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THE STRATEGY OF FRESH FOOD PRE-SALE AND CURRENT SALE BASED ON THE LEVEL OF FRESH-KEEPING EFFORTS

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Abstract. *This paper constructs a decision-making model of competition and cooperation between large omni-channel retailer and "community leader" of fresh food, and explores the pricing strategies of both parties with the degree of fresh-keeping efforts. The research shows that the efforts of large retailers and community leaders on fresh food preservation can help to improve the pre-sale and current sale pricing of fresh food, and thus promote the increase of profits under the corresponding mode. From the perspective of competition, the degree of fresh-keeping efforts can promote the decline of profit growth of large omni-channel retailers and community leaders. From the perspective of cooperation, fresh-keeping efforts will help to accelerate the rise of profits of large omni-channel retailers and realize the transformation of profits from negative to positive, while there is an inverted U-shaped trend in the pre-sale profits of community leaders. The cooperation mode will help to increase the total profits of both parties. Therefore, promoting the cooperation between large omni-channel retailers and community leaders, taking large omni-channel retailers as the active upgrading subject of fresh-keeping, promoting community leaders to standardize the fresh-keeping level, will help to promote the high-quality upgrading of the pre-sale and current sale mode of fresh food.*
Keywords: Effort level of preservation, Fresh food, Pre-sale and current sale, Large omni-channel retailers, Community leaders

1. **Introduction.** With the continuous development of China's economy, the supply of fresh food is abundant, and the consumption scale is huge. The improvement of people's living standards has prompted the consumption concept of fresh food to be no longer limited to basic consumption, achieving a shift from quantity to quality. Consumers not only pursue the abundance and variety of fresh food, but also pay more attention to the quality and added value of fresh food, such as convenient shopping modes and high-quality supporting services. In the post epidemic era, consumers' consumption habits of online pre ordering of fresh food have been cultivated, and the demand for services such as pre-sale of fresh food, non-contact delivery, and self-pickup has surged. Emerging business forms such as pre warehouse mode, store to home mode, and community group purchase mode are emerging in the fresh retail industry. Online fresh retail has become an important development trend in the fresh retail market. Especially under the influence of the COVID, consumers have strong online demand for fresh agricultural products. According to statistical data, the online fresh food retail market in China in 2022 was 560 billion yuan, and the penetration rate of the online fresh food market increased from 4.67% in 2019 to 10.28% in 2022.

On the reality, the online sales of the community fresh food market are mainly divided into two categories. One is to expand the omni-channel business of online sales based on

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the community stores by relying on the large chain fresh food retailers, including the pre-sale on the day and delivery on the next day, etc., such as Baiguoyuan. The second is to join small community stores in the fresh food pre-sale market through cooperation with the fresh food community group buying platform. Consumers place orders through the community group buying platform, and pick up goods in individual stores the next day, such as Duoduo Food, and Meituan Selected. Regardless of the mode, there is competition and cooperation between online pre-sale and offline retail, especially in pricing decisions. Under pre-sale mode, the sale of goods is divided into two stages: pre-sale period and current sale period. By coordinating online pre-sale and offline current sale channels, consumers are provided with fresh food of reasonable price and quality, while controlling the shelf loss of current fresh food and reducing the uncertainty of market demand.

Based on the background of people's consumption upgrading and post epidemic era, this paper focuses on the pricing decisions of large retailers and community leaders for pre-sale and current sale. By introducing the quality dimension into the demand function, this paper simulates the pre-sale and current sale strategies of fresh food under two scenarios: one is the pre-sale and current sale strategy of large fresh food retailers who open online pre-sale on the day and delivery the next day, and the other is the pre-sale and current sale strategy of small fresh food retailers as community leaders. By exploring the optimal pre-sale pricing, ordering and fresh-keeping efforts of fresh food retailers in the two fresh food pre-sale strategies, based on mathematical analysis and simulation, the optimal strategy selection of fresh food retailers in different scenarios is discussed. This study has important theoretical innovation value and practical significance for reducing the shelf-life loss and market risk of fresh food on the spot, promoting the coordinated development of the pre-sale and current sale mode, and achieving a win-win situation in the omni-channel supply chain.

2. **Literature Review.** The pricing and sales strategy of fresh food has been highly concerned by domestic and foreign academic circles, among which, the degree of fresh keeping efforts of supply chain manufacturers is an important factor affecting the pricing and sales strategy of fresh food. In addition, with the rise and development of fresh food pre-sale mode in recent years, many scholars began to pay attention to consumer behavior and supplier decision-making under the pre-sale mode, and then triggered a discussion of competition and cooperation between the pre order mode and the current sale model. The above research has laid a foundation for the development of this paper.

Fresh food generally refers to agricultural products that have undergone primary processing, mainly including meat, fruits and vegetables, aquatic products, etc. [1]. The perishability of fresh food makes freshness an important determinant of the price of fresh agricultural products [2]. In practical problems, the attenuation function of fresh food freshness is generally used to simulate the quality evolution. For example, the freshness function set by Yang and Tang [3] is the sum of the initial freshness and the level of preservation effort; Wang et al. [4] characterized freshness as the product of power function of transportation time and freshness preservation effort level; Zhang and Ma [5], Chen and Liu [6] described freshness as the product of initial freshness and preservation efforts. On this basis, many scholars explored the supply chain management model under the control of fresh-keeping effort level [7].

Pre-sale mode refers to a sales method that provides consumers with an opportunity to place an order or purchase in advance before a product or service enters the consumer market. Pre-sale can help suppliers more accurately grasp market demand and optimize product organization, inventory, and sales modes through the deposit mode of "paying the deposit first and paying the balance later" [8]. In fact, as two retail modes, pre-sale and current sale are very common in the actual consumption of fresh agricultural products. Many scholars have begun to pay attention to the impact of different consumer behaviors

on the decision-making of fresh food suppliers between these two modes. For example, consumers who make purchase decisions when their products and services are valued higher than their pricing are referred to as "short-sighted consumers", and consumers who determine purchase timing and purchase methods through information comparison to maximize utility are referred to as "strategic consumers". Two different consumption patterns determine the manufacturer's pre-sale decision. Wang et al. [9] constructed a differentiated pre-sale and current sale decision model for strategic and short-sighted consumers, focusing on exploring the impact of strategic consumers' risk aversion psychology on pre-sale strategies. Thus, the optimization strategy of supplier's current sale and pre-sale is obtained. Zhou and Li [10] studied the construction of a pricing ordering model based on consumers' pre-sale time preferences when consumers in the market are homogeneous strategic consumers and analyzed the optimal ordering and inventory strategies of suppliers under pre-sale and current sale cooperation modes.

For the pricing decision of pre-sale model, part of the research focuses on analyzing the optimal pricing decision of the supply chain manufacturers under the pre-sale strategy. For example, in view of the existence of dependence on social learning of pre purchase, Peng et al. [11] probed into the price guarantee policies of the seller implementing the pre-sale strategy, including full price refund and fixed refund policies. Wu et al. [12] analyzed whether companies should publicize the early order opportunities they provide and believed that the results are closely related to the proportion of consumers who buy in advance and the discount range of early purchase. The other part of the research focuses on the online channel based on pre-sale strategy under the new sales mode. For example, Ji and Wang [13] elaborated the pre purchase strategy of China's fresh food e-commerce market under the B2C mode, O2O mode and C2B mode, respectively. Wu [14] summarized the diversified channel modes of fresh food e-commerce, including the regional vertical category, pre warehouse, new retail and community group mode of online and offline channel integration, and explored the pre purchase strategies under the corresponding modes. At the same time, more scholars have paid attention to the competition and cooperation between the pre-sale mode and the current sale mode. From a competitive perspective, based on the pre-sale mode, consumers can order goods in advance, which helps sellers reduce ordering risk and inventory, while consumers often receive a certain degree of freshness and discounts from suppliers. Based on the current sale mode, it is more conducive to meeting the temporary needs of consumers and intuitive access to quality information of fresh agricultural products. From the perspective of cooperation, due to the uncertainty of market demand and the heterogeneity of consumer demand, suppliers will optimize the supply chain of fresh agricultural products by adjusting the pre-sale and current sale modes. For example, Zhang et al. [15] analyzed the omni-channel transformation path of coordinated current sale and pre-sale, online and offline, based on the case of "Baiguoyuan". He et al. [16] explored the pricing and ordering decisions of fresh food suppliers for online pre-sale and offline retail under competitive conditions. Zhang et al. [17] compared and analyzed the fresh food pre-sale strategy choices of supplier direct pre-sale, retailer online and offline pre-sale, and retailer as a platform to provide pre-sale information and services.

To sum up, at present, the research on the degree of preservation efforts and online pre-sale mode has been relatively mature, but the research on the impact of preservation efforts on online pre-sale and current sale to adjust supplier pricing decisions is insufficient, the research on the differences of pre-sale mode of different retailers is less, and the research on further in-depth differentiation of different pre-sale modes and comparison of their optimal decision-making differences is even rarer. This paper intends to expand the existing research from three aspects. First, distinguish the different pre-sale modes of large retailers and community leaders, and explore their different pricing strategies; second, focus on the impact of preservation efforts on pricing strategies and total profits

under different pre-sale modes; the third is to explore the competition and cooperation relationship between retailers under different pre-sale modes, as well as the impact on the optimal pricing strategy of fresh food suppliers.

3. **Model Construction and Assumptions.** Based on the perishability, short shelf life and almost zero residual value of fresh food, retailers need to reduce the uncertainty of market demand to reduce losses. According to the above description, it is assumed that there are two kinds of retailers in a community. One is large-scale retailer A with its own omni-channel supply chain, and the other is small-scale "community leader" retailer B relying on third-party e-commerce platform. The former has unified fresh-keeping requirements and supply channels, with complete offline retail categories, but has a high risk of uncertainty of deterioration of fresh food. The latter has weak fresh-keeping conditions, fewer offline retail varieties, and low satisfaction to the demand of current sales. Consumer demand is mainly divided into two types: one is the demand for current sale, with great uncertainty; the other is pre-sale demand, which is based on online pre-sale and overnight distribution. Whether it is for current sale or pre-sale, retailers need to invest in freshness preservation efforts to ensure the freshness of products when consumers buy it.

Suppose that retailers sell in two stages: the pre-sale period and the current sale period. In the pre-sale period, retailers accept online bookings from consumers, and deliver pre-sale orders and sell in store at the same time in the current sale period. Assuming that the level of fresh keeping effort is τ, the freshness of fresh food is $\theta(\tau)$, which is an increasing function of the level of fresh keeping effort τ, and the second derivative is less than 0, that is, the higher the level of fresh keeping effort is, the less the marginal effect on improving the freshness of fresh food is. According to the research of [18], $\theta(\tau) \in [0, 1]$, 0 indicates that the fresh food is completely rotten, and 1 indicates that the fresh food is completely fresh. In addition, the retailer's fresh-keeping cost is set as an increasing function of fresh-keeping effort level, and the second derivative is greater than 0, that is, the higher the fresh-keeping effort level, the greater the growth margin of fresh-keeping cost.

Consumer decision-making: there are two shopping modes: online pre purchase and offline current purchase. The utility of fresh food purchased online is U_1, and the utility of fresh food purchased offline is U_2, as shown in the following formulae:

$$U_1 = U_0 + \alpha\theta_1(\tau) - p_1 \tag{1}$$

$$U_2 = u_0 + \alpha\theta_2(\tau) - p_2 - p_0 \tag{2}$$

Equation (1) shows that the utility of the unit fresh food purchased online by consumers U_1 is equal to the expected utility estimate U_0, plus the sum of the product of the freshness $\theta_1(\tau)$ and freshness sensitivity coefficient α of the pre-sale goods, minus the price of the pre-sale goods p_1. Formula (2) shows that the utility of the unit fresh food bought offline by consumers U_2 is equal to the initial determined utility u_0, plus the sum of the the product of the freshness $\theta_2(\tau)$ and the freshness sensitivity coefficient α, minus the price of the goods p_2 and other procurement costs p_0. According to the research of [19], consumers have prior homogeneity and subsequent heterogeneity, which is consistent with the willingness to pay model [20]. Therefore, the distribution function U_0 is the same as that of u_0. Consumers decide the consumption mode of fresh food by comparing the utility of pre-sale and current sale.

Decision of fresh food retailers: first, publish the pre-sale price of fresh food p_1. After online booking, count the pre-sale demand, complete the distribution of goods together with the current goods, and at the same time publish the price of the current fresh food p_2. Assuming that the cost of fresh food is constant w, for fresh food retailers with both pre-sale and current sale modes, the sale volume includes pre-sale demand Q_1 and current sale demand Q_2. Considering the mutual exclusion of consumers' consumption decisions on fresh food in a small market, the demand for pre-sale and current sale is determined

by consumers' expectations on the freshness of fresh food. Consumers' higher freshness expectation means that they are willing to pay higher prices. According to the basic principle that the demand function is a subtractive function of price, if consumers have higher expectations for the freshness of goods on sale, it means that the demand for goods on sale decreases and turns to pre-sale demand. Therefore, it is assumed that consumer demand is a linear function of freshness of fresh food, β represents the sensitivity coefficient of consumer demand to freshness of fresh food, $\beta > 0$. Assuming that the freshness of pre-sale is determined, consumers' pre-sale and current sale demand can be expressed as $Q_1 = \beta E[\theta_2(\tau)]$, $Q_2 = \beta\theta$, that is, consumers' demand for pre-sale goods is an increasing function of the expected freshness of current goods, and their demand for current goods is an increasing function of the freshness of pre-sale goods. The above scenario does not exist for small "community leader" retailer B, but there is a third-party platform that extracts the sales profit coefficient of h. Therefore, the profit function of retailer A and retailer B is

$$\Pi_A = [p_1 - w - c_1(\tau)]Q_1 + [p_2 - w - c(\tau)]Q_2 \tag{3}$$

$$\Pi_B = (1 - h)[p_1 - w - c_2(\tau)]Q_1 \tag{4}$$

To sum up, this paper proposes the following assumptions.

Hypothesis 3.1. *Fresh food retailers and consumers in the market are rational and their risk preference are neutral.*

Hypothesis 3.2. *$\theta(\tau)$ and $c(\tau)$ are monotone increasing functions, that is, the first derivative of the effort level τ is positive, the second derivative of $\theta(\tau)$ by τ is negative, and the second derivative of $c(\tau)$ by τ is positive.*

Hypothesis 3.3. *Large omnichannel fresh food retailers have both offline retail and online pre-sale business modes. Due to shelf display and consumer selection behaviors, fresh food undergoes losses in offline sale, and there is no such loss in pre-sale.*

Hypothesis 3.4. *Small fresh food retailers of the type of "community leaders" rely on relevant platforms, do not hoard goods themselves, and are distributed by the platform, without shelf loss and offline additional demand.*

Hypothesis 3.5. *The fresh food market is close to a perfectly competitive market, the elasticity of demand is small, and consumers' choices for pre-sale and current sale are mutually exclusive; As the total demand for fresh food is large, the limit on the total market demand can be relaxed when analyzing one retailer.*

Table 1 shows all parameter symbols in the model.

4. Mathematical Model Analysis.

4.1. Competition decisions of fresh food retailers.

It can be seen from the above analysis that consumers' choice of consumption strategies for online pre-sale and offline current sale is judged by the utility of two ways. According to Hypothesis 3.5, this paper releases the limit on total demand, and first determines that for large omni-channel fresh food retailer A, the decision boundary condition for the simultaneous existence of the two consumption modes is to ensure that consumers' online pre-sale and offline current sale have the same consumer utility, $E(U_1) = E(U_2)$, namely

$$\alpha E[\theta_1(\tau)] - p_1 = \alpha E[\theta_2(\tau)] - p_2 - p_0 \tag{5}$$

According to Formula (5), for the large omni-channel fresh food retailer A, consumers' expectation for the freshness of pre-sale food is as follows:

$$E[\theta(\tau)] = \theta - \frac{1}{\alpha}(p_2 + p_0 - p_1) \tag{6}$$

TABLE 1. Description of model parameter symbols

Parameter	Representation
p_1	Pre-sale pricing of fresh food
p_2	Current sale pricing of fresh food
p_0	Additional cost of consumers' offline purchase
α	Consumers' sensitivity to freshness of fresh food
U_0	Consumer's utility valuation of pre-sale fresh food
u_0	Fixed value of consumers' utility on current sale fresh food
w	Retailers' cost of fresh food
τ	Fresh keeping efforts
β	Freshness sensitivity coefficient of pre-sale demand for fresh food
$\theta(\tau)$	Freshness level of fresh food
θ	Basic freshness level of fresh food
$c_1(\tau)$	Unit preservation cost of retailer A's pre-sale
$c_2(\tau)$	Unit preservation cost of retailer B's pre-sale
$c(\tau)$	Unit preservation cost of retailer A's current sale
h	Platform's extraction coefficient for sales profit
Q_1	Pre-sale demand
Q_2	Current sale demand
U_1	Consumer utility of fresh food for pre-sale
U_2	Consumer utility of fresh food for current sale
Π_A	Profit Function of Retailer A
Π_B	Profit Function of Retailer B

As the large omni-channel fresh food retailer A and the "community leader" retailer B are competitive in the pre-sale mode, according to the expected total utility θ, consumers' expectation for pre-sale freshness of "community leader" retailer B can be obtained as follows:

$$E[\theta(\tau)] = \theta + \frac{1}{\alpha}(p_2 + p_0 - p_1) \tag{7}$$

Based on this, it can be concluded that if the basic offline demand of large omni-channel fresh food retailer A is assumed to be $Q_{2A} = \beta\theta$, then the demand of online pre-sale mode of large omni-channel fresh food retailer A is $Q_{1A} = \beta\left[\theta - \frac{1}{\alpha}(p_2 + p_0 - p_1)\right]$. Demand for online pre-sale mode of "community leader" retailer B is $Q_{1B} = \beta\left[\theta + \frac{1}{\alpha}(p_2 + p_0 - p_1)\right]$.

From this, we can get the profit function of the large omni-channel fresh food retailer A and the "community leader" retailer B. Since retailer B does not have the offline current sale mode, retailer B cannot price the offline current sale mode, but can only decide the pre-sale pricing. Based on this, the price strategies for retailer A and retailer B to maximize profits under independent decision-making conditions is calculated as follows:

$$\max \Pi_A = \max\left\{[p_1 - w - c_1(\tau)]\beta\left[\theta - \frac{1}{\alpha}(p_2 + p_0 - p_1)\right] + [p_2 - w - c(\tau)]\beta\theta\right\} \tag{8}$$

$$\max \Pi_B = \max\left\{(1-h)[p_1 - w - c_2(\tau)]\beta\left[\theta + \frac{1}{\alpha}(p_2 + p_0 - p_1)\right]\right\} \tag{9}$$

The pre-sale and current sale pricing strategies under the condition of profit maximization are as follows:

$$\begin{aligned} &p_{1A}^* = \alpha\theta + w + c_1(\tau); \quad p_{2A}^* = 3\alpha\theta - p_0 + w + c_1(\tau) \\ &p_{1B}^* = \alpha\theta + w + [c_1(\tau) + c_2(\tau)]/2; \quad p_{2B}^* = 3\alpha\theta - p_0 + w + c_1(\tau) \end{aligned} \tag{10}$$

Under the competitive decision-making mode of fresh food retailers, pre-sale and current sale can exist simultaneously only if they meet the precondition of equal consumer utility. The pre-sale price difference between large omni-channel fresh food retailers and "community leader" retailer is mainly determined by the unit fresh-keeping cost of both sides. The online pre-sale pricing of fresh food retailer is mainly determined by the freshness sensitivity of fresh food α, the cost of fresh products w, the established freshness of fresh food θ and the preservation cost under each pre-sale mode $c_1(\tau)$, $c_2(\tau)$. Thus, the maximum profits of retailer A and retailer B under independent decision-making conditions are calculated as follows:

$$\Pi_A = \beta\theta[2\alpha\theta + c_1(\tau) - c(\tau) - p_0] \tag{11}$$

$$\Pi_B = \beta(1-h)\beta\theta[4\alpha\theta + c_1(\tau) - c_2(\tau)]^2/4\alpha \tag{12}$$

According to the above assumptions, set $\theta(\tau) = 3 + 2\ln(\tau+1) - \ln(\tau)$; $c_1(\tau) = \sqrt{\tau}$; $c(\tau) = t\sqrt{\tau}$; $c_2(\tau) = k\sqrt{\tau}$, wherein, t refers to time, that is, the sale time for current goods. It is because the pre-sale is set to be sold the next day, so $c(\tau)$ is under the condition $t = 1$. k represents the cost coefficient of the "community leader" retailer's preservation efforts relative to the large omni-channel fresh food retailers. Based on this, the derivative of Π_A and Π_B to fresh-keeping effort τ can be obtained respectively under actual conditions:

$$\frac{\partial\Pi_A}{\partial\tau} > 0; \quad \frac{\partial^2\Pi_A}{\partial\tau^2} < 0; \quad \frac{\partial\Pi_B}{\partial\tau} > 0; \quad \frac{\partial^2\Pi_B}{\partial\tau^2} < 0 \tag{13}$$

Set the variable parameters as follows: $\alpha = 0.5$; $\beta = 1$; $h = 0.2$; $p_0 = 0.5$, $t = 2$; $k = 2$. Figure 1 and Figure 2 show the changing images of the Π_A and Π_B by the level of preservation effort τ under the competitive conditions.

The settings of relevant parameters need to be explained as follows.

First, parameter settings are not nonadjustable, and within a reasonable range of model parameters, adjusting parameters will not change the model results and research conclusions. Secondly, the principle for setting relevant parameters is to meet the aforementioned assumptions while ensuring that the parameter measurement results are within a

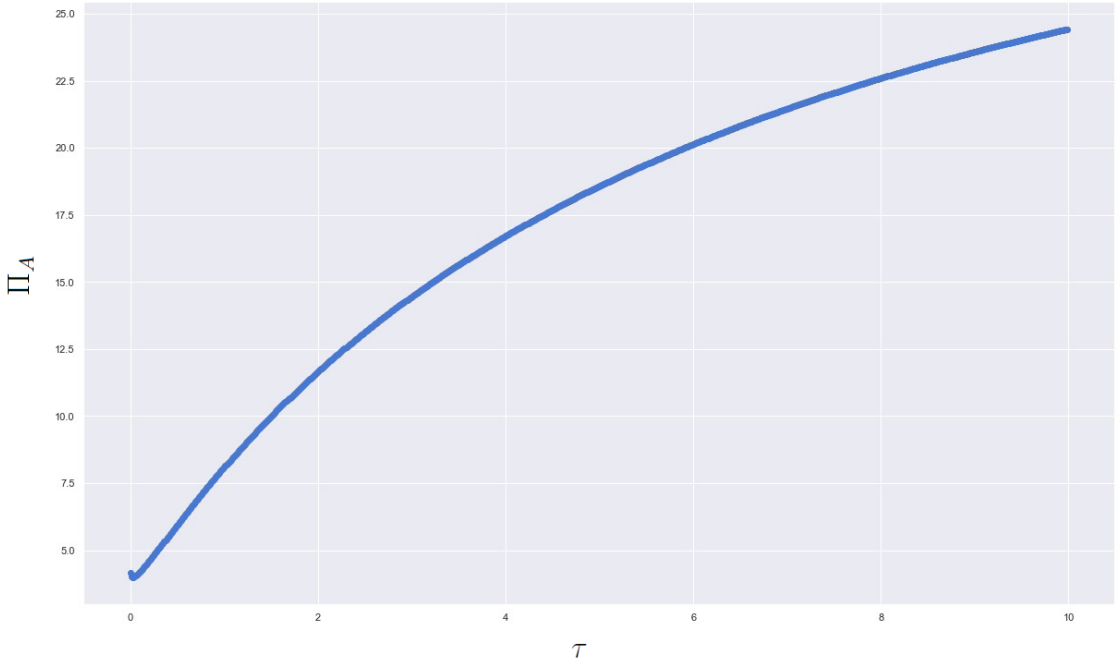

FIGURE 1. Π_A changing image by τ under competitive condition

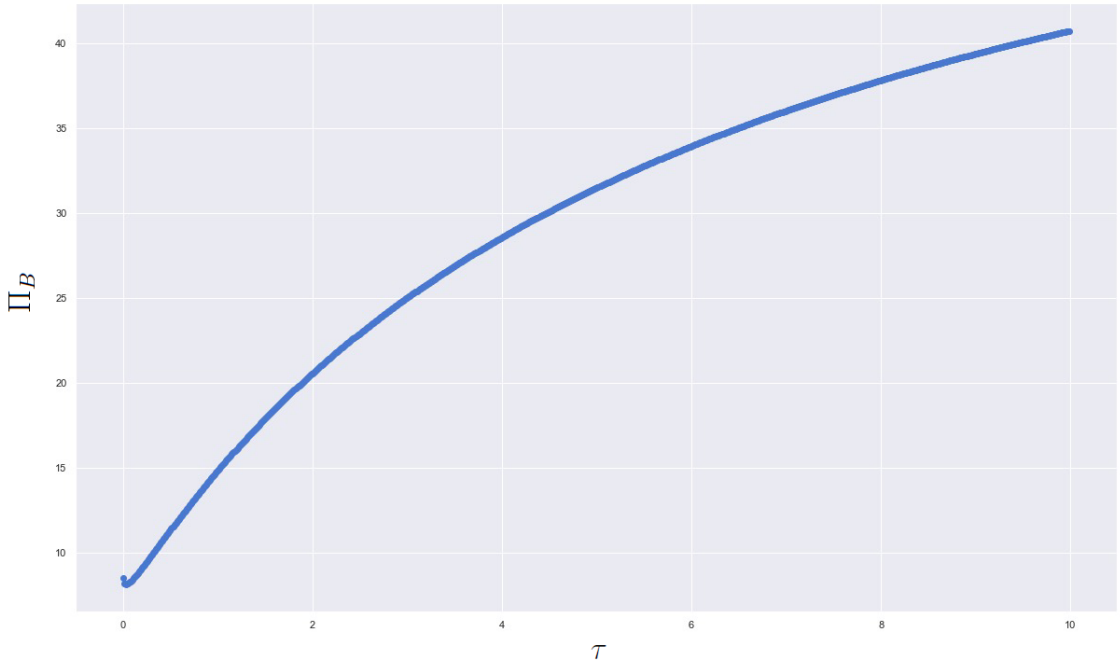

FIGURE 2. Π_B changing image by τ under competitive condition

relatively reasonable range. Third, parameters of the same type are set at the same order of magnitude.

It can be seen from Formula (12), Figure 1 and Figure 2, on the premise of value assignment in line with the actual situation, the profits of large omni-channel retailers and "community leader" retailers are an increasing function of the degree of preservation effort. This is because increasing the degree of preservation effort will reduce the quality degradation of fresh agricultural products, which increases product value. However, the improvement of the degree of preservation efforts cannot limitlessly improve the freshness of fresh agricultural products. The improvement of the degree of preservation efforts will continuously reduce the marginal effect on the improvement of the freshness of fresh agricultural products, but at the same time, the cost of the degree of preservation efforts is increasing. Therefore, the profits of large omni-channel retailers and "community leader" retailers are an increasing function of the degree of preservation efforts, but the growth rate continues to decline. Under the mode of bilateral competition, whether it is a large omni-channel retailer or a "community leader" retailer, there are restrictions on the motivation of improving freshness efforts and promoting profit growth.

Thus, the following propositions are obtained.

Proposition 4.1. *Under the independent decision-making mode of fresh food retailers, the improvement of retailers' fresh-keeping efforts will help to improve the pricing of current sale and pre-sale. The pre-sale pricing and current sale pricing of large omni-channel fresh food retailer are an increasing function of consumers' freshness sensitivity, the established freshness of fresh food, the additional cost of consumers' offline purchase and the cost of fresh food. The difference in pre-sale prices between large omni-channel fresh food retailer and "community leader" retailer is determined by the difference in unit preservation costs between the two sides. That is, when condition $c_1(\tau) > c_2(\tau)$ is satisfied, then $p_{1A}^* > p_{1B}^*$; when $c_1(\tau) < c_2(\tau)$, then $p_{1A}^* < p_{1B}^*$.*

Proposition 4.2. *Under the competition mode, the improvement of fresh-keeping efforts will slow down the increase of profits of large omni-channel retailer and "community leader" retailer. There is a limit margin for different modes of retailers to increase profits by improving fresh-keeping efforts.*

4.2. **Cooperative decisions of fresh food retailers.** Based on the above analysis, under competitive condition, the profit decisions of large omni-channel retailer and "community leaders" retailer are relatively independent, and there are mutual constraints in pricing. Assume that both parties cooperate in pricing, take the maximization of the total profit as the overall goal, and then distribute profits according to their respective profit functions.

Therefore, the total profit function is shown in Equation (14) below:

$$\max \Pi = \max \left\{ [p_1 - w - c_1(\tau)]\beta \left[\theta - \frac{1}{\alpha}(p_2 + p_0 - p_1)\right] + [p_2 - w - c(\tau)]\beta\theta + (1-h)[p_1 - w - c_2(\tau)]\beta \left[\theta + \frac{1}{\alpha}(p_2 + p_0 - p_1)\right] \right\} \tag{14}$$

The pre-sale and current sale pricing strategies under the condition of profit maximization are as follows:

$$\begin{aligned} p_1^* &= \frac{\alpha\theta + c_1(\tau) - (1-h)c_2(\tau)}{2-h} + w; \\ p_2^* &= \frac{(4-h)\alpha\theta + c_1(\tau) - (1-h)c_2(\tau)}{2-h} - p_0 + w \end{aligned} \tag{15}$$

It can be seen that under the cooperative decision-making mode of fresh food retailers, the pre-sale prices of large omni-channel fresh food retailer and "community leader" retailer are the same, which is a decreasing function of the freshness sensitivity of fresh food α, the established freshness of fresh food θ, and an increasing function of the cost of fresh products w, the platform's extraction coefficient for sales profit h, and the preservation cost under each pre-sale mode $c_1(\tau)$, $c_2(\tau)$. On this basis, the current sale price is also an increasing function of the additional cost of offline purchase p_0. Thus, the maximum profit of retailer A and retailer B under the condition of cooperative decision is calculated as

$$\begin{aligned} \Pi_A = -\frac{\beta\theta}{h^2} \{ &\left(h^2 - 6h + 3\right)\alpha + \left(2h^2 - 6h + 3\right)c_1(\tau) + h^2[c(\tau) + p_0] \\ &- 3\left(h^2 - h + 1\right)c_2(\tau)\} \end{aligned} \tag{16}$$

$$\Pi_B = \frac{3\beta\theta(1-h)}{h^2}\{\alpha\theta - c_1(\tau) - c_2(\tau)\} \tag{17}$$

Similarly, take $\theta(\tau) = 3 + 2\ln(\tau+1) - \ln(\tau)$; $c_1(\tau) = \sqrt{\tau}$; $c(\tau) = t\sqrt{\tau}$; $c_2(\tau) = k\sqrt{\tau}$ into Formulas (16) and (17). Calculate the derivative to the level of preservation effort respectively. Under actual conditions, we can get: Under the condition of realistic parameters, $\frac{\partial \Pi_A}{\partial \tau} > 0$; $\frac{\partial^2 \Pi_A}{\partial \tau^2} < 0$. At the same time, there is τ^*, when $\tau < \tau^*$, $\frac{\partial \Pi_B}{\partial \tau} > 0$; $\frac{\partial^2 \Pi_B}{\partial \tau^2} < 0$; when $\tau > \tau^*$, $\frac{\partial \Pi_B}{\partial \tau} < 0$; $\frac{\partial^2 \Pi_B}{\partial \tau^2} > 0$.

The parameter settings of each variable remain unchanged: $\alpha = 0.5$; $\beta = 1$; $h = 0.2$; $p_0 = 0.5$, $t = 2$; $k = 2$. Figure 3 and Figure 4 show the changing images of the Π_A and Π_B by the level of preservation effort τ under the cooperative condition.

It can be seen from the above analysis and Figures 3 and 4, on the premise of value assignment in line with the actual situation, the profit of large omni-channel retailer is an increasing function of the degree of preservation efforts and increases with the increase of preservation efforts. However, the profit of the "community leader" retailer is an inverted U-shaped function of the fresh-keeping effort τ, and there is an optimal fresh-keeping effort value τ^*. Based on the cooperation mode, the profit amount of both parties has significantly increased compared with that under the competition mode. Under this cooperation mode, large omni-channel retailer can give full play to their scale advantages and break through the growth limit of fresh-keeping efforts on profit increase, while "community leader" retailer can determine the optimal standardized fresh-keeping efforts according to

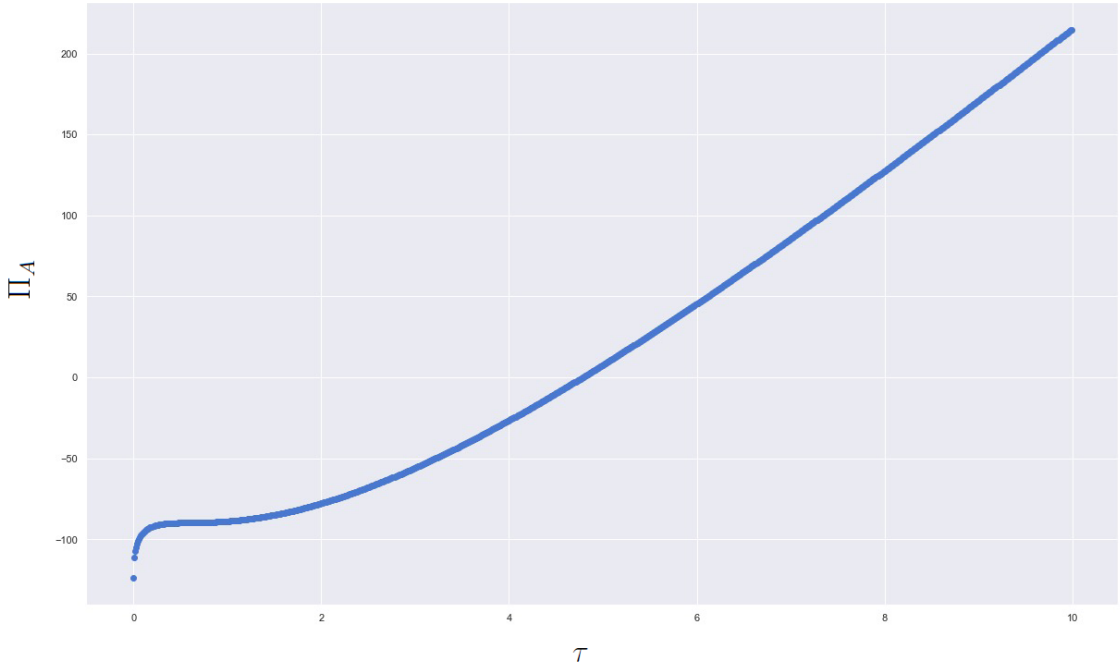

FIGURE 3. Π_A changing image by τ under cooperative condition

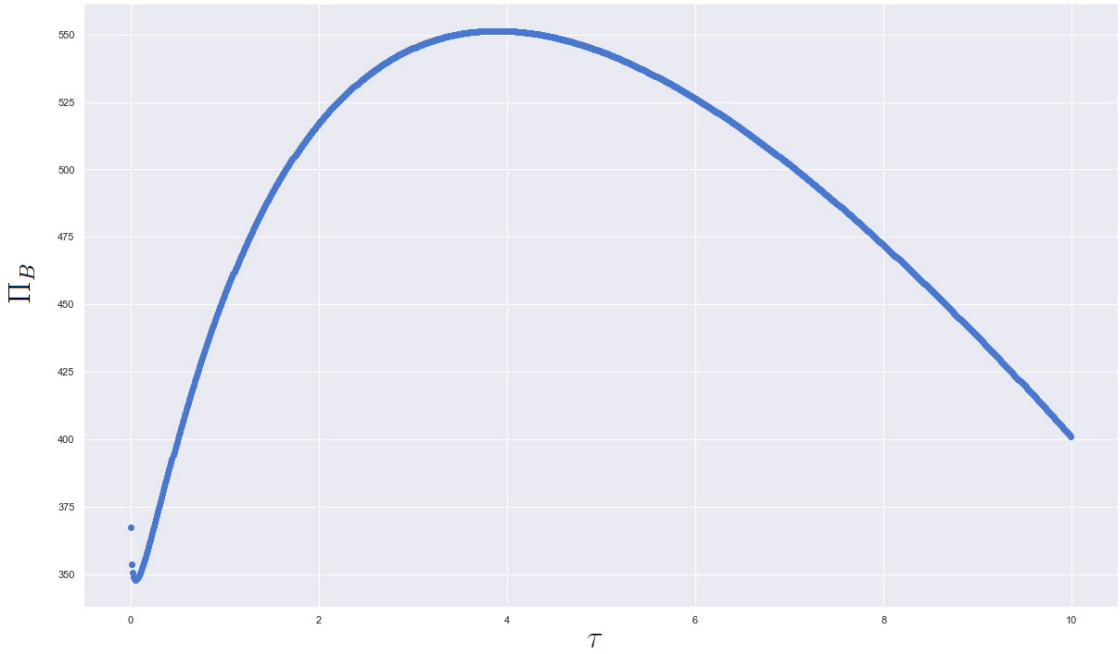

FIGURE 4. Π_B changing image by τ under cooperative condition

the actual situation, which helps to regulate the major problem of increasing consumer uncertainty caused by the uneven fresh-keeping effort of "community leader" retailers in the current market. Finally, it will promote the large-scale omni-channel retailers as the main body, cooperate with the "community leader" retailers to jointly improve the level of fresh-keeping efforts, standardize the market mechanism, and finally achieve the common improvement of the profit level of both sides.

Thus, the following propositions are obtained.

Proposition 4.3. *The improvement of retailers' fresh-keeping effort will help to improve the pricing of current sale and both parties' pre-sale. The pre-sale pricing and current sale*

pricing of fresh food retailers are the increasing functions of consumer freshness sensitivity α, established freshness of fresh food θ and fresh food cost w. The difference between the two modes is mainly determined by the platform's extraction coefficient for sales profit h and other purchase cost p_0.

Proposition 4.4. *Under the cooperative decision-making mode of fresh food retailers, the degree of fresh-keeping efforts has significantly promoted the profits of large omni-channel retailers and "community leader" retailers. However, for large omni-channel retailers, the improvement of fresh-keeping efforts will accelerate the increase of profits, and there is an evolutionary trend of profits from negative to positive. For the retailers of "community leader", the effect of fresh-keeping efforts on profits is in an inverted U-shaped trend.*

5. Conclusions.

The increasing demand for online pre-sale of fresh food in China in the post epidemic era has promoted the innovation and development of various pre-sale models. Currently, the pre-sale model of fresh food in China is not mature, and there is an urgent need for corresponding theoretical mechanisms to guide its pricing and sales decisions.

This article constructs a mathematical model for the online pre-sale and offline current sale of large omni-channel retailer, as well as the online pre-sale of "community leader". With the degree of preservation efforts of large retailers and community leaders as the core element, we explore the pricing strategies and profit changes of fresh food retailers for online pre-sale and offline current sale. The research has shown that the degree of preservation efforts made by omni-channel retailers and community leaders on fresh food can help improve the pre-sale and current sale pricing of fresh food, thereby promoting the improvement of profits under corresponding modes. Large omni-channel retailers and community leaders have a competition and cooperation mechanism between the online and offline modes. From a competitive perspective, a higher degree of preservation effort will improve the profit level of the corresponding mode, but the rate of improvement gradually decreases, and there are extreme limits on the profits of both sides. From the perspective of cooperation, large omni-channel retailers and community leaders can jointly enhance consumer utility, tap market demand, and maximize total profits through high freshness efforts. For large omni-channel retailers, freshness efforts can help accelerate the increase in profits, and there is a tendency for profits to change from negative to positive, stimulating their initiative in improving freshness efforts. For community leaders, there is an optimal degree of preservation effort to maximize profits.

In view of this, this paper puts forward the following three policy recommendations. First, take the community as the center, guide large omni-channel retailers to cooperate with community leaders, and coordinate the distribution of supply channels and delivery methods. Second, take large omni-channel retailers as the core, standardize the fresh-keeping methods of community leaders, and realize the dynamic upgrading path of large omni-channel retailers to drive community leaders to improve the fresh-keeping conditions. Third, share demand resources based on both parties' sales channels, improve sales efficiency, adjust the way of expanding total profits from zero-sum game under the competition mode to win-win game, increase both parties' profits based on expanding total consumption demand, and avoid vicious competition.

This study may provide the following prospects for future research. First, from the perspective of consumer behavior, this study does not consider consumer returns and combinations of purchases. Subsequent research can further explore the impact of consumer behavior on the pre-sale strategy of fresh agricultural products. Secondly, from the perspective of market environment, this article only analyzes the manufacturer's strategy in the context of a unified large market. Future research can distinguish between the current sale and pre-sale strategies in different situations such as competitive and monopolistic markets, and single and multiple suppliers.

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