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Assessment of a Novel Inventory Rotation Policy Using an Empirical Distribution Function (EDF) for Frozen Shrimp Supply Chain

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Abstract

Problem statement: Traditional inventory management plans (IMP) for perishable commodities follow first-in-first-out (FIFO) as a standard policy. In this approach, the entities are regarded as a non-biological and non-deteriorating type based on product age and time spent in storage. The assumption made in the earlier simulation studies for perishable commodities is that deteriorating inventory had a fixed storage life and quality decay process follows a uniform distribution function which leads to higher waste. Therefore, the time-based approach of inventory management is not applicable.

Solution: It is established that temperature and time a perishable product spends at a certain temperature can directly impact the rate of deterioration. Product lots arriving at a distribution center from various suppliers exhibit different remaining shelf life due to product handling scenarios such as distance; geographical location; cooling equipment efficiency; and compliance with the handling codes. With the use of integrated temperature sensors and data logging as required by the FSMA sanitary transportation rule, actual remaining shelf life can be determined at any stage of product transition in a supply chain using predictive-kinetic modeling techniques. Information obtained through these models on the key quality markers of frozen shrimp will allow for a new approach that applies the least quality first out (LQFO).

Methodology: Initial quality level for frozen shrimp was assessed upon arrival (day 0) at a virtual warehouse using a quality scoring scheme depicting effective and threshold quality levels. The data was analyzed and fitted to the Theoretical Distribution Functions (TDF). In most cases, an Empirical Distribution Function (EDF) for quality parameters was developed when TDF fit was not statistically significant. A total of 6,000 cases from 6 different suppliers (and hence different transportation history) were available to issue inventory items. For a 30-day simulation run, there were 23 days in which stock was issued and seven days in which inventory replenishment was made.

Results: Overall, the percent initial Quality Variation ($QV_{initial}$) was between 0 – 23 %. ANOVA revealed that no significant effects of stock issuing policy (LQFO and FIFO) on the average quality of frozen shrimp ($\alpha < 0.05$) at the time of issue. However, the SD of percent Average Quality level (QA_{issue}) at the time of issue was < 2 % in case of FIFO, whereas it as 3.5 – 4.5 when LQFO was used. A higher range of SD, found in case of LQFO policy as compared to FIFO, shows that there was a tendency for retention of higher quality products in the warehouse. It is also remarkable to note that with the increase in variation in $QV_{initial}$ (12 – 23 %), the SD of the corresponding AQ_{issue} also increased which indicates that items with relatively poor quality had a higher chance of being picked up for issuance. This finding was in accordance with the study of Wells and Singh (1989) in which they compared FIFO and SRSL (shortest remaining shelf life) policies for stock rotation of frozen broccoli. In their case, the initial quality variation was 0 – 40%.

For the current study, 30 % of inventory remained in the warehouse for up to 80 days of shelf-life remaining for LQFO compared to only 12.5 % for FIFO with 76 days of on-hand inventory.

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Significance: The LQFO provided an improved inventory rotation solution based on empirical models encompassing information of the actual quality variability in incoming inventory. This policy can allow inventory decision makers to reduce waste through dispatching and redirecting lots with shorter shelf-life sooner to a shorter distance or to the marketplace where lower quality would be acceptable. In conclusion, LQFO policy was more efficient and potential risk of issuance an inferior quality product was minimized.

Keywords
Food quality, cold chain, quality loss, shelf life, frozen shrimp

Reference
Wells, J. H. and R. P. (1989), A Quality-based Inventory Issue Policy for Perishable Foods, Journal of Food Processing and Preservation, 12 (4): 271-292.

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