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Dietary Planning Research Based on Enumeration and Simulated Annealing Algorithms

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Abstract. With the development of society and the improvement of living standards, people are paying more and more attention to healthy eating, especially among college students. Scientifically designing daily recipes which is used to solve the problem of nutritional imbalance when balancing economic benefits has become an important research topic. This study evaluates and adjusts the dietary recipes of male and female college students. The study establishes optimization models with the goals of maximizing protein and amino acid scores, minimizing meal costs, and the both. It also quantifies the values, scores, and meal costs of each protein and amino acid, and constructs a goal programming model with daily energy and nutrient intake as constraints. Based on the principle of balanced dietary recipe optimization design, it constructs an optimization model for goal programming, and uses the enumeration method to solve the problem, construct a 0-1 vector ti, and use Matlab to solve for the typical value ti. It further uses simulated annealing algorithm to enumerate in this numerical direction to obtain the results, and evaluates the dietary nutrition of the daily diet.

Keywords: Dietary Nutrition Evaluation; Goal Programming; Enumeration Method; Simulated Annealing Algorithm.

1. Introduction

With the continuous development of society and the improvement of living standards, people's attention to healthy eating is increasing day by day. Especially among college students, the problem of imbalanced nutrition intake is more common due to academic pressure, the fast pace of life, and unreasonable dietary structure. A reasonable diet is not only the foundation of ensuring physical health, but also an important factor in improving learning efficiency and quality of life. According to the "Chinese Food Composition Table", we can have a detailed understanding of the content of nutrients such as protein, amino acids, fats, carbohydrates, and minerals in various foods. By utilizing these data, daily recipes can be designed more scientifically to meet the nutritional needs of college students at different stages of life. However, how to choose a recipe that meets both nutritional needs and economic benefits from a wide range of foods has become a question worthy of in-depth research. In this research context, this study is of great significance in enhancing the scientific dietary awareness of contemporary college students, enhancing their ability to make good use of scientific dietary plans, and learning to adjust dietary plans.

To better select recipes, this study combined the enumeration method, simulated annealing algorithm, and objective programming algorithm. The basic idea is to list all possible scenarios and verify them one by one. If the conditions required by the problem are met, it is a solution to the problem, reducing computational complexity and improving computational efficiency [1]. Ma et al proposed an improved enumeration method for measuring points and studied the monitoring method of aerodynamic loads on offshore gravity wind turbine towers [2-3]. Simulated annealing algorithm is an optimization algorithm that simulates the annealing process in thermodynamic systems, using the objective function as the energy function to slowly cool high-temperature objects and minimize the energy state of their internal molecules. The stable state at this point is considered the global optimal solution of the algorithm. [4] Wu et al used a simulated annealing algorithm to optimize gratings and studied the generation and optimization of vortex optical arrays based on phase-type sine gratings [5-6]. Goal planning is an effective method for solving multi-objective management in enterprises. It is a mathematical method that searches for the solution with the minimum deviation from the target value given limited resources, based on several target values determined by the decision-maker in advance and their priority order of implementation. It is an operations research method aimed at achieving optimal decision results by setting goals and specifying planning schemes. This model is suitable for situations where there are multiple decision objectives and multiple decision options [7]. Fan et al constructed a multi-objective programming model to optimize the joint layout of charging stations and charging piles under interruption scenarios [8-10]. The above-mentioned studies have shown the feasibility and universality of using the enumeration method and simulated annealing algorithm for solving objective programming research.

This study calculates the content and values of protein and amino acids in various foods, obtains the amino acid score based on the amino acid value, and then constructs a planning model with the amino acid score as the objective function, daily energy intake, and nutrient intake as constraints to construct a goal planning model, and establishes an optimization model to maximize protein and amino acid score. Then, with the total meal cost as the objective function and daily energy and nutrient intake as constraints, a goal-planning model is constructed, and an optimization model is established with the most economical meal cost as the objective. Finally, considering both protein amino acid score and economy, establish an optimization model. Next, we first use the enumeration method to solve the planning model, randomly generate multiple 0-1 decision matrices ti using Matlab, and obtain the 0-1 decision matrices that meet the conditions. The study will further use a simulated annealing algorithm to enumerate in this numerical direction to obtain the results. Finally, we design the maximum protein amino acid score and the minimum total meal cost, as well as the daily diet for both boys and girls and evaluate the dietary nutrition of the daily diet.

2. Nutritional Content Data Processing and Analysis

The data for this study is sourced from http://shumo.neepu.edu.cn.According to the Chinese Food Composition Table, the content of protein, amino acids, fats, carbohydrates, and minerals is obtained. The total mass of each substance M * energy conversion coefficient * proportion of each nutrient component P is calculated. These values of each substance are added up, and then the amino acid score is calculated, taking the minimum value.

The definition of all selectable foods is as follows: if there are n types of foods, the corresponding weight is mi (i=1, 2, 3..., n). Then there exists hi as the decision factor. When hi is 1, it indicates that the i-th food is selected, and when hi is 0, it indicates that the i-th food is not selected

(1) Choose the total weight of food as M

$$M = \sum_{i=1}^{i=n} h_i m_i \tag{1}$$

(2) The proportion of protein content in food selection P_{rotein}

$$P_{protein} = \frac{\sum_{i=1}^{i=n} h_i m_i b_{1i}}{M} \tag{2}$$

Where b_{1i} represents the proportion of protein in the i-th food

(3) The proportion of fat content in food P_{fat}

$$P_{fat} = \frac{\sum_{i=1}^{i=n} h_i m_i b_{2i}}{M} \tag{3}$$

Where b_{2i} represents the proportion of fat in the i-th type of food

(4) The proportion of carbohydrate content in food selection P_{carb}

$$P_{carb} = \frac{\sum_{i=1}^{i=n} h_i m_i b_{3i}}{M} \tag{4}$$

Where b_{3i} represents the proportion of carbohydrates in the i-th food

(5) The proportion of fiber content in food selection P_{fibre}

$$P_{fibre} = \frac{\sum_{i=1}^{i=n} h_i m_i b_{4i}}{M} \tag{5}$$

Where b_{4i} represents the proportion of fiber in the i-th type of food

(6) The proportion of alcohol content in food selection P_{acohol}

$$P_{acohol} = \frac{\sum_{i=1}^{i=n} h_i m_i b_{5i}}{M} \tag{6}$$

Where b_{4i} represents the proportion of alcohol in the i-th type of food

(7) Total energy W

$$W = M\left(4 \cdot P_{protein} + 9 \cdot P_{fat} + 4 \cdot P_{carb} + 2 \cdot P_{fibre} + 2 \cdot P_{acohol}\right) \tag{7}$$

Let the numerical proportions of the main nutrients in the i-th food be: C_{1i}, C_{2i},..., C_{7i}

a. Calcium content

$$W_{\mathrm{Ca}} = \sum_{i=1}^{i=n} C_{1i} h_i m_i \tag{8}$$

b. The calculation formulas for other indicators are shown in equations 9-14

$$W_{\mathrm{Fe}} = \sum_{i=1}^{i=n} C_{2i} h_i m_i \tag{9}$$

$$W_{Zn} = \sum_{i=1}^{i=n} C_{3i} h_i m_i \tag{10}$$

$$W_{\mathrm{VA}} = \sum_{i=1}^{i=n} C_{4i} h_i m_i \tag{11}$$

$$W_{\mathrm{V}B1} = \sum_{i=1}^{i=n} C_{5i} h_i m_i \tag{12}$$

$$W_{\mathrm{V}B2} = \sum_{i=1}^{i=n} C_{6i} h_i m_i \tag{13}$$

$$W_{\mathrm{V}C} = \sum_{i=1}^{i=n} C_{7i} h_i m_i \tag{14}$$

The research needs to establish a goal programming model with amino acid score as the objective function, so it is necessary to refer to the amino acid score formula to quantify the score.

Set the ratio of various amino acids to e_{1i}, e_{2i}, ..., e_{zi}.

For the isocyanate score, there are

$$P_{\mathrm{lle}} = \frac{\sum_{i=1}^{i=n} h_i m_i e_{1i}}{M \cdot 40} \times 100 \tag{15}$$

$$P_{\mathrm{leu}} = \frac{\sum_{i=1}^{i=n} h_i m_i e_{2i}}{M \cdot 70} \times 100 \tag{16}$$

$$P_{\mathrm{lys}} = \frac{\sum_{i=1}^{i=n} h_i m_i e_{3i}}{M \cdot 55} \times 100 \tag{17}$$

$$P_{met} = \frac{\sum_{i=1}^{i=n} h_i m_i e_{4i}}{M \cdot 35} \times 100 \tag{18}$$

$$P_{\mathrm{AAA}} = \frac{\sum_{i=1}^{i=n} h_i m_i e_{5i}}{M \cdot 60} \times 100 \tag{19}$$

$$P_{thr} = \frac{\sum_{i=1}^{i=n} h_i m_i e_{6i}}{M \cdot 40} \times 100 \tag{20}$$

$$P_{\mathrm{trp}} = \frac{\sum_{i=1}^{i=n} h_i m_i e_{7i}}{M \cdot 10} \times 100 \tag{21}$$

$$P_{val} = \frac{\sum_{i=1}^{i=n} h_i m_i e_{8i}}{M \cdot 50} \times 100 \qquad (22)$$

The minimum amino acid score meets the condition, and other amino acid scores also meet the condition, so the amino acid score is P:

$$P = \min\left\{P_{lle}, P_{leu}, P_{lys}, ..., P_{val}\right\} \qquad (23)$$

3. Optimization and Cost Control of Daily Diet for University Students

a. Firstly, this study establishing a goal planning model with maximum protein amino acid score

max P

$$st.\begin{cases} 10\% \le P_{protein} \le 15\% \\ 20\% \le P_{fat} \le 305\% \\ 50\% \le P_{carb} \le 65\% \\ W_{goal}(1-10)\% \le P_{protein} \le W_{goal}(1+10)\% \\ W_{Fe} = 12 \\ W_{Ca} = 800 \\ \cdot \\ \cdot \\ \cdot \\ 25\% \le \frac{W_{\text{bre}}}{W} \le 35\% \\ 30\% \le \frac{W_{lun}}{W} \le 40\% \\ 30\% \le \frac{W_{din}}{W} \le 40\% \\ W = W_{bre} + W_{lun} + W_{din} \end{cases} \qquad (24)$$

b. Secondly, establishing an optimization model to maximize dining costs

The daily cost of purchasing food is P_{ost}

$$P_{\text{cost}} = \sum_{i=1}^{i=n} g_i h_i \qquad (25)$$

g_i represents the price corresponding to each piece of food

$$\min P_{\text{cost}} = \sum_{i=1}^{i=n} g_i h_i \qquad (26)$$

$$st.\begin{cases} 10\% \le P_{protein} \le 15\% \\ 20\% \le P_{fat} \le 305\% \\ 50\% \le P_{carb} \le 65\% \\ W_{goal}(1-10)\% \le P_{protein} \le W_{goal}(1+10)\% \\ W_{Fe} = 12 \\ W_{Ca} = 800 \\ \cdot \\ \cdot \\ \cdot \\ 25\% \le \frac{W_{\mathrm{bre}}}{W} \le 35\% \\ 30\% \le \frac{W_{lun}}{W} \le 40\% \\ 30\% \le \frac{W_{din}}{W} \le 40\% \\ W = W_{bre} + W_{lun} + W_{din} \end{cases} \tag{27}$$

c. Thirdly, constructing a multi-objective programming model that takes into account two conditions

$$\min P_{\mathrm{cost}} = \sum_{i=1}^{i=n} g_i h_i \tag{28}$$

max P

$$st.\begin{cases} 10\% \le P_{protein} \le 15\% \\ 20\% \le P_{fat} \le 305\% \\ 50\% \le P_{carb} \le 65\% \\ W_{goal}(1-10)\% \le P_{protein} \le W_{goal}(1+10)\% \\ W_{Fe} = 12 \\ W_{Ca} = 800 \\ \cdot \\ \cdot \\ \cdot \\ 25\% \le \frac{W_{\mathrm{bre}}}{W} \le 35\% \\ 30\% \le \frac{W_{lun}}{W} \le 40\% \\ 30\% \le \frac{W_{din}}{W} \le 40\% \\ W = W_{bre} + W_{lun} + W_{din} \end{cases} \tag{29}$$

Using the enumeration method, multiple 0-1 decision matrices ti are randomly generated using Matlab to obtain the 0-1 decision matrix that meets the conditions. The enumeration method obtains the direction of the objective programming solution, establishes a simulated annealing algorithm, and further enumerates multiple times to obtain more feasible solutions for the objective programming. The optimal solution is selected from the solutions. The recipes for college students calculated based on this are shown in Tables 1 and 2.

Table 1. Recipe table for male college students (requiring the highest protein and amino acid score)

Recipe	Food names	Main ingredients	Food coding	Edible parts (g/serving)	Serving number
breakfast	Boiled egg	egg	111101x	50	1
	Ravioli noodles	Wheat flour	011201x	50	6
		Pork lean	081110x	15	
		rape	045125	40	
		Soy oil	192004	10	
	grapes	grapes	063101x	100	1
lunch	Braised beef noodles	Wheat flour	011201x	50	8
		beef	082101x	30	
		rape	045125	40	
		Soy oil	192004	5	
	Fish ball soup	Fishball	121305	20	3
		spinach	045301	50	
		Sesame oil	192017	2	
	Honeydew melon	cantaloupe	066104	100	1
dinner	Stir-fried meat garlic table	Garlic table	044106	100	5
		pork	081111x	30	
		Soybean oil	192004	5	
	Braised Pollak tofu	tofu	031301x	150	5
		follow	121239	100	
		Soybean oil	192004	5	
	pomelo	pomelo	064301	100	1

Table 2. Recipe table for female college students (requiring the highest economy)

Recipe	Food names	Main ingredients	Food coding	Edible parts (g/serving)	Serving number
breakfast	pasty	Wheat flour	011201x	25	2
		beef	082101x	10	
		carrot	041201	10	
		Soybean oil	192004	10	
	Boiled egg	egg	111101x	50	1
lunch	Leek box	Wheat flour	011201x	20	2
		leeks	044404	40	
		egg	111101x	20	
		Soybean oil	192004	10	
	grapes	grapes	063101x	100	1
dinner	rice	rice	012001x	25	0.5
	Fish ball soup	Fishball	121305	20	3
		spinach	045301	50	
		Sesame oil	192017	2	

4. Conclusion

This article provides a research approach and framework applied to the field of nutrition, starting from the dietary recipes of male and female college students, which is used to evaluate and adjust them. It establishes optimization models with the goals of maximizing protein and amino acid scores, minimizing meal costs, and the both. The study quantifies the values, scores, and meal costs of each protein and amino acid, and constructs a goal programming model with daily energy and nutrient intake as constraints. Based on the principle of balanced dietary recipe optimization design, it constructs an optimization model for goal programming, and uses the enumeration method to solve the problem, construct a 0-1 vector ti, and uses Matlab to solve for the typical value ti. The study further uses simulated annealing algorithm to enumerate in this numerical direction to obtain the results, and evaluates the dietary nutrition of the daily diet.

This article establishes three models under the conditions of maximum protein amino acid score and minimum total meal cost, as well as the objective function under both conditions. Specific values are obtained by using the enumeration method and simulated annealing algorithm to obtain the daily diet of boys and girls, demonstrating the feasibility of dietary planning research based on the enumeration method and simulated annealing algorithm.

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