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PERISHABLE INVENTORY MANAGEMENT: HUMAN MILK BANKING CASE STUDY

Marta Staff

Centre for Simulation, Analytics & Modeling
The Business School
University of Exeter
Exeter, EX4 4PU, UK

ABSTRACT

Despite providing lifesaving donor human milk to vulnerable premature infants, human milk banking is greatly overlooked from an Operations Research perspective, with yet to be explored distinctive characteristics, offering attractive prospects for Modelling and Simulation research. The effective management of inventory, where products have limited shelf life, adds to its complexity. The commonly utilized newsvendor model to study inventory decisions is unlikely to capture the intricacies of items with extended shelf lives. A milk donor typically accumulates milk over time, resulting in the donation of a "stash" consisting of milk units with different expiry dates. The decision of whether to treat it as a whole, or split it, when the "stash" is progressed out of the ingress inventory into production, will affect the remaining shelf life of the final product, but also the associated production costs. Hence DES is being utilized to investigate the cost-benefit analysis of batch splitting.

1 INTRODUCTION

Despite its widespread use, manufactured infant formula feed has been shown to be inferior to human breast milk in several ways, being unable to match the multiple different functions provided by breast milk. For this reason, the World Health Organization recommends that infants are fed exclusively on human milk for the first six months of life (WHO n.d.). In case that a mother is not able to provide breast milk, which could be due to various reasons such as delayed onset of lactation, or if the mother is taking certain medications incompatible with breastfeeding, the use of donor human milk (DHM) is recommended instead.

The pool of milk donors comprises lactating mothers who produce more milk than their infant(s) require. This oversupply may be donated by such mothers to human milk banks (HMBs), whose role is to collect the donations and undertake processing to ensure a safe supply of donor milk. Typically the processed DHM is provided to hospitals for the feeding of premature infants, but also infants in the wider community may be supplied with milk, for example in the case of maternal illness or death. A secondary role of HMBs via DHM provision is to support and promote breastfeeding (Shenker et al. 2021).

The operations of HMBs includes the screening and recruitment of donors, collection of donated batches, processing (pasteurization), quality assurance via microbiological testing, storage and dispatch, typically to hospitals. These operations result in a relatively high cost of DHM relative to infant formula, despite HMBs operating as not-for-profit organizations. This high cost has been cited as a factor influencing the lack of universal use of DHM in hospitals in England and Wales (Zipitis et al. 2015). However, a recent systematic review demonstrated the cost-effectiveness of DHM when compared to infant formula (Zanganeh et al. 2021).

2 SUPPLY SIDE CHARACTERISICS

The supply of DHM to milk banks is stochastic in nature, where donors are limited to a pool of lactating individuals who are willing and able to share their milk. After being expressed, human milk has a limited shelf life of three to five days, which is typically extended by freezing. For donated milk, guidelines in the UK (NICE 2010) allow up to three months before it is required to undergo pasteurization at the milk bank, and a total maximum shelf life of six months from expression to when it is used for infant feeding.

Human milk donors tend to collect milk over time, building up a "stash" in a home freezer, which is donated at some point in time to a HMB. Therefore, collection is not simultaneous with donation, and each received donation "stash" constitutes multiple discrete frozen samples, having variable volume and age. These features of the milk banking supply are believed to be unique and previously unresearched. They differ significantly from that of the widely researched blood banking field, in which donation and collection times coincide, and donor samples are fixed/deterministic. Milk banks typically defrost and combine all the individual samples within a donated batch, assigning to the entire batch the earliest expression date of all the constituent samples. An alternative approach being researched in this study is to instead perform batch splitting, allowing portions of the split batch which were expressed later to be given a longer shelf life.

3 DES STUDY

As a main objective of HMBs is to maximize DHM provision, effective inventory management of the perishable good that limits wastage is crucial. Batch splitting of donations provides an option for extending the shelf life, however the associated production costs are likely to increase. Our recent literature review indicates that DES is likely to be an appropriate approach for modelling such a perishable inventory system (Staff and Mustafee 2023). Hence, the current study of batch splitting and the associated tradeoffs that incorporates impact of the stochastic nature of the discrete milk donations will use DES. Following the conceptual modelling framework presented by Robinson (2008), we presented the initial stage of the simulation life cycle. It has assisted in gaining a deeper understanding of how to structure the computer model, and what the data requirements might be. During the conceptualization phase, the decision to include all elements that are crucial to capture the process flow related to *Activities* (such as defrosting, pasteurization) and *Queues* (such as freezers) was reached. Subsequently, those were included in the DES model. On the other hand, simplifications of elements related to *Entities* and *Resources* were defined. We focus on the Milk Units as *Entities*, and ignore other consumables such as bottles, also the *Resources* such as human resources and equipment were excluded. Despite those, the agile design principles are being practiced during the computer model development to allow for future extensions.

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