislation Directive 2000/13/EC of the European Parliament and the Council, which it states is implemented in Great Britain by the Food Labelling Regulations 1996 and in Northern Ireland by the Food Labelling Regulations (Northern Ireland) 1996, collectively referred to as the FLR. The guidance indicates that it is an offence to sell food after its use by date, whereas it is not an offence to sell food after its best by date, in accordance with Regulation 44.1(d) of the FLR (FSA/DEFRA 2011).

The guidance illustrates the principles for determining date marks via a decision tree and also provides best practices, which include:

- explore alternative techniques for using date labeling for stock control so that they are less visible to consumers; avoid diluting the key messages of the legally required date marks;
- for foods requiring refrigeration in the home, consider providing instructions that allow flexibility in the temperature of storage depending on the nature of the food (for example, if refrigeration is required for quality reasons, use "keep refrigerated"; if required for safety, use "keep refrigerated below 5 °C");
- keep in mind when setting date marks that use by dates relate to food safety while best before dates relate to quality;
- apply the best before date to shelf-stable foods that are safe to consume or perishable foods that do not deteriorate rapidly and become unsafe to eat after the date mark.

Building on the DEFRA/FSA date labeling guidance, the trade association Dairy UK published guidance for milk and dairy product manufacturers regarding the appropriate date-marking and optimum storage conditions for a range of milk and dairy products, with the aim to reduce food wastage in the home without compromising food safety and quality (Dairy UK 2012).

Other countries in the European Union. The date labeling requirements as of 2011 in France, Germany, The Netherlands, Poland, Italy, Belgium-Luxembourg, and Ireland are provided in LBRO (2011a). In France, nonperishable products carried a "Date Limited d'utilisation optimale" followed by day/month/year and the words "to be consumed before end of . . . " Perishable products carried a "date limited de consummation," followed by day/month/year and the words "to be consumed before . . . ," while extremely perishable foods carried the "date limited de consummation, followed by day/month/year and the words "to be consumed up to . . . " or "to be consumed no later than . . . "

In Germany, with some exceptions, products carried a minimum shelf-life date, which referred to the date until which the product maintains its maximum level of quality under proper storage conditions, unless they may for microbiological reasons pose a health threat after a certain storage period in which case they were required to carry a "latest consumption date." In Ireland, Italy, The Netherlands, and Belgium-Luxembourg, best before dates and variations on day, month, or year were used on products with a shelf life of up to 3 mo, with some exceptions (for example, fresh eggs in Ireland, which were required to be delivered to the consumer within 21 d of laying [at least 7 d before their best before date]); best before end and month and year were used on products with a shelf life of 3 to 18 mo; and best before end and year were used on products with a shelf life of >18 mo. Use by dates with day, month, year, and storage instructions was used in The Netherlands and Belgium-Luxembourg on highly perishable foods. In Italy it was up to those labeling the product to choose between a best before or use by date, and guidance was available. In Poland best before and day/month/year were used, and

very-perishable foods carried the "last day of consumption" and storage and use instructions as necessary (for example, if a product appeared to need refrigeration but did not). Italy provided guidance with detailed information that was required on labels (LBRO 2011a).

United States. In the United States, except for infant formula, thermally processed low-acid canned foods packaged in hermetically sealed containers, and certain packaged milk or milk products, date labeling of foods sold at the retail level is generally not required by federal regulations. Infant formula and some types of baby food are required by federal law (21 U.S.C. § 350a (2010) and 21 CFR 107.20 (2013) (c)) to be labeled with a use by date for the purpose of assuring nutrient content. Thermally processed low-acid foods packaged in hermetically sealed containers are required by federal law (21 CFR 113.60(c)) to be marked on each container with a code identifying the establishment where packed, product, year and day packed, and period during which packed (which may be changed as needed to enable ready identification of lots during sale and distribution). Among other requirements, aseptically processed and packaged milk and milk products must be marked with the words "keep refrigerated after opening"; and condensed or dry milk products must also carry a code or lot number identifying the contents and the quantity in the container, and the specific date, run, or batch of the product (HHS/PHS/FDA 2011).

If date labeling is used on meat or poultry, the USDA requires that the month and day of the month, and the year, in the case of shelf-stable and frozen products, be used. If a calendar date is shown, there must be a phrase (for example, sell by or use before) immediately adjacent to the date that explains the meaning of the date (Food Product Dating 2013).

With respect to poultry products, USDA requires a pack date (date that the finished product is packed into the immediate container/consumer package) in the form of a closed code or a calendar date, which is related to the quality of the product rather than safety, on either the immediate container or the shipping container (9 CFR §381.126(a), USDA/FSIS 2013). If a calendar date is used, it must be accompanied by a statement explaining the meaning of the date, as provided in §381.129(c)(2) and the date must include the month of the year and the day of the month for all products and also the year in the case of products hermetically sealed, dried, or frozen. If a code date is used it should not be misleading to a consumer (must not be able to be mistaken for a calendar date). FSIS permits the use of a sell by or use by date in lieu of the required date of packing. Dressed poultry (slaughtered, defeathered, eviscerated whole birds with the head and feet removed, that is, a ready-to-cook whole bird) must be marked on the immediate container with either a lot number, which shall be the number of the day of the year on which the poultry was slaughtered, or a coded number (9 CFR §381.126(b)).

The USDA requires egg cartons with the USDA grade shield to display the pack date (the day that the eggs were washed, graded, and placed in the carton) in a 3-digit code representing the consecutive day of the year (for example, 001 for January 1, 365 for December 31). Further, if a sell by date is used on a carton displaying the USDA grade shield, the code date may not exceed 45 d from the pack date (Food Product Dating 2013). However, eggs not packed in USDA facilities do not need to follow the same rules; instead, eggs that are not packed under USDA's grading program must be labeled and coded in accordance with egg laws in the state where they are packed and/or sold. Shell eggs packed into containers must also be labeled (for example, with "Keep Refrigerated") to indicate that refrigeration is required (§590.50; §590.410).

At the state and local jurisdiction level, the voluntary Uniform Open Dating Regulation of the Natl. Inst. of Standards and Technology (NIST 2013) allows for 2 options—mandatory uniform date labeling of prepackaged, perishable foods or voluntary uniform date labeling of nonperishable foods. The voluntary regulation serves as a model for state and local jurisdictions to adopt. NIST is a research and advisory body of the U.S. Dept. of Commerce. The Open Dating Regulation was written in 1985 by the Natl. Conference on Weights and Measures (NCWM) in concert with the Assn. of Food and Drug Officials (AFDO). The NCWM is a nonprofit association of state and local weights and measures officials, federal agencies, manufacturers, retailers, and consumers. The purpose of the state-level regulation is "to prescribe mandatory uniform date labeling of prepackaged, perishable foods and to prescribe optional uniform date labeling that must be used whenever a packager elects to use date labeling on prepackaged foods that are not perishable." The regulation is intended "for use and understanding by both distributors and consumers when judging food qualities." The regulation exempts (does not apply to) any food that is not prepackaged, perishable fruits or vegetables in a container permitting sensory examination, and prepackaged perishable foods containing open date labeling according to requirements of federal law or regulation.

In 1979, an assessment of open date labeling requirements by the U.S. OTA indicated that some form of open date labeling regulation was practiced by 22 states (OTA 1979). Of those 22 states, 20 specifically addressed milk. By 1998, this had risen to 29 states and the District of Columbia (Labuza and Szybist 1999b). According to NIST (2013), 18 states (Ark., Conn., D.C., Fla., Ga., Md., Mich., Minn., Nev., N.H., N.Mex., Okla., Oreg., P.R., R.I., S.Dak., Wash., and W.Va.) and the Virgin Islands have a state law or regulation for open date labeling. Ten of the 19 states (D.C., Fla., Ga., Md., Minn., N.H., N.Mex., Oreg., P.R., and R.I.) have a law or regulation in force, but which is not based on the NCWM standard. Among those who use NCWM recommendations, 5 states (Ark., Conn., Nev., Okla., and W.Va.) adopt and update NCWM recommendations automatically on an annual basis, and 4 states (Mich., S.Dak., V.I., Wash.) have an NCWM recommendation in place, in whole or in part, but from a prior year (that is, updates are not automatic; NIST 2013).

The U.S. Open Dating Regulation describes how to determine and express the sell by or best if used by date. For perishable food, the sell by date is determined by the manufacturer, processor, packer, re-packer, retailer, or other person who prepackages the food, on the basis of allowance of a reasonable period after sale for consumption of the food without physical spoilage, loss of value, or loss of palatability. Additionally, the reasonable period for consumption consists of at least one-third of the approximate total shelf life of the perishable food. With regard to semiperishable and long-shelf-life food, the person placing the sell by or best if used by date on the package is to determine the date by taking into consideration the food quality, characteristics, formulation, processing impact, packaging or container, and other protective wrapping or coating, customary transportation, and storage and display conditions. Perishable food may not be offered for sale after the sell by date unless it is wholesome and advertised in a conspicuous manner as being offered for sale after the recommended last date of sale. Semiperishable and long-shelf-life food may be sold beyond the best if used by date provided the food is wholesome and the sensory physical quality standards for that food have not

significantly diminished. The sell by or best if used by date must be shown on the package or its label or attached tag in a way that is easily readable and visible (NIST 2013). This Open Dating Regulation state regulation does not mention that dates are not tied to safety issues, except for the use of the word "wholesome" with respect to selling past-dated food.

The U.S. FDA Food Code (FDA Food Code 2013) represents FDA's best advice for needed provisions for addressing the safety and protection of food in food retail and food service facilities at the state and local levels. State and local agencies adopt any or all sections of the Food Code as part of their regulations for firms including grocery stores and food service establishments. The Food Code addresses options for date labeling of RTE food that requires time/temperature control for safety to limit growth of pathogenic microorganisms or toxin formation.

Intended for active managerial control while the product is in the food facility, the Food Code indicates that, except for packaging food in the retail establishment using a reduced-oxygen packaging method:

- food that is prepared on premises and held cold for more than 24 h shall be clearly marked to indicate the date or day by which the food shall be consumed on the premises, sold, or discarded, being held at 41 °F (5 °C) or less for a maximum of 7 d;
- and except for deli salads, certain hard and semisoft cheeses, cultured dairy products, preserved fish products, shelf-stable dry fermented sausages, and shelf-stable salt-cured products, food that is commercially processed ("prepared and packaged by a food processing plant"), opened on premises, and held cold more than 24 h, shall be clearly marked at the time the original container is opened to indicate the date or day by which the food shall be consumed on the premises, sold, or discarded, being held at 41 °F (5 °C) or less for a maximum of 7 d; and, the day or date marked by the establishment may not exceed a manufacturer's use by date if it is determined on the basis of food safety.

The Food Code also indicates that a refrigerated RTE time/temperature control for safety food ingredient or a portion of a refrigerated RTE time/temperature control for safety food that is subsequently combined with additional ingredients or portions of food shall retain the date marking of the earliest-prepared or first-prepared ingredient. With respect to food establishments that use a reduced-oxygen packaging method for food that must have time and temperature control for safety, they are to control the growth of and toxin formation by *C. botulinum* and growth of *L. monocytogenes.* In addition, with certain exceptions, the establishments are to implement a hazard analysis and critical control points (HACCP) plan that contains certain information and limits the refrigerated shelf life to ≤30 d of packaging, except the time the product is maintained frozen, or the original manufacturer's sell by or use by date, whichever occurs first.

The NRDC and Harvard Food Law and Policy Clinic (NRDC 2013) examined the history of date labeling and pertinent federal and state laws and authorities in the United States. This examination found that 41 states plus the District of Columbia require date labels on at least some food items, whereas 9 states (Ala., Idaho, Ill., Mo., Nebr., N.Y., S.Dak., Tenn., Utah) do not require them on any foods. The NRDC report stated that because state statutes are not preempted by federal law, unless they are in direct conflict with existing federal legislation (35A Am. Jur. 2d *Food* § 10 (2012)), and federal regulation of date labels is limited, states have considerable discretion in regulating date labels. The states differ in the kinds of food required to bear date labeling and the date labeling terminology required. Further, very few states define the meaning of the terminology and few delineate the process for determining the dates (NRDC 2013). Further contributing to date labeling confusion is the potential for regulation at the local level (NRDC 2013). For example, Baltimore, Md., prohibits the sale of any perishable food past its expiration date, while the state of Maryland does not (Baltimore, Md. Code § 6–505.1 (2009)).

The NRDC report grouped the types of date-labeling practices among the states that have date labeling regulations as follows:

- regulate the presence of date labels on certain foods but do not regulate sales after those dates;
- regulate the presence of date labels but broadly regulate sales after such dates if date labels are voluntarily applied;
- regulate both the presence of date labels and, broadly, the sale of products after those dates.

The NRDC (2013) report called for standardizing and clarifying the food date labeling system across the United States, and made the following recommendations:

- make sell by dates invisible to the consumer;
- establish a uniform consumer-facing dating system using unambiguous wording, which distinguishes between safety-based and quality-based dates and includes freeze-by dates where applicable;
- discontinue use of quality-based dates on nonperishable shelf-stable products;
- ensure date labels are clearly and predictably located on packages;
- employ more transparent methods for selecting dates, through a set of best practices for manufacturers and retailers;
- increase use of safe handling instructions and smart labels (time—temperature integrator [TTI] devices)

Additionally, the report indicated that collaboration among industry members, policymakers, food safety experts, consumer behavior experts, and consumer advocates is needed to establish an effective new standardized system (NRDC 2013).

Quality versus Safety

A number of factors influence the perishability, quality, and safety of a food, its shelf life, and the determination of a date for use in date labeling. In the United States there are several major perishability categories of foods:

- perishable foods—those with a shelf life of days to several weeks, and in which spoilage is generally microbial growth or natural aging (senescence). This includes fluid milk; some fresh fruits and vegetables; fresh meat, fish, and poultry; and controlled-atmosphere-packaged meats and deli meats. Perishable foods may carry a use by or freeze by date, or no date (for example, bagged produce).
- semiperishable foods—those that by nature have a longer shelf life than perishable foods or which have an extended shelf life as a result of a processing or preservation method. Semiperishable foods generally are labeled with a use by or best if used by date. This category of foods includes: (a) eggs, some cheeses, ultra-high-temperature-pasteurized dairy products and juices, packaged meals, moist pasta products, and hummus. Semiperishable foods generally have a shelf life of up to 90 d, and

should be refrigerated (32 to 41 °F [0 to 5 °C]) for safety; and (b) low-moisture fatty foods (such as potato chips which oxidize) having a shelf life of 90 d.

- dry stable dehydrated or semimoist foods—those which have a shelf life of 6 mo to 1.5 y if stored in a well-sealed package at room temperature, which are generally labeled with a best if used by label such as: (a) RTE baked or extruded cereals, dry pasta products; (b) low-moisture confectionaries such as chocolate, hard candy, peanut brittle; (c) semimoist foods such as chewy protein/granola bars, semidry fruits (such as raisins, prunes, dried cranberries; many candies [such as fruit gum candy, chewing gum]); (d) frozen foods, which if properly stored at approximately 0°F (−17.8 °C) in well-sealed low-head-space packages, have a shelf life of 6 mo to 1.5 y.
- very-long-shelf-life foods—those, such as most canned foods, which if kept at proper conditions (<70 °F [21.1 °C] and <50% relative humidity) generally have a best if used by date of up to 3 y and a potential shelf life of 5 to 7 y. These products typically will not have safety-related concerns during their shelf life due to either being commercially sterilized by thermal processing (low-acid canned foods), or acidified, naturally acidic, or pasteurized and possibly subsequently hot-filled (such as bottled ketchup, salad dressings, mayonnaise). For these foods, date labeling is based on the very slow quality loss that occurs if they are stored at approximately 71 to 75 °F (approximately 22 to 24 °C) and the package (metal can, retort pouch, glass jar) is impermeable to moisture and oxygen. However, if a metal can is dented, spoilage and pathogenic bacteria may enter through the damaged container, or another phenomenon may lead to foodborne illness (botulism, for example, due to germination of any *Clostridium* spores that may be present).
- infinite shelf life—crystalline foods kept at normal temperature and low humidity. The best example of this category is mined sodium chloride (table salt), which was crystallized in deep caverns underground more than a million years ago (IFT 1981; Labuza 2000).

In the United Kingdom, the food industry categorizes prepared perishable foods differently, as either: (a) short shelf life: 0 to 10 d, or (b) long shelf life: 11 to 42 d.

Food safety is impacted by:

- presence (and growth) of infectious pathogens (for example, *Salmonellae*, *L. monocytogenes*; *Escherichia coli* O157:H7 on meats, fish, and fresh produce) in raw foods, and
- survival and growth of vegetative and spore-forming pathogens in heat-treated foods, for example, psychrotrophic *C. botulinum*, *Bacillus cereus*.

Unless initially contaminated by a pathogen and not pasteurized, frozen foods would not be expected to pose a food safety risk due to the holding temperature being below the temperature range for pathogen growth. Frozen meals designed for microwaving therefore pose a risk if one does not follow the explicit microwave cooking instructions on the package. Acidified bottled or canned foods have microbial growth inhibited by water activity (a_w) or pH control. For dry foods packaged in plastic containers allowing oxygen migration, the date is linked to the amount of time it takes for enough oxygen to permeate the package and cause oxidation of the product to a point at which quality is less than optimum. In general, these foods have a shelf life of 90 d to 1.5 y. In addition, moisture migration into the package at ≥45% RH (relative humidity) leads to loss of crispness, for foods such as potato chips or pretzels, and caking in powdery foods containing sugar, such as infant formula.

Refrigerated foods, on the other hand, present the greater risk for food safety-related issues because some bacterial pathogens such as *L. monocytogenes*, nonproteolytic *C. botulinum*, some *B. cereus* strains, and *Yersinia enterocolitica* are capable of growing at refrigeration temperatures. Additionally, even if refrigerated foods are exposed to a treatment (pasteurizing heat treatment, for example) that inactivates a proportion of vegetative microorganisms, there is the possibility of pathogen growth to infective levels or outgrowth of spores, particularly if temperature abuse occurs during distribution or storage or the food is held for sufficient time at refrigeration temperatures for growth or outgrowth to occur.

At the simplest level, 3 factors—the pathogen, the host, and the environment—and complex interrelationships among them affect the potential for foodborne illness associated with a microorganism (IFT 2002). With respect to host factors, for example, *L. monocytogenes* is of particular concern for the highly susceptible immunocompromised individuals for whom listeriosis can be a very serious, potentially fatal illness. Hence, special considerations are given to the potential for exposure of these populations to *L. monocytogenes* and ensuring the food safety of refrigerated foods, particularly relatively short-shelf-life deli meat, cheeses, deli salads, and prepared foods, for example, that are prepared at retail.

The U.S. FDA has available for food manufacturers model label statements and guidance on labeling of 3 groups (A, B, and C) of PHF that need refrigeration by consumers to maintain safety or quality (FDA 1997). The statements refer to the importance of refrigeration for safety for foods in 2 of the groups (Groups A and B) and importance of refrigeration for quality in the 3rd group (Group C). The 3 groups and related label statements are shown in Table 2.

Given the critical relationship between temperature and length of refrigerated storage on the microbiological safety of extended shelf-life RTE foods that require refrigeration and which support the growth of psychrotrophic pathogens, the NACMCF was asked by its supporting agencies to provide advice on the scientific parameters needed to establish safety-based use-by date labeling (SBDL) for RTE foods and to address the data needs for validating and verifying the adequacy of SBDL (NACMCF 2005). The committee conducted a hazard analysis of refrigerated RTE foods and determined that *L. monocytogenes* is the appropriate target microorganism for SBDL of most refrigerated RTE foods, which support its growth. The committee noted in its report that, although not required by regulation to do so, some companies have historically applied protocols using scientific methods to establish date labeling for certain products, with the storage time and temperature expectations developed to assure consumer safety and product quality throughout the shelf life of the product. To accomplish this, companies conduct or commission microbiological challenge studies, growth modeling, or both to determine potential growth of pathogens in specific foods under specific environmental conditions; and, industry trade associations have provided technical support for determining safety parameters (NACMCF 2005).

The committee also indicated that "given the morbidity and high mortality of *L. monocytogenes* infection and the association of *L. monocytogenes* with refrigerated foods" the use at the consumer and food handler level of an appropriate SBDL (for example, "use within X days" of opening/purchase) on products supporting rapid growth of the pathogen could have a beneficial public health impact if combined with effective consumer education on

Table 2–U.S. FDA guidance and model label statements for 3 groups of foods needing refrigeration by consumers for food safety or quality

Group of foods and characteristics	Model label statement
Group A Potentially hazardous foods, which, if subjected to temperature abuse, will support the growth of infectious or toxigenic microorganisms that may be present, the outgrowth of which would render the food unsafe. Characteristics: Product pH > 4.6; (2) water activity $a_w > 0.85$; (3) do not receive a thermal process or other treatment in the final package that is adequate to destroy foodborne pathogens that can grow under conditions of temperature abuse during storage and distribution; and (4) have no barriers (for example, preservatives such as benzoates, salt, acidification) built into the product formulation that prevent the growth of foodborne pathogens that can grow under conditions of temperature abuse during storage and distribution.	"IMPORTANT" Must Be Kept Refrigerated to Maintain Safety.
Group B Includes foods that are shelf stable as a result of processing, but once opened, the unused portion is potentially hazardous unless refrigerated. Characteristics: (1) Product pH > 4.6; (2) water activity $a_w > 0.85$; (3) receive a thermal process or other treatment that is adequate to destroy or inactivate foodborne pathogens in the unopened package, but after opening, surviving or contaminating microorganisms can grow and render the product unsafe; and (4) have no barriers (for example, preservatives such as benzoates, salt, acidification) built into the product formulation to prevent the growth of foodborne pathogens after opening and subsequent storage under temperature abuse conditions.	"IMPORTANT" Must Be Refrigerated After Opening to Maintain Safety
Group C Foods that do not pose a safety hazard even after opening if temperature abused, but that may experience a more rapid deterioration in quality over time if not refrigerated. The manufacturer determines whether to include on the label a statement that refrigeration is needed to maintain the quality characteristics of the product to maximize acceptance by the consumer. These foods do not pose a safety problem. Characteristics include one or more of the following: (1) Product pH ≤ 4.6 to inhibit the outgrowth and toxin production of *C. botulinum*; or (2) water activity $a_w \leq 0.85$; or (3) have barriers built into the formulation (for example, preservative systems such as benzoates, salt, acidification) to prevent the growth of foodborne pathogens if the product is temperature abused.	"Refrigerate for Quality"[a] or other statement that explains that the storage conditions are recommended to protect the quality of the product

[a]Statement is optional.

Source: FDA (1997)

temperature control. The committee also indicated that the application at the manufacturer level and on a large scale a specific SBDL that is based on a specific food safety objective has many practical limitations, given the magnitude in number, diversity, and complexity of products in the marketplace, and lack of accurate information on initial levels and growth rates of *L. monocytogenes* for many formulations (NACMCF 2005).

A USDA/FSIS risk assessment for *L. monocytogenes* in deli meats (USDA/FSIS 2003) found that combinations of interventions, including pre- and postpackaging interventions and use of growth inhibitors, were more effective than any single intervention in mitigating potential *L. monocytogenes* contamination and reducing the risk of listeriosis (USDA/FSIS 2003). Some manufacturers use ultra-high-pressure processing to postpasteurize deli meats after product packaging.

An Interagency Retail *L. monocytogenes* Risk Assessment Workgroup (USDA 2013a) provided a scientific assessment of the risk of foodborne illness associated with consumption of RTE foods commonly prepared and sold in retail food store delicatessen stores. Among the key findings relating to controlling growth of *L. monocytogenes* was that, although strict temperature control during refrigerated storage in retail delis reduced the risk of listeriosis, for suitable products the use of growth inhibitors which mitigate growth of *L. monocytogenes* in RTE foods at retail and during home storage had a greater impact on risk reduction than temperature control (USDA 2013a).

Zeng and others (2014) used temperature sensors to monitor growth of simulated populations of *E. coli* O157:H7 and *L. monocytogenes* inoculated in packaged fresh-cut lettuce mix at fluctuating temperatures during commercial transportation during 4 different seasons, retail storage, and display. They obtained, during a 16-mo period, a series of time–temperature profiles for the bagged salads from different transportation routes and regions. They found that both microorganisms increased (<2 log CFU/g in most cases and up to a maximum 3-log increase) during 2 to 3 d of transportation from the farm (432 profiles), 1 to 3 d of retail storage (4876 profiles), and 3 d of retail display (3799 profiles).

In answering a specific question about the use of mathematical modeling techniques in establishing safety-based use-by date labels, the NACMCF's response mentioned that given the wide range of products, formulations, and production facilities, as well as the wide diversity of distribution, marketing, and consumption practices associated with RTE foods, it does not seem feasible to conduct inoculated pack studies on more than a limited number of product classes and pathways, and modeling of microbial growth will play an important role in developing SBDL (NACMCF 2005).

Inoculated pack studies involve inoculating foods with a specific amount of a pathogen and monitoring its growth or decline during storage by repeated sampling to determine the risk of growth and/or toxin production (IFT 1994). Microbial modeling, or predictive food microbiology, uses mathematical expressions to describe microbial behavior (growth or inactivation/survival, for example), and provides information that is valuable in predicting shelf life, designing foods, and controlling food processes (IFT 1994). Further, growth models can be useful to date labeling by estimating the time for attaining a specified population of spoilage or pathogenic microorganisms. There are a number of modeling software programs that are valuable in this regard. These include the Food Micromodel managed by the Inst. of Food Research in the United Kingdom, and the U.K. Inst. of Food Research–USDA/Agricultural Research Service—Univ. of

Tasmania Food Safety Centre Consortium's ComBase (UKIFR–USDA–UT 2003; NACMCF 2005). The NACMCF (2005) also commented that such models, which can assess changes in formulation, contamination levels, and storage times and temperatures should be backed by links to challenge studies.

The U.K.-based Chilled Food Assn. (CFA) published "Best Practice Guidelines for the Production of Chilled Food" (CFA 2006), which provides specific technical limits on shelf life for chilled foods in relation to the thermal process used and target microorganism (*L. monocytogenes* or *C. botulinum*):

- maximum 10 d—*L. monocytogenes* is the target organism to be controlled. A 6-log reduction process is required, for example using a thermal process of at least 70 °C for 2 min, or equivalent. Consideration must be given to the possibility of postprocess contamination.
- more than 10 d—psychrotrophic *C. botulinum* is the target organism to be controlled. A 6-log reduction process is required, using a thermal process of at least 90 °C for 10 min, or equivalent. This achieves a shelf life of no more than 42 d. Consideration must be given to the possibility of postprocess contamination. Nonthermal means of preventing growth through intrinsic preservation factors ("hurdles") may also be used, comprising a combination of thermal and nonthermal controls. *B. cereus* should also be considered as a target organism for long-shelf-life products. The microorganism is managed using raw material controls, rapid chilling after cooking, storage temperature control, and shelf-life limitation.

As described by the CFA, chilled foods include a vast range of food products that depend on refrigeration as the primary means of preservation. The guidelines state that "pathogens must be accounted for by safe product and process design," and "identification of the relevant pathogens is critical for the successful assessment of safe shelf life." The guidelines address approaches to shelf-life determination, assignment, monitoring, and verification. The guidelines indicate that shelf-life determination may potentially involve reviewing microbial characteristics, use of predictive modeling programs, and storage trials. The guidelines also indicate that the maximum permissible shelf life is determined on the basis of microbiological safety and stability, physical condition, or organoleptic quality, whichever is shorter. Furthermore, the guidelines indicate that the use by or best before date is determined from the result of the shelf-life determination test, safety margins deducted from the maximum shelf life, and determination of day zero. They also convey that the date of minimum durability must be indicated with a use by date and any exceptions validated through HACCP plans and in accordance with national legislation.

The CFA also published guidance (CFA 2010) that specifically addresses shelf life of RTE food in relation to *L. monocytogenes*. Produced with the involvement of the British Retail Consortium (BRC) and endorsed by the U.K. FSA, the guidance is intended to help address EC regulation No. 2073/2005 and related guidance on microbiological criteria for food. The guidance includes EU-legislated limits on *L. monocytogenes* in RTE food: 100 CFU/g unless the food is intended for infants or particular medical purposes, in which case the food must not contain any *L. monocytogenes* throughout the food's shelf life. Furthermore, the guidance requires evidence, based on shelf-life studies (which should initially consist of information on specific product composition (that is, physical and chemical characteristics, including packaging) and relevant scientific literature data. The guidance indicates that if the results of the studies do not provide sufficient confidence, additional studies will be necessary. The additional studies may include historical data (including HACCP verification data at the beginning and end of shelf life), predictive microbiology, and specific laboratory shelf-life studies (that is, durability studies, challenge testing).

The Codex Alimentarius Commission also provides guidance on shelf life in several Codex texts. Examples include the Codex "Guidelines on the Application of General Principles of Food Hygiene to the Control of *Listeria monocytogenes* in Foods" and the "Code of Hygienic Practice for Refrigerated Packaged Foods with Extended Shelf Life." The Codex "Guidelines on the Application of General Principles of Food Hygiene to the Control of *Listeria monocytogenes* in Foods" (CAC 2007b) indicate the necessity of controlling and monitoring the storage time–temperature combination, and that length of shelf life is an important factor in the risk associated with foods supporting the growth of *L. monocytogenes*. The guidelines indicate that the length of the shelf life should be based on appropriate studies that assess the growth of *L. monocytogenes* in the food and take into account the potential for temperature abuse. Furthermore, the guidelines indicate that countries should consider labeling of certain RTE foods and, where appropriate, labels should include information on safe handling practices and/or advice on the time frame in which a product should be consumed. The guidance also addresses consumer education, with the objective that consumers have enough knowledge of *L. monocytogenes* and food hygiene that they understand the importance of shelf life and sell by or use by dates on the food label.

The Codex "Code of Hygienic Practice for Refrigerated Packaged Foods with Extended Shelf Life" indicates that it is very important to establish the shelf life of the product, using scientific data and technological methods, and to take into account the scheduled heat or other preservation treatments, use of hurdles (combination of subinhibitory levels of factors, such as decreased pH and a_w and addition of preservatives, for microbial control) and anticipated distribution and storage temperatures. Shelf life is defined in the code as "the period during which the product maintains its microbiological safety and sensory qualities at a specific storage temperature." With regard to labeling, the code states that labels should conform to the requirements of the official agency having jurisdiction, and provide a use by date and a statement regarding the need for refrigeration (such as "keep refrigerated at [required temperature] or less"). The code also indicates that when the prescribed use by date has been reached the products should be removed from the display case and not offered for sale.

The Local Better Regulation Office (LBRO) commissioned IFF Research (London, United Kingdom) to conduct a survey of organizations in the food retail, distribution, and production sectors in the United Kingdom, and convened an industry-led review group to address concerns that had been expressed to the organization and issues surrounding use by date labeling regulations (LBRO 2011a, b). The review group was comprised of representatives from retail and manufacturing, with members from the BRC, Assn. of Convenience Stores, Natl. Federation of Retail Newsagents, British Meat Processors Assn., and Provision Trade Federation. LBRO was dissolved in April 2012 and its functions are now exercised by the Better Regulation Delivery Office, an independent unit within the Dept. for Business, Innovation and Skills (LBRO 2013). IFF Research surveyed by questionnaire 17 manufacturers, 4 wholesalers, and 5 retailers and conducted telephone

interviews of 1 wholesaler and 2 retailers, in total comprising 45% of the food manufacturing market, 17% of the food wholesale market, and 3% of the food retail market in the United Kingdom (LBRO 2011b). The survey captured a substantial amount of insight into the practices and concerns of the different business sectors, some of which is provided below.

The LBRO survey found that most products that manufacturers pack require a use by date, and microbiological safety is typically the main reason for application of a use by date rather than a best before date; retailer specification and product quality considerations, however, are also factors for dairy products (LBRO 2011b). LBRO (2011a) reported that several factors influence the establishment and application of use by dates: manufacturing process, handling and storage within the supply chain, microbiological risks, and product composition including food additives, quality, and brand reputation. Further, it was explained that in determining a maximum safe shelf life the potential for suboptimum storage at any stage of the distribution chain, including by the consumer, is taken into account and a safety margin of several days may be included (LBRO 2011a). Thus, in instances of quality deterioration before the maximum safe life, the use by date is shortened, resulting in a use by date actually reflecting a product's optimum quality rather than its microbiological safety, the report noted (LBRO 2011a). Further, LBRO (2011a) stated that "given the desire to protect quality and reputation, avoid product recalls, as well as to ensure that food is safe to eat, the industry tends to take a risk-averse approach applying 'use-by' dates even where the microbiological food risk is low." The survey found that there is a strong feeling that use by dates are increasingly linked to quality rather than safety; and there is the belief that many products do not require a use by date given the low microbiological risk (LBRO 2011b). The survey also found that a main industry-wide criticism of use by dates is the level of waste that they cause.

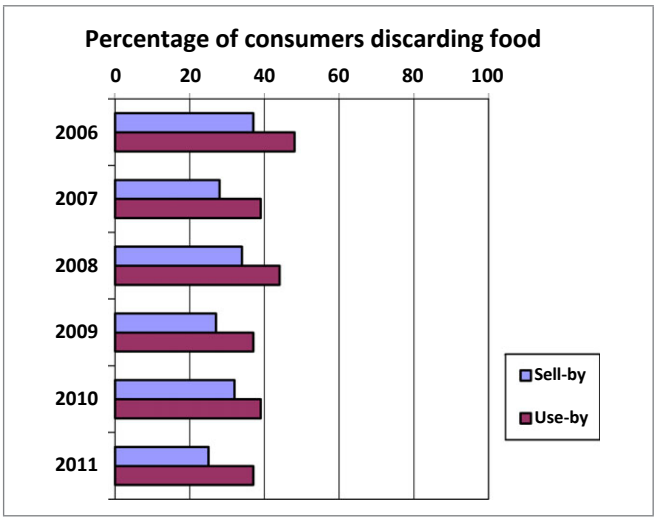

Figure 1–Consumer food discard behavior in the United States relating to sell by and use by date labeling (FMI 2006, 2007, 2008, 2009, 2010, 2011).

Misconceptions and Varying Practices Have Adverse Impacts

A number of surveys of consumer perception and behavior relating to date labeling of foods have been conducted and show that there is considerable lack of understanding of the meaning of date labeling terminology and how the dates relate to food safety or quality. Consumer misperception of date labeling contributes substantially to food wastage. There also is some misunderstanding of date labeling among other stakeholders, and there are a number other challenges that different stakeholders in the marketplace face, which have considerable impacts as well.

Consumer Perception

Consumers exhibit confusion surrounding dates on food products (Sherlock and Labuza 1992; Labuza and Szybist 1999a; Labuza and others 2001; Cates and others 2004; Kosa and others 2007; FMI 2007, 2008, 2009; WRAP 2008). A high percentage of consumers are aware of dates on food product packaging and most U.S. consumers report checking the date before purchasing and/or consuming the product (Labuza and Szybist 1999a; FMI 2006). Few consumers know what the dates on products are intended to mean, however. For example, a survey conducted by the Food Marketing Inst. (FMI)—FMI's 2011 Trends survey (FMI 2011)—found that among their actions to keep food safe, 37% of consumers reported always ("every time") discarding food when it is past the use by date and 25% reported always discarding it when it is past its sell by date (Figure 1). As shown in Table 3, 23% of consumers reported believing that eating food past the use by date is a serious health risk; 13% reported believing that eating food past its sell by date is a serious health risk; and 10% reported believing that eating food past its best by date is a serious health risk (FMI 2011). The percentage difference in consumers discarding product based on either use by or sell by dates—2 dates with completely different purposes—was only 12% (37% and 25%). Discard behavior was similar in 2009 and 2010 to that in 2011, and slightly greater in 2007 and 2008 (Figure 1). The FMI reported in its 2007 US Grocery Shopper Trends Report (FMI 2007) that most shoppers (68%) reported preferring use by date notification (Table 4), and only 21% and 11% preferred sell by and best by dates, respectively. Reporting on a home practices survey, Labuza and others (2001) noted that fewer people at the time seemed to understand the meaning of the open date on milk containers as compared with the level of consumer understanding found in an OTA study conducted 2 decades prior, despite the fact that it was the product on which consumers most often check for a date.

Wansink and Wright (2006) conducted a study that evaluated U.S. consumer perception of freshness, and found that the expiration date impacted the consumer's acceptance of the product. They evaluated yogurt samples in a laboratory with expiration dates either 1 mo or 1 d away or 1 d or 1 mo past presentation of the product. Consumers did not know the purpose of the study. The consumers rated the product with the longest period before reaching the expiration date as the best and the most healthful. The authors hypothesized that freshness dating could impact what consumers think of foods after food has been purchased if a short shelf life is conveyed in the product date.

Kosa and others (2007) conducted a web survey to evaluate consumer knowledge of use by or sell by dates. Most of the survey respondents reported checking product dates before purchasing RTE products, and slightly fewer reported checking product dates before serving RTE foods. Only 44% of the survey respondents correctly identified the sell by date; 31% correctly identified the best if used by date; and 18% correctly identified the use by date. The authors recommended consumer education about recommended storage times, use of open date labeling, when to discard foods, and refrigeration temperature control.

Table 3–U.S. Consumer perception of implied "serious" health risk relating to date labeling (FMI 2006, 2007, 2008, 2009, 2010).

	Percentage of consumers relating date label to a serious health risk Year				
Type of date label	2006	2007	2008	2009	2010
Eating food past the sell by date	22%	17%	18%	17%	11%
Eating food past the best by date		14%	22%	13%	12%
Eating food past the use by date	25%	20%	15%	19%	18%

A study conducted by WRAP had similar findings to data collected in the United States (WRAP 2011). Only 39% of interviewees correctly defined use by, best before, and display until dates on products. WRAP (2010) reported that the use of display until dates was inconsistent among different products and different retailers/brands. WRAP (2011) indicated that use of display until dates negatively influenced consumer understanding of both best before and use by dates with regard to food quality and food safety. In the presence of a display until date, consumer interpretation of a use by date as quality-related increased from 25% to 32%, and interpretation of best before as a safety-related date increased from 14% to 20%.

With regard to the reasoning behind participants' misunderstandings, WRAP (2011) indicated that consumer behavior relating to use of date labels and storage guidance on food is broad and complex. Some participants understand that the definitions are different but choose to ignore them and treat all dates on products as the same. Another common theme identified was confusion of dates intended for retailers versus consumers, without differentiation between the 2 types of dates. The WRAP report also addressed why some people might use date labels more than others, reporting that use of date labels seems to be inherent in personality or habit. For example, individuals with more risk aversion traits used date labels more frequently and were more likely to use the best before date as a cut-off date. Some individuals trying to waste less food were more likely to rely less on labels and look to other indicators of food spoilage. In observational research into consumer understanding and behavior in relation to date labels, WRAP (2008) found that in almost three-fourths of the occasions respondents indicated using the date on a product to decide whether it was okay to consume. However, WRAP found that there is interplay between perceptions of quality and safety, personal perceptions of individual products, and the dates, and that understanding of the type of date "almost plays second fiddle" to overriding concerns about safety and quality (WRAP 2008).

Boxstael and others (2014) conducted an online survey of 907 Belgians to study their understanding and attitude relating to date labels. They found that 67% of participants reported checking the "shelf life date" in judging food product edibility at home but that 30.4% did not know the difference of the meaning between best before and use by dates, indicating, they said, that the intended purpose of the E.U. date labeling framework is not thoroughly understood. They found that most consumers interpret date labels with some flexibility, depending on the type of food, and that they take additional factors (appearance, odor, and taste) into consideration along with the date in deciding whether to consume the food (Boxstael and others 2014). The survey also found some gender- and age-linked differences in willingness to consume an expired product.

Reporting on another study, WRAP (2012a) noted that the use of guidance such as "Do not exceed the use by date" is helpful for reinforcing the message that use by dates relate to safety, whereas use of that guidance on some products carrying a best before date is not helpful because it converts a best before date into a use by date and could cause consumers to think that best before dates are safety dates when they instead relate to quality (WRAP 2012a).

Table 4–U.S. consumer preferences for food product date labeling terms (FMI 2007).

Preferred date labeling term	Percentage of consumers
Use by	68
Sell by	21
Best by	11

WRAP concluded that, in general, there is widespread lack of understanding about date labels, and recommended the following to improve consumer understanding and application of date labels and storage guidance (WRAP 2011, 2012a):

- continue to clarify the meaning of the terms best before and use by;
- remove display until dates;
- aim for consistent use of use by or best before types of terminology within product categories, where appropriate;
- investigate label design to make date labels easier to interpret;
- enhance existing storage guidance, increase the use of storage guidance that reinforces the meaning of use by dates and decrease similar advice for best before dates;
- give the longest possible shelf life (for example, extend the best before or use by date where possible, lengthen "once opened, use within x days" guidance, where possible);
- increase proportion of freezable products that carry freezing and defrosting guidance;
- reduce use of the snowflake logo for anything other than to indicate "suitable for home freezing;"
- move to alternatives (for example, freeze before/date mark) to "freeze on day of purchase" guidance, where possible;
- follow FSA recommended "keep refrigerated below 5 °C where refrigerator temperature guidance is stated on-pack.

Evans and Redmond (2014) reviewed data from published research internationally with respect to consumer food safety behaviors associated with increased risk of listeriosis. The factors that were associated with increased risk of listeriosis included lack of adherence to use by dates and ineffective refrigerated storage of foods. Overall, only 41% of the 165 consumer food safety studies reviewed included assessment of consumer cognitive or behavioral data associated with listeriosis; of these studies 54% included data on storage time for opened RTE foods, and 49% included data on adherence to use by dates. Although 49% to 62% of consumers reported awareness that use by dates were the best indicators of whether food was safe to eat, 71% of consumers misunderstood the terms "use by" and "best before." Similarly, only 18% of consumers correctly defined the use by date, and further research suggests confusion may exist among consumers concerning date labeling of food products. Overall findings indicated consumer understanding of use by dates is lacking. In most

(83%) of the studies, survey-based data collection methods (questionnaires/interviews) were used; thus, the majority of findings were based on self-reporting (74%) and knowledge (44%). Only 7% of studies included food safety data for older adults. Although older adults may fail to implement recommended practices, the review revealed a need for in-depth research to determine food safety attitudes and actual behaviors of older adults in conjunction with knowledge and self-reporting of practices linked to increased risks of listeriosis.

Food Loss and Waste

Food wastage occurs throughout the food supply chain and is a major issue that impacts food safety and quality, food security, the environment (affecting land quality, water quantity, biodiversity, and global climate change), and economic development (Food Wastage Footprint 2013; FAO 2011a, 2013a). The FAO (2014) defines food loss as "the decrease in quantity or quality of food," "meaning agricultural or fisheries products intended for human consumption which are ultimately not eaten by people, or which have incurred a reduced quality reflected by nutritional value, economic value or food safety." "An important part of food loss," food waste "refers to the discarding or alternate (nonfood) use of food which was fit for human consumption, by choice or after it has been left to spoil or expire as a result of negligence" (FAO 2014).

Extent of food wastage. Estimates on the amount of food wastage on a global scale range from about one-third (or 1.3 billion metric tons) to 50% of food produced for human consumption (FAO 2011a; Foresight 2011). FAO (2013a) estimated that the global volume of food losses and waste is 1.3 billion metric tons of edible food. In the United States, the USDA/ERS estimated that in 2010 about 133 billion pounds of food, 31% of the 430 billion pounds of food produced, were not available for human consumption at the retail and consumer levels (Buzby and others 2014). This loss had an estimated $161.6 billion in retail purchase value and 141 trillion calories (or 1249 calories per American per day). This study used data from ERS's Loss-Adjusted Food Availability core food availability data series, adjusted for spoilage, plate waste, and other food losses and converted to daily per capita amounts, calories, and food pattern equivalents (previously called servings and MyPyramid equivalents). Of the losses, 10% (43 billion pounds) were retail-level losses and 21% (90 billion pounds) were consumer-level losses. The food groups with the greatest share of total dollar value of food loss were meat, poultry, and fish; vegetables; and dairy products, with 30%, 19%, and 17%, respectively. Another analysis of food waste generated by U.S. food manufacturers, retailers, and wholesalers found that these sectors generated 48.1 billion pounds of food waste in 2011, of which 4.1 billion pounds was disposed off in landfills and 1.4 billion pounds was diverted via donation to food banks (BSR 2013). Food waste was defined in the report as: "Any solid or liquid food substance, raw or cooked, which is discarded, or intended or required to be discarded. Food waste includes the organic residues (such as carrot or potato peels) generated by the processing, handling, storage, safe, preparation, cooking, and serving of foods."

The numerous causes of food loss and waste vary around the world, depending on specific conditions and local situations in countries, and they are influenced by weather, crop production choices and patterns, internal infrastructure and capacity, marketing chains and distribution channels, retail and food service operations (for example, stock removed from retail shelves because it reached its sell by date), consumer purchasing (for example, over-buying in response to buy-one-get-one-free offers) and food use practices, and exaggerated concern about best before dates (USDA/ERS 1997; FAO 2011a, 2011b, 2012, 2013a, 2013b; Verghese and others 2013).

Only recently, the FAO produced the 1st global Food Wastage Footprint to quantify the impact of food loss and waste on the environment and the economy to assist decision making along the food chain and with the ultimate objective of communicating "that investment in food wastage reduction is the most logical step in the pursuit of sustainable production and consumption, including food security, climate change and other adverse environmental effects" (Food Wastage Footprints 2013). The FAO found, based on the overall amount of food waste in 2007, that the carbon footprint of food wastage is an estimated 3.3 billion metric tons of CO_2 equivalent; the blue water footprint (consumption of surface and groundwater resources) was about 250 km^3; and the economic cost was about 750 billion U.S. dollars (FAO 2013a). In industrialized countries, ordering and stocking retail store shelves with large quantities of food and a wide variety of food products and brands for consumer choice increases the likelihood that some of the products, mainly fresh perishable items such as dairy and bakery products, will reach their sell by dates before being sold and need to be removed and are wasted (USDA/ERS 1997; FAO 2011a). A discussion paper of the United Nations Environment Programme—"The Critical Role of Global Food Consumption Patterns in Achieving Sustainable Food Systems and Food for All"—included a case study on supermarket and household waste in the United Kingdom (Moomaw and others 2012). The case study indicated that in the developed world one of the factors contributing to food waste is consumer behavior, and one aspect of that is confusion about food date labeling. Consumer behavior that is based on misunderstanding of expiration and best before dates is recognized as a contributor to large amounts of food waste (USDA/ERS 1997; FAO 2011b). Addressing this misunderstanding has been mentioned among recommendations for reducing food wastage (Food Wastage Footprints 2013).

The NRDC reported in an issue paper—"Wasted: How America is Losing up to 40% of its Food from Farm to Fork to Landfill"—that expired or nearly expired sell by dates on foods contribute to loss/waste of food at retail and that most of it is still consumable (NRDC 2012). NRDC indicated that better consumer understanding of sell by and use by dates would help reduce food waste, and use of codes instead of dates to manage inventory at the store level could help reduce customer confusion about sell by dates. The NRDC also called for further research to determine the best approach for achieving more clarity on date labeling.

In a report in 2013 on household food and drink waste in the United Kingdom, WRAP reported that the amount of food thrown away that could have been eaten decreased 21% between 2007 and 2012, but was still substantial—4.2 million metric tons, worth £12.5 billion, wasted each year (WRAP 2013a). Half of that food and drink wasted in 2012, worth £5.6 billion, was classified as "not used in time"—discarded because it was either no longer desirable or was past the date on the packaging. The top 10 types of food unnecessarily wasted, by weight, were: standard bread, fresh potatoes, milk, home-made and prepared meals, carbonated soft drinks, fruit juice and smoothies, poultry meat, pork meat, cakes, and processed potatoes (chips; WRAP 2013a). Findings were from research funded by the U.K. government and based on detailed measurements of the weight and types of food and drink waste from approximately 1800 households, a week-long

food and drink diary involving 950 households, and a synthesis of waste data from more than 80 local authorities. The report noted that a range of behaviors and technical innovations were thought to have contributed to the reductions in waste during the time period evaluated. The behaviors thought to have reduced waste included buying appropriate amounts, storing food under optimal conditions, portion control, and using the freezer more effectively. Technical innovations thought to have contributed to the waste reduction included availability of a range of pack sizes, improved storage and freezing guidance, clearer date labeling, increased shelf life, and packaging innovations. The report mentioned that for food categories (fresh vegetables and salad, for example) that did not contribute as greatly as others to reductions in waste or which had very little change in waste contributions (meat and fish, for example), there are some actions that could make it easier for people to waste less food. Beneficial consumer-related actions identified were: buying the right amounts, storing produce correctly, understanding use by and best before dates, knowing what can be done with "tired" vegetables, and making more use of the freezer. The report also mentioned that retailers and manufacturers are evaluating how changing pack sizes, promotions, date labeling, freezing guidance, and shelf life (through innovative packaging, for example) can help people reduce waste (WRAP 2013a).

A steering group of representatives of several organizations—the Industry Council for Packaging and the Environment, WRAP, The Packaging Federation, the Food and Drink Federation, Kent Waste Partnership, and the BRC—explored consumer attitudes and behavior relating to food packaging and waste (WRAP 2013b). The report of the activity indicated that a priority for consumers is how long food stays fresh, and that there is an opportunity for consumers to make more use of labels and packaging with regard to keeping food fresher for a longer period of time (WRAP 2013b). The report noted examples of packaging innovation to help reduce food waste, which included changes in food labels, such as removal of display until dates and moving away from use by dates and instead toward use of best before dates. Among the conclusions reported from the study is the potential for reducing food waste in the home by providing clear and consistent information on use by/best before dates and product storage guidance, and indicating the benefits of using that information. Vergh ese and others (2013) also examined packaging (primary, secondary, and tertiary) for insights into minimizing food waste across the supply chain, along with industry, resource, and lifestyle trends most likely to impact food waste in urban and regional Australia to the year 2030. Their recommendations included:

- clearly communicate best before and use by dates on primary packaging;
- inform consumers about date marking and packaging features that maintain product quality and shelf life after opening, and
- incorporate label storage advice into packaging design (Verghese and others 2013).

WRAP reported that in the United Kingdom confusion about whether a product is suitable for freezing and how best to freeze it to maximize its quality are 2 of the reasons that food is thrown away rather than frozen (WRAP 2012b). WRAP made 5 key recommendations for how food businesses can help their customers and the environment, by helping them make the best out of the food they buy:

- make it clear that the food can be frozen,
- use freeze-before date-mark labeling,
- provide "use within X months of freezing" and defrosting guidance,
- use logos and text appropriately,
- communicate freezing and defrosting guidance on the package, online, and in the store (WRAP 2012a).

Food wastage reduction efforts and initiatives. The world population is now approximately 7.2 billion, and is expected to reach 9.6 billion in 2050 and 10.9 billion in 2100 (UN 2013). It is estimated that currently about 925 million people suffer from hunger and an additional 1 billion may suffer from hidden hunger (that is, insufficient levels of high-quality protein, vitamins, and minerals). Dietary trends worldwide are moving away from cereal- and grain-based foods toward increased consumption of animal products, which will require greater land use and resources (Foresight 2011; IME 2013). Sustainably balancing future food demand and supply, and ending hunger, are key food system challenges that were identified in a report commissioned as part of the U.K. Government's Foresight Project: Global Food and Farming Futures (Foresight 2011). Reducing food loss and waste is a significant opportunity for addressing the challenge of meeting the need for food as the world population grows (FAO 2011b; Foresight 2011; IME 2013), and for conserving diminishing resources, given that food loss incurs not only nutrient loss but also loss relating to the land, water, and energy resources used in producing the food (IME 2013).

An analysis based on a survey of a targeted group of Grocery Manufacturers Assn. (GMA) and FMI members with extrapolation to the entire U.S. food manufacturing and retail/wholesale sectors that was prepared for the Alliance identified several categories of barriers to donating a greater proportion of food waste (BSR 2013). "Regulatory and external policy" was identified as one of the categories of barriers to donating larger amounts of food; specific examples cited were "good food past saleable date," limitations on what food banks will accept, and inability to donate private-label items without customer approval.

There are numerous activities and initiatives in the United States and other countries, and at the FAO, to address food wastage. In the United States, a Food Waste Reduction Alliance—a cross-industry initiative of the GMA, FMI, and the Natl. Restaurant Assn. was launched in 2010 to:

- avoid and reduce food waste wherever possible within members' operations and supply chains;
- increase the donation of safe and wholesome foods that would have gone to waste to send food to food banks to help address hunger issues; and
- divert unavoidable food waste away from landfills toward higher value uses such as animal feed, composting, and waste-to-energy (BSR 2013).

Noting the extent of food waste in the United States, the USDA and the U.S. Environmental Protection Agency launched a U.S. Food Waste Challenge in June, 2013 (USDA 2013b). The challenge calls on others across the food chain—including producer groups, processors, manufacturers, retailers, communities, and various government agencies—to join the effort to reduce, recover, and recycle food waste. The goal of the challenge is to grow to 400 partners by 2015, and 1000 by 2020, and lead a fundamental shift in how food is thought about and managed. Consumer educational outreach activities to provide information on safe food storage, package date labeling and expiration dates, and

reducing food waste are among the challenge-related activities being initiated (USDA 2013c).

Prompted by a food manufacturer missed-donation opportunity, in 2012 the U.S. food bank network—Feeding America—worked with the USDA to obtain flexibility in working with food manufacturers willing to donate food that would otherwise be deemed misbranded due to not meeting purchase specifications (with regard to weight, for example, and not health concern-related). The agency's flexibility now allows manufacturers to donate food that is outside of nonhealth-related purchase specifications without seeking temporary label approval from the agency or applying "not for sale" statements to each immediate product container. Since the agency issued a letter on December 27, 2012, expressing this flexibility, donations have increased, from 4749 pounds of meat/month prior to the letter to 5167 pounds of meat/month after the letter (Mitzi Baum, Feeding America, personal communication, September 6, 2013). Additionally, Feeding America is not required to label products as "not offered for sale" or "donated not for sale" unless requested or required by the donor.

Outside the United States, in recognition of World Food Day, the European Commission announced a commitment to reducing edible food waste 50% by 2020. Mentioning confusion about best before and use by dates as a contributor to food waste, the announcement indicated that clarification of these terms has been produced in E.U. languages and that a Working Group on Food Waste will address date labeling and donation of surplus food to food banks, among other actions to reduce food waste (EC 2013).

The Joint Food Wastage Declaration "Every Crumb Counts" (2014) is a joint initiative involving stakeholders across Europe's food supply chain, with 18 signatory organizations and 4 supporting organizations committing to "reducing food wastage throughout the food chain and to contributing to halving edible food waste in the EU by 2020." The declaration's co-signers "call on all stakeholders involved in the food chain from farm to fork and beyond to take further action to prevent and reduce edible food wastage on a European and global scale." The declaration lists 21 actions and includes "encouraging food operators to provide information about the actual meaning of use by and best before dates in collaboration with the EC's information campaign."

The United Nations Environment Program, FAO, and multiple partners launched in 2013 the "Think, Eat, Save, Reduce your Foodprint" campaign (Think Eat Save 2014) to target reduction of food wasted by consumers and within the retail and hospitality industry. The campaign supports the Save Food Initiative that was launched by the FAO and Messe Duesseldorf at the Interpack 2011 and which is supported by other U.N. organizations including, in particular, the World Food Program, Intl. Fund for Agricultural Development, and the U.N. Environment Program, and work together under the UN Secretary General's Zero Hunger Challenge (Zero Hunger Challenge 2014). The campaign has an information-sharing portal to advice, resources, and news on initiatives around the world. The advice for consumers includes understanding expiration dates; the advice for retailers and the hospitality industry includes offering discounts for near-expiration items, standardizing labeling, and increasing food donations (Think Eat Save 2013). The Save Food Initiative of FAO parallels its Global Initiative on Food Loss and Waste Reduction, which has 4 main pillars and develops regional programs and supports national implementation. The pillars are: collaboration and coordination of world-wide initiatives on food loss and waste reduction; raising awareness on the impact of and solutions for food loss and waste; research for policy, strategy, and program development for food loss and waste reduction; and support of projects implemented by private and public sectors to pilot and implement food loss reduction strategies (FAO 2014).

Date Labeling Challenges

A report prepared by Raftery Resource Network for the Joint Industry Unsaleables Steering Committee of GMA and FMI addressed practices that manufacturers, retailers, wholesalers, and sales agencies can use to reduce the amount of date-expired and unsaleable products and listed the pros and cons of open and closed date labeling. The report indicated that there are valid reasons for using both types of date labeling (Raftery Resource Network 2003). A Joint Industry Unsaleables Report (GMA and others 2008) indicated that at the retail and manufacturer levels standards and procedures for code date labeling and lack of product rotation practices, respectively, were among the leading causes of unsaleables. The report noted that from the retailer perspective, without best by dates that consumers understand it is very difficult to effectively manage stock rotation, while manufacturers feel that retailers do not allocate sufficient resources to product rotation and that product expires on the back of the shelf. One of the report's recommendations was the development of code-dating and rotation procedures. The report also indicated that as more products are marketed with visible and intuitive expiration dates, manufacturers become more conservative in determining shelf life and the effective shelf life is reduced.

An interview of executives of food manufacturing firms found that a number of factors influence manufacturer decisions about whether to add or modify open dating (ERG 2003). The factors identified were: the potential need for changes in inventory control practices, purchase or modification of in-line printing equipment, changes to label and/or package design, and/or additional shelf-life testing for validation purposes depending on the specific requirements of any FDA regulation." ERG (2003) also reported that there was agreement among the majority of manufacturers about the factors influencing their decisions to use open date labeling, which were: perishability, shelf-life duration, existing regulations, and marketing considerations.

Historically, product shelf-life testing was conducted prior to the product being introduced to the marketplace. Typical product development timelines were 12 to 18 mo. The current marketplace environment has caused product development timelines to become more aggressive, and shelf-life testing has to some extent been negatively impacted by a "speed to market" mindset among some manufacturers. Rather than having shelf-life data prior to market introduction, some companies conduct shelf-life testing in conjunction with the product being in the marketplace and adjust the date labeling as data become available. In many instances, the date labeling is established using experience with similar products and the testing confirms that the product quality remains intact. There are occasions when the shelf-life data show that the date may need to be shortened or could be extended.

Another challenge is the limited space on some containers for applying date labeling and limitations on the print field for inkjet coding heads. A simplified standard date-labeling method could prove beneficial to the industry and consumers. Additionally, there are field limitations to date labeling within barcoding applied to cases or pallets.

A recurring issue that all food banks deal with is receiving, on a daily basis, offers of donations of a product that is close

to code (approaching best if used by, sell by, and consume by dates), a situation that makes it very difficult for the food banks to determine whether to accept the donations and whether they would be able to distribute them quickly enough. Further, the end users—presumably the most vulnerable populations (seniors, children, and adults who may be immunocompromised)—who receive products are afraid to consume them or call to complain that they have received expired/bad food.

Limited resources. In the era of diminishing public health resources, regulators are finding it increasingly difficult to maintain the same level of scrutiny at retail as they have in the past. Budget cuts and resulting furloughs at the local, state, and federal levels have fostered an environment in which the need is for the regulator at retail to be focused on risk as opposed to checking expiration dates. In many states, it is the "Weights and Measures" officials that have the authority to regulate date labeling and not the food safety officials. Additionally, a number of large city health agencies may enforce local date marking requirements only within their jurisdiction.

The LBRO-commissioned survey found that in the United Kingdom wholesalers check best before labels usually weekly or every other week, and check for use by date labels on a daily basis (LBRO 2011b). Retailers tend to have 4 types of checks to ensure products are not displayed past their use by dates: stock rotation checks, due diligence checks, and internal and external auditing checks, which can be of significant cost to the organization (LBRO 2011b). LBRO (2011a) reported that the checks that retailers and wholesalers have in place for compliance to ensure that products past the use by date are not offered for sale cost an estimated £110 million per year, excluding the cost of food thrown away. Further, the desire to minimize the risk of product staying on the shelf beyond its use by date and leading to enforcement action motivates retailers to remove stock prior to the use by date. Additionally, LBRO (2011a) found that a challenge in checking date labels and a factor in the time required is the lack of uniformity in the size, font, and package location of the date label. And, as a result of the shopper sorting dilemma, retailers regularly check and re-rotate stock on the shelves to ensure sale within the use by date (LBRO 2011a).

Legality, enforcement, and liability.

United Kingdom. The LBRO survey (2011b) found that one of the main grievances expressed primarily by retailers that businesses have with use by dates, in addition to the waste generated, is the criminal punishment that can result from noncompliance. The survey report indicated that the criminal prosecution that retailers can be subject to is largely viewed as unjustified because many products that exceed their use by date are not an immediate health risk. The report indicated that during a 3-y period, there were 109 prosecutions for expired use by date labels with fines totaling £268955. The survey report noted that other business costs relating to enforcement include costs related to legal advice and staff time surrounding cases that either did not go to court or were found not guilty. The report also noted 3 main themes of changes that businesses in the retail, distribution, and production sectors would like to have made to use by date labeling regulations:

- use by dates should only apply to products that are a microbiological risk past their use by date;
- use by date labeling should reflect the point at which the product becomes unsafe, rather than when it passes optimum quality;
- regulatory punishment for noncompliance should be decriminalized.

LBRO (2011a) made several recommendations:
Use and determination of use by dates:

- use by dates should be established and applied on the basis of microbiologically highly perishable nature with the potential to pose a danger to human health after a short period;
- government and industry should jointly develop product-specific guidance to complement the revised DEFRA guidance;
- government should provide training and guidance for enforcement officers, based on DEFRA and sectoral guidances, to aid competency in advising on and challenging date marks and assessing product safety risks.

Regulatory framework:

- government should remove the current offence for selling items past their use by date;
- enforcement authorities should prosecute only in instances of genuine safety risks in the sale of products past their use by date;
- enforcement authorities should communicate with primary authorities at an early stage in instances in which noncompliance is suspected;
- primary authorities should review businesses' date control processes and implementation.

Consumer Guidance:

- government and industry should provide education for consumers on the importance of the use by date and food practices in the home.

United States. In the United States, regulation by some states of the sale of products after some label dates (past-date products, for example) influences routine retail establishment inspections by local or state health inspectors. In many cases, an inspector will spend a significant amount of time going through a particular section item by item and listing each item found outside of labeled date ranges. In most cases these findings are punitive in nature and carry a penalty of fines.

In U.S. 499, 505–06 (1983); United States v. Boyd, 55 F.3d 239, 241–42 (7th Cir. 1995), Mr. Boyd was convicted by a jury of wire fraud, 18 U.S.C. § 1343, and of introducing into interstate commerce a misbranded food with intent to defraud or mislead, 21 U.S.C. §§ 331(a), 333(a)(2). In that case, Mr. Boyd bought from a food salvage dealer out-of-date food, "Henri's Salad Dressing," that was past its "best-when-purchased-by" date. He relabeled the date and sold the product to Dollar discount stores. The prosecution's expert witnesses claimed that the product was rotten, spoiled, and a food safety hazard, yet provided no evidence. Upon appeal to the U.S. Court of Appeals Seventh District, Circuit Court Judge Posner who wrote the case opinion (Numbers 08–1839, 08–1860) overturned the lower court's finding. The food product was a bottled, pasteurized acidified food with an impermeable seal; thus, the product could have a shelf life of more than 3 y. The only other judicial case is the GMA v. the Public Health Dept. of Massachusetts (393 NE 2d 881, 1979) so as to overturn the Massachusetts Open Dating policy requiring all foods to have a date of last use or a "pull date." The Supreme Judicial Court of Massachusetts upheld the Public Health Dept. on the basis that

under the 10th Amendment, anything not stated in the U.S. Constitution may be regulated by the states based on the concept of the law being to protect human health.

As described by Labuza and Szybist (2001), the presence or absence of an open date on a food package in the United States has legal implications, with respect to either being misleading or misbranded. They noted the challenge of determining the basis on which to set a date, and mentioned that a food that is not held at proper temperature distribution conditions to meet the legality of the date (for example, is temperature abused during transportation or storage to an extent that allows pathogen growth to a level hazardous to health is potentially adulterated [as per Sec 402(a)(1) of the FD&C Act]). Thus, they stated that the food processor must design proper tests to assure that the date set is defendable in terms of quality and safety. They mentioned that TTI devices that integrate product time and temperature exposure in the cold chain with the same temperature response as the spoilage rate of the food or the growth rate of a pathogenic microorganism of concern could be a solution to this problem. They described what is needed to model the growth of pathogens on foods and collect data on the time to detection (TTD; generally the time to be able to detect 1 CFU/25 g) of a pathogen of concern to design a TTI device. They indicated that data on growth kinetics and TTI devices can be used to design a TTI device that chemically or electronically integrates a specific pathogen or toxin level to set an expiration date based on some level of risk (TTD or a regulatory action level). They commented that products could be labeled as "use by XXX unless indicator shows . . . ," with the latter depending on the TTI design. In addition, radio frequency identification (RFID) and electronic sensing and broadcasting capabilities broaden the advantages of TTIs (Pal and others 2007).

Advantages of Technological Innovations

In an article on intelligent packaging concepts and applications, Yam and others (2005) stated that "For the first time, packaging science, food science, biotechnology, sensor science, information technology, nanotechnology, and other disciplines are coming together to develop a breakthrough packaging technology." They defined intelligent packaging as a "packaging system that is capable of carrying out intelligent functions (such as detecting, sensing, recording, tracing, communicating, and applying scientific logic) to facilitate decision making to extend shelf life, enhance safety, improve quality, provide information, and warn about possible problems." They emphasized that it is a system that involves not only the package, but also the food product, the external environment, and other considerations. They presented a conceptual framework for intelligent packaging and described how advances in smart package devices—including bar code labels, RFID tags, time-temperature indicators, gas indicators, and biosensors—are incorporated into applications for enhancing traceability, HACCP, and other systems. They also identified several areas where multidisciplinary research is needed, which included integration of data carriers (such as barcode and RFID) and package indicators (such as TTIs) into small hybrid smart-package devices, and efficient integration of intelligent packaging into the packaging function model they presented (Yam and others 2005).

Labuza (2000) described simple, inexpensive TTI devices that can show an easily measurable time–temperature (*t*–*T*)-dependent change that reflects all or part of a food product's temperature history. TTI devices may operate on the basis of mechanical, chemical, enzymatic, or microbiologic systems, and may be used to monitor temperatures throughout a product's distribution cycle and indicate temperature abuse of individual food packages, cartons, or loaded pallets, or indicate when intended storage times have been exceeded (Taoukis and others 1991; Sherlock and Labuza 1992; Labuza 1996; Labuza and Szybist 1999a).

Sherlock and Labuza (1992) pursued consumer perceptions of a shelf-life TTI tag in conjunction with open dating on refrigerated dairy products through small focus groups and a survey. They found that general attitudes about readable TTI tags were very positive, but that immediate acceptance may be limited until consumers become more educated about food spoilage. A 2-part door-to-door survey of consumers conducted by the Univ. of Minnesota (Labuza and others 2001) found that participants believe TTI tags can be useful, and that TTI tags used in conjunction with open dates can help to assure high product quality once products leave the manufacturer.

Pal and others (2007) indicated that TTI devices based on the TTD for a pathogen of concern could help improve food distribution on the basis of the concept of "least-shelf-life-left first-out" instead of the "first-in first-out" distribution concept. Diez-Gonzalez and others (2007) modeled the growth of *L. monocytogenes* based on a TTD model in culture media and frankfurters, and determined that there is potential for the use of a TTI device with SBDL date labeling of RTE foods. They reported that a TTI device would be useful because it would predict at what point 1 CFU of a pathogen/25 g sample is detectable; in addition, they indicated that the TTI device would also be able to estimate growth under abusive temperature conditions. They concluded that setting the SBDL date of RTE foods to the time to detect *L. monocytogenes* would offer a significant degree of protection to the consumer and food manufacturers. Pal and others (2009) studied the estimation of the TTD for *L. monocytogenes* on frankfurters at levels below detection and modeled the TTD at 3 temperatures to deduce a safety-based shelf-life equation. They indicated that using a TTI device that matches the model they presented can show a point at which the product is unacceptable based on the time–temperature history of the food product, and that one could therefore label frankfurter packages with a statement such as "use by MM-DD-YY unless tag turns grey." They stated that this could be a valuable tool for risk-based management of listeriosis.

WRAP (2013c) briefly addressed developments in TTIs and stated that they are most commonly applied to multiple-unit, secondary, or tertiary packaging. "Time-It" (Time-It 2014) is a device, being developed by Freshpoint™ (2014), that indicates the time elapsed since opening and informs consumers about the time in which the product must be used. The device, which has a patent pending, is activated upon product opening by the carbon dioxide/oxygen change within the package. TTIs are a valuable technology amenable to a number of applications that have benefits for stakeholders in the supply chain and consumers. The technology is not without limitations (cost and validation-related barriers, for example) and manufacturer concerns, however.

Verghese and others 2013 reported that intelligent food packaging (for example, thermal sensors coupled with RFID smart tags with applications in primary, secondary, or tertiary packaging) can provide real-time data feedback to various supply chain stakeholders on quality, safety, shelf life, and logistics efficiency, and ensure that products are sold before they are out of date and require disposal. Their report included the recommendation that manufacturers investigate the value that could be added by intelligent packaging solutions to improve inventory management and reduce waste.

Kampers (Newsome 2014) mentioned the pursuit of incorporating TTIs with RFID labels, and a foil-electronics system that was developed through the Pasteur Project, a public–private partnership involving Wageningen UR. He commented that the system has been implemented on large food product containers but not on individual food packages, given its cost. He said that if the economics and business case for the system were optimized, the devices may also be used with refrigerators to indicate the need to consume a food before it spoils (Newsome 2014).

An RFID-Electronic Product Code smart sensor tag, software, and solutions system, collectively known as Freshtime^{TM} (Infratab^{TM} 2014), monitors and logs time, temperature, and product freshness used on the basis of Freshtime Points^{TM} metrics. The color-coded points system, beginning at 100% and ending at 0%, incorporates the use-by date concept representing a brand owner's quality assessment. The RFID sensor tags and software are based on several issued and pending U.S. and international patents (Infratab 2014). A critical element of this is the use of a handheld reader that can sense the remaining shelf life of multiple cases in a truck, railroad car, or distribution center. Then instead of First-In First-Out (FIFO)-logistics management one can switch to Least Shelf life Left First Out (LSLFO), which essentially can eliminate shrink (loss) of short-shelf life products at retail.

Joseph (2012) indicated that trials were underway to test on a number of food products a chemical-based color-changing smart-label prototype with an elapsed-time indicator that triggers a device when the product is opened to indicate product freshness. The development is a collaboration of UWI Label and Heriot Watt Univ. (Developing the Award-winning UWI Label 2014).

Packaging Scotland (2013) described several developments. Insignia Technologies, a spin-off from research conducted at Strathclyde University, announced creation of a smart label extruded into plastic film based on smart pigment technology that is activated by carbon dioxide in modified atmosphere packaging and which changes color upon opening. Thin Film Electronics developed with Bemis a printed electronic-based temperature sensor tag. Researchers at Eindhoven University of Technology, Universita di Catania, CEA-Liten, and ST Microelectronics are pursuing analog-to-digital converters (ADCs) that can be printed onto plastic (Packaging Scotland 2013). Brody (2013a) mentioned ADCs and noted that they can indicate freshness by monitoring the acid level of a food and transmit a signal for scanning or reading with a mobile phone.

Brody (2013b) addressed additional systems (including, for example, a nanosignaler and a TTI–RFID coupled device) designed to extend shelf life of perishable foods, and to sense and signal spoilage. Some of the devices he mentioned can send information (preparation instructions, for example) to a consumer's smart phone. Another device, he noted, integrates signals of protein degradation with algorithms, with transmission through RFID devices, to predict microbiological quality for appropriate action in product distribution channels.

An IFT study relating to capabilities of product tracing technologies reported that several traceability solution providers are working toward a number of optional value-added services, including providing expiration and shelf-life analysis and temperature tracking to generate better return on investment for food companies (Bhatt and Zhang 2014).

WRAP (2013c) investigated the potential of thermochromic inks (which are temperature-sensitive and change color upon exposure to heat) for use in packaging applications to reduce household food and drink waste. In this study WRAP interviewed 20 companies including 5 major retailers and food producers; 6 TTI technology companies; 3 packaging manufacturers; and thermochromic ink developers, manufacturers, and packaging converters. Among the current applications the study identified were a few food safety-related applications (for example, indicating when a food product is out of date, and whether a food or beverage is at the proper storage temperature). Although there are considerations (such as cost, lifespan, and applicability to specific packaging surfaces and for food contact use) to address in pursuing potential thermochromic ink applications, the investigators concluded that they have potential for use in alerting consumers that a product is not being stored at the correct temperature and providing educational messages that could change behavior and lead to reduction of food waste (for example, by encouraging storage of food at temperatures that prolong shelf life, such as keeping apples in a refrigerator). Additional TTI, RFID, and other innovations that could increase food system efficiencies and reduce waste (by extending product shelf life, for example) are identified and described in a database—Resource Efficient Innovations Database (REID; 2013)—created by WRAP to showcase resource-efficient technologies, particularly innovations in packaging, hospitality, and product preservation for the retail sector (REID 2014).

However, the view of the European chilled food manufacturers, represented by the European Chilled Food Federation, is that TTIs should not be used on consumer packages given the potential for consumer misuse in terms of use by dates and potential liability issues, particularly if temperature abuse has occurred outside of the commercial chill chain (Kaarin Goodburn, CFA, personal communication, April 2, 2014).

Conclusions

Date labeling of food products has been practiced and studied for decades. Regulatory frameworks for date labeling vary considerably around the world; frameworks may be based on health or nutrition, quality, food safety, or more than one focus. In the United States, beyond the few varying federal requirements for date labeling, there is considerable variation among the states in date labeling practices. Some states prohibit and impose fines on those who sell food upon or after expiration of the date label.

The date labeling variations in the United States, and among other countries and other factors, contribute to confusion and misunderstanding in the marketplace regarding how the dates on labels relate to food quality or safety. This confusion and misunderstanding along with the different regulatory date labeling frameworks have substantial impacts, including unnecessarily detracting from limited regulatory resources, causing financial loss, and contributing to significant food wastage.

Nevertheless, there are certain perishable products with a short shelf life and for which time and temperature are important that should be consumed quickly, and if not used they should be discarded. Examples of these products, which may simply have a pack date, include fresh-squeezed juices, deli meats sliced at the retail store, fresh-cut fruit, ground beef ground at the store, and deli salads. If time and temperature are not adequately controlled in these limited-shelf-life products they may present a safety risk, particularly for vulnerable subpopulations.

However, in contrast to the E.U. framework, which requires that foods that are highly perishable from a microbiological point of view carry a use by date after which the "food shall be deemed unsafe," the application of a use by date to distinguish when a food product becomes unsafe is not advisable. The 1st reason is the lack of absolute control of the temperature to which food products are

exposed throughout the complex food supply chain. Pathogenic bacteria can grow in many foods if at or above 41 °F (5 °C), unless other measures are taken to inactivate them with a pasteurization technique or to inhibit their growth by acidifying, lowering water activity, using preservatives, or controlled-atmospheric packaging. Although these control techniques are possible for some foods, they are not plausible for others (lettuce, for example). Second, the pathogen *L. monocytogenes* can grow at temperatures below 41°F (5 °C), even at 29.3 °F (−1.5 °C); hence there is benefit of pasteurizing product in the finished sealed package, if possible, to ensure the level of any *L. monocytogenes* is considerably below the limit of detection (1 CFU/25 g). To guarantee safety one would need to establish GMPs to ensure that the initial pathogen level is below X/(CFU/g), where X may be much less than 0.01 to 0.001 and the pasteurization level of destruction is at least 5 log cycles. This then would have to be followed by employing on individual food packages a TTI tag that uses this information to display an end of shelf life based on the time–temperature exposure of the package to indicate food safety. This could be done with currently available modeling procedures and available tags, but would have a high cost.

The findings of Zeng and others (2014) show that because of varying time–temperature profiles during transportation and retail storage and display, if perishable foods have a use by date that is perceived as a statement indicating that the product is safe to eat, the product may be consumed, although potentially adulterated, and possibly lead to foodborne illness. If the perishable product had a TTI based on pathogen growth kinetics and the shelf-life end point were set for no more than a 0.5 log increase, a use by date could be conveyed as "use by XXX unless bullet color on the tag is the same as or darker than the circle around it," for chemical tags, for example. If the TTI on this product had an electronic tag, the percentage of shelf life that remained could be conveyed to the retailer for the purpose of better managing stock. Further development and use of TTIs for susceptible perishable refrigerated foods are needed.

Call to Action

Given the current date labeling situation in the United States and around the world, collaboration to develop a simple workable solution to address the challenges faced by food manufacturers, retailers, government officials, consumers, and other stakeholders would have significant benefit.

Date Labeling Uniformity

To move toward much needed uniformity in date labeling, the food industry should align to develop a more consistent or single best practices date-marking system, and one which takes into consideration on-package storage instructions. Because of the wide range of variability within the current system, there is unnecessary stakeholder confusion and food waste. A focus on prioritizing measures based on food waste data would be a logical approach to identify effective ways to implement such a date-labeling initiative. Research has shown that the top categories for food waste are produce and dairy and bakery items. A partnership with manufacturers for date labeling, as well as an alliance among retailers for in-store dating schemes, is necessary to adequately address date labeling concerns with these products. Often supplier-led date labeling conflicts with in-store dating schemes. These 2 areas need to be aligned in order to decrease consumer confusion and ultimately lead to a decrease in food waste related to date marking. Further, uniformity in date marking would preempt a patchwork of state-by-state regulations in the United States, contributing further to eliminating customer and consumer confusion and reducing food waste. Ideally, the terminology and format would be consumer-poll tested to ensure efficacy and understanding.

Regulatory Enforcement

In some cases, U.S. and international regulators have devoted excessive resources and inspectional focus on food quality date labeling at retail. In fact, in some jurisdictions and countries, retailers can be criminally prosecuted for such offenses. Regulatory agencies should revisit the emphasis they place on this issue, in light of its lack of correlation to public health significance and the role it plays in contributing to unnecessary food waste. This is not to suggest that date labeling that relates to reducing food safety risk should not be an emphasis of regulatory activities. For instance, date marking at retail that is required in the FDA Food Code and is designed for controlling the growth of *L. monocytogenes* is an example where date labeling is a public health issue. A coordinated federal and state approach with uniformity in date labeling would increase consistency across labels and decrease confusion, including at the regulatory level. Quality-based date labeling is not a critical food safety issue; thus, resources could be shifted to ensure that regulatory efforts are focused around more significant health and safety risks rather than on labeling concerns that are food quality in nature. Furthermore, regulatory discretion and allowances for collaborative industry-led development of a solution for uniform date labeling would be desirable.

Consumer Education

Education will be a key component for this initiative, given the percentages of consumers who do not understand the difference between a use by and best before date and the extent of food waste occurring within the household. Uniformity in food date labeling is the 1st step to better inform and educate the customer and provide clear, simple consumer direction on food quality and safety. Food waste behavior can be altered through education regarding the meaning of date labeling, the importance for some products of limited shelf life and temperature control, availability and understanding of food storage guidance, and safe handling methods. Improved understanding of a streamlined, uniform food date labeling scheme will also improve purchasing decisions by the consumer. Possible educational solutions could include signage or other materials at the point of sale, QR codes, and education campaigns such as the U.K. government-backed "Love Food Hate Waste" initiative, which has proven to be very successful in reducing food waste overall among U.K. consumers. Ideally, existing literature and research studies would be used as reference points and further research would be conducted to determine the date labeling language and format that consumers would prefer.

Indicator Technologies

More research is needed in this area to advance and develop technologies that could help inform stakeholders when food products no longer meet quality or safety-related criteria. It would help decrease food waste. There are companies that have developed, or are currently developing, indicator technologies that address this need. Many types of time–temperature devices, for example, have been created; however, few use time–temperature integration to provide the actual fraction of remaining shelf life. Without such a device, the transporter, processor, and retailer have no knowledge of whether the product has been improperly stored. In addition, consumers who look for and choose products with the youngest

date or the longer use buy or best if used before date, would do so without knowledge of any temperature abuse. Nevertheless, use of TTIs is a consideration, as the U.S. FDA has indicated for certain fish and fish products, meriting further evaluation. Technology enhancement and improvements along the supply chain to monitor temperature handling and storage information could help better gauge true shelf life, and also reduce food shrink (waste), particularly with respect to fresh produce.

Another area to pursue is addressing date marking in expanded bar codes. Improving the packaging used at the retail store level can also increase the lifespan of fresh produce. The development of technology for use at the household level will be key in order to reduce waste in the home. This could be addressed by developing packaging options geared toward use at the consumer level to decrease spoilage and increase shelf life, which would also help minimize food prices, especially for produce, and thus contribute to increased health. Social media actions and smartphone technologies could be used in the home to help consumers understand dates that appear on food. For example, more efficient meal planning, better use of leftovers, and improvements in shopping and keeping track of food at home are components of the "Love Food Hate Waste" campaign as iPhone and Android applications.

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Abbreviations

ADC	Analog-to-digital converter
AFDO	Assn. of Food and Drug Officials
BRC	British Retail Consortium
CFIA	Canadian Food Inspection Agency
CFA	Chilled Food Assn.
DEFRA	Dept. for Environment Food and Rural Affairs
ERS	Economic Research Service
EC	European Commission
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FDA	Food and Drug Administration
FD&C Act	Food Drug and Cosmetic Act
FMI	Food Marketing Inst.
FSIS	Food Safety and Inspection Service
FSA	Food Standards Agency
FSANZ	Food Standards Australia New Zealand
GAO	General Accounting Office
GMA	Grocery Manufacturers Assn.
HACCP	Hazard Analysis and Critical Control Points
LBRO	Local Better Regulation Office
NACMCF	Natl. Advisory Committee on Microbiological Criteria for Foods
NCWM	Natl. Conference on Weights and Measures
NIST	Natl. Inst. of Standards and Technology
NRDC	Natural Resources Defense Council
NZFSA	New Zealand Food Safety Authority
OTA	Office of Technology Assessment
PHF	Potentially hazardous food
RFID	Radio frequency identification
RTE	Ready-to-eat
SBDL	Safety based use-by date labeling
TTI	Time–temperature integrator
TTD	Time to detection
UK	United Kingdom
US	United States
USDA	United States Dept. of Agriculture
WRAP	Waste and Resource Action Program

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