On Search For Cost-Effective Balanced Meal Option in College Through Linear Programming

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Abstract

Having a balanced amount of macro and micro nutrient intake is essential for our health. As college students, however, it might be hard for us to eat a healthy and balanced diet on campus within our budget. We want to propose a linear programming model to help with this college diet problem. To make the problem simple, we will only consider macronutrients – carbohydrates, proteins, and fats. We will only use the grain bowl (priced by weight) at Union Market at the OSU campus as an example of where the student can eat from. We get our data about the grain bowl station macronutrients from the website Net Nutrition. Given a student's gender, height, weight, age, meal type, and activity level. We can calculate the recommended calories and macronutrients they need to take each day from the website Macro Calculator. Since our college students have limited budgets, our objective is to minimize the cost of the meal.

1 Introduction

Previous studies have demonstrated that nutrients are critical components of human bodies and that having the right amount of nutrient intake is an essential part of our health [1][2][3], especially for teenagers. While traditional studies normally focus on finding the optimal percentage of the intake of each nutrient kind, in this paper, we instead focus on a less-studied but practical issue: how to maximize the optimality of nutrient intake while minimizing the cost associated with it. This issue is particularly in the interest of college students who are in their teenage period but often have limited dining funds [4]. To this end, we propose a novel study of the best nutriments intake combination a student can achieve while minimizing the cost associated with it. Specifically, we calculate the recommended calories and macronutrients each student needs to take each day from the Macro Calculator [5][6] given their gender, height, weight, age, meal type, and activity level information. Taking the grain bowl section in the Union Market as an example, our study serves as health guidance for all OSU students and builds the foundation for more in-depth or personalized studies in the future. Please note that all our data in the following study are drawn from the following sites [7][8][9][5][6][10]. To summarize, our contributions are three-fold:

- We identify the practical problem regarding the balancing between necessary nutrient intake as well as dining funds and propose a novel study of the best dining combinations/options optimized toward the best nutrient intake and minimized cost.
- We formulate this problem as a Generalized Knapsack Problem in linear programming problem and solve for the best parameters in Python.
- We perform an analysis of our result and form a dinning-advisory for the current student while suggesting future study directions

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2 Motivation

In short, our project is motivated by the fact that the issue at stake is worth studying for the reasons stated in section 1 and can be solved using linear programming techniques. In fact, our result shows that linear programming can reach a optimal solution to our problem.

3 Problem Formulation

3.1 Method Description

We first calculate the daily recommended calories based on gender, weight, height, age, meal type, and activity level. Assume that this meal is for lunch. Then we get the proper calories by multiplying the suggested percentage of calories for lunch (40%). In addition, in order to provide a healthy meal, we need to meet the requirement of three macronutrients: carbohydrates, proteins, and fats. We achieve this by calculating the suggested serving for each macronutrient and make sure that the lunch we recommend can meet the requirement based on the nutrient data from the OSU Net Nutrition website [7]. We will form this question as a Generalized Knapsack Problem in LP problem and find the best solution in Python using Gurobi solver.

3.2 Assumptions

Several assumptions must hold for our project.

- The user must be a Ohio State student, who have limited dining funds and want to have a meal at the grain bowl station at the Union Market.
- The inputs of weight, height, age, gender, meal type, and activity level are known.
- The equations to calculate the recommended calories are correct.
- For each meal, we need 4 ounces of vegetables. Or, since vegetables do not contain much carbohydrates, protein, and fats, we would get 0 for the outcome.

3.3 Preliminaries

To calculate the cost-effective option for nutrient intake, we first need to know the optimal amount of total nutrient intake required, we term this as calories needed. Here we introduce our program in a step-wise manner.

Step 1 Our program starts by collecting basic information such as weight W, height H, age A, gender G, meal type M, and activity type V.

```
H = float(input("Please input your height(cm): "))
W = float(input("Please input your weight(kg): "))
G = input("Please input your gender(F/M): ")
A = int(input("Please input your age: "))
M = input("Which meal is it? (B for Breakfast / L for Lunch / D for Dinner): ")
V = input("What is your activity level?
(S for Sedentary / L for Lightly active / M for Moderately active / V for Very active / E for Extra active): ")
```

Step 2 We then use this information to calculate the Basal Metabolism Rate(BMR) through the BMR in Harris Benedict equations. There are two equations with different coefficients for calculating male and female's BMR.

$$Male : BMR = 66.5 + 13.8 * W + 5.0 * H - 6.8 * A \tag{1}$$

$$Female : BMR = 655.1 + 9.6 * W + 1.9 * H - 4.7 * A \tag{2}$$

Step 3 Then, we calculate the Total daily energy expenditure(TDEE) by multiplying the activity factor based on the activity level.

Activity Multiplier:

Sedentary(little or no exercise, desk job):
TDEE = BMR x 1.2
Lightly active(light exercise/ sports 1-3 days/week):
TDEE = BMR x 1.375
Moderately active(moderate exercise/ sports 6-7 days/week):
TDEE = BMR x 1.55
Very active(hard exercise every day, or exercising 2 hs/day):
TDEE = BMR x 1.725
Extra active (hard exercise 2 or more times per day, or training for marathon, or triathlon, etc.):
TDEE = BMR x 1.9

Step 4 After that, we calculate the recommended calories for the specific meal(breakfast/lunch/dinner) by multiplying TDEE by the percentage. The percentage is in a range, with upper percentage and lower percentage, to give some flexibility for the meal.

If you eat three meals a day, you should consume:

meal_calories_percentage:
25-30% of daily calories for breakfast
35-40% of daily calories for lunch
25-30% of daily calories for dinner

calories_upper= TDEE * meal_calories_percentage_upper
calories_lower = TDEE * meal_calories_percentage_lower

Step 5 We calculate the recommended grams of carbohydrates, proteins, and fats based on the percentage each of them takes in the daily calories and the calories each gram provides and get the recommended grams of carbohydrates, proteins, and fats for the meal.

Carbohydrates make up 40% of total daily calories
Proteins make up 30% of total daily calories
Fats make up 30% of total daily calories

Carbohydrates provide 4 calories per gram
Protein provides 4 calories per gram
Fat provides 9 calories per gram

carb_needed_lower = calories_lower*0.4/4
protein_needed_lower = calories_lower*0.3/4
fat_needed_lower = calories_lower*0.3/9

carb_needed_upper = calories_upper*0.4/4
protein_needed_upper = calories_upper*0.3/4
fat_needed_upper = calories_upper*0.3/9

For instance, for men, the required calories BMR can be calculated as (line 17 of the code). Similarly, we ask a series of questions to form a profile for the particular student. The following questions include how much they exercise, which can be used to determine the $TDEE$ (line 21-30 of the code). Importantly, studies have shown that calories needed for each meal in the day can be actually bounded by different factors. Meaning that as long as the calories needed fall into this range, the result is optimal. We also take this fact into consideration. We ask the user for the meal they were trying to get (breakfast, launch, or dinner) and calculate the respective bounds for calories needed (line 33-41 of the code).

3.4 Mathematical Formulation

We use the following decision variables:

c_i : staple food in ounce, $i \in [1:5]$
p_i : protein food in ounce, $i \in [1:2]$
ps : number of salmon (1 salmon = 7.18 ounce)
v_i : vegetable in ounce, $i \in [1:4]$
s_i : sauce in ounce, $i \in [1:4]$

Our problem can thus be formulated as:

$$Min.\ z = 9.5 * ((c_1 + c_2 + c_3 + c_4 + c_5) + (p_1 + p_2) + (v_1 + v_2 + v_3 + v_4) + (s_1 + s_2 + s_3 + s_4))/16 + 4.5 * ps \tag{3}$$

(we divide by 16 to convert ounce into pound)

(The price is $\$9.5/pound$, we multiply by 9.5 to get the price)

(The salmon is sold by per piece ($4.5/piece) not by the weight)

$$s.t.\ c_1 + c_2 + c_3 + c_4 + c_5 >= 0 \tag{4}$$
$$p_1 + p_2 >= 0 \tag{5}$$
$$v_1 + v_2 + v_3 + v_4 >= 4 \tag{6}$$
$$s_1 + s_2 + s_3 + s_4 >= 0 \tag{7}$$
$$ps >= 0 \tag{8}$$
$$c, p, ps, v, s >= 0 \tag{9}$$

Lower bounds:

$$8.17 * c_1 + 5.71 * c_2 + 5.83 * c_3 + 4.33 * c_4 + 6 * c_5 + 0.33 * p_1 + 1.25 * p_2 + 1 * v_1 + 1 * v_2 + 2 * v_3 + 3 * v_4 + 5 * s_1 + 5 * s_2 + 2 * s_3 + 2 * s_4 + 0 * ps >= carbNeededLower \tag{10}$$

$$0.83 * c_1 + 0.46 * c_2 + 1.33 * c_3 + 1 * c_4 + 0 * c_5 + 6 * p_1 + 3 * p_2 + 0 * v_1 + 0 * v_2 + 0 * v_3 + 0 * v_4 + 0 * s_1 + 0 * s_2 + 2 * s_3 + 3 * s_4 + 33 * ps >= proteinNeededLower \tag{11}$$

$$0.25 * c_1 + 0.03 * c_2 + 0.58 * c_3 + 1 * c_4 + 0 * c_5 + 1.67 * p_1 + 2 * p_2 + 1 * v_1 + 0 * v_2 + 2 * v_3 + 0 * v_4 + 1 * s_1 + 1 * s_2 + 1.5 * s_3 + 0 * s_4 + 34 * ps >= fatNeededLower \tag{12}$$

$$38.33 * c_1 + 24.57 * c_2 + 33.33 * c_3 + 31.67 * c_4 + 25 * c_5 + 43.33 * p_1 + 35 * p_2 + 20 * v_1 + 10 * v_2 + 25 * v_3 + 15 * v_4 + 30 * s_1 + 25 * s_2 + 20 * s_3 + 15 * s_4 + 440 * ps >= caloriesLower \tag{13}$$

Upper bounds:

$$8.17 * c_1 + 5.71 * c_2 + 5.83 * c_3 + 4.33 * c_4 + 6 * c_5 + 0.33 * p_1 + 1.25 * p_2 + 1 * v_1 + 1 * v_2 + 2 * v_3 + 3 * v_4 + 5 * s_1 + 5 * s_2 + 2 * s_3 + 2 * s_4 + 0 * ps <= carbNeededUpper \tag{14}$$

$$0.83 * c_1 + 0.46 * c_2 + 1.33 * c_3 + 1 * c_4 + 0 * c_5 + 6 * p_1 + 3 * p_2 + 0 * v_1 + 0 * v_2 + 0 * v_3 + 0 * v_4 + 0 * s_1 + 0 * s_2 + 2 * s_3 + 3 * s_4 + 33 * ps <= proteinNeededUpper \tag{15}$$

$$
\begin{gathered}
0.25 * c_1 + 0.03 * c_2 + 0.58 * c_3 + 1 * c_4 + 0 * c_5 + 1.67 * p_1 + 2 * p_2 + 1 * v_1 + \\
0 * v_2 + 2 * v_3 + 0 * v_4 + 1 * s_1 + 1 * s_2 + 1.5 * s_3 + 0 * s_4 + \\
34 * ps <= fatNeededUpper
\end{gathered} \tag{16}
$$

$$
\begin{gathered}
38.33 * c_1 + 24.57 * c_2 + 33.33 * c_3 + 31.67 * c_4 + 25 * c_5 + 43.33 * p_1 + 35 * p_2 + \\
20 * v_1 + 10 * v_2 + 25 * v_3 + 15 * v_4 + 30 * s_1 + 25 * s_2 + 20 * s_3 + 15 * s_4 + \\
440 * ps <= caloriesUpper
\end{gathered} \tag{17}
$$

4 Post Optimality Analysis

4.1 Results

Suppose we have two very different students, one is a female who is 19 years old, 155 cm tall, weighs 42kg, lightly active, and wants to get dinner, another is a make who is 22 years old, 195 cm in height, 90 kg in weight, very active, and wants to get lunch. For the female, 450 kcal calories are needed for her profile and our linear programming model yields that the most cost-effective option is to have 3.97 ounces of brown rice, 4.87 ounces of chipotle chicken, 2.67 ounces of tikka cauliflower, and 1.33 ounces of pickled red onion for a total of $7.63 without dinning dollar or $4.96 with dinning dollar. For the male, 1287 kcal calories are required for his profile and our optimization yields that the most cost-effective option for him is to have 13.01 ounces of brown rice, 10.74 ounce of chipotle chicken, 6.38 ounce of Tofu Sofritas, and 4 ounces of Tikka Cauliflower for a total of $20.26 without dinning dollar and $13.17 with dinning dollar.

Our results effectively demonstrated the legitimacy of our approach as the results are very close to the actual cost at the station. We also respectfully think that our results give the best dining option for OSU students because it gives a balanced diet that contains all the nutrients one might need but is also the cheapest in price. We also observed similar results when we tried different settings as well.

4.2 Future Studies

While we have established a baseline in finding the cost-effective dining option for students considering the balance of nutrient intake, there are several future studies can be carried out based on our study. First, different stations or restaurants can be considered. Second, different factors can be considered, for example, sleep, stress, and allergy factors. Third, bulking ordering could be considered. Last but not least, different meals for different weeks could be an interesting consideration as well. All in all, we hope our study shades light on the issue as well as the future study of this matter so that we can help OSU students become healthier while saving more.

References

[1] Derbyshire, E. Nutrition in pregnant teenagers: how can nurses help. *British journal of nursing*, 16(3):144–145, 2007.

[2] Koch, M., M. Naumann, E. Pawelzik, et al. The importance of nutrient management for potato production part i: Plant nutrition and yield. *Potato research*, 63(1):97–119, 2020.

[3] Salama, A., N. Esmail. Assessing nutritional awareness and dietary practices of college-aged students for developing an effective nutrition educational plan. *Canadian Journal of clinical nutrition*, 6(2), 2018.

[4] Henry, L. Understanding food insecurity among college students: Experience, motivation, and local solutions. *Annals of Anthropological Practice*, 41(1):6–19, 2017.

[5] author. Meal calories percentage. https://www.omnicalculator.com/health/meal-calorie#:~:text=25%2D30%25%20of%20daily%20calories,of%20daily%20calories%20for%20dinner, 2022 (accessed December 7, 2022).

[6] —. Harris-benedict calculator. https://www.omnicalculator.com/health/bmr-harris-benedict-equation, 2022 (accessed December 7, 2022).

[7] —. Net nutrition. https://dining.osu.edu/NetNutrition/1#, 2022 (accessed December 7, 2022).

[8] —. Equation for calories. https://www.thejakartapost.com/life/2016/09/27/how-to-calculate-your-ideal-calorie-intake.html, 2022 (accessed December 7, 2022).

[9] —. Calories per gram for carbohydrate, protein, and fat. https://www.nal.usda.gov/programs/fnic#:~:text=How%20many%20calories%20are%20in,provides%209%20calories%20per%20gram, 2022 (accessed December 7, 2022).

[10] —. Activity level multiplier. https://www.k-state.edu/paccats/Contents/PA/PDF/Physical%20Activity%20and%20Controlling%20Weight.pdf, 2022 (accessed December 7, 2022).

Appendices

A Link to video

The link to our video can be found here

B Link to GitHub repository

The link to our GitHub repository can be found here

C Work Distribution

Work was mostly evenly distributed among our group. Please note that although each member was assigned to lead a part, we jointly discussed all parts together. Maxine was the lead on video production. Yahui was the lead on information gathering and problem formulation. Jike was the lead on the report writing.