Int. J. Production Economics 139 (2012) 14–21

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

Retail benefits of dynamic expiry dates—Simulating opportunity losses due to product loss, discount policy and out of stock

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ARTICLE INFO

Article history:
Received 27 August 2009
Accepted 26 April 2011
Available online 19 May 2011

Keywords:
Discrete-event simulation
Intelligent packaging
Shelf life
Distribution chains

ABSTRACT

When setting an expiry date on fresh food products producing companies have to buffer against two major uncertainties. The initial number of microbes is unknown in practice, and will be variable. Moreover the storage and transport temperatures until consumption will be uncertain and variable too, which will make microbial growth uncertain and variable. In order to cope with these two uncertainties, expiry dates are set at a rather cautious level, resulting into high numbers of product losses or out of stock (lost sales) at retail. In this paper we propose a so-called dynamic expiry date (DED) as an alternative for the fixed expiry date (FED) as applied nowadays. On the basis of a quality decay model that describes the growth of the number of microbes as a function of time and temperature, the expiry date can be dynamically adjusted depending on the measured temperature profile along the distribution chain and the initial number of microbes on the product. We present computer simulation experiments that quantify the effect of a dynamic expiry date on product losses and out of stock at retail outlets. For this purpose, a logistics simulation model of a Dutch pork supply chain was developed. Simulation results show that the DED concept is a promising concept. We predict that a dynamic expiry date decreases opportunity losses by almost 80%. Moreover, advantages are higher when having lower shelf temperatures. Therefore, implementing DED may be an incentive for retailers to optimize their climate control.

1. Introduction

Fresh food products are given expiry dates to guarantee quality towards consumers. Producing companies are obliged to put a certain date on the package, but are rather free in determining the exact number of days after production. Companies guarantee their expiry dates by testing product quality after simulated chain conditions. An example of common practice is represented by a company that produces pork product. The company sets the expiry date at $p+7$ (7 days after production), at a maximum temperature of 4 °C. On a regular basis a part of a production batch is stored for 1 day at 1 °C, and subsequently for 6 days at 4 °C. Subsequently, it is checked whether the total number of microbes is still below a maximum accepted level. Log 7.0 CFU/cm^2 was selected as the endpoint of shelf life because researchers generally agree that spoilage defects in meat become evident when the surface spoilage bacteria reach approximately 7 log CFU/cm^2 (Knox et al., 2008).

When setting an expiry date one has to anticipate two major uncertainties. First, the initial number of microbes (directly after packaging) is unknown in practice, and will be variable. Second, storage and transport temperatures until consumption will be uncertain and variable too, which will make microbial growth uncertain and variable. Until the point of sale, these temperatures are more or less controlled (but variable) according to food safety protocols like HACCP, but from the point of sale to the point of consumption, temperature is totally uncontrolled. If the product is stored or transported at temperatures above the maximum storage temperature given on the package, the expiry date may become misleading. In order to cope with these two uncertainties regarding initial contamination and chain temperatures, expiry dates are set at a rather cautious level. For this reason, most of the consumer units of fresh food will have a shelf life that will exceed the expiry date at their packaging.

From the viewpoint of sustainability and cost effectiveness, this situation is rather non-optimal. We expect these fixed expiry dates to be responsible for high numbers of product losses and out of stock (lost sales) at retail (and waste at consumers, which aspect is, however, beyond the scope of this paper). Trying to avoid product losses and out of stock, retailers will attempt to optimize their ordering policies in hopes to find a suitable balance between product losses and out of stock. Summarized, the consequence of fixed expiry dates becomes visible in product losses on the one hand, and out of stocks on the other hand, where the preferred balance between these two will differ per retailer and product category.

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doi:10.1016/j.ijpe.2011.04.029

In this paper we propose a so-called dynamic expiry date (DED) as an alternative for a fixed expiry date (FED) as applied nowadays. In short, a dynamic expiry date is calculated on the basis of a quality decay model that describes the growth of the number of microbes as a function of time and temperature The expiry date is adjusted dynamically according to the measured temperature profile along the distribution chain and the initial number of microbes on the product. We assume that technical devices (printed electronics, moving displays) that perform temperature sensing, calculations and communication can be developed and applied in or on the product package. The developments in printed electronics increase at high pace and applications as moving images and temperature sensing might be available in the coming years. In comparison with other alternatives, printed electronics are a low cost technology that can be applied at each consumer packaging. Issues as complex calculations and two-ways communication with printed electronics require further development. The development of this type of applications is more difficult to predict at the moment. Intelligent packaging, especially when integrating with science-based principles, is a useful tool for tracking products and monitoring conditions, facilitating real-time data access and exchange, and enabling rapid response and timely decision making as described by Yam et al. (2005). By doing so, the two major uncertainties as mentioned earlier will decrease or even disappear, as for each individual product the actual number of microbes is estimated from its own time–temperature profile.

This paper presents computer simulation experiments, where the effect of a dynamic expiry date on product losses and out of stock at retail outlets is quantified. The advantages of a DED can even go beyond increasing the shelf life. In the Netherlands, discounting is a widely applied strategy for reducing product losses. In general, products that approach the expiry date are labelled manually with discount stickers (one or two days before passing the expiry date). Therefore, by extending the technical devices needed for a DED with an automatic discounter, personnel time is saved for labelling. Moreover a DED may enable dynamic pricing systems, i.e. different percentages of discount dependent of the actual shelf life of the product. The DED concept can also be seen as a service concept towards consumers. When logging time and temperature on the way home and at home in or outside the refrigerator, it can provide consumers with the actual expiry date (and thus microbial quality) of the product at the moment of preparing the meal. Analyzing the advantages of this service aspect is, however, beyond the scope of this paper.

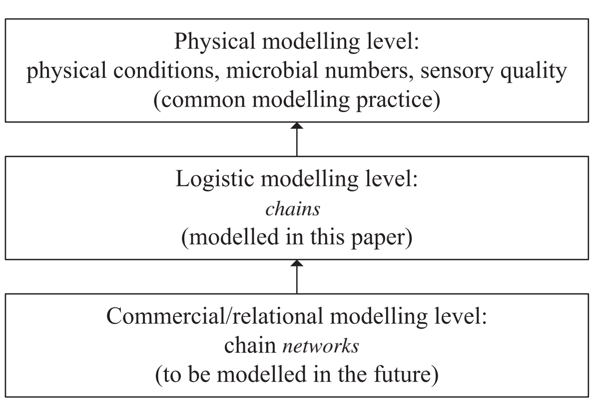

Fig. 1. Our modelling vision. For a description see the paragraphs above. The arrows indicate parameter or data input dependencies.

Based on principles of modelling food spoilage and time–temperature monitoring a shelf life management system has been developed by Giannakourou et al. (2001). Koutsoumanis et al. (2005) present the principles of development of an intelligent Safety Monitoring and Assurance System (SMAS). The SMAS is an effective chill chain management tool that leads to an optimized distribution of risk and a significant quality improvement of foods at consumption time. The applicability and effectiveness of SMAS compared to the FIFO (First In First Out) principle is demonstrated. At specific decision points along the supply chain (distribution centre, retail outlet) each package's time–temperature profile is read by a device. Based on software within that device (containing growth models) one can decide about for example export or local market or about which products to promote first. Using Monte Carlo simulation the benefits of SMAS were calculated regarding an increase in remaining shelf life at consumption time. However, the analysis of product losses and out of stock was not taken into account.

2. Methods

We analyzed the concept of dynamic expiry dates using the Monte Carlo discrete-event simulation (Mitrani, 1988) for modelling logistics. A Dutch supply chain of fresh pork chops was modelled. Currently, as described by Rijgersberg et al. (2010), we are able to model lead times in the logistics chain by describing the underlying planning and scheduling mechanisms. In this manner, interdependencies between lead times of different processes are modelled. Interdependencies of lead times are difficult to determine in practice—the underlying logistics mechanisms appear to be to determined more easily. Modelling (interdependencies between) lead times is crucial in modelling microbial numbers, because these interdependencies may be responsible for exceeding maximum accepted levels.

Our modelling vision regarding food supply chains can be visualized as follows (Fig. 1). The physical level (the upper level) concerns physical aspects such as microbial numbers, sensory quality and physical conditions such as temperatures and oxygen fractions in modified-atmosphere packages. In the logistics level (the middle level) lead times are modelled. These lead times are input to the physical level. The bottom level concerns the commercial and relational levels. The relations between chain actors in a chain network (possibly varying over time) are input to the logistics level.

The simulation model was programmed using Aladin. Aladin (Agro Logistics Analysis and Design INstrument) is a visual interactive simulation environment built in the Logistics Suite of the (entity-based, discrete-event) simulation package Enterprise Dynamics. Aladin consists of a library of generic building blocks for modelling fresh supply chains and networks (Van der Vorst et al., 2005).

2.1. Modelling logistics

The following chain was simulated (Fig. 2).

The modelled planning and scheduling mechanisms and the values of the logistics model parameters are based on a Dutch supply chain of pork chops. This supply chain consists of a Dutch regional operating retailer exploiting about 70 retail outlets and having its own centralized production lines inclusive packaging and labelling. One 'average' supply chain was modelled based on point of sale data and product loss data from 15 retail outlets

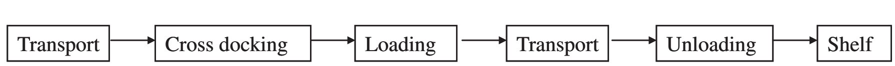

Fig. 2. Physical processes within the pork chops supply chain. The arrows indicate input dependencies.