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Research on Optimization of Sales Strategy for Supermarket Based on Linear Programming

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Abstract: *As an important bridge between suppliers and customers, supermarket vegetables are responsible for introducing growers' vegetable products into the market and selling them to end customers. However, due to various factors, the profits of supermarket vegetables are not stable and unchanging. The growth environment, seasonal changes, market demand fluctuations, and transportation costs of vegetables will all have an impact on the profits of supermarket vegetables. Based on this background, this article first obtains the following expression by considering various factors such as vegetable planting costs, sales prices, market demand forecasting, and resource constraints. Then, this article uses a single objective optimization model to solve the problem of maximizing vegetable profits in supermarkets, and provide decision-making basis through reasonable algorithms and strategies to establish an objective function for maximizing profits. The replenishment quantity is the decision variable, and the minimum replenishment quantity needs to be greater than 2.5kg and the number of units available for saleGong within a day is between [27, 33] as the constraint conditions. Finally, the calculation of maximizing profits was achieved, and key data was visualized to validate the value and significance of the optimization model.*

Keywords: *Spearman, Correlation coefficient ARIMA time series, Linear programming*

1. Introduction

In order to facilitate the solution of the problem, this article provides the following symbol explanations (table 1):

Table 1: Variable names

symbol	Description
p_i	Single item selling price
P_j	Average selling price of the category
s_i	Single item sales volume
S_j	Category sales volume
c_i	Cost per item
C_j	Average cost of category
r	profit rate
L_i	Loss rate
SF	Total profit
B_i	Replenishment quantity
l	Minimum number of columns
rP_j	Predicted sales volume

As people's attention to healthy food continues to increase, the demand for vegetables in the market continues to increase. Supermarket vegetables, as an important channel to meet market demand, have also become the focus of interest disputes between vegetable growers and supermarkets. How to maximize the profit of supermarket vegetables under limited resources is a challenging issue. This paper aims to establish a single objective optimization model, which aims to maximize the profit of supermarket vegetables through reasonable allocation of resources and formulation of strategies.

Xu, Y., Li, K.,&Zhang, J. scholars considered the impact of price discounts and shelf life constraints on the profit of the fresh food supply chain when studying the profit, and established corresponding objective functions and constraints. By determining the optimal price discount strategy while considering the interests of all parties in the supply chain, we aim to increase profits. They used genetic algorithms and multi-objective optimization algorithms to solve optimization problems. Their research results indicate that considering price discounts and shelf life constraints can significantly improve the profits of the supply chain, and the proposed optimization model and algorithm can be effectively applied to practical situations[1-2].

Zhang, W., Li, Y.,&Zhang, X. Scholars' research has focused on the replenishment and distribution of perishable goods. They considered the uncertainty of inventory and sales forecasts and established corresponding models to address this issue. By establishing an optimization model, combining uncertainty prediction model and replenishment decision model, a fusion method is proposed to solve the replenishment and allocation problem of perishable goods. Their experimental results indicate that the proposed method can achieve a balance between inventory and sales risks while maximizing profits, thereby improving the efficiency of the supply chain[3-5].

The model construction of this article will integrate the ideas, methods, and conclusions of the above literature. In the model preparation stage, we will lay the groundwork for resource allocation and sales strategies in the supermarket vegetable supply chain. Then, in the establishment stage of the objective function, we will consider factors such as vegetable purchase costs, sales prices, and market demand prediction to establish a comprehensive objective function that considers profit maximization. Next, we will consider factors such as resource constraints, inventory management, transportation costs, and provide corresponding constraints. Finally, in the solving method stage, we adopt a mathematical model of the linear objective function optimization problem under linear constraints. The purpose of the objective function is to maximize the returns of supermarkets.

2. Model construction

2.1 Data preprocessing

We predicted the replenishment volume on July 1st based on the individual products sold from June 24th to June 30th. We observed the table and found a large number of duplicate products. We removed the duplicate values, and the results are shown in the table 2.

Table 2: Sales data of individual products from June 24th to June 30th

Date	Item Code	Wholesale Price	Category	UnitPrice	Sales	Loss Rate
2023-06-24	102900005115250	15.60	edible fungi	23.6	0.196	10.8
2023-06-24	102900005115762	2.31	Florifolias	6	0.686	18.52
2023-06-24	102900005115779	5.75	Florifolias	8	0.338	15.25
……	……	……	……	……	……	……
2023-06-24	102900005118824	11.14	edible fungi	10	0.251	29.25
2023-06-24	102900005118831	4.75	edible fungi	6.9	1	2.48

2.2 Establishment of optimization model

(1) Theoretical derivation

We use the "cost plus pricing" method to develop pricing strategies. We assume that sales volume and selling price follow market laws, thereby satisfying the linear demand function, namely

$$S = a - bP$$

Analysis confirms that the formula for calculating total profit is

$$SF = SC(1 + \frac{P - C}{C}) - CB \tag{1}$$

Also

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$$S = a - bC(1 + \frac{P - C}{C}) \tag{2}$$

So the total profit formula is simplified as

$$SF = (a - bP)P - CB \tag{3}$$

It can be seen that this is a univariate quadratic function. We used MATLAB to optimize and obtain the pricing for each category at the maximum profit, as shown in the table 3.

Table 3: Final Forecast Pricing

	Solanaceae	florescent vegetables	Chili peppers	Florifolias	Edible fungi	Aquatic rhizomes
7.1	10.00000043	12.0478179	10.00000031	10.34370278	11.5284736	12.57168279
7.2	10.00000015	12.04781805	10.00000015	10.34370232	11.52847349	12.57168278
7.3	10.00000044	12.04781818	10.00000006	10.34370251	11.52847357	12.57168264
7.4	10.00000036	12.04781776	10.00000002	10.34370243	11.52847376	21.63037713
7.5	10.0000001	12.04781776	9.999999936	10.34370253	11.52847353	12.57168268
7.6	10.00000017	12.04781766	9.999999917	10.34370258	11.52847347	12.57168265
7.7	9.999999951	12.04781777	9.999999826	10.34370252	11.52847364	12.57168262

(2) Basic Quantity Calculation and Random Variable Hypothesis

The relationship between each quantity is calculated using the following formula:

$$SF = (a - b \times (P))(P) - C \times B \tag{4}$$

Assuming that the selling price and wholesale price of individual products sold from June 24th to June 30th remain unchanged.

Calculate the average loss rate of all items sold on June 24th and June 30th by adding them together9.426693227%。

(2) Objective function

This goal requires that the replenishment of the solution be "most profitable", meaning that the more profitable the individual products, the better.

Therefore, the objective function is:

$$SF_{\max} = -SF_{\min} = \sum(S * P) - \sum(B * c) \tag{5}$$

The objective function is to maximize total profit, which is equal to total sales revenue minus total cost.

(3) Constraint function

The constraints known from the title are summarized as follows:

1) Each item's replenishment quantity must meet the minimum display quantity requirement, with each item's replenishment quantity ≥ 2.5kg.

2) The quantity of sellable items must be between [27,33].

In order not to cause losses, we stipulate that the total cost cannot exceed the total sales revenue.

In order to ensure the quality of vegetable products and avoid waste, we set a loss rate threshold. We calculated the average loss rate of all single products sold on June 24th and June 30th by adding them together, which is 9.426693227%, close to 10%. Therefore, we set this threshold as 10%.

Objective programming equation.

$$SF_{\max} = -SF_{\min} = \sum(S * P) - \sum(B * c)$$
$$s.t.\begin{cases} B_i \geq 2.5 \\ 27 \leq i \leq 33 \end{cases} \tag{6}$$

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3. Results

The results are shown in Tables 4 and 5.

Table 4: Single item sales data from June 24th to June 30th

Date	Item Code	unit price	Wholesale Price	Category	Sales	Loss Rate
2023-06-24	102900005115250	23.6	15.60	edible fungi	0.195	10.8
2023-06-24	102900005115762	6	2.31	Florifolias	0.686	18.52
……	……	……	……	……	……	……
2023-06-27	102900011018132	16	16.07	Aquatic rhizomes	0.826	12.69
2023-06-27	102900011033982	11	4.34	Solanaceae	0.373	9.43
2023-06-27	102900011036686	4.9	1.46	Florifolias	1	9.43

Table 5: Final Results

Selected item on July 1st	Selected item display quantity	category
102900005115762	1.0644	Florifolias
102900005115779	0.4472	Florifolias
102900005115823	1.7543	Florifolias
102900005115908	1.5921	Florifolias
102900005115960	1.3443	Florifolias
102900005116219	0.3058	Chili peppers
102900005116233	0.8383	Chili peppers
102900005116257	1.2672	Solanaceae
102900005116509	1.6116	Solanaceae
102900005116899	1.0961	Aquatic rhizomes
102900005118824	0.9785	Aquatic rhizomes
102900005118831	0.7616	Florifolias
102900011001691	1.0677	Aquatic rhizomes
102900011006948	2.1927	Florifolias
102900011008164	1.0756	Florifolias
102900011009970	0.9636	florescent vegetables
102900011016701	1.0002	Chili peppers
102900011030097	0.2564	Florifolias
102900011032343	0.9361	Chili peppers
102900011032848	0.2534	Chili peppers
102900011034330	1.3048	edible fungi
102900011034439	1.2483	Chili peppers
102900011035740	1.0918	edible fungi
102900051000944	0.8342	Aquatic rhizomes
102900051004294	1.606	Chili peppers
102900011031216	0.7981	Florifolias
102900011013274	1.0538	edible fungi
102900011033982	1.5542	Solanaceae
102900011036686	0.4994	Florifolias

This model is constructed based on historical sales data and other related variables, ensuring the practicality and accuracy of the solution.

This model not only considers sales volume and cost, but also comprehensively considers factors such as seasonal changes and loss rates, making the model more realistic.

This article predicts future sales, wholesale prices, and damage rates based on time series, which may be influenced by some location factors, resulting in errors.

4. Conclusions

This article discusses the challenge of maximizing profits for supermarket vegetables in the face of various influencing factors. Factors such as growth environment, seasonal changes, market demand fluctuations, and transportation costs can impact the stability of supermarket vegetable profits. To address this issue, the article proposes a single objective optimization model that aims to maximize the

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profit of supermarket vegetables through resource allocation and strategic formulation.The model utilizes factors like vegetable planting costs, sales prices, market demand forecasting, and resource constraints to establish an objective function for maximizing profits. The decision variable is the replenishment quantity, which needs to meet the constraint conditions of being greater than 2.5kg and within a range of units available for sale per day. By solving the optimization model, the article achieves the calculation of maximizing profits and visualizes key data to validate the value of the model. The introduction highlights the increasing demand for vegetables and the importance of maximizing supermarket vegetable profits with limited resources. The article references prior research on price discounts, shelf life constraints, inventory management, and replenishment decisions to inform its model construction. The objective function aims to maximize supermarket returns, and the model utilizes linear objective function optimization under linear constraints.Data preprocessing is conducted to remove duplicate product values, and the model establishes basic quantity calculations and random variable hypotheses. The objective function is to maximize total profit, which is achieved by maximizing total sales revenue while considering total costs. Constraint functions include minimum replenishment quantity requirements, sellable quantity constraints, and thresholds to avoid losses and maintain product quality.

Overall, this article provides a comprehensive approach to maximizing profits for supermarket vegetables through the use of an optimization model considering various influencing factors and constraints.

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