Research on RFID Investment Decision and Coordination of Fresh Agricultural Products Supply Chain Based on Fixed Price

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Abstract

Considering the use of technology to monitor and manage fresh agricultural products, this paper studies the pricing and ordering strategy of retailers based on the real-time value loss information of agricultural products. Considering the effect of technology application on the circulation of fresh agricultural products, the profit model of two stages of fresh agricultural products supply chain is constructed, and the three key parameters are emphasized. The results show that: for the upstream and downstream of the supply chain, the technical tag cost investment interval can be consistent; the upstream suppliers bear the cost of technology label under certain conditions, and the decision of wholesale price and retail price is incremental transmission. Within a certain range of parameters, the order quantity of the downstream retailer increases with the decrease of double loss in the circulation process. Using the improved game theory, optimization theory and supply chain contract theory based on RFID technology, it can effectively solve information asymmetry and improve the efficiency of the supply chain, a supply chain model based on RFID technology centralized mode and decentralized mode is established. Finally, numerical examples are given to illustrate the correctness of the results.

Keywords: Fresh Produce, Supply Chain, RFID Technology, Investment Decision.

1. INTRODUCTION

Since the 1990s, with the development and scale of emerging retail business (such as department stores, fresh supermarkets, chain stores, etc.), more and more fresh agricultural products enter the market, and promote the profound changes in the production and circulation of fresh agricultural products. The circulation of fresh produce is restricted by many factors, such as low rank of transportation road, long transportation time and lack of funds. Fresh produce is lack of storage and storage facilities for fresh agricultural products (Yan et al., 2015). The loss of fresh produce is up to 20 % in the purchase and transportation of fresh produce. The loss is about 10 % in the market, which is not conducive to the whole performance level of fresh agricultural products supply chain. Therefore, the members of the supply chain pay corresponding efforts to control the loss, promoting the effective management of fresh agricultural products supply chain is of great significance.

With the maturity of RFID technology in the core technology of the internet of things, this technology has become the preferred technology of the cold chain logistics in the circulation process of fresh agricultural products (Lin and Fan, 2014; Chen et al., 2014). The application of RFID technology can support the automatic identification and automatic collection of data, accelerate the rate of relevant logistics link in circulation. With the help of sensor network, embedded system and other means, can timely master and control the appropriate temperature humidity in the circulation process, which is the effective means to reduce the loss of fresh agricultural products, and is the key to trace and trace the agricultural products (Yang and Zhang, 2014). At present, the supply chain quantitative research under the consideration of RFID technology is mainly focused on the application of technology compressed retail supply chain in advance to improve order accuracy. In order to reduce inventory error rate and inventory loss rate and so on, there is little literature on the application of technology in fresh agricultural supply chain. Furthermore, the application cost of technology (such as label cost) is assumed by a single enterprise in the supply chain. Therefore, the investment decision-making problem of the technology application neglects the influence of the application of the technology on the key decision parameters, such as the demand of the supply chain enterprises in the order pricing market (Sun, 2013). In fact, the impact mechanism is very important for the performance of supply chain enterprises to improve the benefit sharing and risk sharing. It is the key problem that RFID technology needs to study in the wide application of fresh agricultural products supply chain.
2. PROBLEM DESCRIPTION

For a single cycle supply chain system, which is composed of a single supplier s and a single retailer r, the retailer sets an order policy according to the wholesale price w provided by the supplier. The supplier based on the retailer's order demand takes into account the relevant losses and costs in the circulation links, such as supply transportation, determines the optimal wholesale price to maximize its profit (Zhang et al., 2015). After the retailer receives the product shipped by the supplier, it determines the final retail price p according to the freshness of the product and market reaction, see Figure 1.

![Figure 1. Supply chain of fresh agricultural products](image)

The model considers the deterministic demand function, and is a function of the subtraction of time and retail price, and defines:

\[ D(t, P) = \frac{a + V_r - P}{b} \]  

(1)

Among them, a represents the general market size, b is the customer's sensitivity to the "price / performance" of fresh agricultural products. Obviously, when and only the demand value is non-negative, we mark:

\[ D(t, P) = Max(\frac{a + V_r - P}{b}, 0) \]  

(2)

The main parameters and variables used in the model are as follows: pi respectively represents the retail price decision variables under the premise of fixed price, dynamic price and single time point price, wherein the pricing strategy corresponding to the time point of price adjustment, pd1 and pd2 respectively represent the retail price decision variables before and after the price adjustment; Clearly, this level should meet the subsequent consumer needs in the sales cycle.

\[ I_i(t,T) = \int_0^T D(s, P_i)ds \]  

(3)

Under the deterministic demand, the order quantity is expressed in three different pricing modes, which is obviously satisfied.

\[ Q_i = \int_0^T D(t, P_i)dt = I(0, T) \]  

(4)

Pi: the average profit of retailers under the premise of three different pricing models.

3. OPTIMAL DECISION MODEL UNDER FIXED PRICE

In the limited sales week of fresh agricultural products, the average of profit function expression of the retailer is satisfied:

\[ \pi_j(P_j) = \frac{1}{T} \left[ \int_0^T (P_j - C)D(t, P_j) - hI_j(t,T)dt - K \right] \]  

(5)
The first part of the upper integral number represents the marginal profit of the unit product under the product’s own cost (such as the production cost, RFID product grade label cost, etc.), while the second part represents the inventory cost of the change over time in the cycle. The fixed price of the average profit function of the retailer during the sales period is the best price.

\[
\frac{d\pi_f(P_f)}{dP_f} = 0
\]

(6)

\[P_f^* = \frac{a + C}{2} + \frac{hT}{4} + \frac{V_o - V_r}{2\lambda T}
\]

(7)

When the inventory cost is relatively high (monitoring the cost of the value of the goods), the longer the validity of the goods, the higher the total inventory cost in the sales cycle, so retailers take a relatively high selling price to make up for this loss. While the inventory cost is relatively small, retailers are more concerned with the reasonable inventory supervision cost in exchange for the real time value information of the goods, the longer the sales cycle, the more necessary to attract the retail price to attract all possible demand in the sales cycle.

This paper takes two-level supply chain as the research object, taking into account the information asymmetry of supply chain and retailer commodity wrong and losses, using the submitted to model to establish the income model of each member of the supply chain, through game theory and supply chain coordination theory, respectively study the four scenarios of RFID in supply chain investment, and draw the corresponding conclusions (Mainetti et al., 2013). And further explore the supply chain members to share RFID cost, effective coordination of the benefits of the members of the scheme. The development of the institute. The study will enrich the supply chain RFID technology application related theory about RFID. The coordination scheme of technology application has certain reference value and guidance significance to the operation practice.

![Diagram of commodity flow](image)

**Figure 2.** Order of commodity flow

### 4. SUPPLY CHAIN DECISION MODEL OF FRESH AGRICULTURAL PRODUCTS BASED ON RFID TECHNOLOGY

After adopting the technology of fresh agricultural products supply chain, the rate of the related logistics link in circulation is accelerated, and the consumption time is reduced to reduce the double loss of fresh agricultural products (Bertolini et al., 2013). In particular, for the supplier, due to the reduction in the physical loss of the entity, the number of goods required by the supplier can be reduced in order to meet the demand for the same number of orders by the retailer, thereby reducing the cost of the physical loss incurred by the supplier. At the same time, through a new round of decision making at wholesale prices, retailers may be able to share a certain amount of technical use cost for their real benefits. For retailers, the fresh degree of agricultural products obtained after the use of technology is greatly improved, and the retail price can be adjusted appropriately to obtain larger unit profit margin. Through the model solution, the optimal wholesale price decision of the supplier can be satisfied after the technical investment (Chen and Liu, 2016):
\[
\omega^R_{t_1} = \left(\frac{c + s + C_R}{\beta(t_1)} + h\right) \times \frac{k}{k-1}
\]
\[
Q^R_{t_1} = A\theta(t_1) \times \left(\frac{c + s + C_R + h}{\beta(t_1)}\right)^{k-1} \times \left(\frac{k-1}{k}\right)^{2k}
\]
\[
P^R_{t_1} = \left(\frac{c + s + C_R}{\beta(t_1)} + h\right)^2
\]
\[
\Pi^R_{t_1} = A\theta(t_1) \left(\frac{c + s + C_R}{\beta(t_1)} + h\right)^{k+1} \times \left(\frac{k-1}{k}\right)^{2k-1}
\]
\[
\Pi^R_{t_1} = A\theta(t_1) \left(\frac{c + s + C_R}{\beta(t_1)} + h\right)^{k+1} \times \left(\frac{k-1}{k}\right)^{2k}
\]

5. SIMULATION AND VERIFICATION

In this paper, based on the actual data of the circulation of fresh litchi, a numerical example is given to verify the model and theoretical discussion. In view of the sensitivity of litchi freshness to transportation efficiency, in order to improve the perfect ratio and freshness of the product, it is proposed to adopt RFID technology, the effective ratio of quantity in circulation is increased to 0.95, the value of fresh degree factor is improved to 0.9, and the label cost of technology \( C_R = 1 \).

Under the premise of the other parameters in the example, firstly, the RFID technology application cost will be used to get a diagram of the profit change value of the supply chain parties before and after the technology application, the supplier, the retailer and the total profit of the supply chain are all higher than before. With the increase of the label cost, the profit growth will slow down until the cost of the label is higher than that of the technology application.

![Figure 3](image_url)

**Figure 3.** Profit-added value of each party in the supply chain of fresh agricultural products

In the determination of dynamic price, we do not take \( \lambda = 0.04, 0.08 \) and \( h = 0.02, 0.05 \), which constitute four groups of comparative data, and the dynamic trend of pricing in each group is shown in Figure 4 below. First of
all, the dynamic pricing rules under the four groups of data are shown as follows: with the delay of sales time, the price is gradually reduced. Moreover, it is easy to find that the greater the value of h value when the $\lambda$ value is constant, the larger the value of h value (such as the contrast between the first and second curves, and the comparison of the third and fourth curves); Similarly, when the value is constant, with the increase of attenuation rate $\lambda$, the decrease of the price will decrease with time (such as the comparison between the first the third curve, and the second and fourth curves). The price in the sales cycle of dynamic changes in the rule and bottom lines.

Retailers' expectations are the biggest, and manufacturers' expectations are minimal. This is because retailers use RFID technology alone, eliminating the gains in the wrong and consuming goods to increase the cost of RFID technology; In addition, the supply chain still has the problem of information asymmetry, the wholesale price of the manufacturer does not change, but the level of retailers' operation is up, resulting in a decline in order quantity. The manufacturer's expected return is the largest, the period of business is expected to be the lowest. This is because of the single use of RFID technology, eliminate the problem of asymmetric message, it can set the optimal wholesale price to ensure its own optimal expected return; at the same time, the manufacturer will use the RFID technology. The cost of technology is transferred to downstream retailers through the wholesale price segment, thereby reducing the retailer's profitability. This is also in line with the "who invests who benefits" principle in the supply chain.

![Figure 4](image.png)

**Figure 4.** Diagram of parameter combination relationship under optimal pricing

6. CONCLUSIONS

In this paper, we consider the simplified two-stage decentralized supply chain of fresh and fresh agricultural products, such as rural docking, and the research only on the product freshness and price related deterministic demand further study can consider the demand of random type, and the three-level supply chain with distributors. In addition, this paper only considers the application of technology in the circulation field, in fact, retail enterprises can use the technology to understand the freshness of agricultural products on the shelf, and then develop flexible replenishment and discount strategy, which is our next research direction.

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