Finding the Worthiest Meal Combination for First Year UBC Students

MATH 340 Optional Project

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1. Introduction

When first-year students apply to live on UBC Vancouver campus, they are usually assigned to one of the three first-year residences: Totem Park, Orchard Commons, or Place Vanier. For these residences, students are required to buy the residence meal plan. After purchasing it, funds are loaded onto the UBCcard where students can use to pay for food at many locations on campus including the residence dining halls. There is one residence dining hall located in each of the first-year residences. According to UBC, the dining halls are consulted by registered dietitians, offering high nutritional support. With the residence meal plan, students can get a 25% discount when eating at any of the three residence dining halls. This makes them a relatively good option in comparison to other restaurants on campus.

Therefore, it is in the first-year students' best interests to eat as often as possible at the residence dining halls as they are cheap and offer high nutrition value. However, deciding on what to eat can be tricky as the residence halls offer a huge variety of dishes. Despite the discount, it is not easy to order a meal with a reasonable price that meets the suggested nutrition requirement. Hence, the goal of this project is to build a model where given the available dishes' costs and nutrients, it can determine the most nutritious meal combos while maintaining costs. For demonstration, we will create a simple model where one can calculate the worthiest options for three weekday dinners at the first-year student residence dining halls.

1.1 Data

To build our model, we needed to know the food that each residence dining hall offers, their price and nutritional information. We gathered most of our data from Nutrislice which is a website that shows the menu in each residence dining halls on each day for all three meals. It provided detailed nutritional information for each dish including fats, carbs, sodium, etc. Additionally, we typed in all the data by ourselves and generated the datasets. Though the website displayed prices for some of the dishes, a large portion of them were missing. We therefore went to the residence dining halls in-person to collect those data. With the data, we were able to create a dataset for each residence dining halls on the food they provided for dinner on the weekdays of the week October 4th-9th (see TP.csv, OC.csv, PV.csv).

For each residence dining hall, we collected information on the meal's name, type (main or side), price (CAD), calorie (kcal), total fat (g), saturate fat (g), trans fat (g), cholesterol (mg), sodium (mg), total carbs (g), dietary fiber (g), sugar (g), protein (g). As mentioned, student can get a 25% discount when using residence meal plan. Hence, we multiplied the price in all datasets by 0.75 to get the price a first-year student would pay for the food (See 1.1 of program.ipynb). Few dishes that were missing at least one of the mentioned information were omitted from the dataset. We also assigned each dish an ID based on their location, and dish type for easy computation later (See 1.1 of program.ipynb). We will assume, for all three days, the menu for dinner in each residence is the same.

2. Constructing the Linear Programming Problem

2.1 Decision variable

The gaol of the model is to maximize the worthiness of the dinners eaten for three days. In this case, the decision variable, x, is an variable representing a dish which we define by four aspects: the type, an index, the residence it was purchased, and the day it was purchased (See 3.2 of programm.ipynb). Dish types include main course and side corresponding to 1 and 2 in dataset. The residences of Totem Park, Orchard Commons, or Place Vanier, corresponding to 1, 2, and 3 respectively when writing the equation. The index is simply a numeric value differentiating the meals of the same type, available at the same residence on the same day. The index value also corresponds to the numeric value of the ID from the data frame. The number 1, 2, and 3 represents the day on which students eat the meal.

2.2 Objective function

For the coefficients of the objective function, we define the worthiness of the dish w_{trid} by its nutrition value per dollar, given by:

$$w_{trid} = \frac{n_{trid}}{p_{trid}} \quad s.t.\ \ t \in \{1,2,3\}, r \in \{1,2,3\}, i\ = 1,2..., d \in \{1,2,3\}$$

p is the price of the corresponding dish, and n is the nutrition value that we calculated for each dish. The nutrition value is a calculation based on nine nutrition aspects (total fat, saturate fat, trans fat, cholesterol, sodium, total carbs, dietary fiber, sugar protein) we have collected within our data. Calorie was not involved in the computation of nutrition value because the calculation of calories is based on fat, protein, and carbohydrates, making it highly correlated with those variables. Hence, the inclusion of calories in the nutrition value become redundant. The detailed calculation for nutrition value will be explained later when talking about computation. Dishes with higher nutrition value per dollar are considered worthier. Same as before, the subscripts represent the dish type, residence, index, and day respectively. Hence our objective function is:

$$max \sum_{t,r,i,d} w_{trid}x_{trid} \quad s.t. \quad t \in \{1,2,3\}, r \in \{1,2,3\}, i\ = 1,2..., d \in \{1,2,3\}$$

2.3 Price Constraints

After having the objective function, we will now construct the constraints for the linear programming problem. Since the residence meal plan involves prepaid money loaded into the student card, there is an upper limit on how much a student can spend on the meals. The Meal Plan Budget Calculator provided by UBC allow students to estimate how much they should aim to spend every day at the residence dining halls. According to the default setting on term 1, a student should spend about $26.70 per day at the residence dining halls. We divided the price by a ratio of 2.2 to get a price around \$12.136, which is about 45.5% of \$26.70. This becomes our rough estimate on how much a student should spend for one dinner every day. We want to have some flexibility on the spending, so we only need to make sure the total cost of three dinners doesn't exceed the expected budget amount. Hence, multiplying \$12.136 by 3, we have the budget constraint where p is the price for the corresponding dish:

$$\sum_{t,r,i,d} p_{trid} x_{trid} \leq 36.41$$

2.4 Nutrient Constraints

Another group of constraints are related to meeting the minimum and/or maximum requirement for specific nutrition group including calories, total fat, saturate fat, trans fat, cholesterol, sodium, total carbs, dietary fiber, sugar, and protein. The amount of nutrients needed for each person depends on gender, age, activity level etc. We used the Dietary Reference Intakes (DRI) calculator (National Agricultural Library) along with other resources to find the advised daily intake of nutrients for an active, 19-year-old female student with normal height and weight (See Table 1 or 1.2 of program.ipynb). Based on this result, we assume 45% of all daily nutrients will be gained from dinner. Hence, we calculated some of the nutrient intake per dinner (i.e., calorie, calorie, cholesterol, and sodium) by dividing the value in the daily dietary intakes by a ratio of 2.2, a similar procedure to price. Other nutrients, such as total fat, are advised to have their range based on the calories intake. For those, we calculated the range using calculations based on several health websites (Check Notes of Table 1).

Using the values in the limit constraint column from table 1.2 of program.ipynb, we can construct the constraint functions related to nutrient intake in the forms of:

$$\sum_{t,r,i} v_{trid} x_{trid} \leq nutrient's\ Constraint\_LB \quad \text{for every } d \in \{1,2,3\}$$

$$\sum_{t,r,i} v_{trid} x_{trid} \leq nutrient's\ Constraint\_UB \quad \text{for every } d \in \{1,2,3\}$$

In this case, v represents the value of any nutrient for dish x. There should be a total of 39 constraints related to the nutrient intake.

Table 1. Advised dietary intake per day and per dinner

Nutrient	Daily Dietary Intakes	Dietary Intakes per Dinner
Calorie (kcal)	1250-3000	568.18-1363.64
Total fat (g)	59-103	12.63-53.03
Saturated fat (g)	0-22	0-15.15
Trans fat (g)	0-2	0-1.52
Cholesterol (mg)	0-300	0-136.36
Sodium (mg)	0-2300	0-1045.45
Total carbs (g)	225-325	102.27-147.73
Dietary fiber (g)	≥21	≥9.55
Sugar (g)	0-24	0-34.09
Protein (g)	27.20-95.18	14.20-119.32

Notes. It is recommended that 20%-35% of total calorie from total fat, less than 10% of calorie from saturated fat, and less than less than 0.84% of calorie from saturated fat (Cleveland Clinic). 1g of fat equals 9kcal (National Agricultural Library). It is recommended that no more than 10% of calorie should be from sugar and 10%-35% of calorie should come from protein (Gunnars, 2021; Jaret, 2020). For both sugar and protein, 1g is equal to about 4kcal (National Agricultural Library; Picincu, 2019).

2.5 Constraints based on Assumptions

We also have constraints based on some reasonable assumptions. One assumption is that for each dinner, a student must pick a meal that includes a main and a side. This also implies all x are indicator variable taking value of either 1 or 0. These constraints can be written as:

$$\sum_{r,i} x_{trid} = 1 \text{ for every } t \in \{1,2\}\ and\ d \in \{1,2,3\}$$

$$x_{trid} \leq 1$$

$$x_{trid} \geq 0$$

Another constraint is based on our assumption that students would not repeat the same main dish in the same dining hall.

$$\sum_{d} x_{trid} \leq 1 \text{ for every } i\ and\ r \in \{1,2,3\}\ and\ t = 1$$

Furthermore, on a given day, the main and the side should be from the same residence dining hall. This means when building the model, the student needs to choose where they would have their dinner for each day. The general idea would be that for the sum of variables of one day from the chosen dining hall should equal to 2. The sum of variables of one day from the two not chosen dining halls should equal to 0. For example, if the student plans to have all three dinners at Totem Park, the constraints would be:

$$\begin{cases} \sum_{t,i} x_{trid} = 2 & \forall d \text{ where } r{=}1 \\ \sum_{t,i} x_{trid} = 0 & \text{otherwise} \end{cases}$$

Similarly, if the student chooses to eat all three meals at Orchard Commons, the constraints would be:

$$\begin{cases} \sum_{t,i} x_{trid} = 2 & \forall d \text{ where } r{=}2 \\ \sum_{t,i} x_{trid} = 0 & \text{otherwise} \end{cases}$$

If the student chooses to eat all three meals at Place Vanier, the constraints would be written as:

$$\begin{cases} \sum_{t,i} x_{trid} = 2 & \forall d \text{ where } r{=}3 \\ \sum_{t,i} x_{trid} = 0 & \text{otherwise} \end{cases}$$

Finally, if the student is planning to eat at Totem Park, Orchard Commons, and Place Vanier in order respectively for three days, the constraints would be:

$$\begin{cases} \sum_{t,i} x_{trid} = 2 & when \begin{cases} r = 1 \\ d = 1 \end{cases}, \begin{cases} r = 2 \\ d = 2 \end{cases} or \begin{cases} r = 3 \\ d = 3 \end{cases} \\ \sum_{t,i} x_{trid} = 0 & \text{otherwise} \end{cases}$$

3. Computation

3.1 Nutrition Value

First, we processed the daily requirement data frame to get the range for each nutrient per dinner intake (See 2 of program.ipynb). The calculation and value are explained in Table 1. Next, we calculated the nutrition value for each dish as well as the coefficient for the decision variable in the objective function (See 3 of program.ipynb). As mentioned previously, we used total fat, saturate fat, trans fat, cholesterol, sodium, total carbs, dietary fiber, sugar, and protein to calculate the nutrition value for each dish. There are 9 nutrient aspects that each make up to 1 point of the nutrition value. For nutrient aspects that have 0 as the lower bound intake, the score is calculated using the following function:

$$\begin{cases} 1 - \dfrac{dish's\ value\ on\ the\ nutrient\ aspect}{max\ intake\ on\ the\ nutrient\ aspect} & dish's\ nutrient\ aspect \leq max\ nutrient\ aspect \\ 0 & dish's\ nutrient\ aspect > max\ nutrient\ aspect \end{cases}$$

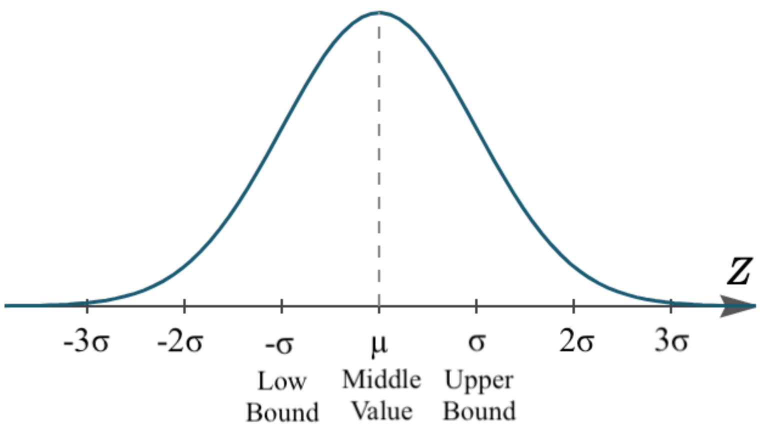
For dietary fiber, which only has a lower bound, the score function is the following:

$$\begin{cases} \dfrac{dish's\ dietary\ fiber}{min\ dietary\ fiber\ intake} & dish's\ dietary\ fiber \leq min\ dietary\ fiber \\ 1 & dish's\ dietary\ fiber > min\ dietary\ fiber \end{cases}$$

In these cases, we created the function based on the uniform distribution when computing (See 3.4 of program.ipynb).

We created a Gaussian function (See Figure 1) for the rest of nutrients (i.e., total fat, total carbs, protein) where the mean is the middle value of each nutrient constraints while the lower and upper bound are set as 1 standard deviation away from the mean. The reason we chose 1 standard deviation is because most value would fall below μ and even the lower bound as a single main or side usually won't exceed the mid value. Hence, 1 standard deviation would make the curve smoother. After creating the normal function, we used function map_01 to map the pdf of Gaussian distribution into range (0,1]. Adding all the scores together, we get the nutrition value for each dish. Dividing the nutrition value by price, we get the coefficient w for each decision variable in the objective function.

Figure 1. Gaussian function to calculate score on nutrients aspect (i.e., total fat, total carbs, protein)



Notes. The figure is an example of the function, the specific value on the horizontal axis varies depending on the nutrient aspect.

3.2 Implementing the Objective Function and Constraints

Next, we introduced more details about how we implemented the linear programming problems. We have constructed four different examples. The first LP problem is eating at three different places each day in the order of Totem Park, Orchard Commons, and Place Vanier. The other three are eating at each residence for all three days.

We first defined all the LP problem to be maximizing (See 5.1 of program.ipynb) as a goal to maximize effectiveness of the meal. We then defined our LP variables (See 5.2 of program.ipynb) in the integer category with lower bound of 0 and upper bound of 1. We constructed the decision variables by dividing them into nine sub-sections (TP_1st_vars, TP_2nd_vars, TP_3rd_vars, OC_1st_vars, OC_2nd_vars, OC_3rd_vars, PV_1st_vars, PV_2nd_vars, PV_3rd_vars) based on residence (r) and day (d) for easier computation when writing the constraints. Additionally, we partitioned each sub-section into main decision variables and the side decision variable (e.g. OC_1st_vars partitioned into OC_side_1st_vars, OC_main_1st_vars).

Since we divided the decision variable into nine sub-sections, we were able to select only the relevant decision variables when computing our LP problem. Using the example of eating at Totem Park on day 1, Orchard Common on day 2, and Place Vanier on day 3, we only used TP_1st_vars, OC_2nd_vars, and PV_3rd_vars. Furthermore, while the other constraints remained the same, constraints on a student must pick a combo of the main and side ($\sum_{r,i} x_{trid} = 1$ for every $t \in \{1,2\}$ and $d \in \{1,2,3\}$) as well as both dishes should be from the residence dining halls were combined and replaced by a group of functions. With the new version, the constraints we need to write based on our assumption would just be

$$\sum_i x_{trid} = 1 \text{ for every } t \in \{1,2\} \text{ and when } \begin{cases} r = 1 \\ d = 1 \end{cases}, \begin{cases} r = 2 \\ d = 2 \end{cases} or \begin{cases} r = 3 \\ d = 3 \end{cases}$$

Similarly, in the case where the student eats all three dinners at Totem Park, we would only use TP_1st_vars, TP_2nd_vars, TP_3rd_vars as decision variables. The constraints based on assumption will be written as:

$$\sum_i x_{trid} = 1 \text{ for every } t \in \{1,2\}, d \in \{1,2,3\} \text{ and } r = 1$$

3.3 Solving the LP problems

We use Python pulp built-in solver to solve our well-built linear programming problems. There are five types of LP problem solution: 0 means the LP problem cannot be solved, -1 means it is infeasible, -2 means it is unbounded, -3 means it is undefined, 1 means it has an optimal solution. Since we only need to know the dishes that the student will eat for three days, we only produced variables that have optimal value 1. We also computed the optimal value of each example if it has one as well as the total price for the optimal dishes.

4. Result

When eating at three different residence dining halls for each day, the optimal solution is to have mushroom pot pie and steamed basmati rice in Totem Park, harvest squash pasta and plain bagel in Orchard Commons, Havana bowl tofu and side garlic mashed potatoes in Place Vanier. The optimal value for this example is around 12.96 and the total price is $26.655 (See 6.1.3 of program.ipynb). We were unable to find an optimal solution for the example where all three meals are eaten at Totem Park (See 6.2.3 of program.ipynb). When eating all three days at Orchard Commons, the combos are: king oyster mushroom and lemon loaf on day 1, chickpea burger and white chocolate macadamia cookie on day 2, and harvest squash pasta and plain bagel on day 3. The optimal value for this example is about 11.85 and the total price is $29.73 (See 6.3.3 of program.ipynb). When eating all three days at Place Vanier, the dishes are: acorn squash poke bowl and side garlic mashed potatoes on day 1, Thai coconut bowl and side garlic mashed potatoes on day 2, and Havana Bowl Tofu and side garlic mashed potatoes on day 3. The optimal value is 13.27 and the total price is $24.33 (See 6.4.3 of program.ipynb).

5. Discussion

We were able to build a simple model to calculate the most effective options to eat for 3 weekday dinners at the three residence dining halls. Comparing our examples, we were unable to find an optimal solution for eating 3 days at Totem Park. This suggests the dining hall in Totem Park has relatively less worthy meal in general. We suspect a potential reason is the relatively high sodium level for dishes from Totem Park. It is worth noting that there may be some errors with Totem Park's data on Nutrislice as we were able to identify some unrealistic value. This could also cause us to not find an optimal result. Comparing the optimal value of the three examples that were able to produce a result, eating at Place Vanier is the worthiest option out of the three.

It's difficult for us to interpret the meaning of the duality of the linear programming function as it contains a lot of variables. There are many constraints for one linear problem, and they mean different things with different units as we have divided into three different sections (prices, nutrients, assumption) when computing. Despite the large data sets and many constraints, the model is still rather small if we consider from a realistic standpoint. Besides, the data omitted dishes with missing information. We didn't consider drinks, which is a dish type on its own, as there were no nutrition data on them. We assumed the food for weekdays is the same and that is not the case. This simplified our original dataset. Furthermore, it may be more common for students to plan their meals for all weekdays or even a whole week. In that case, we will need more variables as there are more days to consider. There will also be more constraints though the idea behind constructing them are the same as before.

With the current model, the student must decide where they would like to eat for each day. This is quite realistic as each student may have their own preference for where to eat based on where they live. If the goal is to purely maximize worthiness, as long as the meal combo is from the same residence dining hall, where to eat would not matter. However, we were unable to write the constraints for not specifying where to eat each day. In this case, all $\sum_{t,i} x_{trid}$ must equal to 2 or 0 and $\sum_{t,r,i} x_{trid} = 2$ for each day. With our current understanding, we cannot write constraints where it must satisfy one of the two possible values. Still, it may be a possible randomizable improvement in the future.

Our current model is based on many assumptions including how much money students will spend in residence dining halls and how much nutrient they will intake. We also assumed students would always choose to have a main and a side. However, in real life, each student's needs and preferences are differently. Some may choose to spend less money in residence dining halls so that they can use it in other places; some may choose to eat less calories as they are not physically active; some may just prefer having a main for each dinner instead of a combo. To make the model suitable for everyone, it would be nice each student can customize their own constraints value for the model. If Nutrislice decides to utilize such improved version of our model, each student can have their own personalized nutritious meal recommendation from the website. In this case, a student can decide how many days they are planning, where they planned to eat and how many dishes they would like to eat. Then the model can calculate the worthiest options based on their own preferences. Therefore, our worthiest meal linear programming model is potentially beneficial for future UBC students.

References

Cleveland Clinic. (n.d.). *Fat: What you need to know*. https://my.clevelandclinic.org/health/articles/11208-fat-what-you-need-to-know

Gunnars, K. (2021, June 10). Daily intake of sugar – How much sugar should you eat per day?. Healthline. https://www.healthline.com/nutrition/how-much-sugar-per-day

Jaret, P. (2020, November 11). *Protein: Are you getting enough?.* WebMD. https://www.webmd.com/food-recipes/protein

National Agricultural Library. (n.d.). *DRI calculator for healthcare professionals.* US Department of Agriculture. https://www.nal.usda.gov/legacy/fnic/dri-calculator/index.php

National Agricultural Library. (n.d.). *How many calories are in one gram of fat, carbohydrate, or protein?.* US Department of Agriculture. https://www.nal.usda.gov/legacy/fnic/how-many-calories-are-one-gram-fat-carbohydrate-or-protein

Picincu, A. (2019, November 1). *How many calories are in one gram of sugar?.* Livestrong.com. https://www.livestrong.com/article/295626-how-many-calories-are-in-one-gram-of-sugar/

University of British Columbia. (n.d.) [Food Menu]. Nutrislice. Retrieved October 9, 2021, from https://ubc.nutrislice.com/

University of British Columbia. (n.d.) *Meal plan budget calculator.* UBC. https://food.ubc.ca/budget/