Research on the Solution of Mathematical Contest in Modeling based on Artificial Bee Colony Algorithm

Zhen Wang and Xiangyu Kong

Abstract—**Mathematical contest in modeling, as a discipline competition to measure students' extracurricular practice ability, is of great significance to cultivate students' logical thinking ability and innovation ability. In recent years, with the development of science and technology, the mathematical contest in modeling is derived from practical problems. Its complexity is increasing rapidly. For solving these problem properly, intelligent algorithms are widely used in such complex problems. Based on this, combined with the development of modeling technology, this paper focuses on the application of artificial bee colony algorithm in the last two China Undergraduate Mathematical Contest in Modeling, in order to put forward a new and effective method for mathematical contest in modeling problems.**

Index Terms—**Artificial bee colony algorithm, constraint handling strategy, mathematical contest in modeling, supermarket optimal replenishment pricing model, crop planting strategy model**

I. Introduction

IN the 1960s, mathematical contest in modeling entered the universities of western countries, and appeared in the United States in 1985. In the early 1980s, China introduced mathematical modeling into the university. The China Undergraduate Mathematical Contest in Modeling (CUMCM) started in 1992, and is co-sponsored by the Department of Higher Education of the Ministry of Education and the Chinese Society of Industrial and Applied Mathematics (CSIAM). It is held every year. Over the past decade, the scale of this competition has grown at an average annual rate of more than 25 percent. As a science and technology competition for college students, the CUMCM has the characteristics of high popularity, high difficulty, strong interdisciplinary and high recognition. [1]

Mathematical modeling is mainly described by the actual problems using mathematical symbols, formulas, programs, graphs, etc., which can provide new methods and ideas for solving practical problems. After more than 30 years of development, most colleges and universities in China have set up various forms of mathematical modeling courses to train students in applying mathematical methods for practical problems. In the course of mathematical modeling, classification teaching is implemented, that is, case teaching based on knowledge classification. In teaching, more attention is paid to the understanding and application of knowledge, as well as knowledge transfer and integration. In all kinds of mathematical modeling textbooks, mathematical programming is regarded as an important part. In real life, people often encounter optimization problems in engineering technology, economic management, scientific research and other fields. These problems can usually be constructed as mathematical programming models. Mathematical programming models occupy a very large proportion in CUMCU for college students. According to statistics, at least 60% of the problems in CUMCU can be solved by establishing mathematical programming model. Therefore, it is very important for students to master the modeling method and solving methods of mathematical programming model for the competition. It has a far-reaching impact on the training of students' scientific literacy and the ability to solve practical problems.

In recent years, with the rapid development of computer technology and artificial intelligence technology, intelligent algorithm has been widely used in the problem solving of mathematical contest in modeling. The proposal of intelligent algorithm has played a vital role in promoting the development of mathematical modeling. [2] Intelligent algorithm is an stochastic optimization algorithm designed on the basis of the intelligent phenomena of natural biological groups. The intelligent algorithm has the advantages of simple mechanism, easy to understand, concise algorithm design, no special requirements on the objective function, easy to program and calculate, and can give a satisfactory solution to the problem within an acceptable time range [3]. Moreover, this kind of algorithm has the advantages of self-learning, self-organization, self-adaptation, strong robustness and parallel processing, which can be widely used in parallel search, associative memory, pattern recognition, automatic knowledge acquisition and so on. Therefore, intelligent algorithm is a commonly used algorithm for optimization problems in modeling contest.

With the deepening of the research of intelligent algorithms, a large number of algorithms based on the natural characteristics of natural organisms have been proposed. Among many intelligent algorithms, artificial bee colony (ABC) algorithm has attracted much attention because of its

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excellent optimization performance. ABC algorithm is an intelligent algorithm proposed by Karaboga[4] in 2005. It has the advantages of fewer control parameters, fast convergence and so on. In 2010, Zhu et al. [5] proposed GABC algorithm in order to improve the exploitation ability of ABC algorithm by using Gbest to guide the population to search. Mezura et al. [6] proposed the Elitist-ABC algorithm by using equation-constrained dynamic tolerance mechanism and modifying three bee search equations. In 2011, Karaboga et al. [7] proposed an improved ABC algorithm (MABC), which uses feasible selection rule to replace the original ABC selection method. Kang et al. [8] proposed a hybrid Hooke Jeeves ABC algorithm based on Hooke Jeeves pattern search. In 2017, Bansal et al. [9] improved GABC by combining the concept based on the probability of individual mobility fitness in the employed bee and onlooker bee phases. In 2018, Gao et al. [10] proposed a new mechanism based on the artificial bee colony algorithm, which consists of two new learning strategies - directional learning and elite learning, which complement each other and improve the performance of the algorithm. Wang et al. [11] proposed an artificial bee colony algorithm based on co-evolution of multiple search strategies by dynamically adjusting the search dimension in the stages of employed bees and onlooker bees. In 2020, Guo et al. [12] proposed the IMABC algorithm, which divides the evolutionary process of the algorithm into two stages to reduce the random search of the algorithm and avoid the precocity of the algorithm. Mo et al. [13] proposed the ABCIS algorithm, which abandoned the traditional greedy selection mechanism and improved the search performance of the algorithm through intelligent search and special division. Through the literature review above, it can be seen that ABC algorithm has been applied to solve various optimization problems. Based on this, this paper will use the ABC algorithm to solve the mathematical programming problems in the mathematical contest in modeling, and verify the feasibility and effectiveness of the ABC algorithm through the actual calculation of the relevant questions in the last two CUMCM.

II. Problem Description

A. Optimal replenishment pricing problem of supermarket

The C question of 2023 CUMCM is "automatic pricing and replenishment decisions for vegetable products", which is described as follows. [14]

In fresh supermarkets, the shelf life of vegetables is usually very limited. Their quality will gradually decline with the increase of sales time. Most vegetables can no longer be sold after the end of the day if they are unsold. Therefore, fresh replenishment decisions in supermarkets usually need to be made on a daily basis based on the historical sales and demand of each item. Considering the large variety of vegetables sold in the supermarket, and they come from different places of origin, merchants usually need to make replenishment plans for each vegetable category on the day without determining the specific item and purchase price. From the demand side, the sales volume of vegetables is often related to the time. On the supply side, from April to October, the supply of vegetables is relatively rich. However, as the sales space of supermarkets is limited, how to sell products in a reasonable mix has become crucial. According to the existing data information, it is crucial to establish a mathematical model to solve the automatic pricing and replenishment decision of vegetables.The following problems should be solved:

Question 1: There may be a certain correlation between different categories or different items of vegetables. Please analyze the distribution law and mutual relationship of the sales volume of each category and single item of vegetables.

Question 2: Considering the replenishment plan of the supermarket based on the category, please analyze the relationship between the total sales volume of each vegetable category and the cost, and give the daily replenishment volume and pricing strategy of each vegetable category in the next week (July 1-7, 2023), so as to maximize the profit of the supermarket.

Question 3: Due to the limited sales space of vegetable commodities, the supermarket hopes to further develop the replenishment plan of a single item, requiring that the total number of salable items be controlled at 27-33, and the order quantity of each single item meets the minimum display quantity of 2.5kg. According to the available varieties from June 24 to 30, 2023, the replenishment quantity and pricing strategy of a single item on July 1 are given, so as to maximize the profit of the supermarket under the premise of meeting the market demand for various categories of vegetables as far as possible.

From the analysis of the above problems, we can see that Question 2 and 3 need to establish a mathematical programming model on the basis of the original data and Question 1. After the analysis of Question 1 and data pre-processing, the daily average sales quantity, daily average sales price, value range of sales volume, price demand elasticity and cost of each category can be obtained, as shown in Table I.

Suppose $P_{ti}, i=1,...,6$ representing the price of 6 types of vegetables, $Q_{ti}, i=1,...,6$ representing the sales volume of 6 types of vegetables. Based on the given elasticity of market price demand, the relationship between the expected sales volumes of each type and the adjusted prices is as follows:

TABLE I
SALES DATA OF EACH VEGETABLE CATEGORY.

	Selling Quantity	Selling Price	Maximum Selling Price	Minimum Selling Price	Price Demand Elasticity	Costs
Cauliflower	38.14287763	9.1385376	19.8	3.46	-0.711	8.122415
Leaves	181.2976968	6.317257386	11.06	2.61	-0.368	4.927193
Capsicum	83.64258356	10.57821641	32.3	3.2	-0.331	6.30685
Nightshade	20.48564566	8.695458595	17.87	3.04	-0.475	6.490859
Edible mushrooms	69.48559361	12.03694146	19.84	3.62	-0.989	7.50604
Aquatic rhizomes	37.06059635	9.689851143	30.19	4.49	-1.162	9.138922

$$Q_{ti} = Q_{(t-1),i} + e_i \times \frac{P_{ti} - P_{(t-1),i}}{P_{(t-1),i}} \times Q_{(t-1),i} , \quad (1)$$

where, $e_i, i = 1,...,6$ denotes the elasticity of market price demand of 6 types of vegetables. The total profit of each category of vegetables is equal to the sum of the income of each category minus the costs. Therefore, the following mathematical programming model is established:

$$\begin{aligned} \max \quad & R = \sum_{i=1}^{6} Q_{ti} P_{ti} - C_i , \\ s.t. \quad & P_{ti}^{\min} < P_{ti} < P_{ti}^{\max}, \ i = 1,...,6 \end{aligned} \quad (2)$$

where, $C_i, i = 1,...,6$ represents the cost of 6 types of vegetables. Then Question 2 can be solved by the above quadratic programming problem. Similarly, according to the requirements, Question 3 can be built as the following mathematical programming model:

$$\begin{aligned} \max \quad & R = \sum_{i=1}^{n} Q_i (P_i - C_i) * z_i \\ s.t. \quad & Q_i \geq 2.5 \\ & 27 \leq \sum_{i=1}^{n} z_i \leq 33 \\ & P_i^{\min} \leq P_i \leq P_i^{\max} \quad i = 1,...,n \\ & Q_i^{\min} \leq Q_i \leq Q_i^{\max} \quad i = 1,...,n \\ & z_i \in \{0,1\} \quad i = 1,...,n \end{aligned} \quad (3)$$

Obviously, Question 3 is a Mixed-Integer Nonlinear Programming (MINLP) model, in which the decision variables are both continuous (Real-valued) and discrete (Integer-valued), and several constraints are involved. This kind of problem is complicated and difficult to be solved by traditional optimization methods. Therefore, an artificial bee colony algorithm is constructed for constrained mixed integer programming.

B. Crop planting strategy problem

The C question of 2024 CUMCM is crop planting strategy problem, which is described as follows. [15]

Selecting suitable crops and optimizing planting strategies will facilitate field management, improve production efficiency and reduce planting risks. Taking a village in a mountainous area of North China as the background, it is necessary to select different planting crops for different plots (greenhouses) in the village, and the crops planted should meet various constraints, including but not limited to no repeat planting, planting pulses every three years. Combined with the background of the problem and the analysis of practical problems, the following problems need to be solved:

Question 1: Assuming that the future expected sales volume, planting cost, per mu yield and selling price of crops remain stable compared with 2023, the optimal planting plan from 2024 to 2030 is given considering the situation that unmarketable crops are wasted or sold at half price.

Question 2: Considering the trend of expected sales volume, yield per mu, planting cost and selling price of different crops over time, the optimal planting strategy for 2024~2030 is given.

Question 3: Considering the sustainability and complementary among crops, as well as the correlation between expected sales volume, selling price and planting cost, taking these factors into account, the optimal planting strategy for 2024~2030 is given, and compared with the result of question 2.

For solving the above questions, assume X_{ijk} is the decision variable, a_i is the area of the i th field, U_{ij} is the unit selling price, S_{ij} is the sales volume, C_{ij} is the planting costs, P_{ij} is yield per mu, s_{grain} is the number of food crops; s_{gbean} is the number of pulses food crops; s_{gveg} is the number for vegetable crops; s_{vbean} is the number of bean vegetable crops; $s_{mustard}$ is the number of Chinese cabbage, carrot and white radish; s_{mush} is the numbers of edible fungi. For the requirement "legume crops must be planted within three years" in the problem, a fertility vector f_i is introduced into the model, which represents the time between each plot (greenhouse) and the next need to plant legume crops, with an initial value of 6. For each crop planted, the value is reduced by 1, and for each full-season crop planted, subtract the value by 2. If the value is equal to 1 or 0, plant a bean crop in the plot. For the requirement of "no continuous cropping" in the problem, a vector p_i is introduced into the model to represent the crops planted in the corresponding plot in the second quarter of the previous year. The corresponding vector value is updated after the calculation is completed every year. Considering the requirements of the problem comprehensively, only one crop is planted in each plot. Flat dry lands, terraced fields and hillsides can only grow single-season grain crops. Irrigated land can grow a variety of vegetables (except Chinese cabbage, white radish and carrot) in the first season and Chinese cabbage, white radish and carrot in the second season, or single-season rice. Ordinary greenhouses can grow a variety of vegetables (except Chinese cabbage, white radish and carrot) in the first season and edible fungi in the second season. Smart greenhouses can grow a variety of vegetables in two seasons (except Chinese cabbage, white radish and carrot). Crops can not be planted in consecutive crops. Under the constraint conditions such as planting legumes in the plots with too low fertility, the integer constraint model is established as follows model (4) in view of the situation (1) that extra part of the crop is unsalable causing waste. Assume the constraints in model (4) construct a feasible set F so that the decision variable should fit, which can represented as $X \in F$. Therefore for case (2), the excess part is sold at 50% discount of the 2023 sales price, an integer constraint model is established as model (5).

According to the requirements of Question 2, random disturbance terms are introduced to the expected sales volume, yield per mu, planting cost and selling price of various crops in the model to reflect their uncertainties and potential planting risks. For Question 2, the model (4) of problem 1 is used as the basis of the model, and the matrix of expected sales volume, selling price, planting cost with perturbation items introduced is substituted to construct model (6) as follows, which represented as $\hat{S}_{ij}$, $\hat{U}_{ij}$ and $\hat{C}_{ij}$.

$$\begin{aligned}
\max \quad & \sum_{i=1}^{58}\sum_{j=1}^{41}\sum_{k=1}^{2} X_{ijk}(S_{ij}U_{ij} - a_i C_{ij}) \\
s.t. \quad & \sum_{j=1}^{41} X_{ijk} = 1, \qquad i \in \{1,2,...,58\}, k \in \{1,2\} \\
& \sum_{i\in\{\text{Flat dry lands, terraced fields,hillsides}\}} \sum_{j \notin S_{grain}} X_{ij1} = 0, \\
& \sum_{i\in\{\text{Flat dry lands, terraced fields,hillsides}\}} \sum_{j=1}^{41} X_{ij2} = 0, \\
& \sum_{i\in\{\text{Irrigated land}\}} \sum_{j \notin S_{veg} \wedge j \in \{\text{edible fungi}\}} X_{ij1} = 0, \\
& \sum_{i\in\{\text{Irrigated land}\}} \sum_{j=1}^{41} X_{ij2} = 0, \\
& \sum_{i\in\{\text{Irrigated land}\}} \sum_{j \in S_{mustard}} X_{ij2} = 0, \\
& \sum_{i\in\{\text{Ordinary greenhouses}\}} \sum_{j \notin S_{veg}} X_{ij1} = 0, \\
& \sum_{i\in\{\text{Ordinary greenhouses}\}} \sum_{j \notin S_{mush}} X_{ij2} = 0, \\
& \sum_{i\in\{\text{Smart greenhouses}\}} \sum_{j \notin S_{veg}} \sum_{k=1}^{2} X_{ijk} = 0, \\
& X_{i,p_j,1} = 0, \qquad i \in \{1,2,...,58\}, \\
& \sum_{j \in S_{gbean}} X_{ij1} = 1, \qquad i \in \{\text{Flat dry lands, terraced fields,hills ides}\} \wedge f_i \le 1, \\
& \sum_{j \in S_{vbean}} X_{ij1} = 1, \qquad i \in \{\text{Irrigated land, Ordinary greenhouses}\} \wedge f_i \le 1, \\
& \sum_{j \in S_{vbean}} \sum_{k=1}^{2} X_{ijk} = 1, \quad i \in \{\text{smart greenhouses}\} \wedge f_i = 0.
\end{aligned} \tag{4}$$

$$\begin{aligned}
\max \quad & \sum_{i=1}^{58}\sum_{j=1}^{41}\sum_{k=1}^{2} X_{ijk}(S_{ij}U_{ij} - a_i C_{ij} + \frac{1}{2}(a_i P_{ij} - S_{ij})U_{ij}) \\
s.t. \quad & X \in F.
\end{aligned} \tag{5}$$

$$\begin{aligned}
\max \quad & \sum_{i=1}^{58}\sum_{j=1}^{41}\sum_{k=1}^{2} X_{ijk}(\hat{S}_{ij}\hat{U}_{ij} - a_i \hat{C}_{ij}) \\
s.t. \quad & X \in F.
\end{aligned} \tag{6}$$

Question 3 adopts the same constraints as the optimization model in Question 1, and then makes the optimization model as the following model (7).

$$\begin{aligned}
\max \quad & \sum_{i=1}^{58}\sum_{j=1}^{41}\sum_{k=1}^{2} X_{ijk}(S_{ij}U_{ij} - a_i C_{ij}) + \sum_{j=1}^{41}\sum_{m=1}^{41}\sum_{k=1}^{2} \alpha_{jm} X_{ijk} X_{imk} \\
s.t. \quad & X \in F.
\end{aligned} \tag{7}$$

where α_{jm} is the reward/penalty term. If the correlation coefficient of crops is positive, it is 1, otherwise it is -1. The reward/penalty term is introduced here. If plant a complementary crop, the strategy is rewarded, and if plant a fungible crop, the strategy is penalized.

III. Artificial Bee Colony Algorithm

A. Basic principles of ABC algorithm

The ABC Algorithm is a swarm intelligence algorithm inspired by the foraging behavior of bees. The ABC algorithm simulates the collaborative behavior of bee colonies when searching for food resources to solve optimization problems. Here are the main features and principles of the ABC algorithm.

1. Basic principle: ABC algorithm is based on the foraging behavior of bees and regards the solution space of the problem as a potential food resource, and bees represent the individuals searching the solution space. Bees are divided into three types of roles: employed bees, onlooker bees, and scout bees. The employed bees and onlooker bees search for surrounding food resources, and the scout bees search for new sources of food.

2. Search process: The search process of the algorithm starts from initializing a group of artificial bees, randomly selecting the initial solution in the solution space, and

calculating the fitness value of the solution. The artificial bees then update their solutions by sharing information with other artificial bees and look for better solutions in a local search. The scout bees periodically select a solution to perturb and evaluate the quality of the perturb solution.

3. Fitness function: ABC algorithm is suitable for all kinds of optimization problems, just provide the fitness function, which is the evaluation criterion of the problem. The goal of the algorithm is to minimize or maximize the fitness function in order to find the best solution.

4. Bees collaboration: The ABC algorithm achieves collaboration through the exchange of information between employed bees, onlooker bees, and scout bees. ABC algorithm is a typical swarm intelligence algorithm. Due to its random search characteristics, ABC algorithm performs well in solving various optimization problems, especially for complex optimization problems without differentiable.

B. Modified search equation

For all the problems constructed in section 2, some modification need to be done in original ABC algorithm. Firstly, in the initial stage and scout bee stage, the food sources should be randomly constructed as follows:

$$z_{ij} = round\left(\frac{1}{1+e^{-z_j^{\min}+rand(0,1)(z_j^{\max}-z_j^{\min})}} - 0.06\right), \tag{6}$$

$$x_{ij} = x_j^{\min} + rand(0,1)(x_j^{\max} - x_j^{\min}), \tag{7}$$

where, z represents all the integer variables and x represents all the continuous variables.

Secondly, in the employed bee stage and onlooker bee stage, the food sources should be update by the following equations:

$$\tilde{z}_{ij} = round\left(\frac{1}{1+e^{-z_{ij}+\phi_{ij}(z_{ij}-z_{lj})}} - 0.06\right), \tag{8}$$

$$\tilde{x}_{ij} = \begin{cases} x_{ij} + \phi_{ij}(x_{ij} - x_{lj}), & if\ \tilde{z}_{ij} = 1, \\ x_{ij}, & otherwise, \end{cases} \tag{9}$$

where j is a random integer in $\{1,2,...,N\}$, $l \in \{1,2,...,SN\}$ is a randomly chosen index that has to be different to i, and ϕ_{ij} is a uniformly distributed real random number in the range [-1,1].

Finally, the probability of onlooker bee selected is described by equation (10), where $violation_i$ is the constraint violation value of the solution.

C. Constraint handling mechanism

The mathematical programming models constructed in mathematical contest in modeling are usually constraint optimization problems. There needs a proper constraint handling mechanism. The feasibility criterion is a constraint

$$p_i = \begin{cases} 0.5 + \left(\dfrac{fit_i}{\sum_{i=1}^{SN} fit_i}\right) \times 0.5 & if\ solution\ is\ feasible, \\ \left(1 - \dfrac{violation_i}{\sum_{i=1}^{SN} violation_i}\right) & if\ solution\ is\ infeasible, \end{cases} . \tag{10}$$

handling method proposed by Deb[16] in 2000. It is widely used by researchers because of its simple, convenient implementation and fast convergence speed. In the feasibility criteria, the following rules are used to compare individuals:

(1) Both individuals are feasible solutions, and the individual with the lowest objective function value is dominant.

(2) One individual is a feasible solution, the other is an infeasible solution, and the feasible individual is dominant.

(3) Both individuals are infeasible solutions, and the individual with a small degree of constraint violation is dominant.

D. The main steps of ABC

The specific steps of the ABC algorithm are as follows:

Algorithm 1: Artificial bee colony algorithm

Step 1: Set the current iteration $t = 1$, maximum number of iterations $max\,Gen$, initialize the population P_t by formula (6)-(7), and maximum number of mining $Limit = SN \times D$;

Step 2: In the employed bee phase, formula (8) - (9) and feasibility rule are used to update the population;

Step 3: Calculate the probability p_i of each food source according to formula (10); and the onlooker bees according to p_i select of food sources and search for new food sources using formula (8) - (9);

Step 4: Use the feasibility rule to retain better individuals between the old and new food sources and renew the population P_t;

Step 5: If there is a food source whose mining times are greater than Limit, a new food source is randomly initialized according to formula (6)-(7);

Step 6: Determine whether $t \le max\,Gen$ is satisfied. If yes, $t = t + 1$, go to Step 2; otherwise, output the global optimal solution.

IV. Experimental results and analysis

In order to test the feasibility of ABC algorithm for mathematical programming model of mathematical contest in modeling, the experiments are conducted on the mathematical programming problems in C question of CUMCM in 2023 and 2024.

A. C question of CUMCM in 2023

(1) Question 2

Using the modified ABC algorithm presented above, combined with the data of C question of CUMCM in 2023, the mathematical programming model (2) can be solved easily. According to the experiment results, it can be concluded that on the first day, the optimal price and total daily optimal replenishment of 6 kinds of vegetables are given in Table II.

Therefore, the predicted value of each day will use the optimal result of the previous day. Then, for the next 6 days, the optimal results will be obtained by solving model (2) based on the first day's optimal results. Table III and table IV show all the optimal results of the 7 days.

TABLE II
THE PRICE AND REPLENISHMENT IN FIRST DAY.

	Price	Replenishment
Cauliflower	9.6273	36.692423
Leaves	11.06	131.20884
Capsicum	20.0634	58.817614
Nightshade	10.6007	18.353579
Edible mushrooms	11.4465	72.856539
Aquatic rhizomes	7.9862	44.632099

(2) Question 3

From the model (3), we can see that it is a mixed integer nonlinear programming problem. By using the modified ABC algorithm, the experiment results of model (3) are shown in Table V. The replenishment quantity and price strategy of single vegetable product on July 1, 2023 can be seen from Table V. All the single item that was not selected on July 1, 2023 are not shown in Table V.

B. *C question of CUMCM in 2024*

(1) Question 1

Using the modified ABC algorithm presented above, combined with the data of C question of CUMCM in 2024, the mathematical programming model (4) and (5) can be solved for Question 1.

TABLE III
TOTAL DAILY REPLENISHMENT.

	Cauliflower	Leaves	Capsicum	Nightshade	Edible mushrooms	Aquatic rhizomes
Day 1	36.692423	131.20884	58.817614	18.353579	72.856539	44.632099
Day 2	35.451593	131.20884	46.943762	16.781162	76.208599	52.816506
Day 3	34.390135	131.20884	46.943762	15.621499	79.542737	61.663953
Day 4	33.481865	131.20884	46.943762	14.766367	82.858017	71.227631
Day5	32.705038	131.20884	46.943762	14.135562	86.155039	79.491007
Day 6	32.040452	131.20884	46.943762	13.963101	89.434636	79.491007
Day 7	31.471803	131.20884	46.943762	13.963101	72.856539	79.491007

TABLE IV
DAILY PRICING BY CATEGORY FOR THE COMING WEEK.

	Cauliflower	Leaves	Capsicum	Nightshade	Edible mushrooms	Aquatic rhizomes
Day 1	9.6273	11.06	20.0634	10.6007	11.4465	7.9862
Day 2	10.0852	11.06	32.2	12.5127	10.914	6.7259
Day 3	10.5099	11.06	32.2	14.3331	10.4312	5.7563
Day 4	10.9003	11.06	32.2	15.9849	9.9916	4.988
Day5	11.256	11.06	32.2	17.4225	9.5896	4.49
Day 6	11.5777	11.06	32.2	17.87	9.2205	4.49
Day 7	11.8667	11.06	32.2	17.87	8.8805	4.49

TABLE V
REPLENISHMENT VOLUME AND PRICING STRATEGY OF SINGLE ITEM.

Single Item	Price	Replenishment
White Jade Mushroom	11.20	232.586733
Spinach	6.50	38.74221474
Cordyceps flowers	6.00	9.94224
Tall melon	4.80	28.09937417
Seafood Mushrooms	2.30	18.99715892
Sweet potato tips	4.10	56.086268
Ginger, garlic, millet and pepper	3.40	38.56850317
Net lotus root	2.70	118.8162526
Water caltrop	2.70	76.34323357
Black fungus	12.00	32.08643125
Colorful Peppers	3.50	82.07664755
Green and red Hangzhou pepper	11.90	16.30582904
Baby Cabbage	1.40	19.00750827
Field coronarium Artemisia	6.00	22.40551786
Wuhu green pepper	5.20	7.72719778
Broccoli	12.00	72.59353214
Western Gorge mushrooms	6.00	92.57301825
Amaranth	2.30	9.017200593
Baby greens	1.20	28.33724439
Crab-flavored mushrooms	24.00	216.1648061
Round Eggplant	2.90	5.863707937
Yunnan lettuce	8.00	64.18932146
Yunnan romaine lettuce	9.20	12.29653234
Long-line eggplant	13.00	110.3230642
Branch Jiangqing stem loose flower	8.00	100.3403355
Bamboo leaf vegetables	14.00	50.827392

The modified ABC algorithm has two parameters: the maximum number of iterations and the number of food sources. The number of food sources is 20 and the maximum number of iterations is 200. The optimal profits of each strategy are shown in Table VI and Table VII. And the profit curve are given in Fig. 1 and Fig. 2.

TABLE VI
OPTIMAL STRATEGY AND PROFIT FOR QUESTION 1 CASE 1

Year	Profit
2024	4952508.25
2025	3294724.25
2026	3273267.75
2027	3271651.75
2028	3387486.25
2029	4654162.75
2030	4660093.75

TABLE VII
OPTIMAL STRATEGY AND PROFIT FOR QUESTION 1 CASE 2

Year	Profit
2024	8291424.75
2025	7589258.75
2026	5960373.13
2027	8013535.38
2028	6758478.50
2029	7839623.88
2030	7909450.75

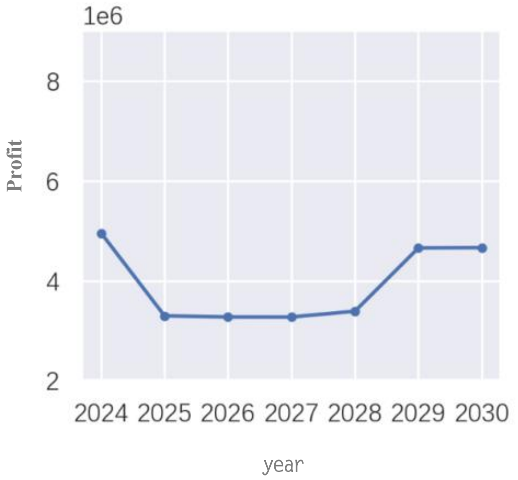

Fig. 1. Optimal strategy and profit for Question 1 case 1.

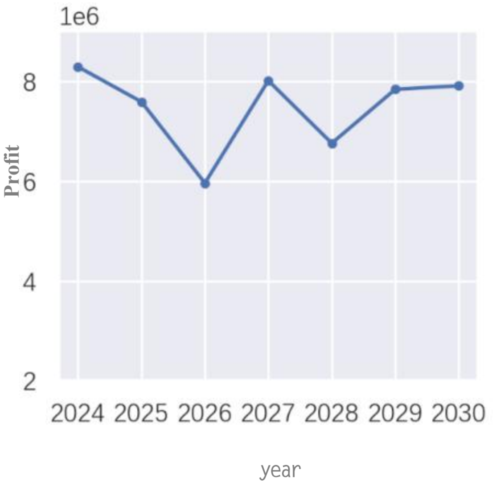

Fig. 2. Optimal strategy and profit for Question 1 case 2.

From Table VI-VII and Fig. 1-2, it can be seen that the profit obtained when extra goods are sold at half price is much higher than the profit when extra goods are wasted, so the extra goods should be sold at half price.

(2) Question 2

For the Question 2, different maximum iterations are tested, and it is finally determined that the effect is better and the profit is higher after 50 iterations.

TABLE VIII
OPTIMAL STRATEGY AND PROFIT FOR QUESTION 2

Year	Profit
2024	3543883.34
2025	4882480.88
2026	4667780.91
2027	8105325.51
2028	9398628.40
2029	12711306.44
2030	16656257.95

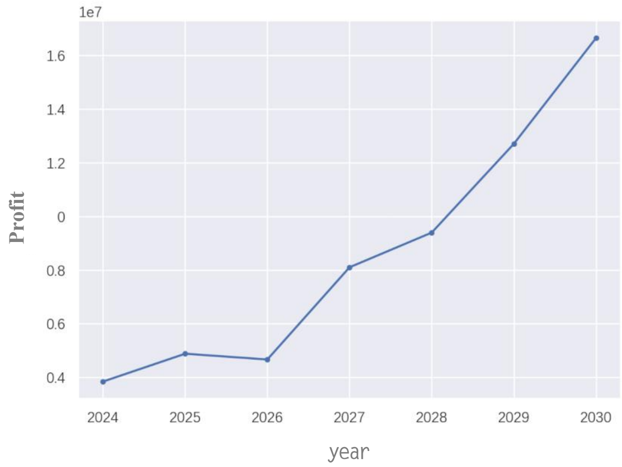

Fig. 3. Optimal strategy and profit for Question 2.

According to Table VIII, the total profit of this strategy is 60265663.43, and the average annual profit is 8609380.49. The profit is satisfactory. From Fig. 3, it can be seen that the profit increases gradually with each year.

(3) Question 3

The modified ABC algorithm is used again to solve Question 3. The maximum number of iterations is 20. The profit of the strategy is shown in Table IX. From Table IX, it is shown that the profit increases gradually with each year.

TABLE IX
THE OPTIMAL STRATEGY AND PROFIT OF PROBLEM 3

Year	Fitness	Profit	Fitness - profit difference (sum of rewards and penalties)
2024	4274170.11	4274071.42	98.69
2025	3795196.88	3795098.36	98.52
2026	4080539.80	4080414.40	125.4
2027	6538861.08	6538787.13	73.95
2028	7419380.32	7419271.66	108.66
2029	11959336.34	11959240.88	95.46
2030	14121122.32	14121043.82	78.5

V. CONCLUSIONS

Aiming at the mathematical programming model established in mathematical contest in modeling, this paper proposes an algorithm based on ABC algorithm. Through the analysis of the practical application results in the recent two mathematical contest on modeling, the ABC algorithm is feasible and effective to solve this kind of problems. Therefore, ABC algorithm can be properly used in mathematical contest on modeling, which can effectively solve the problem and increase the reliability of the model.

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