

Optimizing the Sales Law and Replenishment Decision Analysis of Fresh Supermarket Products

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Abstract: In the field of fresh food supermarkets, due to the relatively limited shelf-life of vegetable products, their quality will gradually deteriorate with the sales time. Therefore, supermarkets need to perform daily rationing replenishment operations based on the historical sales data and demand of the products. This paper is based on the collected product information of vegetable categories, detailed vegetable sales flow data, wholesale prices of vegetable products, and recent vegetable product wastage rates. Data analysis and visualization techniques are used to analyze the distribution pattern of vegetable sales in each category and single product. Next, a functional relationship between total sales volume and cost-plus pricing of vegetable categories was constructed. Regression forecasts were used to simulate the future wholesale prices of vegetable categories.

Keywords: Replenishment Strategy; Pricing Strategy; Sales Forecast.

1. Introduction

One of the main production periods for fresh vegetable commodities is commodity management, which is influenced by various factors such as pricing strategies, supply chain management, and market demand. The pricing of fresh products in supermarkets has become a thorny issue. The natural characteristic of fresh products is that they have a short shelf life and are prone to quality loss due to the passage of sales time. Some vegetable varieties may be stranded until the next day and not sold on that day. Therefore, supermarkets will restock based on the historical sales and demand situation of each variety. To meet people's diversified consumption needs, it is necessary to consider the variety, origin, and Market demand conditions require trading for replenishment, and the purchase transaction time is usually between 3:00 a.m. and 4:00 a.m. Most supermarkets make daily replenishment decisions when they cannot accurately understand the specific items and purchase prices of the next day. The "cost plus pricing" method is generally used for various vegetable products, which discounts the sales of products affected by transportation losses and reduced product quality. Reliable market demand analysis is an important research direction for replenishment and pricing decisions. From the demand side, the sales volume of vegetable products often has a certain

correlation with time; From a supply side perspective, during the period from April to October, due to abundant vegetable supply but limited sales space in supermarkets, a reasonable sales mix plan is crucial [1].

This article balances sales profit and customer price sensitivity based on sales status and cost wholesale prices, and develops pricing models for different categories. The factors are product cost, expected sales volume, and sales profit, respectively. This predicts the maximization of sales profit to obtain a sales combination, enabling supermarkets to establish appropriate replenishment quantities and achieve profit maximization. Based on the sales situation and changes in demand, it is urgent to further optimize the replenishment volume and pricing strategy of supermarkets in order to meet the purchasing needs of various types of vegetables while ensuring maximum revenue. By using a combination optimization method to solve the economic replenishment batch and pricing problems of sellable items in the next week, fully combining factors such as expected profits and minimum display volume to achieve efficient operation of supermarkets.

2. Vegetable Sales Patterns by Category

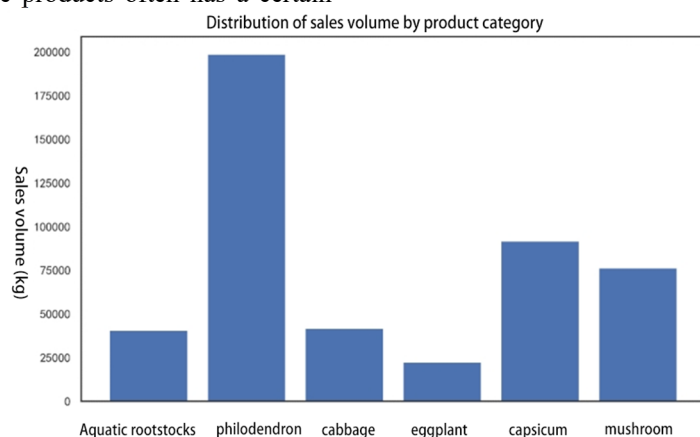


Figure 1. Distribution of sales volume of vegetables by category

According to the sales volume of each category of individual vegetables collected in this paper over the past three years, we can get a preliminary understanding of the distribution of sales volume of each category of vegetables in supermarkets, as shown in Figure 1.

First of all, we can see more intuitively through the flat histogram in Figure 1 that the sales volume of leafy vegetables in the superstore was the highest in the past time, followed by chili peppers and edible mushrooms, while the

sales volume of cauliflower and aquatic roots and tubers were almost equal, and the sales volume of eggplant was the lowest among the sales volume of each category of vegetables.

We then took a quarter as a cycle to calculate the total sales volume of each category of vegetables in the superstore in each quarter. We took the sales volume of the vegetable category for the nine quarters from 2020-09 to 2023-05 as our study and plotted the quarterly trend of sales volume as shown in Figure 2 below:

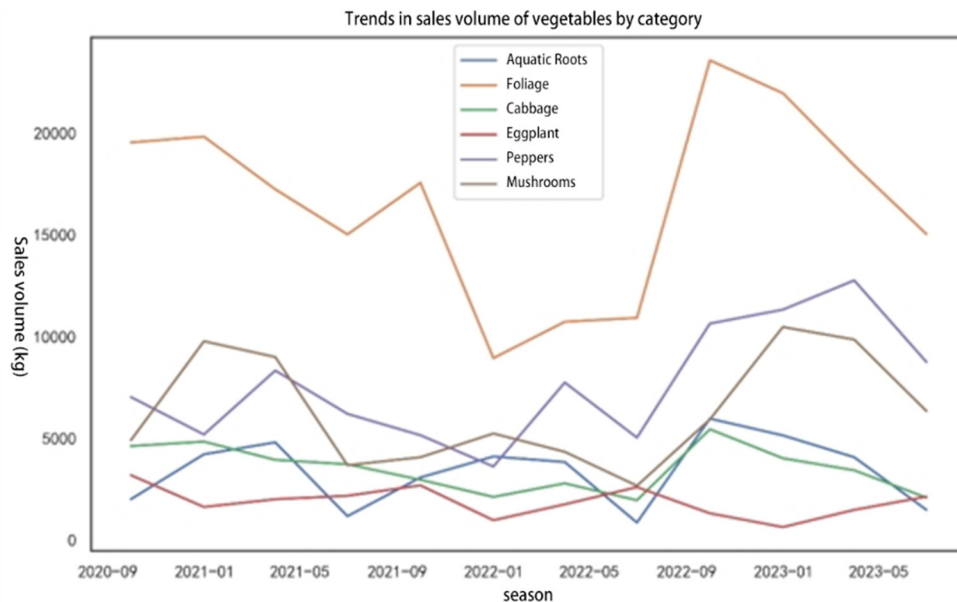


Figure 2. Trends in sales volume by vegetable category over the quarter

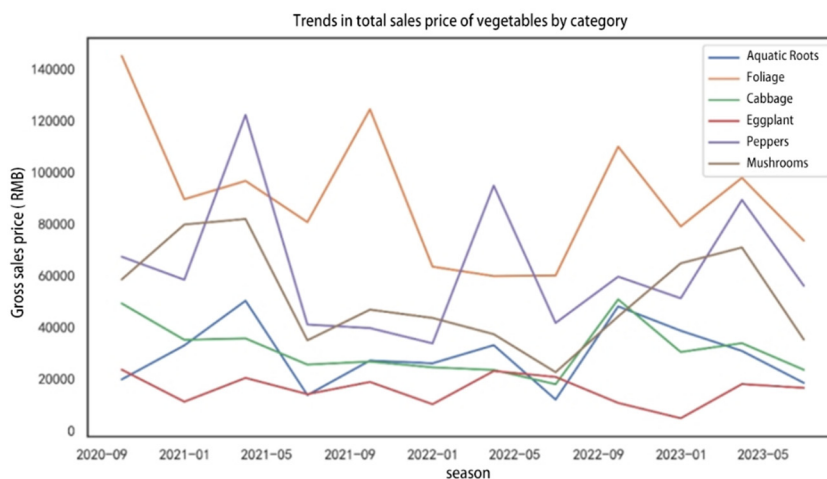
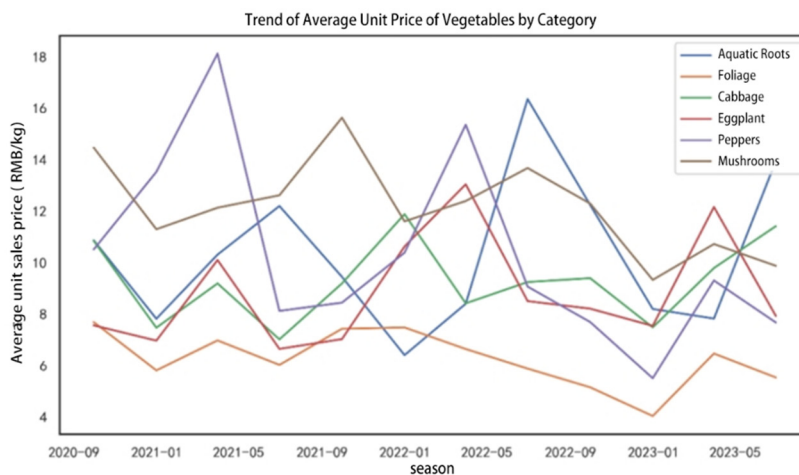


Figure 3. Trend of total sales price of vegetables by category in supermarkets

From Figure 2, we can see that the sales volume of vegetable categories in supermarkets will fluctuate due to the influence of time and month, in which the sales volume of leafy vegetables has the largest fluctuation in these nine seasons, and the peak sales period is generally in the fall and winter, and edibles are also usually found in the fall and winter, so their sales volume in the spring and summer seasons are lower. Pepper category is exactly the opposite of the former, this category tends to appear in the spring and summer, although sales tend to show an upward trend in the spring and summer seasons. Therefore, in order to develop a better replenishment plan and pricing planning, supermarkets should fully consider the impact of quarterly factors.

Figure 3 below shows the trend of total sales price and average unit price for each category of vegetables in supermarkets in a quarterly cycle.

In this case, the average unit sales price for each category

$$\text{profit}_i = \sum_d \sum_j \text{sale}_{j,d} * \text{sale}_n \text{um}_{j,d} - \sum_d \sum_j \text{sale}_{j,d} * \text{return}_{j,d} - \sum_d \sum_j \text{wholesale}_{j,d} * (1 + \text{attrition}_i) * \text{sale}_n \text{um}_{j,d} \quad (2)$$

Below, again on a quarterly cycle, are plotted the trends in

of vegetables is calculated:

$$\text{sale}_a \text{vg}_i = \frac{\sum_d \sum_j \text{sale}_{j,d} * \text{sale}_n \text{um}_{j,d}}{\sum_d \sum_j \text{sale}_n \text{um}_{j,d}} \quad (1)$$

The trend chart in Figure 3 shows that the total sales price of leafy and flowering vegetables is basically the highest in every season, but its sales unit price is lower in almost every quarter, in addition to combining the sales volume with the quarterly change in Figure 2, it can be shown that the higher sales volume of vegetable categories tend to have a lower sales unit price, and therefore it can be deduced that there is a relationship between the sales volume of the vegetable categories and their pricing.

Combined with the collected data, the trend of the profit of each category of vegetables in the supermarket can be calculated, where the profit is calculated as [2]:

profits for each category of vegetables in Figure 4.

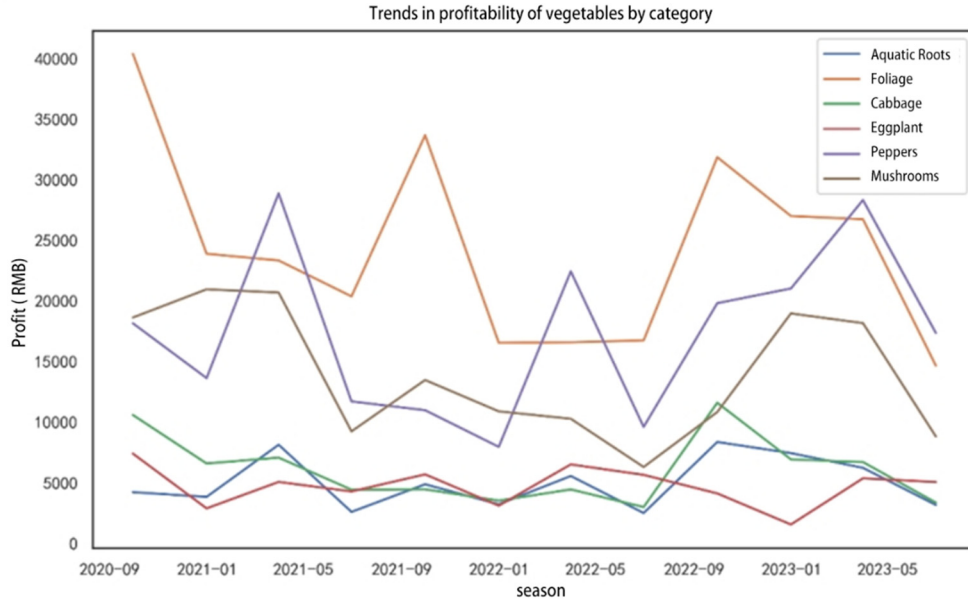


Figure 4. Quarterly Trends in Vegetable Profits by Category

From Figure 4, we can see that the trend of changes in the profits of various categories of supermarket vegetables and the trend of changes in the total sales price are generally consistent, in which the flower and leafy vegetables bring the most profits, followed by chili peppers and edible mushrooms, and the profits brought by the other three categories of vegetables are almost flat.

3. Pricing Model for Each Vegetable Category in Supermarkets

In order to develop the total daily replenishment and pricing strategy for each vegetable category for the coming week to maximize the superstore's revenue, we can analyze and consider the relationship between the total sales volume of each vegetable category and the cost-plus pricing to determine the impact of the pricing of each vegetable category on its sales volume. First, we can calculate the average daily sales pricing for each vegetable category and

use this pricing to replace the cost-plus pricing, which is calculated by the formula:

In order to develop a daily replenishment total and pricing strategy for each vegetable category in the next week (July 1-7, 2023), in order to maximize supermarket revenue, we can analyze and consider the relationship between the total sales volume of each vegetable category and cost plus pricing to determine the impact of the pricing of each vegetable category on its sales volume. Firstly, we can calculate the daily average sales pricing for each vegetable category, using this pricing as a substitute for cost plus pricing [3]. The calculation formula for pricing is:

$$\text{sale}_a \text{vg}_{i,d} = \frac{\sum_{j \in i} \text{sale}_{j,d} * \text{sale}_n \text{um}_{j,d}}{\sum_{j \in i} \text{sale}_n \text{um}_{j,d}} \quad (3)$$

The formula for calculating the total daily sales of various vegetable categories is:

$$\text{sale}_{n\text{um}_{i,d}} = \sum_{j \in i} \text{sale}_{n\text{um}_{j,d}} \quad (4)$$

In order to better fit the relationship between total sales volume and sales pricing for each vegetable category, the

functions we considered were logarithmic, linear and power functions, while the best fitting model was selected as the pricing sales model, and some of the fitted images are shown in Figure 5.

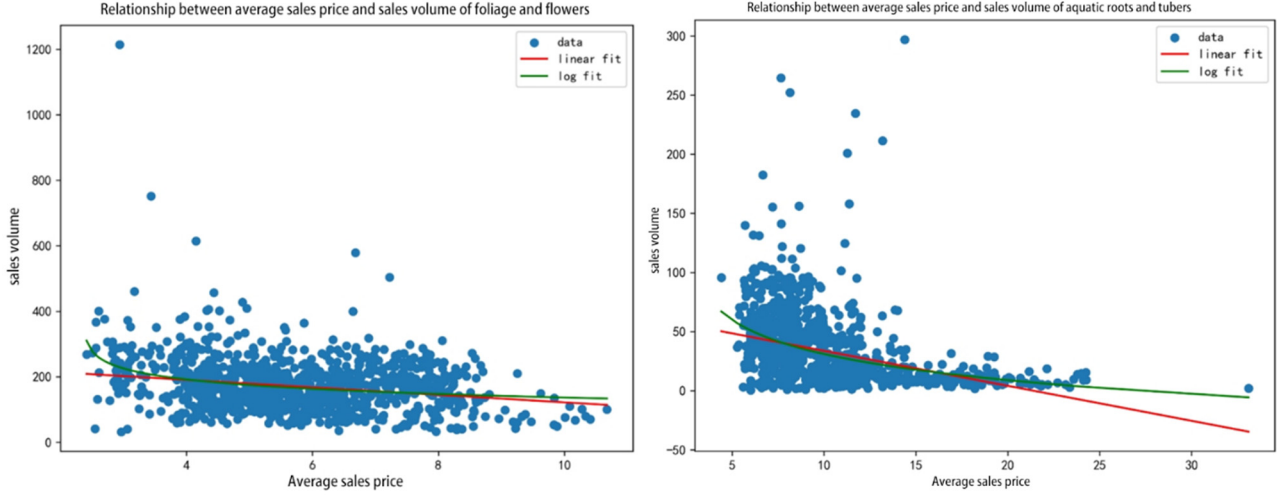


Figure 5. part of the fitted image

To maximize the profit margin of supermarkets, it is also necessary to predict the average wholesale prices of vegetable categories. The formula for calculating the daily average

wholesale price of vegetable categories in supermarkets is:

$$\text{whole}_{a\text{vg}_s\text{ale}_{i,d}} = \frac{\sum_{j \in i} (1 + \text{attrition}_i) * \text{sale}_{n\text{um}_{j,d}} * \text{wholesale}_{j,d}}{\sum_{j \in i} (1 + \text{attrition}_i) * \text{sale}_{n\text{um}_{j,d}}} \quad (5)$$

Figure 6 illustrates the trend in average wholesale prices of vegetables by category within the superstore on a month-to-

month cycle.

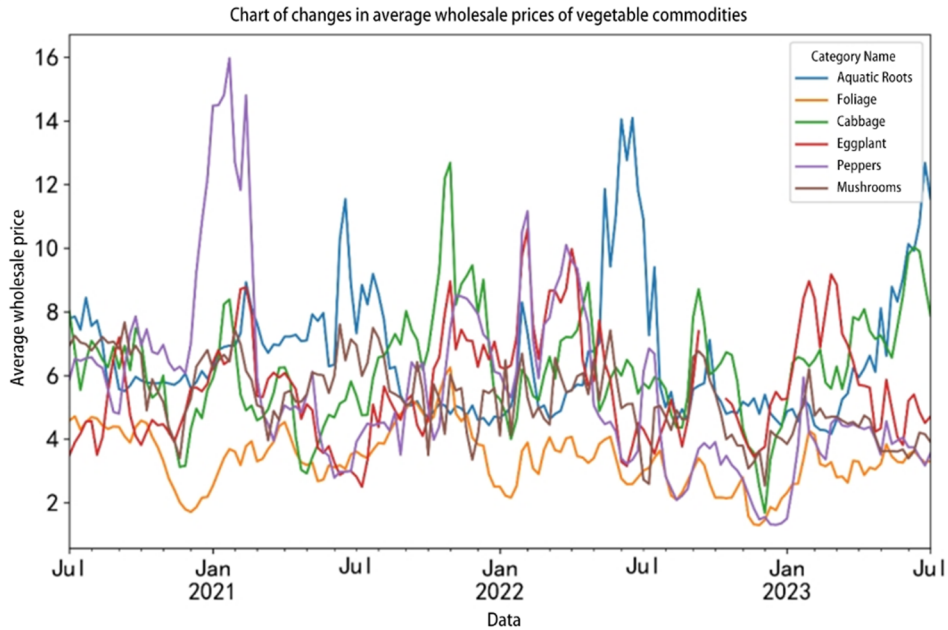


Figure 6. Trend chart of changes in average wholesale prices of vegetables by category

4. Supermarket Replenishment Strategy Model

Supermarket replenishment needs to control the total number of saleable single product, and to meet the minimum display quantity requirements of single product ordering quantity, under the premise of trying to meet the market

demand for various categories of vegetable goods, making the supermarket revenue maximization [4].

We first need to predict the wholesale price of each single product in the next day, where we use the historical average prediction method to get the future wholesale price $\text{wholesale}_{j,d}$, define the nonlinear programming model as follows:

$$\begin{aligned} \text{objective: } & \max(\text{profit}_d = \text{select}_d * \text{sale}_d * \text{sale_num}_d - \text{select}_d * \text{supply}_d * \text{wholesale}_d) & (6) \\ \text{s. t. : } & \text{select}_d * \text{supply}_{j,d} > \text{select}_d * \text{sale_num}_{j,d} + \text{select}_d * \text{attrition}_i * \text{supply}_{j,d}, \text{ where } j \in i; & (7) \\ & \text{sale}_{j,d} > \text{wholesale}_{j,d} & (8) \\ & \text{select}_d * \text{supply}_{j,d} > \text{select}_d * \text{Minimum Display} & (9) \\ & \text{select}_{\min} \leq \text{sum}(\text{select}_d) \leq \text{select}_{\max} & (10) \\ & \text{select}_d * \text{supply}_{j,d} = \text{supply}_{j,d} & (11) \\ & \text{select}_d * \text{sale}_{j,d} = \text{sale}_{j,d} & (12) \\ & \text{sale_num}_{j,d} = \text{func}(\text{sale}_{j,d}), \text{ where } j \in I & (13) \\ & \text{num}(i) = 6 & (14) \\ & \text{select}_d = [\text{random.randint}(0, 1) \text{ for } _ \text{ in range}(n)] & (15) \end{aligned}$$

Our goal is to maximize the sales profit of the superstore, which consists of the sum of the sales profit of each vegetable item. To achieve this goal, we use an intelligent decision-making method, the choice list, which is a list containing alternative elements, each of which is either 0 (indicating that the vegetable item is not purchased) or 1 (indicating that the vegetable item is purchased).

In addition, we have the following key elements:

Replenishment list, which represents the actual quantity of vegetable items purchased.

The selling price list, which is used to determine the unit price at which the vegetable items are sold.

Also, our model is subject to several constraints which include:

Constraint Function 1: Ensure that the replenishment quantity is greater than or equal to the sales quantity plus wastage requirement to ensure adequate supply.

Constraint Function 2: Ensure that the selling unit price is higher than the wholesale price to maintain profitability.

Constraint function 3: Meet the minimum display quantity requirement of vegetable single product to ensure product visibility.

Constraint function 4: Limit the number of choices of vegetable products in each category to maintain diversity.

Constraint function 5 and 6: Ensure that the replenishment quantity list and sales price list have the same 0 element value position with the selection list to avoid purchasing unneeded commodities.

Constraint Function 7: Determine the sales volume through the category and pricing of vegetable individual items to meet the market demand.

Constraint Function 8: Ensure that the category to which the restocked vegetable single item belongs has a total of six categories to meet the market demand for different vegetable categories.

This model uses a combination of data analytics and logical decision-making to maximize sales margins and meet market demand, and is designed to provide an intelligent approach to

merchandise replenishment and pricing decisions for superstores [5].

5. Conclusion

The trend of mass data in power system provides a basis for load characteristic analysis and prediction model establishment, but the classical load forecasting method cannot afford such a huge time and computing resource consumption. The problem of over fitting in large sample set will affect the prediction accuracy. In this paper, a power load forecasting model is built by using the BP neural network model, making full use of the powerful data processing function of Clementine and preventing the over fitting function. The experimental results show that the BP neural network model has good predictability and robustness, and has a certain practical application value.

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