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AN ECO-FRIENDLY INVENTORY MODEL FOR FOOD ITEMS TO REDUCE QUALITY LOSS WITH PROFIT MAXIMIZATION

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ABSTRACT

The liberalization of the worldwide business and growing consumer demands, request the quality-oriented food production. Access to great quality food has been man's venture from the earlier days. A standout amongst the most difficult errands in today's sustenance industry is controlling the item’s quality all through the food supply chain. The objective of this study is to optimize an inventory model concentrating on the quality of the food items with the deliberation on environment issues. Moreover the food waste from the industry is subjected to waste management. This strategy offers the firm with profit maximization. The total relevant cost of the model is minimized with the reduction of quality loss which is represented by a kinetic modeling function and the optimal values are found. A numerical example is presented to illustrate the advantage of the proposed model.

KEYWORDS: Disposal, food safety, inventory, quality loss, waste management.

1. INTRODUCTION

In today's industrialized world and expanding populace, the regular assets has been quickly used and our surroundings are progressively corrupted by human activities, so we have to guard our earth. Quality items keep up consumer loyalty with reliability and decrease the danger as well as the expense of supplanting defective merchandise. Consumer concerns incorporate nourishment, food safety, shelf-life as well as social and environmental aspects; however customers especially expect qualities. Desires are turning out to be more particular all the time as customer's information of nourishment quality increments. Research on the inventory models for deteriorating things has been broadly done. An extraordinary dominant part of these studies accept that the amount of stock is drained by demand and deterioration which is appropriate for specific things like liquor, gas or radioactive materials. For food items amid a specific time-frame the quantity is exhausted just by demand while the quality is debased over time. Following the time when the inventory model for deteriorating things was firstly presented by Ghare and Schrader [5], numerous researchers persistently modify it because of the more illustrative model in investigating genuine cases. An overview of current and emerging issues in food safety have been major issue in the area of food inventory and have pulled attention from many researchers. Food and beverage items are regularly an objective of adulteration while supply chains as a rule manage perishable items that could be hurtful to customers if they are not managed appropriately. Pathogenic and toxin-producing microorganisms are a continuing problem in food safety in the food industry, and food safety objectives need to be set.

Food adulteration:

As indicated by a recent distributed report, oils (primarily olive oil) denote 24% of food adulteration cases. Milk (14%), organic product juices 12%, flavors (11%) and sweeteners (8%) complete the main five fixing classes most ordinarily connected with adulteration [7]. Other food product categories affected include natural flavoring items, dairy items and milk subsidiaries, oats, grains and pulses (each at 4%) while the gums, functional food ingredients, flavor chemicals, fish and wines, spirits and vinegars (each at 2%). In the US, it was accounted for that 33% of the fish samples gathered from 674 retail outlets in 21 US states were mislabeled [10]. In India, 64.8% of milk-based and grain based desserts and savory items were adulterated [9]. As food is the basic necessity of the human existence and life span there must be a careful examination towards food safety.

The processed products should follow the Food Safety and Standard Authority of India (FSSAI) act 2006. FSSAI Act is applicable pan India for all food products. It prescribes minimum standards operating procedures, food safety norms, packaging & labeling norms.

Waste management:

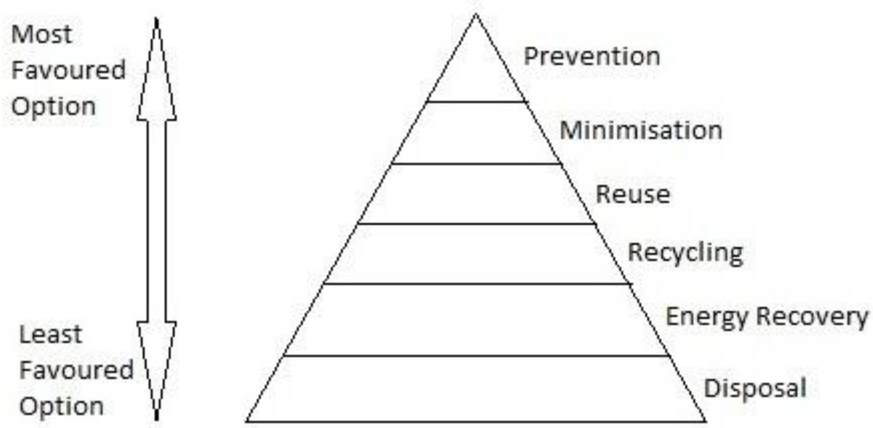

Figure 1

Reducing or eradicating harmful effects on the environmental through reducing, reusing and recycling, and diminishing resource extraction can supply improved air and water quality. It also helps in the reduction of greenhouse emissions. A significant technique of waste management is the prevention of waste material being produced, also known as waste reduction. Prevention methods can be carried out by the reuse of second-hand products, remanufacturing broken items, planning products to be reusable for example cotton bags instead of plastic bags, promoting consumers to avoid disposable products. Figure 1 represents the hierarchy of waste management.

Recycling is a resource retrieval practice that refers to the collection and reuse of waste materials such as empty containers. Biological processing technique is used to control and accelerate the natural process of decomposition of organic matter. Energy recovery from waste is the conversion of non-recyclable waste materials into usable heat, electricity, or fuel through a variety of processes, including combustion, gasification, anaerobic digestion, and landfill gas recovery. [16]. With proper planning wastes can be reduced and recycled to a large amount, which can help in conserving treasured natural resources and also saving energy spent in manufacturing new products.

Waste into Profit:

Food waste can be used in the industries for renovating these materials to soaps, cosmetics and even biodiesel fuel which is an alternative fuel created from virgin oils such as soybean, canola and palm; cooking oil and other bio-waste feedstock. Feeding food by-products directly to livestock allows the by-products to be useful. Waste materials that are organic in nature, for example plant material, food scraps, and paper products, can be recovered through composting and digestion processes to decompose the organic matter. The obtained organic material is then recycled as mulch or compost for agricultural or landscaping purposes. Moreover waste gas from the process such as methane can be collected and used for generating electricity. Source reduction, diminishing the volume of waste material and by-product generated, is the most effective method to reduce your disposal costs.

2. LITERATURE REVIEW

Deteriorating inventory had been discussed in the past decades and they usually concentrated on: constant or variable deterioration rate, quantity discount and supply chain coordination. Preservation technology is considered for reducing the deterioration rate and it has received attention in the past years. The consideration of preservation technology is vital due to rapid social changes and the fact that it can reduce the deterioration rate notably. Research in the area of inventory models for deteriorating things is separated into two groups. Research in the first group is dealing with an inventory model that assumes the quantity is depleted by demand and decay, while the second group deals with inventory models incorporating a situation where the quality or value of the items is reduced. Basically, a mathematical approach by Ghare and Schrader [5] considering quantity depletion of inventory has been applied by the majority research in the first category. Murr and Morris [8] showed that a lower temperature will increase the storage life and decrease decay. Moreover, drying or vacuum technology is introduced to reduce the deterioration rate of medicine and food stuff. Zauberman et al [15] developed a method for color retention of Litchi fruits with SO2 fumigation.

Park [11] extended the deteriorating model into an integrated procurement-production problem which is then developed by Raafat[12] using a more realistic assumption. Later, Yang and Wee [14] advanced the integrated model by implementing a multi-shipment policy. Recently, some scholars [1] accommodated preservation technology investment to reduce the deterioration rate. Basically, research in this group has become the mainstream research on inventory models for perishable items. For degradation in value, Weiss [13] considered a non-linear holding cost unconventional EOQ since the value of the inventoried item decreases non-linearly during the storage time. Later, Ferguson et al. [3] applied this model to manage perishable items with food retailers. In reality, it is common that industries apply preservation effort such as temperature control to prevent the food product from early decay. On one hand, this effort could extend the product's shelf-life; the outdated items could, therefore, be reduced and as a result the benefit would increase. On the other hand, this attempt requires the additional costs for transporting, emission cost of transportation, and cost of inspection for adulteration or food safety in order to meet the practical needs. The real market behavior gets fulfilled with the consideration of waste produced by change in weather conditions & the inventory system. This formulation should be optimized to find the best results. Hence, this research fills the crevice by building up an inventory model considering the preservation cost to control the temperature to diminish the rate of quality loss. Therefore, this paper deals with the development of a mathematical model of inventory policy for food products with quality loss function. The objective is to minimize the total cost by specifying two decision variables, namely the ordering cycle and the ordering quantity. The strategy of profit gaining is executed by the use of waste into by-products.

The remaining part of this paper is organized as follows: Section 3 presents a mathematical inventory model with assumptions and notations and section 4 discusses a numerical example to validate the established model. The last section of the paper comprises the conclusion.

3. MATHEMATICAL MODEL

This section formulates the cost effective inventory model with ordering quantity, cycle time as the decision variables.

a. Notations

Following notations are used in this model

O_c	-	Procurement cost
T	-	Procurement cycle
h	-	Holding cost
D	-	Demand rate
t	-	Time interval
C_q	-	Cost of quality loss
K_o	-	Arrhenius equation constant
τ	-	Temperature
E_a	-	Activation energy
R	-	Universal gas constant
m	-	Cost of energy
λ	-	Rate parameter

$\Delta\ \tau$	-	Temperature change in storage
Q	-	Ordering quantity
b	-	Shortage quantity
p	-	Penalty for shortage
n	-	Number of shipments
F	-	Freight cost
β	-	Social cost due to emission
d	-	Distance travelled from supplier to buyer
v	-	Average velocity
γ_0	-	Fixed disposal cost
γ	-	Variable disposal cost
θ	-	Proportion of waste produced due to inventory operations
I	-	Inspection cost for adulteration and safety
F_w	-	Proportion of food waste produced
P_r	-	Unit cost obtained by selling the food waste produced perkg

b. Assumptions

The model is based on the following assumptions [2]

i. Demand rate is constant
ii. Homogeneous quality of the food product is considered
iii. Quality of the food losses over time
iv. Shortages are allowed
v. Every item is inspected and after screening the items are free from adulteration and safe up to the satisfied percentage

The quality of the food depends on storage condition such as storage time‘t’, Temperature ‘T’ and preservation items. Here it is recommended as Natural preservatives such as Ascorbic acid and tocopherol, rosemary extract, hops, salt, sugar, vinegar, alcohol, diatomaceous earth and castor oil. Figure 2 shows that increase in temperature increases the deterioration rate. Figure 3 elucidates that increase in t deterioration rate increases the temperature, which leads to quality loss of the food.

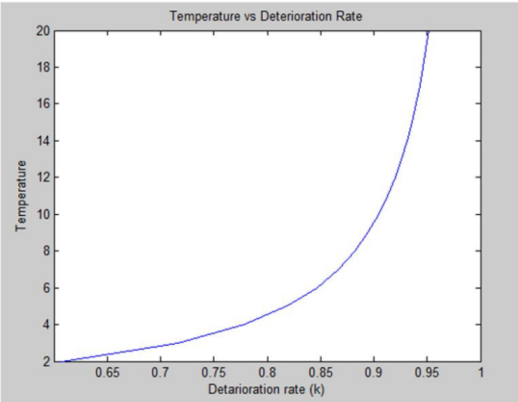

Figure 2

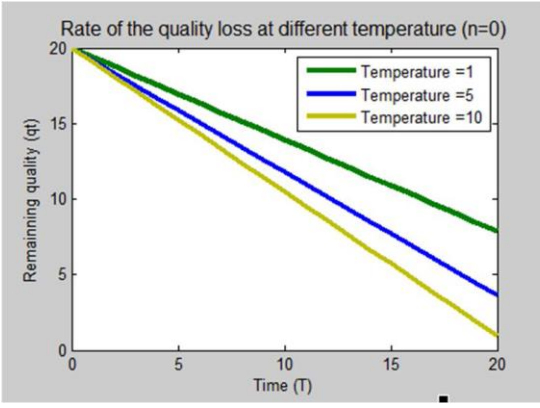

Figure3

Referring to the quality loss function mentioned in Fauza, G., Amer, Y., & Lee, S. [2] the following equation is considered. $L(T,\tau)=\int_0^T \frac{tC_q DK_0 \exp\left[-\frac{Ea}{R\tau}\right]dt}{T}$ - (1)

Now the total cost of the system consists of procuring cost, holding cost, quality loss, energy cost, shortage cost, freight cost, emission cost, waste disposal cost, inspection cost and the ordering cycle T = Q/D

$$Total\ cost\ TC\ (Q,T)=\frac{h(Q-b)^2}{2Q}+\frac{O_c D}{Q}+\frac{b^2 p}{2Q}+\frac{nFD}{Q}+\frac{2\beta dD}{vQ}+\frac{\gamma_0 D}{Q}+\frac{\gamma\theta D}{Q}$$

$$+\frac{nID}{Q}+me^{\lambda\Delta\tau}+\int_0^T \frac{tC_q D^2 K_0 \exp\left[-\frac{Ea}{R\tau}\right]dt}{Q}-\frac{F_w \mathrm{P_r} D}{Q}$$

- (2)

Rearranging the terms we get,

$$TC\ (Q,T)=\frac{h(Q-b)^2+b^2 p}{2Q}+\frac{C_q D^2 K_0 \exp\left[-\frac{Ea}{R\tau}\right]t^2}{2Q}+me^{\lambda\Delta\tau}+C+\frac{(O_c+nF+\frac{2\beta d}{v}+\gamma_0+nI+\gamma\theta-F_w \mathrm{P_r})D}{Q}$$

where C is the Integral constant. In order to derive an optimal solution for order quantity, differentiate the above equation with respect to Q and equate it to zero.

$$\frac{dTC}{dQ}=0=\frac{hQ^2-b^2 p-b^2 h}{2Q^2}-\frac{HD}{Q^2}-\frac{C_q D^2 K_0\, e^{\left[-\frac{Ea}{R\tau}\right]} t^2}{2Q}$$

Where H = $O_c+nF+\frac{2\beta d}{v}+\gamma_0+nI+\gamma\theta-F_w \mathrm{P_r}$

Rearranging the terms we get the optimal order quantity Q* as follows

$$Q^* = \sqrt{\frac{D(2H + C_q DK_0\, e^{\left[-\frac{Ea}{R\tau}\right]} t^2) + b^2(p+h)}{h}} \qquad -(3)$$

Arranging the total cost terms with respect to cycle time and deriving optimal solution we get,

$$TC\ (Q,T) = \frac{h(Q-b)^2 T}{2} + \frac{O_c}{T} + \frac{b^2 p}{2TD} + \frac{nF}{T} + \frac{2\beta d}{vT} + \frac{\gamma_0}{T} + \frac{\gamma\theta}{T} + \frac{nI}{T} - \frac{F_w \mathrm{P_r}}{T} + me^{\lambda\Delta\tau} + \int_0^T \frac{tC_q DK_0 \exp\left[-\frac{Ea}{R\tau}\right] dt}{T}$$

$$\frac{dTC}{dT} = 0 = \frac{h(Q-b)^2}{2} - \frac{O_c}{T^2} - \frac{b^2 p}{2T^2 D} - \frac{nF}{T^2} - \frac{2\beta d}{vT^2} - \frac{\gamma_0 + \gamma\theta}{T^2} - \frac{nI}{T^2} + \frac{F_w \mathrm{P_r}}{T^2} + C_q DK_0\, e^{\left[-\frac{Ea}{R\tau}\right]}$$

Rearranging the terms we get the optimal cycle time T* as follows

$$T^* = \sqrt{\frac{O_c + nF + \gamma_0 + nI + \gamma\theta Q^{*2} - F_w \mathrm{P_r} + \frac{2\beta d}{v} + \frac{b^2 p}{2D}}{\frac{h(Q^* - b)^2}{2} + C_q DK_0\, e^{\left[-\frac{Ea}{R\tau}\right]}}} \qquad -(4)$$

The convexity of the above equation with respect to Q and T is verified by finding the second order derivative and the result is positive. Since it satisfies the convexity condition the obtained values are optimal values.

4. NUMERICAL EXAMPLE

Consider the following data to examine the behavior of the proposed model [2]:

O_c	= 20	λ	= 0.02	v	= 180
D	= 10 (in lakhs)	n	= 2	γ_0	= 1
C_q	= 0.4	K_0	= 200	b	= 4
h	= 0.04	τ	= 287.106^0 k	p	= 3
m	= 1.5	τ_0	= 300	F	= 15
E_a	= 20	β	= 0.5	I	= 10
R	= 0.0083	d	= 250	γ	= 25
Θ	= 0.08	F_w	= 0.2	P_r	= 30

H= $O_c + nF + \frac{2\beta d}{v} + \gamma_0 + nI + \gamma\theta - F_w \mathrm{P_r}$

Substituting the values we get H = 68.388

Using the data in the equation of optimal order quantity we get Q* approximately as 188.29

Q*=188 units
Similarly the optimal cycle time **T*=10.22 days**
The storage temperature τ **= 14 ^{0} C**
The total inventory cost **TC = Rs.8.97 (in lakhs)**

On comparing the numerical example result with the already proposed models mentioned in the literature review, example (EOQ (non-deterioration model), Ghare and Schrader [5], Fujiwara and Perera[4], we get the percentage of total cost reduced by 3.3%.The original price of a unit item in the existing model is approximately Rs.31, now the new price of a unit item in the proposed model is Rs.20.99.The profit is obtained by using the preservation technology which controls the temperature and reduces the deterioration rate. Waste utilization and minimization technique is used to improve the profit.

5. CONCLUSION

The items with high deterioration rate are constantly threatening to the retailer's business. This paper develops a new inventory model for food items with the concern on environmental issues and food safety. When the food waste is converted into by-product there is a significant increase in the company's profit. Quality debasement is the fundamental attribute of perishable food which has been given importance. The realistic market behavior and their associated costs are considered to develop the inventory model. This new model gives the cost minimization strategy among the other specified models in the literature. The outcome shows that the proposed model is more suited to be executed for taking care of the procurement of food items.

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