

Research on Evaluation and Optimization Design Based on Balanced Diet Recipes

Yuwei Cui *

Electric Power Engineering, Shanghai University of Electric Power, Shanghai, China, 200090

* Corresponding Author Email: ccx10611@163.com

Abstract. This paper mainly studies how to evaluate the recipe scheme and optimization problem of college students under the condition of existing college canteen food information. The focus is on the data processing of food information. The matrix representation of recipe selection is established, and a mixed integer nonlinear programming model is established. The bi-objective coordinated programming model and so on, according to the characteristics of BARON solution, the objective function is processed, and the balanced diet recipe constrained by food nutrition is obtained, and the results are analyzed and evaluated. According to the existing recipe scheme, based on the nutritional evaluation of five aspects, the weight vector of the scheme is obtained by progressive normalization, and the calculation score is obtained after the evaluation matrix of the scheme is obtained. Aiming at the problem of recipe planning with the largest protein amino acid score, an integer nonlinear programming model with the goal of protein amino acid score is established, and the goal is transformed according to the solution characteristics of BARON. An integer linear programming model with minimum cost is established to solve the most economical recipe planning problem. For taking into account the protein amino acid score and economic issues, a two-objective integer nonlinear programming model with the highest protein amino acid score and the lowest cost was established. According to the actual situation, the benchmark normalization process was set, and it was transformed into a single-objective integer nonlinear programming model. Finally, the advantages and disadvantages of the model proposed in the paper are studied in depth, and the model is promoted.

Keywords: Nonlinear Programming, Bi-objective Programming, Balanced Diet, Optimization for Design.

1. Introduction

College students are a special group that transitions from adolescence to adulthood. They are in a critical period of growth and development. They have relatively more mental and physical activities and need to continuously consume energy and various nutrients. Good eating habits and reasonable dietary structure are the solid foundation of college students' physical and mental health and learning life. The optimization design of the recipe is an important part of nutrition, and its core purpose is to design a healthy recipe that meets the user's preferences and nutritional needs. Literature ^[1] In the context of the elderly nutrition improvement action, the traditional Chinese medicine physique diet health is innovatively integrated into the modern nutrition catering, and the design and evaluation of one-day health recipes for the elderly in specific seasons are carried out. Reference ^[2] applied Chinese Lactation Dietary Balance Index (DBI-L) to evaluate the dietary quality of lactating mothers in puerperium in 5 cities. In Reference ^[3], the latest revision of China's dietary balance index (DBI) was carried out in order to better evaluate dietary nutrition. Literatures ^{[4]-[5]} are based on the latest version of the "Dietary Guidelines for Chinese Residents (2022)". According to the nutritional needs of college students, a scientific and reasonable one-week healthy diet for college students is designed by digital method. In Reference ^[6], eight representative dietary fiber complexes (DFC) with specific proportions in recipes were used as research objects, and ultrasonic-assisted enzymatic extraction was used. The optimal conditions of the extraction process were explored by single factor experiment and response surface experiment, and the basic components and physical and chemical properties were

analyzed. Reference ^[7] proposed a recipe intelligent optimization method based on interactive evolutionary computation and compared it with the traditional interactive genetic algorithm and food exchange method. It is verified that this method is superior to the comparison method in three aspects: personalized adaptability, effectiveness and usability. In the literature ^[8], taking the design of nutritional recipes as an example, nutrition and health education is developed to the whole school, and the students are guided to arrange their daily diet scientifically and reasonably, so as to truly achieve reasonable diet and balanced nutrition, so as to achieve the purpose of improving the health level of all students in school. Literature ^[9] established a multi-objective optimization model of dietary nutrition that can adapt to different genders, height, weight, age and other requirements according to the needs of individualized nutritional therapy and then used non-dominated sorting genetic algorithm II (NSGA-II) to solve the model. The experimental results show the effectiveness and feasibility of the model and algorithm, which is helpful to improve the accuracy of dietary recipe design. Literature ^[10] A stratified cluster sampling method was used to conduct a three-day dietary survey on 641 college students in a medical college, and the DBI scoring method was used to evaluate the dietary quality of college students. The experimental results show that the DBI evaluation system can comprehensively reflect the dietary quality of college students. Stratified cluster sampling is easy to organize and implement, easy to control the quality of the survey, timesaving, labor-saving, and money-saving, but the sampling is more troublesome, requires a lot of data, and the overall estimation from the sample is more complicated, which may affect the evaluation of dietary recipes. And the accuracy of the design. In order to solve this problem, this paper uses the method of mathematical modeling, three-layer progressive algorithm and global optimization algorithm to establish and solve the model according to the basic criteria of balanced diet and related quantitative requirements, so as to optimize and evaluate the balanced diet recipes of college students. The experimental results show that the evaluation and optimization model established in this paper is accurate, practical and close to reality. It can achieve better evaluation and optimization results through non-massive data, and the results are more accurate and reliable.

2. Three-layer progressive algorithm

2.1. Establishment of the model

According to the basic requirements of analysis, evaluation and optimization design of college dietary recipes, the daily recipes of male and female college students are analyzed. The three-layer optimization method is used to solve the score problem corresponding to each scheme. This paper uses a three-layer progressive algorithm to solve the problem. Fill out the nutritional elements corresponding to each recipe by querying the first and second volumes of the 'China Food Composition Table'; according to the daily recipe, various nutrients were calculated and summarized to form meal ratio, energy ratio of three meals, protein amino acid score and total energy intake, as shown in Fig.1, Fig.2 and Table 1. Finally, build the model.

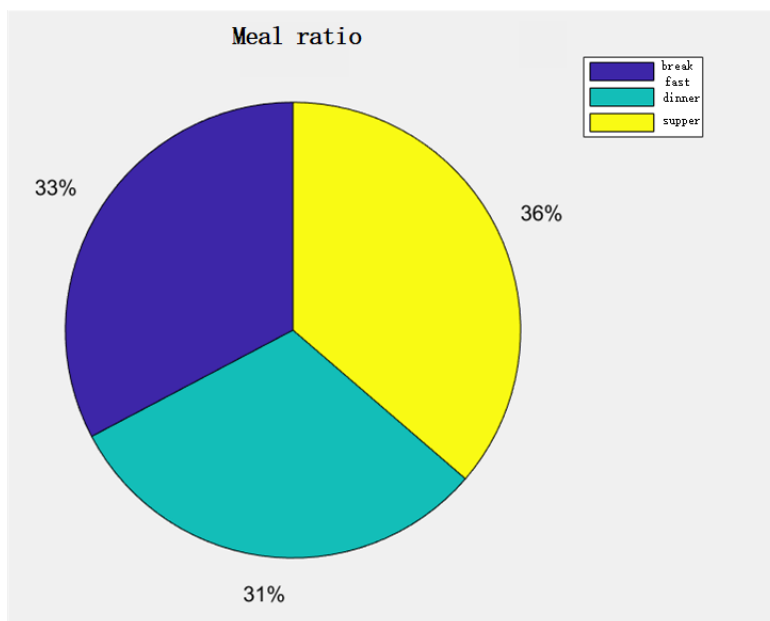


Figure 1. Girls' recipe meal ratio

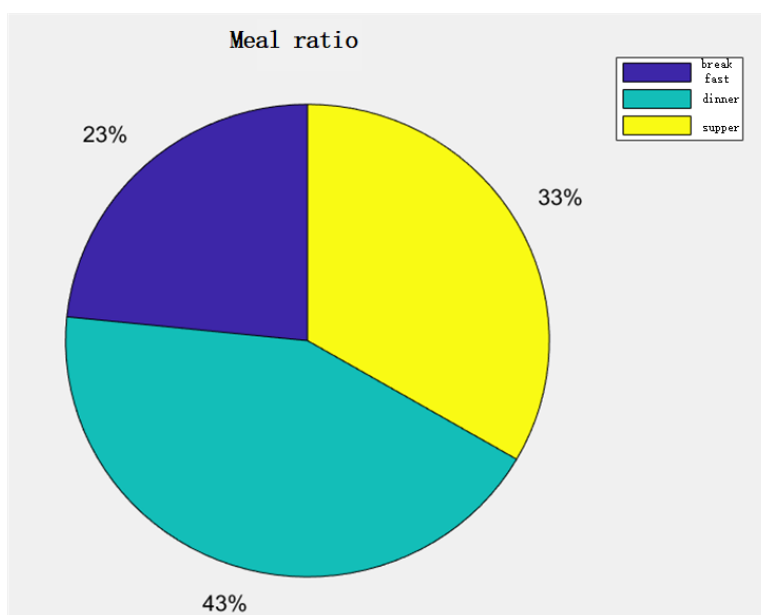


Figure 2. Men's recipe meal ratio

Table 1 Protein score and total energy intake

Protein score and total energy intake	
The proportion of three meals a day energy	30.32%:38.68%:31.00%
The proportion of energy of the three major nutrients	13.85%:28.98%:60.52%
Total energy of a day	1909.44 kilocalorie
One day total protein	66.11 kilogram
Total fat of the day	61.49 kilogram
Total carbohydrates in a day	288.89 kilogram
Minimum amino acid score for breakfast	77.93
Minimum amino acid score for dinner	58.94
Minimum amino acid score for supper	53.43

2.2. Solution of the model

Calculate the relevant parameters, initialize and read the data into the program; construct judgment matrix and comparison matrix; consistency test of the matrix, if the test does not pass, then reconstruct; after the normalization of the judgment matrix, the weights are obtained by the arithmetic average method. Comparing the matrix, the result is to obtain the weight vector of the scheme; by multiplying the weight matrix composed of the judgment matrix and the weight vector composed of the comparison matrix, the calculation score is obtained, and the output result is obtained.

The results of one-day recipes for boys are shown in Table 2:

Table 2 One-day recipe results for boys

One-day recipe results for boys	
Food species diversity score	0.96
Nutrient content diversity score	0.31
Dining proportion diversity score	0.58
Nutritional evaluation score	0.65
Amino acid score	0.75
The final score of the scheme	0.538161

2.3. Consistency check

First, construct a judgment matrix:

$$\begin{bmatrix} 1 & 2 & 9/4 & 7/4 & 3 \\ 2 & 1 & 9/5 & 11/10 & 3/2 \\ 4/9 & 5/9 & 1 & 11/10 & 13/10 \\ 4/7 & 10/11 & 10/11 & 1 & 11/10 \\ 1/3 & 2/3 & 10/13 & 10/11 & 1 \end{bmatrix}$$

Secondly, consistency tests are carried out. If $a_{ij} > 0$ and $a_{ij} \times a_{ji} = 1$ for each element in the matrix, then we call the matrix a positive reciprocal matrix. In the analytic hierarchy process, the judgment matrices we construct are all positive reciprocal matrices. If the positive reciprocal matrix satisfies $a_{ij} \times a_{jk} = a_{ik}$, we call it a consistent matrix. The consistency test results are shown in Table 3.

Table 3 Consistency test results

Judgment matrix	O	C1	C2	C3	C4	C5
Coincidence indicator	0.0666	0.0046	0.0123	0.0091	0.0046	0.0091
Consistency ratio	0.0594	0.0088	0.0236	0.0176	0.0088	0.0176
Whether to meet the consistency	Yes	Yes	Yes	Yes	Yes	Yes

The relative weight is calculated by the judgment matrix, and the score is calculated according to the weight matrix, and the order is sorted to select the recipe plan, as shown in Table 4.

Table 4 The weight matrix of each index

	Index weight	P1	P2	P3
C1	0.3507	0.5390	0.2973	0.1638
C2	0.2031	0.0982	0.3339	0.5679
C3	0.1530	0.4429	0.3873	0.1698
C4	0.1646	0.6327	0.1924	0.1749
C5	0.1286	0.2395	0.1373	0.6232

3. Global optimization algorithm

BARON (Branch-and-Reduce Optimization Navigator) is particularly good at dealing with Mixed-Integer NonLinear Programming (MINLP). It uses a powerful branch-and-bound and global optimization algorithm, which is suitable for finding the global optimal solution.

3.1. Establishment of optimal model

Taking the daily recipe as the decision variable and the protein amino acid score as the objective function, the optimization model is established as follows:

The objective function is the protein amino acid score maximization model.

$$\max(\min \text{AAS} = \sum_k \frac{\sum_{i,j} x_{i,j} \cdot \text{Essential amino acid content}_j}{\text{Reference protein amino acid content}_k \cdot \sum_i x_i \cdot \text{Protein content}_i}) \quad (1)$$

In the formula, AAS - amino acid score.

x_{ij} - Decision variables, indicating the weight of the i th food selected by the student in the j th meal (unit: gram) .

Constraint conditions:

(1) The daily energy intake target (girls 1900kcal / d, boys 2400kcal / d), the difference is within $\pm 10\%$.

$$0.9 \times E_{\text{target}} \leq \sum_{i,j} (x_{i,j} \cdot e_i) \leq 1.1 \times E_{\text{target}} \quad (2)$$

In the formula, E_{target} - daily energy intake target.

e_i - The calories of each food.

(2) Percentage of energy distribution of three meals to total energy, namely meal ratio (breakfast 25 % -35 %, lunch 30 % -40 %, dinner 30 % -40 %).

$$0.25 \leq \frac{\sum_i (x_{i,1} \cdot \text{Energy}_i)}{E_{\text{total}}} \leq 0.35 \quad (3)$$

$$0.30 \leq \frac{\sum_i (x_{i,2} \cdot \text{Energy}_i)}{E_{\text{total}}} \leq 0.40 \quad (4)$$

$$0.30 \leq \frac{\sum_i (x_{i,3} \cdot \text{Energy}_i)}{E_{\text{total}}} \leq 0.40 \quad (5)$$

In the formula, E_{total} - total energy intake per day.

(3) The main nutrient content of non-capacity is as close as possible to the reference intake, and the difference is within $\pm 10\%$.

$$0.9 \times 800 \leq \sum_{i,j} (x_{i,j} \cdot \text{Ca}_i) \leq 1.1 \times 800 \quad (6)$$

$$0.9 \times \text{Reference iron} \leq \sum_{i,j} (x_{i,j} \cdot \text{Fe}_i) \leq 1.1 \times \text{Reference iron} \quad (7)$$

$$0.9 \times \text{Reference zinc} \leq \sum_{i,j} (x_{i,j} \cdot \text{Zn}_i) \leq 1.1 \times \text{Reference zinc} \quad (8)$$

$$0.9 \times \text{Reference vitamin A} \leq \sum_{i,j} (x_{i,j} \cdot \text{VitaminA}_i) \leq 1.1 \times \text{Reference vitamin A} \quad (9)$$

$$0.9 \times \text{Reference vitamin B1} \leq \sum_{i,j} (x_{i,j} \cdot \text{Vitamin B1}_i) \leq 1.1 \times \text{Reference vitamin B1} \quad (10)$$

$$0.9 \times \text{Reference vitamin B2} \leq \sum_{i,j} (x_{i,j} \cdot \text{VitaminB2}_i) \leq 1.1 \times \text{Reference vitamin B2} \quad (11)$$

In the formula , Ca_i , Fe_i , Zn_i - the content of calcium, iron and zinc in each type of food ;

VA_i ——Vitamin A content of each type of food;

VB_{1_i} ——Vitamin B1 content of each type of food.

VB_{2_i} ——Vitamin B2 content of each type of food.

(4) The percentage of macronutrients in total energy (protein 10 % -15 % , fat 20 % -30 % , carbohydrate 50 % -65 %).

$$0.10 \leq \frac{\sum_i (x_{i,j} \cdot \text{Protein}_i) \cdot 4}{E_{total}} \leq 0.15 \quad (12)$$

$$0.20 \leq \frac{\sum_i (x_{i,j} \cdot \text{Fat}_i) \cdot 9}{E_{total}} \leq 0.30 \quad (13)$$

$$0.50 \leq \frac{\sum_i (x_{i,j} \cdot \text{CHO}_i) \cdot 4}{E_{total}} \leq 0.65 \quad (14)$$

In the formula, Protein_i - protein content in each type of food.

Fat_i - Fat content in each type of food;

CHO_i - Carbohydrate content in each type of food.

3.2. solution of the model

Firstly, each food-related parameter is calculated, initialized and the data is read into the program ; secondly, each target and demand are processed into a matrix form ; then, the objective function is established according to the protein amino acid score, and the log function is converted to set various constraints. Finally, by calling BARON to solve the integer nonlinear programming model, the calculation results are obtained, as shown in the table 5.

Table 5 The index scores of daily balanced diet recipes

Maximize protein amino acid score	145.4262
Minimize the total cost	40.7479
Taking into account the protein amino acid score and economy	-44.5638

Based on the nutritional composition data of breakfast, lunch and dinner dishes and the nutritional goals corresponding to gender, the model constructs three optimization goals: maximizing protein amino acid score, minimizing total cost, and taking into account the comprehensive goals of both. The constraints such as energy intake, macronutrient energy supply ratio, and non-capacity nutrient intake are set. The solution results give the optimal choice of three meals (in 100g) and the corresponding target values when achieving each goal. These results intuitively show the differences in dietary choices under different goals, which is helpful for making reasonable dietary decisions.

4. Conclusions

Aiming at the accuracy of college students' recipe design and optimization caused by the shortcomings of stratified cluster sampling method, this paper proposes a three-layer progressive algorithm and a global optimization algorithm. Based on the basic criteria and quantitative requirements of balanced diet, the energy supply ratio and protein score of each nutrient element in a college student's three meals a day are calculated, so as to evaluate and optimize the recipe of a college and establish a mathematical model. After a series of solutions and consistency tests, it is proved that the evaluation and optimization model established in this paper is accurate, practical and close to reality. It can achieve better evaluation and optimization effects through non-massive data. The results are accurate and reliable and can provide a certain reference for the design of comprehensive nutrition dietary recipes for college students. At the same time, the model can also be applied to other evaluation and optimization problems.

References

- [1] Cheng Xiaohua, Chen Jie, and Kong Haifeng. Design and Evaluation of Autumn Health Recipes for the Elderly with Yin Deficiency [J]. Food Industry, 2024, 45(06): 180-184.
- [2] Jiang Junyue, Huang Jiating, Su Yanyan, et al. Chinese Lactation Dietary Balance Index (DBI-L) was used to evaluate the dietary quality of puerperal lactating mothers in 5 cities [J]. Nutritional Journal, 2024, 46(01): 7-12+17.
- [3] He Yuna, Ye Chen, Fang Yuehui, et al. Revision of Chinese Dietary Balance Index: DBI_22 [J]. ACTA NUTRIMENTA SINICA, 2024, 46(03): 209-214.
- [4] Xue, Yang, Zhu. Design and evaluation of college students' visual health recipes [J]. Modern food, 2022, 28(21): 91-95.
- [5] Gao, Rosa, Zhao, et al. Evaluation of students' lunch recipes based on digital platform [J]. China School Health, 2022, 43(03): 359-362+366.
- [6] Shi Fengcui, Yu Xiaohan, Han Kunchen, et al. Optimization of extraction process and characteristics of dietary fiber complex in recipes of longevity population in Guangxi [J]. Food Industry Science and Technology, 2022, 43(14): 215-223.
- [7] Guo Guangsong, Xi Junjie, and Wen Zhenhua. Individualized recipe intelligent optimization system [J]. Computer Engineering and Design, 2021, 42(04): 1143-1150.
- [8] Na Rong, Duan Yan, Xu Rui, et al. Information-based instructional design and application of 'Food Nutrition and Health' course - taking 'Design of Nutritional Recipes' as an example [J]. Modern Food, 2020, (01): 31-34.
- [9] Kong Weijian, Wang Yongfang, Tong Zilei, et al. Nutrition optimization modeling and algorithm implementation of individualized diet for diabetic patients [J]. Journal of Shanghai University (Natural Science Edition), 2018, 24 (04): 583-591.
- [10] Shu Li, Zhao Wenhong, Wu Xuesen. Evaluation of dietary quality of medical college students by dietary balance index [J]. Journal of Bengbu Medical College, 2015, 40 (11): 1570-1572+1575.