Inventory management of perishable products : a case of melon in Tunisia

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Abstract

Inventory management is the branch of business management that covers inventory planning and control. For this reason, we are considering the use of performance indicators in continuous control models specifically for inventory management of perishable products. Indeed, the high rate of deterioration of food products under ambient storage conditions calls for specific storage conditions in the store or at the consumer's premises to slow the rate of deterioration. This article presents a multi-level inventory management model for melons. The melon chain comprises a non-linear programming model, formulated and evaluated in CPLEX, which minimizes the total cost of inventory in the chain formed by a wholesaler, hypermarket, retailer and resellers in order to calculate the optimal order quantity and total cost of melon for each actor.

Key words: *Inventory management, deterioration, perishable products, melon.*

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1. Introduction

Inventory management is one of the most developed areas of operations management, and the subject has devoted considerable space in management science and operations research. An interesting subset of inventory theory is the mathematical model of perishable items.

The literature on deteriorating items is scattered and no comprehensive and up-to-date discussion of these models is readily available. This paper presents a comprehensive review of the published literature on mathematical modeling of deteriorating inventory systems. Specifically, this review focuses on inventory models where corruption is a function of existing inventory levels. Consider the problem of managing an inventory system consisting of perishable foods that deteriorate in a deterministic environment. Examples of perishable products are dairy, meat, fruits, vegetables, drugs and pharmaceuticals.

2. Literature revue

Inventory management is one of the most important logistics operations in agricultural supply chains (Chung et al., (2014)), (Bhat et al., (2021)), especially for products such as fruits and vegetables, due to the high perishability rate of these types of products. In fact, fresh fruits even lose their quality when they are in motion, and the supply of fruits is seasonal, resulting in volatile demand (Scotto di Perta et al. (2022)), (Distefano et al. (2022)), which allows consumer choice to be influenced by the availability of the fruit at the time of purchase and its quality (Massaglia et al., (2019)). Therefore, achieving an efficient food supply chain for perishable products poses great challenges (Olafare et al. (2022)), (Batero & Orjuela (2018)). Although it has been in the interest of research regarding inventory management in these supply chains, there are no models that take into account perishable supply chains, especially for fruits.

Food supply chains are different from other supply chains (Behnke & Janssen, (2020)), (Zanoni & Zavanella, (2012)), From the time of harvest to delivery to the final consumer, there are variations in food quality, which is likely to change even under optimal distribution conditions along the chain.

There are a small number of articles related to inventory management models for the food supply chain and in particular, there is no research on the fruit supply chain. The complexity of this problem is due to the high perishability of fruits and their variability in terms of quality levels, which, even under optimal storage and distribution conditions, tend to decrease. In addition, some models do not cover the entire supply chain and focus only on the study of one or two actors involved in the chain.

After reviewing the state of the art, we used as a basis for our research the work done by (Wang et al. (2011)) that considered inventory management behavior for perishable products. In this research, these studies were supplemented with particular variables in the formulation of a model, for inventory management in the melon supply chain in Tunisia, we also included some constraints that had not been considered before, as well as the model covers four echelons of the fruit supply chain, which has never been done before. The model allows for the calculation of losses due to the time elapsed in the stocks of the different actors, to be accumulated and compared with the life cycle of the fruit, post-harvest.

3. Methodology

Before designing the model, we make a diagnosis on the behavior of stock management by the actors of the melon supply chain in Tunisia, we conducted a survey, for wholesaler, a hypermarket, a retailer, and resellers. This model is characterized by a restricted production rate, which depends on prices and supply-demand. The model calculates both the cost to each actor independently and the total cost generated in the supply chain.

The melon deterioration rate was defined based on the estimated average time in each actor of the chain. We estimated the time taken by each actor in the chain, the maximum and minimum duration of permanence, which was iterated until reaching a value that converges to the average rate of deterioration of the melon.

In formulating the models, we made the following assumptions:

- ✓ Only one product is sold.
- ✓ One replenishment cycle.
- ✓ Shortage is not allowed.
- ✓ The demand rate is deterministic.
- ✓ The planning horizon is determined by the life of the fruit.
- ✓ The ability to receive and send product is unlimited.
- ✓ Each actor in the supply chain must meet a minimum demand per cycle.

The rate of product deterioration depends on the actor, is constant and is also known. The following notations are used for the decision variables and parameters considered in the model.

4. Model notations

We adapt the following notations for the melon inventory management model as follows:

a. Indice

i : The index of each actor, or i = 1, ..., 4.

b. The parameters

Q : The quantity of melon.

D : The demand for melon.

t : The length of time the melon is in storage

Cs : The unit cost of maintaining of inventory.

Cp : The unit cost of ordering melon.

Cd : The unit cost of melon deterioration.

r : The rate of deterioration.

CT : The total cost of melon.

c. Decision variables

Yi **:** Binary variable: equal to 1 when there is a melon flow and 0 when there is no flow.

Xi *:* Binary variable: equal to 1 when there is a melon order and 0 when there is not.

Wi : Binary variable: equal to 1 when there is a deterioration of the melon and 0 when there is no deterioration.

Vi : Binary variable: equal to 1 when there is a melon order and 0 when there is not.

Z **:** Binary variable: equal to 1 when there is a melon flow and 0 when there is no flow.

5. Formulation of the model

F The total cost of the melon is represented by equation (1). Equation (2) represents the total cost to the actors, corresponding to the sum of the cost of maintaining, deterioration, ordering, and loss costs resulting from the supply-demand imbalance. Similarly, equation (3) ensures that the size of the melon order is greater than or equal to the exposed demand, so that the demand can be satisfied. Equation (4) describes the optimal number of orders each actor should place with its supplier(s). Equation (5) represents the maximum time that fruit can remain in each link of the chain, so that it does not exceed the time that fruit can be consumed where Z = 1 when there is a flow of fruit and Z = 0 when there is no flow. At the same time, equation (6) considers that this time must be greater than zero. Equation (7) shows the losses in each link of the chain due to the differences between supply and demand. Finally, constraint (8) is the non-negativity constraint.

$$\text{Min F} = \sum_{i=1}^{4} CT_i t_i \quad (1)$$

$$\text{F} =[\left(Cs_i * \frac{Qi-(Di*ti)}{ri}\right) * Yi + (Cp_i * Q_i) * Xi + ((Cd_i * \left(Q_i - (D_i * t_i)\right) * W_i + P_i * V_i] \quad (2)$$

$$\sum_{i=1}^{4} Q_i > \sum_{i=1}^{4} D_i \quad (3)$$

$$Q_i = \frac{D_i}{ri} * (e^{r_i t_i} - 1) \quad (4)$$

$$\sum_{i=1}^{4} t_i Z \le T \quad (5)$$

$$t_i \ge 0 \quad (6)$$

$$P_i = \sum_{i=1}^{4} Q_i - Q_j \quad (7)$$

$$Z \ge 0, Xi \ge 0,\ Wi \ge 0, Yi \ge 0, Vi \ge 0 \quad (8)$$

6. Findings – case study

Melon is one of the climacteric fruits whose harvest is seasonal. This aspect is strongly taken into account when making relevant decisions for stock management. Based on surveys conducted in 2022, specifically for the case of Tunisia, we established the configuration of the supply chain. Fig. 1 shows the average stock to be maintained by each actor in the chain. The retailer has the lowest storage requirements.

Fig. 1 : the average stock by each actor in the chain.

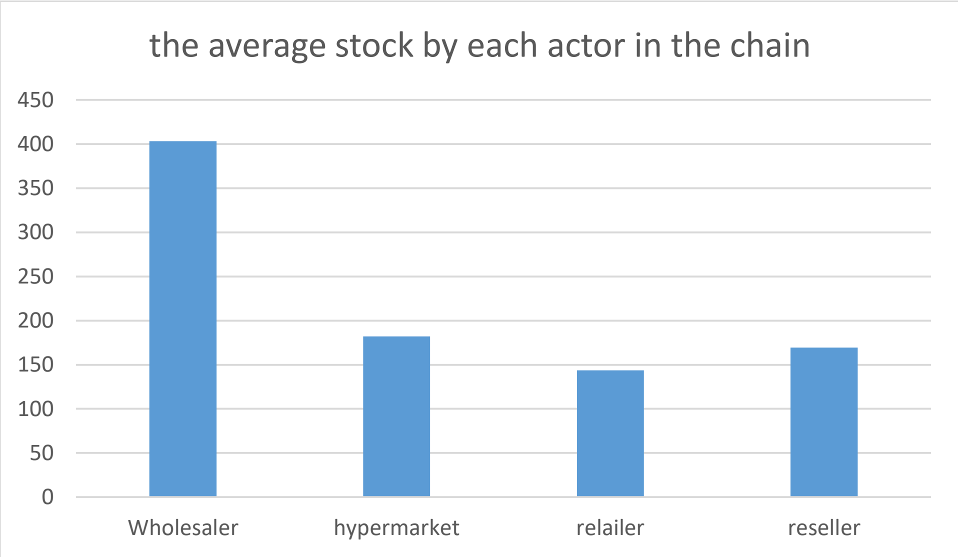


Fig. 2 shows the main optimal values obtained. The wholesaler's production is high because it is the principal actor in the chain, so the size is 820.2 kg of melon, with a cost of 14.525 milles dinars. On the other hand, it is obvious that the retailer has the minimum time to replenish the stocks because he orders products. stocks because he orders small size lots.

Fig. 2 optimal values

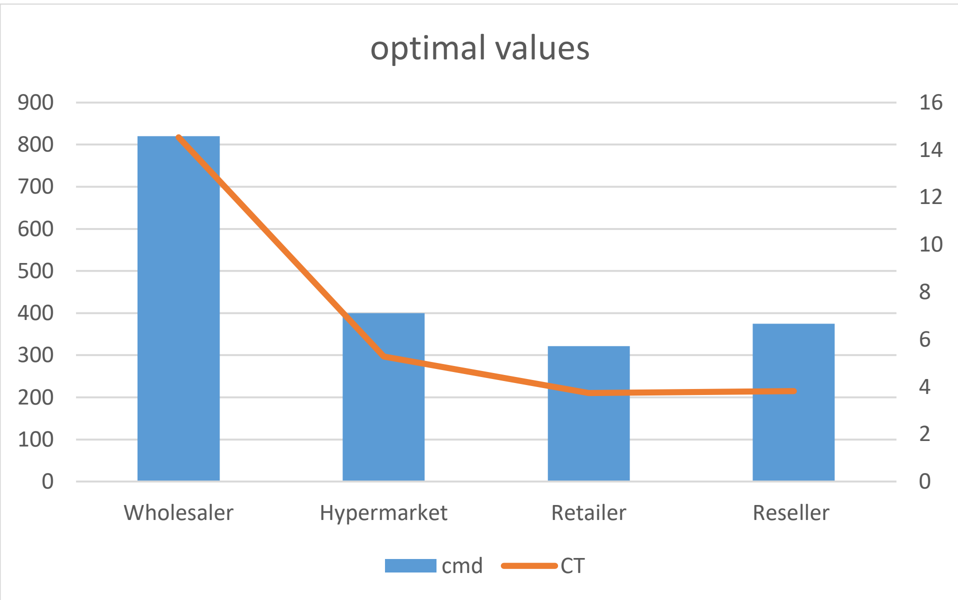
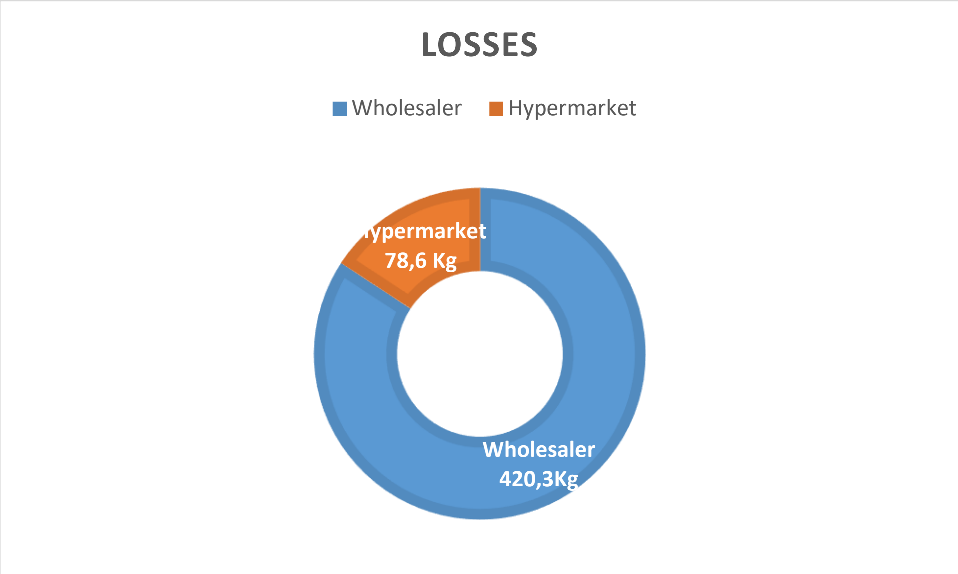


Fig. 3 shows the losses caused by the imbalance between supply and demand, as the wholesaler sends a orders to the hypermarket in the chain expecting all the melon to be received, however the order size of each actor is different from the expected one, therefore, there are drops in shipment, which are supported by the wholesaler and the hypermarket. then, the wholesaler lost 420.3 kg of melon and the hypermarket lost 78.6Kg.

Fig. 3 losses of melon for wholesaler and hypermarket



7. Conclusion

We present an inventory management model that aims to minimize the total cost of inventory in the supply chain, considering deterioration losses, the cost of ordering in a perishable fruit supply chain, incorporates inventory costs for the wholesaler, agribusiness, hypermarket, retailer and reseller, all involved in the melon chain. With the proposed model, we obtained optimal results with respect to replenishment time and order size, thus improving the performance of the melon supply chain in Tunisia.

We measured the effect of melon deterioration rate on ordering decisions. We found that with lower deterioration rates, costs tend to decrease, and an improvement is reflected in cycle times and replenishment quantities, leading to the conclusion that by reducing the melon deterioration rate, it is possible to achieve efficient agricultural chains, with lower costs for each actor.

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