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Linear programming model of university canteen management

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Abstract: It is necessary to research the optimized management models of university canteen management. The optimized management models can improve operational efficiency, student satisfaction and campus life quality, and provide important reference and support for the improvement and development of campus catering services. Based on the balanced nutrition of students' meals, a linear programming model is established in this paper. The goal function of the linear programming is to maximize the canteen profit and students' satisfaction with dishes. The optimal solution of linear programming model achieves a win-win situation for the canteen, teachers and students. The research result of this article provides a new method for university canteen management.

1. Question raised

Dietary issues are an important part of university life. As the quality of life of our people continues to improve, students' nutritional intake has attracted increasing attention. In terms of balancing the economic benefits of canteens and student needs, our universities have insufficient strategic reserves. On the basis of ensuring the nutritional intake of college students [1], how to maximize the profits of the canteen and maximize student satisfaction with the dishes is the main issue in university canteen management. The linear programming model provides decision support and a scientific basis for optimizing university canteen management[2]. This article takes the planning and management of the university cafeteria as the starting point, establishes a linear programming model, and uses the mathematical software LINGO to solve the programming problem, and gives the optimal cafeteria management plan. It provides a reference strategy for better improving students' dining satisfaction and provides data support for formulating cafeteria management for the school.

2. A linear programming model

Now we take a representative cafeteria window in colleges and universities as the research object. The cafeteria window has a certain initial capital as cost expenditure, a fixed menu list, and a certain amount of dishes. Students' satisfaction with various dishes in this window can be obtained through questionnaire surveys. Taking the nutritional needs of students and the amount of food that can be supplied by the canteen window as constraints and using the maximum profit of the canteen window and the highest student satisfaction as the objective function, we establish a linear model to give the optimal portion of each dish ,which can improve the operating efficiency of the canteen and student satisfaction, and reduce benefit losses caused by improper decision-making.

Now suppose that the canteen window launches m kind of dishes, which is recorded as $A_i(i = 1,2,3,\ldots,m)$, the number of copies sold for each dish is recorded as $x_i(i = 1,2,3,\ldots,m)$, the total number of raw materials is recorded as $B_j(j = 1,2,3,\ldots,n)$, the amount of raw materials used in these dishes is recorded as b_{ij} (the quality of the j ingredient in the i dish), the profit of each dish $P_i(i = 1,2,3,\ldots,m)$, the student's satisfaction with each dish is recorded as $S_i(i = 1,2,3,..,m)$, the daily supply of raw materials in the canteen is recorded as$C_j(j = 1,2,3,\ldots,n)$, the content of nutrients protein, fat, and carbohydrates required by students for a day is recorded asQ_p,Q_f,Q_c, nutrients in each dish protein, fat, and carbohydrates content is recorded asq_{ip},q_{if},q_{ic} (the amount of protein, fat, and carbohydrates contained in the i dish). In addition, there will be a variety of t dishes per meal per person to meet dietary needs, so it is assumed that the dishes$\sum_{i=1}^{m} x_i$ provided at the counter can be served to ($\sum_{i=1}^{m} x_i \div t$) students.

The weighted sum of the cafeteria profit maximization function and the student satisfaction function is set to the objective function, so that the objective function is obtained:

$$max\, H = \theta \sum_{i=1}^{m} P_i\, x_i + (1-\theta) \sum_{i=1}^{m} S_i x_i$$

Constraints:

$$s.t. \begin{cases} \sum_{i=1}^{m} b_{ij} x_i \le C_j, (j = 1, \ldots, n), \\ \sum_{i=1}^{m} q_{ip} x_i \ge 90\% Q_p * \sum_{i=1}^{m} x_i \div t, \\ \sum_{i=1}^{m} q_{ip} x_i \le 110\% Q_p * \sum_{i=1}^{m} x_i \div t, \\ \sum_{i=1}^{m} q_{if} x_i \ge 90\% Q_f * \sum_{i=1}^{m} x_i \div t, \\ \sum_{i=1}^{m} q_{if} x_i \le 110\% Q_f * \sum_{i=1}^{m} x_i \div t, \\ \sum_{i=1}^{m} q_{ic} x_i \ge 90\% Q_c * \sum_{i=1}^{m} x_i \div t, \\ \sum_{i=1}^{m} q_{ic} x_i \le 110\% Q_c * \sum_{i=1}^{m} x_i \div t, \\ x_i \ge 0, i = 1, \ldots, m. \end{cases}$$

Among them, the first constraint limits the consumption of various raw materials not to exceed the supply. It is known from the literature [3] that the caloric intake is usually allowed to have a 10% error, and the overall nutrient intake is maintained at 90% to 110%. The second and third constraints limit the ingestible protein to 90% to 110% of the required amount. The fourth and fifth constraint conditions limit the ingestible fat to 90% to 110% of the required amount. The sixth and seventh constraints limit the ingestible fat to 90% to 110% of the required amount. This constraint limits the amount of carbohydrates that can be consumed to 90% to 110% of the required amount.

3. Analysis of simulation examples

3.1. Data collection

Now the one-day lunch at Daoxiang window in the cafeteria of Dalian Minzu University is used as the research object, with 14 kinds of dishes (A_i) and 18 kinds of raw materials (B_j), that is obtained in the following Table 1 & Table 2: $m = 14, n = 18$.

Table 1 Name of dishes

A_i	A_1	A_2	A_3	A_4	A_5	A_6
dish	Sauteed Tofu Sheets with Chili Pepper	Scrambled eggs with tomatoes	Double Cooked Pork Slices	Shredded fish-flavored pork	Stir-fried fungus with winter melon	Kung pao chicken
A_i	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}
dish	Stir Fried Eggplant, Potato and Pepper	Stir Fried Pork with Peppers	Boiled pork slices	Saliva Chicken	Fried Broccoli with Plain	Fried Lettuce with Plain

Table 2 Name of raw materials

B_j	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9
raw materials	chili Pepper	tofu Sheet	tomato	egg	carrot	lean meat	green Chinese onion	black fungus	wax gourd
B_j	B_{10}	B_{11}	B_{12}	B_{13}	B_{14}	B_{15}	B_{16}	B_{17}	B_{18}
raw materials	cucumber	corn kernels	potato	egg plant	green bean sprouts	chicken	broccoli	lettuce	ribs

Through on-the-spot research, the market prices of various vegetable markets in Jinzhou District, Dalian City were averaged to participate in the establishment of the model. After interviewing and questioning the person in charge of purchasing at Daoxiang Canteen, the data on the supply of food ingredients were obtained in the following Table 3:

Table 3 Market unit price of raw materials k_j (yuan/500g), raw material supply per meal C_j (kg)

B_j	k_j	C_j
B_1	3.13	36
B_2	4.25	42
B_3	4.5	20
B_4	4.57	30
B_5	2.25	90
B_6	13.25	100
B_7	1.7	6
B_8	40	15
B_9	1.8	26
B_{10}	4.75	10
B_{11}	2.25	18

B_{12}	2.25	22
B_{13}	3.5	16
B_{14}	1.2	9
B_{15}	12	24
B_{16}	3.2	20
B_{17}	3.2	30
B_{18}	15.75	20

The selling price data of the dishes obtained through actual collection are as follows Table 4:

Table 4 Price of dishes (yuan/portion)

A_i	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}
M_i	3	4	5	5	4	5	3	3	4	5	5	4	4	6

The calculated dish profit data table is as follows Table 5:

Table 5 Profit of dishes (yuan/portion)

A_i	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}
P_i	1	1.7	1.7	0.9	1.1	2	1.8	1.8	1.1	1.9	2.0	1.7	1.5	2

Among them, the profit of each dish, $P_i = M_i - \sum_{j=1}^{18} k_j b_{ij}$,$(i = 1,2,3,\dots,14)$, profit = selling price – cost, the cost of each dish is sum of the products of the market unit price of the various raw materials required (denoted ask_j,$j = 1,2,3,..,18$) and its required portion (denoted asb_{ij}, the mass of the j ingredient in the i dish).

Through the preparation and distribution of questionnaires to students of Dalian University for Nationalities, the sum of the data collected and the satisfaction data obtained are as follows Table 6:

Table 6 Students' satisfaction with dishes

A_i	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}
S_i	0.73	0.75	0.74	0.76	0.72	0.75	0.74	0.76	0.75	0.76	0.77	0.74	0.74	0.77

Among them, the questionnaire surveyed students from four aspects of taste, nutritional intake, portion, and price of the dishes. With 0 as extremely dissatisfied and 1 as very satisfied, the students were rated between 0 and 1 to obtain the above data.

Through research and inquiries from the person in charge of catering at Daoxiang Canteen, the data on the content of the dishes is obtained in the following Table 7:

Through the Food Nutrient Inquiry Platform, a food nutrient inquiry website authoritatively released by the Chinese Nutrition Society and the Nutrition and Health Institute of the Chinese Center for Disease Control and Prevention, the following data were collected in the following Table 8, Table 9&Table 10:

Table 7 The mass of the j ingredient in the i dish (g/portion)

A_i \ B_j	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}
B_1	100	0	0	0	0	0	0	30	30	0	0	0	10	10

B_2	150	0	0	0	0	0	0	0	0	30	0	0	0	30
B_3	0	100	0	0	0	0	0	0	0	0	0	0	0	20
B_4	0	150	0	0	0	0	0	0	0	0	0	0	0	0
B_5	0	0	120	80	0	30	100	0	0	0	0	90	0	30
B_6	0	0	100	80	0	100	0	0	100	95	0	0	0	0
B_7	0	0	10	0	0	0	0	0	0	0	10	0	0	10
B_8	0	0	0	20	30	0	0	0	0	0	0	15	20	0
B_9	0	0	0	0	130	0	0	0	0	0	0	0	0	0
B_{10}	0	0	0	0	0	20	30	0	0	0	0	0	0	0
B_{11}	0	0	0	0	0	0	90	0	0	0	0	0	0	0
B_{12}	0	0	0	0	0	0	0	80	0	0	0	0	0	30
B_{13}	0	0	0	0	0	0	0	80	0	0	0	0	0	0
B_{14}	0	0	0	0	0	0	0	0	0	30	0	0	0	15
B_{15}	0	0	0	0	0	0	0	0	0	0	120	0	0	0
B_{16}	0	0	0	0	0	0	0	0	0	0	0	100	0	0
B_{17}	0	0	0	0	0	0	0	0	0	30	0	0	120	0
B_{18}	0	0	0	0	0	0	0	0	0	0	0	0	0	100

Table 8 Protein, fat and carbohydrate content per 100g of material d_{jp}, d_{jf}, d_{jc} (g)

B_j	d_{jp}	d_{jf}	d_{jc}
B_1	1.4	0.3	5.8
B_2	44.6	17.4	18.8
B_3	0.9	0.2	4
B_4	13.3	8.8	2.8
B_5	1	0.2	8.8
B_6	20.3	6.2	1.5
B_7	1.7	0.3	6.5
B_8	12.1	1.5	65.6
B_9	0.4	0.2	2.6
B_{10}	0.65	0.11	3.63
B_{11}	9.42	4.74	74.26
B_{12}	2	0.2	17.2
B_{13}	1.1	0.2	4.9
B_{14}	2.1	0.1	2.9
B_{15}	20.29	18.86	0.4

B_{16}	2.82	0.37	6.64
B_{17}	1.4	0.4	2.1
B_{18}	15.47	23.4	0

Table 9 Nutrient composition data table of rice

Nutritional content per 100g of rice	Protein/g	Fat/g	Carbohydrate/g
	2.6	0.3	25.9

Table 10 Nutrient composition data table of peanut oil

Nutritional content per 100g of peanut oil	Protein/g	Fat/g	Carbohydrate/g
	0	99.9	0

In view of the actual situation, in addition to absorbing nutrients through each dish, the window usually provides 100g per person per serving of rice, and the per capita intake of peanut oil is 11g, so when calculating, we include the nutritional content of rice and peanut oil into the nutrients students need to consume, and do not include the nutritional content of dishes. According to the Reference Intake of Dietary Nutrients for Chinese Residents (2023 Edition) [4], the protein content required for people aged 18 to 29 years old is 60g (15%) and the fat content is 100g (25%) per day, the carbohydrate content is 230g (57.5%). According to the literature [3], the caloric distribution of breakfast, lunch and dinner is $1:2:2$, then the protein, fat and carbohydrate required for lunch for college students are 24g, 40g and 92g per day. Based on the above calculation, the nutritional content of protein, fat and carbohydrate required for students' daily lunch is calculated, protein content Q_p, fat content Q_f, carbohydrate content Q_c, that is:

$$Q_P = 24 - 2.6 = 21.4(g), Q_f = 40 - 0.3 - 11 = 28.7(g), Q_c = 92 - 25.9 = 66.1(g)$$

Through calculation, the nutritional composition data of each dish is obtained in the following Table 11:

Table 11 Protein, fat and carbohydrate content q_{ip}, q_{if}, q_{ic} (g) in each dish

A_i	A_1	A_2	A_3	A_4	A_5	A_6	A_7
q_{ip}	69.1	20.85	21.67	19.46	4.15	20.37	9.673
q_{if}	26.4	13.4	6.47	5.42	0.71	6.282	4.499
q_{ic}	34	8.2	12.71	21.36	23.06	4.866	76.723
A_i	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}
q_{ip}	2.9	20.72	33.715	24.518	5.535	4.24	30.555
q_{if}	0.41	6.29	11.26	22.662	0.775	0.774	28.855
q_{ic}	19.42	3.24	8.565	1.13	24.4	21.668	15.905

Among them, the content of protein, fat, and carbohydrates contained in the i dish q_{ip}, q_{if}, q_{ic}, $q_{ip} = \sum_{j=1}^{18}(b_{ij}d_{jp} \div 100)$, $q_{if} = \sum_{j=1}^{18}(b_{ij}d_{jf} \div 100)$, $q_{ic} = \sum_{j=1}^{18}(b_{ij}d_{jc} \div 100)$, the nutrient protein content of each dish = the protein content of various raw materials per unit amount $(d_{jp} \div 100)$and the mass of the raw materials(b_{ij}) ,the sum of the products. The fat and carbohydrate contents are similar.

3.2. Establishment of the linear programming model

In view of the fact that the canteen is essentially a profit-making enterprise, facing the student group, and satisfaction cannot be ignored, so we set the 3:2 weight sum of the canteen's profit maximization function and the student satisfaction function as the objective function, thus obtaining the objective function: $max\ H = 0.6\sum_{i=1}^{m} P_i\, x_i + (1-0.6)\sum_{i=1}^{m} S_i x_i$

To maximize canteen profits and student satisfaction while satisfying constraints, the following linear model is established:

$$max\ H = 0.6\sum_{i=1}^{m} P_i\, x_i + (1-0.6)\sum_{i=1}^{m} S_i x_i$$

$$s.t.\begin{cases} \sum_{i=1}^{14} b_{ij}x_i \le C_j (j = 1,2,3,\ldots,18), \\ \sum_{i=1}^{14} q_{ip}x_i \ge 90\%Q_p * \sum_{i=1}^{14} x_i \div 2, \\ \sum_{i=1}^{14} q_{ip}x_i \le 110\%Q_p * \sum_{i=1}^{14} x_i \div 2, \\ \sum_{i=1}^{14} q_{if}x_i \ge 90\%Q_f * \sum_{i=1}^{14} x_i \div 2, \\ \sum_{i=1}^{14} q_{if}x_i \le 110\%Q_f * \sum_{i=1}^{14} x_i \div 2, \\ \sum_{i=1}^{14} q_{ic}x_i \ge 90\%Q_c * \sum_{i=1}^{14} x_i \div 2, \\ \sum_{i=1}^{14} q_{ic}x_i \le 110\%Q_c * \sum_{i=1}^{14} x_i \div 2, \\ x_i \ge 0, i = 1, \ldots, 14. \end{cases}$$

Since the protein contentQ_p,fat contentQ_f, and carbohydrate content $Q_c$are the nutrients a student needs at noon a day, through surveys, each person has two dishes for each meal to meet their dietary needs. Based on this, it is inferred that the portions provided by the window $\sum_{i=1}^{14} x_i$Dishes can be supplied to $(\sum_{i=1}^{14} x_i \div 2)$ students.

3.3. Data analysis

We use the mathematical software LINGO to solve the programming problem. The optimal solution is x1=0, x2=0, x3=0, x4=0, x5=200, x6=0, x7=96, x8=200, x9=0, x10=249, x11=200, x12=200, x13=187, x14=102.

In view of the fact that this linear programming model maximizes canteen profits and student satisfaction under the conditions of satisfying nutritional constraints, the optimal number of servings of each dish can be obtained by solving:

Among them, the optimal solution for the number of dishes A_1 andA_2, A_3, A_4, A_6, A_9 is 0, the optimal solution for the number of dishesA_5, A_8, A_{11}, A_{12} is 200, the optimal solution for the number of dish A_7 is 96, the optimal solution for the number of dish A_{10} is 249, the optimal solution for the number of dish A_{13}score is 187, and the optimal solution for the number of dish A_{14} is 102.

The premise of the conclusion of this project is to ensure that the nutritional intake is reasonable and the consumables are within the supply, and then the comprehensive goal. The protein content of each serving of A_1 Sauteed Tofu Sheets with Chili Pepper is 69.1g, which is far more than half of the protein intake standard of 10.7g per person in this example (there will be two dishes per person per meal to meet dietary needs).It does not meet the nutritional constraints, and compared with other dishes, it ranks second to last with a profit of 1 yuan per serving and the satisfaction value of 0.73 ranks second to the bottom, and finally the optimal solution is 0.The carbohydrate content of A_2scrambled eggs with tomatoes is 8.2g per serving, which is far less than half of the carbohydrate intake standard of 33.05g.It does not meet the nutritional constraints, and with the profit value of 1.7 yuan per portion and the satisfaction value of 0.75,which is ranked neither high nor low, finally the optimal solution is 0. The protein and fat content of each serving of A_{10}boiled meat slices meet the nutritional intake standards, and the carbohydrate content is considerable compared with other dishes. With a higher profit value of 1.9 yuan per portion and a higher satisfaction value of 0.76, the best comprehensive comparison calculation is the optimal solution, 249, and the other optimal solutions are also based on the comprehensive nutritional content, consumables, profit value and Satisfaction values are obtained by comparing various aspects.

According to the results of this operation, it can be seen that this linear programming model, on the premise of ensuring students' healthy diet, takes the maximum profit of the canteen window and student satisfaction as the goal, and gives the optimal number of dishes for the Daoxiang canteen window. The linear programming model proposed in this article provides a tool for optimizing resource allocation for the management of college canteens, and provides a scientific and reliable basis for the management of college canteens.

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