JOINT OPTIMIZATION OF DISPLAYED STOCK, INVENTORY AND PRICING DECISIONS FOR FRESH PRODUCE IN RETAIL STORE

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Abstract

Customers' interest in fresh produce has grown in recent years due to the improved standard of living and increased health consciousness (Chen et al., 2016; Dobson et al., 2017). It is well documented in the literature that fresh produce's demand depends on its freshness, price, and stock displayed on shelves in the retail store. Customers can accurately assess and compare the price and displayed stock of various items, but they usually rely on their perception about the freshness of the item. The perceived freshness is an important measure of fresh produce's quality that significantly impacts customers' purchase decision (Chen et al., 2016). For some fresh produce (e.g., bread, milk, etc.), freshness can be judged more accurately by the customers based on the expiry date available on the package unlike other products such as fruits and vegetables for which such information is generally not available. Considering the effects of freshness, price and displayed stock level; several types of demand functions for the fresh produce are proposed in the literature.

Various studies are available in the literature for jointly determining either displayed stock level, inventory or pricing for the perishable items. However, freshness effect is generally ignored in these models. Majority of them have used various forms of deterioration rate in their demand functions assuming that item gets expired during the planning horizon based on the given deterioration or decay rate. Very few studies (Wu et al., 2016; Chen et al., 2016; and Feng et al., 2017) have incorporated freshness effect in the demand function for fresh produce assuming that freshness linearly decreases to zero on its expiry date from its initial level. In this study, we consider the deterministic demand setting in which fresh produce's demand is a function of its freshness, price and displayed stock.

We propose optimization models for the fresh produce to jointly determine the displayed stock, inventory and pricing decisions to maximize the retailer's profit. Our study compliments the previous works (Wu et al., 2016; Chen et al., 2016; and Feng et al., 2017) that did not consider all the three decisions in their models.

In the first study, we extend the joint optimization model of Chen et al. (2016) by incorporating the pricing decision. We consider both the forms of pricing effect on demand, i.e. linear and power form. We have adopted analytical modeling method to solve the proposed models. Necessary and sufficient conditions are derived to obtain the optimal solution for the these models. Numerical examples and sensitivity analysis are carried out to illustrate the theoretical and managerial implications. In the above models, we considered only single item and ignored the shelf space constraint. We further extend these models for multiple items considering the shelf space constraint and develop a heuristic to solve it.

In previous models, we considered a single price throughout the planning horizon. In reality, retailers offer price discounts to their customers to boost the fresh produce's demand that otherwise decreases over time due to reduction in freshness level. Therefore,

we explore this opportunity by determining the optimal amount and timing of single price discount, and its impact on the retailer's profitability.

Since freshness plays an important role in purchasing of the fresh produce, retailers can preserve the freshness by investing into better storage technology. In this study, we extend our previous models considering the investment opportunity in better storage facilities and their impact on the retailer's profitability. In previous models, we considered same freshness level of the item in the front room, i.e. displayed stock as well as in the back room. In this study, we consider the better storage facility in the back room which preserves the freshness, i.e. freshness level of item stored in back room is higher than that of displayed on the shelves in the front room. Due to continuous replenishment of item from the back room to front room upon its sales, units of item with different freshness level get mixed and hence measuring the resultant freshness index becomes challenging. We attempt to capture this aspect in our model. We show that by investing in technology to preserve the freshness of items in the back room, retailer can improve the sales as well as profitability.

Our study contributes to the existing literature in three-fold; (i) incorporating pricing decisions and obtaining the optimal price level along with other variables (ii) determining the optimal discount i.e. second price and its impact on retailer's profitability (iii) exploring the investment opportunity in preservation technology in back room storage and its impact on retailer's profitability.

Keywords: Retail, fresh produce, freshness, optimization models, inventory, displayed stock, pricing, heuristics.

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Notations

c	Purchase cost per unit
h	Holding cost per unit per year
o	Ordering cost per order
u	Shelf cost per unit per year
u'	Shelf cost per unit space per year
m	Lifetime (i.e., the time to its expiration date) of fresh produce in years
m_f	Lifetime of fresh produce stored in the front room (i.e. display shelf)
m_b	Lifetime of fresh produce stored in the back room
m_e	Effective lifetime when back room has better storage condition than front room
μ	Selling time per unit
τ_i	Time of selling of i^{th} unit
t_1	Time in years at which inventory level reaches to W
t_{1i}	Time in years at which inventory level reaches to W for item i
$I(t)$	Inventory position at time t
t_p	Time of providing discount
θ	Fixed price discount applied at time t_p
S	Total shelf space available
p	Selling price per unit with
p_1	Initial price in model 4(a) and 4(b)
p_2	Discounted price triggered at time t_p
s	Salvage price per unit
q	Inventory position at the time of price discount
Q	Economic order quantity in units

α	Scale parameter
β	Space elasticity
a	Non-negative constant
b	Price elasticity
l	Shelf space required for one unit of item
E	Ending inventory level in units
T	Replenishment cycle time in years
W	Number of displayed units on shelf
W_L	Lower bound on the number of units displayed on shelf
W_U	Upper bound on the number of units displayed on shelf
$f(t)$	Freshness index at time t
$D(t)$	Freshness, price and displayed stock dependent demand at time t
TP	Total annual profit in dollars

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