Minimizing Costs of Restaurants near Campus Subject to Nutrients Constraints

Xi Chen, Jingyan Xu, Eugene Li

Project Advisor: Professor Alan Frieze

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1 Abstract

Our research project aims to design a 5 day diet for adults by applying linear programming to minimize food cost at Piada and Chipotle with respect to optimizing nutrition. The nutrients considered are protein, carbohydrates, fat, sodium, and calories. We will create a program to calculate the nutrition required by every person sorted by gender. To make sure that the menus create the best result, we will use data collected from restaurants' web-based calculator to train our program. These data will be put in to spreadsheets with constraints for the amount of nutrients needed for each category. The spreadsheets will output the most optimized number of each menu items required while having the lowest cost. Taking as input answers to the specifically customized problems, the program will create the cheapest menu for an interval of 5 days satisfying the nutritional standard.

2 Introduction

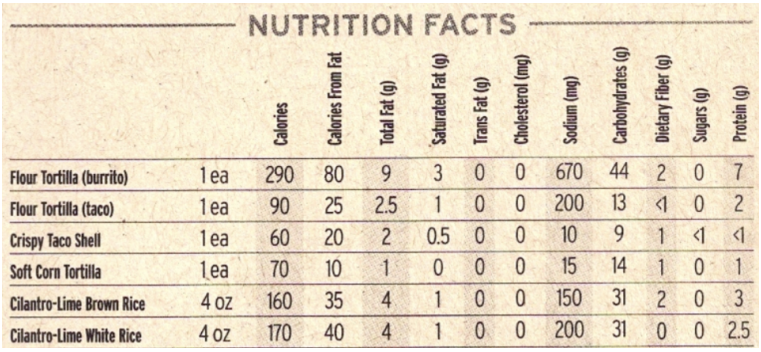
Students in Carnegie Mellon University have quite a few choices of food to choose from. However, how many of these choices are actually good in terms of being healthy and tasty? While the burgers from the University Center and the Chinese food from Inoodle are appealing at first, they get pretty bland and boring after you have had it for a few times. Furthermore, the amount of unhealthy nutrients in these foods are excessive. If you cannot have the tastiest and healthiest food in school, why not go out to have something better. Why not have foods that are cheaper! While we cannot calculate how tasty foods are, we can in fact calculate how healthy they are. The goal of this project is to create a system that allows students in Carnegie Mellon University to gain control of their diet by creating the healthiest and cheapest meal plans for 5 days.

The focus of this project will be mainly focused on Chipotle and Piada. The reason that we use these two restaurants is because their structures of selling foods are very similar in that customers pick their meal by choosing a combination of items with distinct nutrients. With this set up, we can easily create meals with regard to the nutritional standards for each day. We can easily extend our calculation to more restaurants by adding their menu items. We collected data of nutritional contents and ingredients of menu items from Chipotle and Piada from their web-based nutrition calculators. We sought to use linear programming to maximize healthy nutritional take-in while at the same time minimizing the cost.

We first take in to consideration the gender of the person. The daily nutrients for male and female are vastly different. While we did not create a system for female, it is as simple as taking the same table and change up number of sodium, calories, fats, carbohydrates, and proteins. Then, we set up constraints as to how much nutrients can be taken in daily for each gender. For example, the number of calories a male can take in is significantly higher than that of a female. Next, we will input the data from web-based nutrition calculator in to our table, showing the nutrients obtained from consuming each menu item. We make assumptions for the price of each individual item on the menu. In addition to these constraints, we need to limit the number of times a menu item can be used to prevent the system from generating a meal with an uneven number of items (e.g 83 lettuces, 0.1 meat, 0.1 noodle, 0.1 sauce for a meal would not be considered). We require that for every meal there be a staple, proteins, toppings, and sauces. For each run, we will run for two restaurants separately. Furthermore, after each run, we will not use the same staple and proteins for any future run. The goal of this is to create variety and not have the person eat the same exact meal every day. With all these constraints in mind, we will create the meal with the cheapest cost. Through this linear programming, we managed to create a 5 day meal plan for Carnegie Mellon University students.

3 Data

We retrieve nutrients data from Chipotle's official nutrition facts chart which records amount of different nutrients contained in each available item from Chipotle and similarly Piada's official nutrition facts. They are partially displayed in Figure 1 and Figure 2.



NUTRITION FACTS

		Calories	Calories From Fat	Total Fat (g)	Saturated Fat (g)	Trans Fat (g)	Cholesterol (mg)	Sodium (mg)	Carbohydrates (g)	Dietary Fiber (g)	Sugars (g)	Protein (g)
Flour Tortilla (burrito)	1 ea	290	80	9	3	0	0	670	44	2	0	7
Flour Tortilla (taco)	1 ea	90	25	2.5	1	0	0	200	13	<1	0	2
Crispy Taco Shell	1 ea	60	20	2	0.5	0	0	10	9	1	<1	<1
Soft Corn Tortilla	1 ea	70	10	1	0	0	0	15	14	1	0	1
Cilantro-Lime Brown Rice	4 oz	160	35	4	1	0	0	150	31	2	0	3
Cilantro-Lime White Rice	4 oz	170	40	4	1	0	0	200	31	0	0	2.5

Figure 1: Partial nutrition facts chart of Chipotle

	SEERVING SIZE	CALORIES	CALORIES FROM FAT	TOTAL FAT (G)	SATURATED FAT (G)	TRANS FAT (G)	CHOLESTEROL (MG)	SODIUM (MG)	POTASSIUM (MG)	CARBOHYDRATE	FIBER (G)	SUGARS (G)	PROTIEN (G)
PIADA DOUGH													
Piada Dough (Regular)	1 ea	320	81	9	3	0	0	410	0	52	2	6	8
Piada Dough (Kids)	1 ea	200	54	6	2	0	0	260	0	33	1	3	5
PASTA - *.5 oz pasta for Piada, 5 oz for small bowl & 7 oz for regular bowl*													
Angel Hair Pasta	1 oz	52	15	1.5	.5	0	0	90	0	8	0	0	1
SALAD - *2.5 oz for small salad & 4 oz for regular salad*													
Mixed Greens	1 oz	5	2	0	0	0	0	5	0	1	<1	0	0
Romaine	1 oz	5	0	0	0	0	0	2	0	1	1	0	0

Figure 2: Partial nutrition facts chart of Piada

These two charts contain information of amount of calories(cal), total fat(g), Cholesterol(mg), sodium(mg), carbohydrate(g), sugar(g) and protein(g), vitamins and some chemical elements associated with each item. To ensure that our model would be not too complicated while relatively comprehensive, we only consider five primary nutrients: calories, fat, protein, carbohydrate and sodium.

We retrieve prices from the menus of Chipotle and Piada published online, from which we found that both restaurants tend to set prices for designed meals consisting of several items instead of assigning prices for each individual item. To make our problem solvable, we assign reasonable price for each individual

item that for each designed meal, the prices of the items in it would add up to be roughly the same as the price of the meal.(e.g: Price of Chicken bowl in Chipotle: 6.5 dollars; we set rice to be 1.5 dollars, chicken to be 2.5 dollars, sauce/dressing to be 0.5 dollars and 4 free-to-choose veggies to be 0.5 dollar per each).

4 Model Assumptions

We make the following assumptions about the input data in order to formulate a solvable problem:

- For Piada and Chipotle, they set prices for certain designed meals(eg: For Chipotle, it's 6.50 dollars for a bowl with one serving of rice, one protein and 3 to 4 vegetables (excluding avacado)). So it's hard to formulate a model this way. Thus, our program assigns price for each individual item for both restaurants.
- Since our model does not account for body attributes such as height and weight, we design diets for average males and females. We found daily nutrients lower bounds and upper bounds online and multiplied them by five to generate a weekly diet (We only consider weekdays).
- To make sure that our diet allows people to consume a diversified sequence of meals for every day, we will not consider the same staples and proteins for two consecutive days by setting variety constraints for our model.

5 Model

Objective: Minimize $\sum_{k=1}^{5}(\sum_{j=1}^{21} m_{cjk} * p_{cj} + \sum_{i=1}^{94} m_{pik} * p_{pi})$

m_{cjk} – number of item j consumed from Chipotle on the kth day of a week.
p_{cj} – price of item j consumed from Chipotle.
m_{pik} – number of item i consumed from Piada on the kth day of a week.
p_{pi} – price of item i consumed from Piada.

5.1 Nutrients Constraints

5.1.1 Calories Constraint

$$K_{lower} <= \sum_{k=1}^{5}(\sum_{j=1}^{21} k_{cj} * m_{cjk} + \sum_{i=1}^{94} k_{pi} * m_{pik}) <= K_{upper}$$

K_{lower} – weekly calories lower bound
K_{upper} – weekly calories upper bound
k_{cj} – amount of calories in item j from Chipotle
k_{cj} – amount of calories in item i from Piada

5.1.2 Carbohydrate Constraint

$$C_{lower} <= \sum_{k=1}^{5}(\sum_{j=1}^{21} c_{cj} * m_{cjk} + \sum_{i=1}^{94} c_{pi} * m_{pik}) <= C_{upper}$$

C_{lower} – weekly carbohydrate lower bound
C_{upper} – weekly carbohydrate upper bound
c_{cj} – amount of carbohydrate in item j from Chipotle
c_{cj} – amount of carbohydrate in item i from Piada

5.1.3 Fat Constraint

$$F_{lower} <= \sum_{k=1}^{5}(\sum_{j=1}^{21} f_{cj} * m_{cjk} + \sum_{i=1}^{94} f_{pi} * m_{pik}) <= F_{upper}$$

F_{lower} – weekly fat lower bound
F_{upper} – weekly fat upper bound
f_{cj} – amount of fat in item j from Chipotle
f_{cj} – amount of fat in item i from Piada

5.1.4 Protein Constraint

$$P_{lower} <= \sum_{k=1}^{5}(\sum_{j=1}^{21} p_{cj} * m_{cjk} + \sum_{i=1}^{94} p_{pi} * m_{pik}) <= P_{upper}$$

P_{lower} – weekly protein lower bound
P_{upper} – weekly protein upper bound
p_{cj} – amount of protein in item j from Chipotle
p_{cj} – amount of protein in item i from Piada

5.1.5 Sodium Constraint

$$S_{lower} <= \sum_{k=1}^{5}(\sum_{j=1}^{21} s_{cj} * m_{cjk} + \sum_{i=1}^{94} s_{pi} * m_{pik}) <= S_{upper}$$

S_{lower} – weekly sodium lower bound
S_{upper} – weekly sodium upper bound
s_{cj} – amount of sodium in item j from Chipotle
s_{cj} – amount of sodium in item i from Piada

5.2 Other Constraints

Since for both restaurants proteins and staples all tend to have relatively high prices compared with other items such as veggies and dressings, diets created tend to be imbalanced due to these price differences. Thus, to retrieve a reasonable diet, we set constraints for certain items for both Chipotle and Piada.

For Chipotle:

- Our program assigns one staple per meal
- Our program assigns at most one serving of beans per meal
- Our program larger than or equal to one serving of proteins per meal
- Our program assigns less than or equal to one kind of sauce per meal
- Our program assigns one topping per meal

For Piada:

- Our program sets the first four constraints above for Piada as well
- Our program assigns less than or equal to two toppings per meal

6 Methods

We use linear programming to solve this problem by first finding the cost objective function, then looking up for the nutrient constraints and other variety constraints. We solve this problem with Google spreadsheet and OpenSolver which is an add-on tool for the spreadsheet to solve large optimization problems.

We run linear programming algorithm separately for the two restaurants since people cannot buy an entree from one restaurant and toppings from the other one at the same time. We set our nutrient constraints for weekly consumption and run several times for each restaurant. After finding an optimal solution, we divide the quantity of food by 5 weekdays to find the daily quantity and round the numbers if needed. Then we would set new constraint that the same combination of protein and staple is not allowed two meals in a row to ensure diversity. We run the model again to find the next optimal solution. After we find several optimal options, we would manually make up each meal from the options to ensure diversity and fit into the weekly diet.

7 Result and Conclusion

Here is our designed weekly diet including breakfast, lunch and dinner for a male as well as the cost for each day and the total cost.

	Monday	Tuesday	Wednesday	Thursday	Friday	
Breakfast	Flour Tortilla (taco)	Pasta - regular bowl	Pasta - regular bowl (Lite)	Pomodoro (small pasta and regular salad)	Crispy Taco Shell	
	Pinto Beans	Balsamic Dressing (catering and pasta)*	Add Chicken Tender	Add Chicken Tender(Lite)	Black Beans	
	Fajita Vegetables				Fajita Vegetables	
	Cheese				Chips(Lite)	
Lunch	Pasta - regular bowl	Flour Tortilla (burrito)	Flour Tortilla (taco)	Crispy Taco Shell(3)	Pasta - regular bowl	
	Add Chicken Tender	Chicken	Black Beans	Fajita Vegetables	Add Chicken Tender	
	Balsamic Dressing (catering and pasta)(Lite)	Pinto Beans	Fajita Vegetables	Corn Salsa(Lite)	Sweet & Spicy Pickles	
	Glazed Chickpeas	Corn Salsa	Sour Cream	Cheese	Balsamic Dressing (Piada)*	
	Quinoa	Cheese			Sweet & Spicy Peppers	
		Chips				
Dinner	Romaine - small	Mixed Greens - regular	Piada Dough (Regular) 14"	Pasta - regular bowl	Flour Tortilla (burrito)	
	Add Crispy Chicken Fritte	Add Chicken Tender	Add Steak*	Add Chicken Tender	Black Beans	
	Bruschetta Tomatoes(Lite)	Balsamic Dressing (Piada)*	Balsamic Dressing (Piada)*	Glazed Chickpeas	Chicken	
	Sweet & Spicy Pickles	Sweet & Spicy Peppers	Sweet & Spicy Pickles	Quinoa	Corn Salsa	
					Sour Cream	
price	15.13	14.87	16.07	19.77	18.28	84.12

The cost for this weekly diet menu is $84.12. With this diet, a normal male is able to satisfy his daily nutritional needs. As we can see from the menu, people are able to get food from both Chipotle and Piada and do not need to have the same staple in one day so that they would not get bored of the food. In addition, we guarantee that each meal is nutritious by itself and there's not any big discrepancy between meal prices between meals/days. In all, the weekly menu is a feasible and less costly diet.

However, while running the model to find the optimal options, we find out that food in both restaurants contain higher sodium than expected which is unhealthy for human-being. In addition, since our model tend to pick food with lower price but higher nutrients(energy), carbohydrate and fat always reach the higher bound for the optimal solution which is not ideal in reality. People have different preference for food. Some people might prefer eating healthy, others might prefer saving money. From our project, we can see for these two restaurants, there is always a trade-off between eating healthy and the cost of meal.

We might have the following improvements:

- Consider more restaurants around campus, especially healthy ones. The limited number of restaurants in this project is more likely to cause repetitiveness. Moreover, the food in the picked restaurants is not so healthy as we first expected.

- Consider the distance and time for students to travel. Students always have limited time for meals because of the tight class schedule. The time to travel to the restaurants is also a opportunity cost we should consider and optimize.
- Consider personalized diet for each person. In this project, we only consider male and female with average height and weight which is not always the case. Designing a program that can let each user type in his/her own height, weight and preference and output a personalize diet would be more useful.
- Consider people with special needs. Some people might have allergy on some particular ingredient, or some people might have other special needs. Taking these into consideration would be more useful as well.

Designing a perfect personalized weekly diet is complicated because there are so many attributes that should be taken into consideration. Our suggested weekly diet could be used as a basic template for people with limited budget to satisfy daily nutrition needs.

8 Reference

1. Chipotle food nutrition: https://chipotle.com/nutrition-calculator
2. Chipotle menu: https://www.fastfoodmenuprices.com/chipotle-prices/
3. Piada food nutrition: https://mypiada.com/documents/PiadaNutrition-02-18-19.pdf
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