Preference-Based Daily Diet Optimization

A dissertation presented
by

A dissertation is a term reserved for the work one does to attain a PhD. This is not a dissertation.

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1. Introduction

Solving?

In this project, our team is doing a diet problem. In particular, we are modeling a daily diet problem to maximize the happiness of every group member in our group. That is, in hope of getting the greatest joy and a health body, from a possible diet we can eat every day, meeting all the nutrition levels each person needs every day and controlling our daily calorie and sodium intakes. In this project, we used the linear programming as our method to solve our model and get an optimal solution for each one in our group. Specifically, we give advice for our group members on what recipe or what combination of food we should eat to make our week the most cheerful, based on the given solution to the linear program of our model.

2. Background

When we started discussing the possible problems we want to solve, we came up with several ideas. For instance, we discussed about the sports league ranking optimization that treats seasonal budgets and athletes' skill levels as constraints to maximize the team's rank, the students working scheduling problem based on working efficiency, students' available time, their preference time to work, and their current class credits, and also the movie festival problem to determine possible list for movies on screen to maximize the preference of audience within a certain time available and the cost constraint. However, before we went further with any of these topics, we found that we would like to solve a problem that was closer to our daily life. That is, we were more interested in working on a topic whose result can directly affect our life. Hence, a new topic came to our mind -- the daily diet preference optimization. As students, we wish to handle the busy school work as well as keep fit. Having a healthy diet is critical for us, not only controlling the calories and fats we take in every day but also ensuring the food we eat contains enough amount of essential nutrients, such as several kinds of vitamins, proteins, Calcium, and so on. On the other hand, we probably do not want to eat food that we dislike but is indeed low in calories and high in protein and fiber. And thus, we wish to have a diet that makes us the happiest and achieves our fitness goal at the same time.

Good!

Our diet preference maximization problem is basically a knapsack problem. According to the Wikipedia, the knapsack problem is a combinatorial optimization problem. We have to determine from a set of items, each with a weight and a value, the amount of each item to include in the knapsack so that the total weight is less than or equal to a given limit and the total value is as large as possible [11]. The similar thing is that, both our diet preference problem and the knapsack problem are designed to figure out an optimal solution to maximize the total value we wish to get without exceeding the certain constraints. The constraints in the knapsack problem are the limit of the sum weight of the items. In our diet preference maximization problem, we cannot let some kinds of elements, like fats and calories, that we take in each day to exceed upper limits, but we also have to ensure that our daily ingestion of essential nutrients reaches the necessary amounts. Furthermore, the daily nutrition levels for male and female are not identical, so we have to deal with them in separate

sets. Hence, our constraints on the intakes of the food are far more complicated than the weight constraint of the items to put in the knapsack.

This is not a very strong history section. It would have been good to address LP applied to problems involving preference ratings.

Besides, our diet preference optimization is related to diet problem. The diet problem is a classic application of linear programming. It was one of the first optimization problems researched in the 1930s and 1940s [4]. The main goal is to select different types of food to meet daily nutritional requirements at the minimum cost. Geroge Stigle, one of the earliest researchers studying the problem, came up with an optimization problem called the Stifler diet. He wanted to find the amount of each of 77 items of food to be eaten per day in order to at least meet the requirements of dietary allowances suggested by National Research Council with minimal cost [12]. He used heuristic methods to get the optimal solution at $39.69 in 1939. Both of diet problem and diet preference optimization fulfill the requirements of different nutrients. However, diet preference optimization is not exactly the same as Stifler diet. While Stifler diet aimed to minimize the cost of food with the constraints of nutrition, our diet preference optimization aims to maximize people's happiness from having meals with the constraints of nutrition. We define happiness in different categories of food in a Likert scale of 1 to 10, in which 1 implies total dislike and 10 implies total love. Besides, the sample size and sample objects are distinct. Stifler diet's sample object is male, and it used 77 items of food to fulfill the nutrition requirement. On the other hand, in our diet preference optimization, we separate sample objects to male and female and we conducted a survey of preferences in our group. Also, the variety of food is as large as 2835 items of food.

spelling

What is a Likert scale? You should define this and/or give references.

I don't know what you mean. What is the "sample size" and what are th "sample ob

Before digging into the process of generating code, we first downloaded an integrated dataset of the composition of foods on the nutrient contents from Public Health England's governmental website https://www.gov.uk/government/publications/composition-of-foods-integrated-dataset-cofid [5]. This entire dataset actually categorizes food into hundreds of different kinds of food groups. We then conducted a survey on the preference of different categories of food in a Likert scale of 1 to 10 within our group.

3. The Model Itself

The Mathematical Model

You did not develop linear programming.

The mathematical model we have developed for investigating the diet preference optimization problem was linear programming. Linear programming has an objective function in terms of optimized variables subject to some constraints those variables are linearly related to. For our diet preference optimization model, our objective was to have the maximum preference rating from the optimized set of food items. The amount of each item, therefore, represented each of our variables as x_i. The unit of the amount was in 100 grams because the nutrient data we had was in per 100 grams of food. Each of 2835 food items on the data list was already classified into different food groups by the source. Since it is extremely time-consuming for each member to rate each food item, we decided

to rate each of 135 food groups. These ratings were then averaged based on gender due to the difference in nutrient requirements for each gender. These averaged ratings became our coefficients for the objective funtion as p_i, after the automated process - to be discussed in the solution section - to assign each food group's rating to corresponding food items. The final objective funtion was to maximize the sum of the products of each item's preference rating and amount of each item in 100 grams as below, in which **H** is defined as the happiness score from the diet:

$$\mathbf{H} = \sum_{i=0}^{2834} p_i x_i$$

As for the constraints the objective funtion is subject to, we had various nutrient constraint constants excerpted from several websites. The sum of the specific nutrient values among the optimized set could not be smaller than the minimum nor larger than the maximum amount of the daily recommended value for that nutrient. Most of these nutritional constraints were different for each gender because each gender has a different calorie requirement each day, and most constraints are related to the calorie consumption. The calorie requirements for each gender were taken from U.S. Department of Agriculture website [8]. The calorie requirement for moderately active men was from 2200 to 2800kcal, and that for moderately active women was from 1800 to 2200kcal. Using this and the relationship between calorie consumption and daily recommended ranges of nutrients from the websites "SF Gate" and the American Heart Association, we could find the maximum and minimum amounts of each nutrient that is related to calorie [2][1]. For example, 10% to 35% of daily calories has to be from protein, which is 4 grams per kcal. If we convert this relationship, we get that 55 to 245 grams of protein have to be consumed daily for men, 45 to 192 grams for women. Likewise, we could build constraint inequalities for all nutrients that are related to calories such as protein, fat, carbohydrates, saturated fats, and trans-fats. For the other nutrient requirements or limits that are not related to calories such as cholesterol, sodium, potassium, calcium, and all the vitamins, the maximum and/or minimum values for each nutrient could be sourced from other websites such as "ConsumerLab.com" [6]. These values could be used as common values for each gender. The resulting contraints of the model are set for each nutrient individually and are listed as follows:

$$\sum_{i=0}^{2834} n_i x_i \leq N_{max}$$

$$\sum_{i=0}^{2834} n_i x_i \geq N_{min}$$

where n_i is the amount of each nutrient in 100 grams of each food x_i, and N_{max} and N_{min} are the maximum and minimum values for each nutrient.

One of the final constraints was to limit the amount of beverages and alcohol beverages in the optimized food set under 96 ounces according to "SparkPeople" and this is approximately 3000 grams [7]. Another was to limit the amount of each food item in the optmized set under 3000 grams

because more than that amount would be unrealistically excessive of the same food. These two types of constraints can be described as below:

$$\sum_{i=0}^{2834} x_i \leq B_{max} \text{ for } x_i \text{ in the group of beverages and alcoholic beverages}$$

where $B_{max} = 30$ (hunderd grams of food)

$$x_i \leq 30 \quad (i = 0, 1, 2 \ldots, 2834)$$

Implementation of the Model

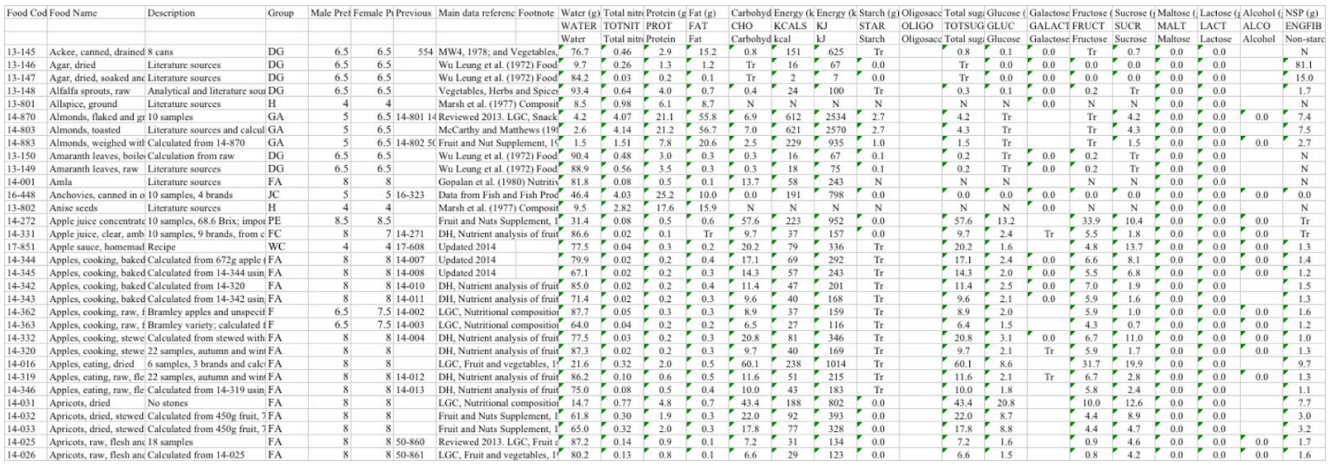
In order to get the preference parameters for the objective function, a survey was conducted on the preference on different food groups. The survey took samples within our team. The preference was defined as a score of 1 to 10 in a Likert scale, in which 1 implies total dislike and 10 implies total satisfaction. Considering the potential physical difference and psychological disparity, this preference dataset based on satisfaction was furthered divided into the preference scores for male and female.

??

In order to prepare our datasets for further linear programming, we rearranged the data into a single graph with each row indicating an individual type of food. In our final arranged datasheet, these 2835 possible food items featured in the McCance and Widdowson's dataset each consists of a row with nutrition information on each column.

In order to integrate preference data to correspond each individual food item, we wrote several Bash codes to automate the process in Mac OSX terminal. `Preference_Switch.sh` (Appendix) generated proper data format of two columns of preference data for male and female corresponding to each food item. These two columns are later copied and pasted into Excel sheet of all data.

`Preference_Switch.sh` consists of two parts: part I aims to generate pattern matching arguments for part II, with input files `FoodGroup.list`, `pref.list`, `prefMF.list` and generate output file `pref_ind_switch_final.sh` (Appendix). `FoodGroup.list` contains the list of food group abbrevations in 2835 items in alphabetical order of the food names. `pref.list` contains the list of sorted food group abbrevations. `prefMF.list` contains the list of sorted food group abbrevations, as well as the preference scores on these food groups for male and female. `pref_ind_switch_final.sh` was further copied and pasted into part II for `Preference_Switch.sh` to match the preference scores to each food item based on their food group abbreviation. After these rearrangements, the initial dataset was ready for next step's calculation (Figure 1).



Food Cod	Food Name	Description	Group	Male Pref	Female Pi	Previous	Main data referenc	Footnote	Water (g)	Total nitr	Protein (g	Fat (g)	Carbohyd	Energy (k	Energy (k	Starch (g)	Oligosacc	Total sug	Glucose (	Galactose	Fructose (	Sucrose (g	Maltose (g	Lactose (g	Alcohol (g	NSP (g)
									WATER	TOTNIT	PROT	FAT	CHO	KCALS	KJ	STAR	OLIGO	TOTSUG	GLUC	GALACT	FRUCT	SUCR	MALT	LACT	ALCO	ENGFIB
									Water	Total nitr	Protein	Fat	Carbohyd	kcal	kJ	Starch	Oligosacc	Total sug	Glucose	Galactose	Fructose	Sucrose	Maltose	Lactose	Alcohol	Non-starc
13-145	Ackee, canned, drained	8 cans	DG	6.5	6.5	554	MW4, 1978; and Vegetables,		76.7	0.46	2.9	15.2	0.8	151	625	Tr		0.8	0.1	0.0	Tr	0.7	0.0	0.0		N
13-146	Agar, dried	Literature sources	DG	6.5	6.5		Wu Leung et al. (1972) Food		9.7	0.26	1.3	1.2	Tr	16	67	0.0		Tr	0.0	0.0	0.0	0.0	0.0	0.0		81.1
13-147	Agar, dried, soaked anc	Literature sources	DG	6.5	6.5		Wu Leung et al. (1972) Food		84.2	0.03	0.2	0.1	Tr	2	7	0.0		Tr	0.0	0.0	0.0	0.0	0.0	0.0		15.0
13-148	Alfalfa sprouts, raw	Analytical and literature sour	DG	6.5	6.5		Vegetables, Herbs and Spices		93.4	0.64	4.0	0.7	0.4	24	100	Tr		0.3	0.1	0.0	0.2	Tr	0.0	0.0		1.7
13-801	Allspice, ground	Literature sources	H	4	4		Marsh et al. (1977) Composit		8.5	0.98	6.1	8.7	N	N	N	N		N	N	0.0	N	N	0.0	0.0		N
14-870	Almonds, flaked and gr	10 samples	GA	5	6.5	14-801 14	Reviewed 2013. LGC, Snack		4.2	4.07	21.1	55.8	6.9	612	2534	2.7		4.2	Tr		Tr	4.2	0.0	0.0	0.0	7.4
14-803	Almonds, toasted	Literature sources and calcul	GA	5	6.5		McCarthy and Matthews (19		2.6	4.14	21.2	56.7	7.0	621	2570	2.7		4.3	Tr		Tr	4.3	0.0	0.0		7.5
14-883	Almonds, weighed with	Calculated from 14-870	GA	5	6.5	14-802 5(	Fruit and Nut Supplement, 1		1.5	1.51	7.8	20.6	2.5	229	935	1.0		1.5	Tr		Tr	1.5	0.0	0.0	0.0	2.7
13-150	Amaranth leaves, boile	Calculation from raw	DG	6.5	6.5		Wu Leung et al. (1972) Food		90.4	0.48	3.0	0.3	0.3	16	67	0.1		0.2	Tr	0.0	0.2	Tr	0.0	0.0		N
13-149	Amaranth leaves, raw	Literature sources	DG	6.5	6.5		Wu Leung et al. (1972) Food		88.9	0.56	3.5	0.3	0.3	18	75	0.1		0.2	Tr	0.0	0.2	Tr	0.0	0.0		N
14-001	Amla	Literature sources	FA	8	8		Gopalan et al. (1980) Nutritiv		81.8	0.08	0.5	0.1	13.7	58	243	N		N	N		N	N	0.0	0.0		N
16-448	Anchovies, canned in o	10 samples, 4 brands	JC	5	5	16-323	Data from Fish and Fish Prod		46.4	4.03	25.2	10.0	0.0	191	798	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13-802	Anise seeds	Literature sources	H	4	4		Marsh et al. (1977) Composit		9.5	2.82	17.6	15.9	N	N	N	N		N	N	0.0	N	N	0.0	0.0		N
14-272	Apple juice concentrate	10 samples, 68.6 Brix; impor	PE	8.5	8.5		Fruit and Nuts Supplement, 1		31.4	0.08	0.5	0.6	57.6	223	952	0.0		57.6	13.2		33.9	10.4	0.0	0.0	0.0	Tr
14-331	Apple juice, clear, amb	10 samples, 9 brands, from c	FC	8	7	14-271	DH, Nutrient analysis of fruit		86.6	0.02	0.1	Tr	9.7	37	157	0.0		9.7	2.4	Tr	5.5	1.8	0.0	0.0	0.0	Tr
17-851	Apple sauce, homemad	Recipe	WC	4	4	17-608	Updated 2014		77.5	0.04	0.3	0.2	20.2	79	336	Tr		20.2	1.6		4.8	13.7	0.0	0.0	0.0	1.3
14-344	Apples, cooking, baked	Calculated from 672g apple (	FA	8	8	14-007	Updated 2014		79.9	0.02	0.2	0.4	17.1	69	292	Tr		17.1	2.4	0.0	6.6	8.1	0.0	0.0	0.0	1.4
14-345	Apples, cooking, baked	Calculated from 14-344 usin	FA	8	8	14-008	Updated 2014		67.1	0.02	0.2	0.3	14.3	57	243	Tr		14.3	2.0	0.0	5.5	6.8	0.0	0.0	0.0	1.2
14-342	Apples, cooking, baked	Calculated from 14-320	FA	8	8	14-010	DH, Nutrient analysis of fruit		85.0	0.02	0.2	0.4	11.4	47	201	Tr		11.4	2.5	0.0	7.0	1.9	0.0	0.0		1.5
14-343	Apples, cooking, baked	Calculated from 14-342 usin	FA	8	8	14-011	DH, Nutrient analysis of fruit		71.4	0.02	0.2	0.3	9.6	40	168	Tr		9.6	2.1	0.0	5.9	1.6	0.0	0.0		1.3
14-362	Apples, cooking, raw, t	Bramley apples and unspecif	F	6.5	7.5	14-002	LGC, Nutritional composition		87.7	0.05	0.3	0.3	8.9	37	159	Tr		8.9	2.0		5.9	1.0	0.0	0.0	0.0	1.6
14-363	Apples, cooking, raw, t	Bramley variety; calculated f	F	6.5	7.5	14-003	LGC, Nutritional composition		64.0	0.04	0.2	0.2	6.5	27	116	Tr		6.4	1.5		4.3	0.7	0.0	0.0	0.0	1.2
14-332	Apples, cooking, stewe	Calculated from stewed with	FA	8	8	14-004	DH, Nutrient analysis of fruit		77.5	0.03	0.2	0.3	20.8	81	346	Tr		20.8	3.1	0.0	6.7	11.0	0.0	0.0	0.0	1.0
14-320	Apples, cooking, stewe	22 samples, autumn and wint	FA	8	8		DH, Nutrient analysis of fruit		87.3	0.02	0.2	0.3	9.7	40	169	Tr		9.7	2.1	Tr	5.9	1.7	0.0	0.0	0.0	1.3
14-016	Apples, eating, dried	6 samples, 3 brands and calc	FA	8	8		LGC, Fruit and vegetables, 1		21.6	0.32	2.0	0.5	60.1	238	1014	Tr		60.1	8.6		31.7	19.9	0.0	0.0		9.7
14-319	Apples, eating, raw, fle	22 samples, autumn and wint	FA	8	8	14-012	DH, Nutrient analysis of fruit		86.2	0.10	0.6	0.5	11.6	51	215	Tr		11.6	2.1	Tr	6.7	2.8	0.0	0.0	0.0	1.3
14-346	Apples, eating, raw, fle	Calculated from 14-319 usin	FA	8	8	14-013	DH, Nutrient analysis of fruit		75.0	0.08	0.5	0.4	10.0	43	183	Tr		10.0	1.8		5.8	2.4	0.0	0.0		1.1
14-031	Apricots, dried	No stones	FA	8	8		LGC, Nutritional composition		14.7	0.77	4.8	0.7	43.4	188	802	0.0		43.4	20.8		10.0	12.6	0.0	0.0		7.7
14-032	Apricots, dried, stewed	Calculated from 450g fruit, 7	FA	8	8		Fruit and Nuts Supplement, 1		61.8	0.30	1.9	0.3	22.0	92	393	0.0		22.0	8.7		4.4	8.9	0.0	0.0		3.0
14-033	Apricots, dried, stewed	Calculated from 450g fruit, 7	FA	8	8		Fruit and Nuts Supplement, 1		65.0	0.32	2.0	0.3	17.8	77	328	0.0		17.8	8.8		4.4	4.7	0.0	0.0		3.2
14-025	Apricots, raw, flesh and	18 samples	FA	8	8	50-860	Reviewed 2013. LGC, Fruit a		87.2	0.14	0.9	0.1	7.2	31	134	0.0		7.2	1.6		0.9	4.6	0.0	0.0	0.0	1.7
14-026	Apricots, raw, flesh and	Calculated from 14-025	FA	8	8	50-861	LGC, Fruit and vegetables, 1		80.2	0.13	0.8	0.1	6.6	29	123	0.0		6.6	1.5		0.8	4.2	0.0	0.0	0.0	1.6

Figure 1. An extraction of the data sheet.

In order to generate the lpsolve script file for lp_solve as input based on our model, we wrote several Python (3.5.2) codes (which can be run in Windows, Mac, Linux) to automate the process. `lp_diet.py` extracted the necessary data from the CSV file using the CSV package and placed the data into a list of lists. This list of lists would essentially represent a table with each row containing appropriate data for each food item. The gender variable was set as 2 for male, or 3 for female. The code then generated the objective of the Linear Programming script using a for loop that loops through the data table to extract the preference rating for each item depending on the gender variable.

As for the constraints, the minimum and maximum values for each nutrient for each gender were set as variables to certain constants according to the websites discussed above. Then a for-loop looped through the data table for each nutrient constraint, to print out the corresponding inequalities. At the end, `lp_diet.py` looped through each variable from male and female preferences, protein (g), fat (g), carb (g), energy (kcal), sat_fat (g), trans_fat (g), cholesterol (mg), sodium (mg), potassium (mg), calcium (mg), Vitamin D (mcg), Vitamin E (mg), Vitamin B6 (mg), Vitamin B12 (mcg), and Vitamin C (mg), and the output lpsolve script `lp_diet_*.txt` (Appendix) was generated with the objective and the constraints encoded.

Then we used lpsolve software [3] to solve our model, and saved its output into a seperate file `lp_output_*.txt` (Appendix). This process had some challenges because lpsolve software initially failed to give a desired output saying the lp is unbounded. We realized this resulted from our model not having the upper limit for the calories. Because most of the other nutrient constraints were linearly related to the calorie constraints, not having the upper boundary for calories would have caused the optimization problem being unbounded. After we provided a maximum value to the calorie requirements for each gender and changed the other nutrient constraints that are related to calories, the lpsolve software produced a desired output. It took less than a second to generate the LP script as well as the output file. Further descriptions of the coding methods are below in the actual code as well as other supporting files in the Appendix:

(code) lp_diet.py

```
# The following python code can be run to
# generate an lpsolve script file as outpt, like this:
# python lp_diet.py > lp_diet_*.txt
#
# It will write a LP script file that can be run on the command line
# to generate an lpoutput file, like this:
# lp_solve lp_diet_*.txt > lp_output_*.txt

import csv

# checks if the string represents a number (int/float)
# this function will be used to find out whether an element
# is a number or something else like a string.
def is_number(s):
    try:
        float(s)
        return True
    except ValueError:
        return False

gender = 2; # int of gender: 2 - male, 3 - female

# open the csv file annd excerpt data from the file
with open('./NewNew_Data.csv') as f:
    reader = csv.reader(f)
    next(reader) # skip headers (3 lines)
    next(reader)
    next(reader)
    data = [] # stores necessary food data (going to be a list of lists)
    for row in reader:
        # stores each item's
        # Food Name, Group Name, male prefrence, female preference, protein(g), fat(g),
        # carb(g), energy(kcal), sat fat(g), trans fat(g), cholesterol(mg), sodium(mg),
        # potassium(mg), calcium(mg), Vitamin D(mcg), Vitamin E(mg), Vitamin B6(mg),
        # Vitamin B12(mcg), Vitamin C(mg)
        item = [row[1], row[3], row[4], row[5], row[11], row[12], row[13], row[14], row[29],
row[47],
                row[48], row[49], row[50], row[51], row[64], row[65], row[72], row[73], row[77]]
        # append each row(item) to the list
        data.append(item)

    # Change non-number elements of the columns that should contain numbers such as Tr and N to 0.0
    for i in range(len(data)):
        for j in range(2, 19):
            if (is_number(data[i][j]) == False):
                data[i][j] = 0.0

    # print out objective function which optimizes the preference rating based on gender
    print('max:', end='')
    for i in range(len(data)):
        print('+' , data[i][gender], 'x_', i, sep='', end='')
    print(';')
    print('')

    # Nutrient Requirements
    # male (age 19-30) calorie requirement: 2200-2800kcal
    # female (age 19-30) calorie requirement: 1800-2200kcal

    # protein: 4 grams per kcal, 10% to 35% of daily calories
    # male protein requirement: 55g to 245g
    # female protein requirement: 45g to 192.5g
```

```
# fat: 9 grams per kcal, 20% to 35% of daily calories
# male fat requirement: 48.9g to 108.9g
# female fat requirement: 40g to 85.6g

# carbs: 4 grams per kcal, 45% to 65% of daily calories
# male carb requirement: 247.5g to 455g
# female carb requirement: 202.5g to 357.5g

# saturated fat: up to 7% of daily calories
# male: limit to 21.8g
# female: limit to 17.1g

# trans fat: up to 1% of daily calories
# male: limit to 3.1g
# female: limit to 2.4g

# cholesterol: limit to 300mg
# sodium: limit to 2400mg

# potassium: from 4700mg
# calcium: from 1000mg to 2500mg

# Vitamin D: 600 IU to 4000 IU, 15mcg to 100mcg
# Vitamin E: 22 IU to 1500 IU, 0.55mcg to 37.5mcg, 0.00055mg to 0.0375mg
# Vitamin B6: 1.3mg to 100mg
# Vitamin B12: from 2.4mcg
# Vitamin C: male: 90 to 2000mg | female: 75 to 2000mg

# According to the nutrient requirements above, set each nutrient's
# daily recommended minimum and maximum values based on gender
if gender == 2:
    calorie_min = 2200
    calorie_max = 2800
    protein_min = 55
    protein_max = 245
    fat_min = 48.9
    fat_max = 108.9
    carb_min = 247.5
    carb_max = 455
    sat_max = 21.8
    trans_max = 3.1
    VitC_min = 90
elif gender == 3:
    calorie_min = 1800
    calorie_max = 2200
    protein_min = 55
    protein_max = 192.5
    fat_min = 48.9
    fat_max = 85.6
    carb_min = 247.5
    carb_max = 357.5
    sat_max = 17.1
    trans_max = 2.4
    VitC_min = 75
choles_max = 300
sodium_max = 2400
potassium_min = 4700
calcium_min = 1000
calcium_max = 2500
VitD_min = 15
VitD_max = 100
VitE_min = 0.00055
```

```
VitE_max = 0.0375
VitB6_min = 1.3
VitB6_max = 100
VitB12_min = 2.4
VitC_max = 2000
bev_max = 30
amount_max = 30

# print out lp constraints for each daily nutrient requirement

# calorie requirement
for i in range(len(data)):
    print('+', data[i][7], 'x_', i, sep='', end='')
print('>=', calorie_min, ';', sep='')
print('')

for i in range(len(data)):
    print('+', data[i][7], 'x_', i, sep='', end='')
print('<=', calorie_max, ';', sep='')
print('')

# protein requirement
for i in range(len(data)):
    print('+', data[i][4], 'x_', i, sep='', end='')
print('>=', protein_min, ';', sep='')
print('')

for i in range(len(data)):
    print('+', data[i][4], 'x_', i, sep='', end='')
print('<=', protein_max, ';', sep='')
print('')

# fat requirement
for i in range(len(data)):
    print('+', data[i][5], 'x_', i, sep='', end='')
print('>=', fat_min, ';', sep='')
print('')

for i in range(len(data)):
    print('+', data[i][5], 'x_', i, sep='', end='')
print('<=', fat_max, ';', sep='')
print('')

# carbs requirement
for i in range(len(data)):
    print('+', data[i][6], 'x_', i, sep='', end='')
print('>=', carb_min, ';', sep='')
print('')

for i in range(len(data)):
    print('+', data[i][6], 'x_', i, sep='', end='')
print('<=', carb_max, ';', sep='')
print('')

# saturated fat requirement
for i in range(len(data)):
    print('+', data[i][8], 'x_', i, sep='', end='')
print('<=', sat_max, ';', sep='')
print('')

# trans fat requirement
for i in range(len(data)):
```

```
    print('+', data[i][9], 'x_', i, sep='', end='')
print('<=', trans_max, ';', sep='')
print('')

# cholesterol requirement
for i in range(len(data)):
    print('+', data[i][10], 'x_', i, sep='', end='')
print('<=', choles_max, ';', sep='')
print('')

# sodium requirement
for i in range(len(data)):
    print('+', data[i][11], 'x_', i, sep='', end='')
print('<=', sodium_max, ';', sep='')
print('')

# potassium requirement
for i in range(len(data)):
    print('+', data[i][12], 'x_', i, sep='', end='')
print('>=', potassium_min, ';', sep='')
print('')

# calcium requirement
for i in range(len(data)):
    print('+', data[i][13], 'x_', i, sep='', end='')
print('>=', calcium_min, ';', sep='')
print('')

for i in range(len(data)):
    print('+', data[i][13], 'x_', i, sep='', end='')
print('<=', calcium_max, ';', sep='')
print('')

# Vitamin D requirement
for i in range(len(data)):
    print('+', data[i][14], 'x_', i, sep='', end='')
print('>=', VitD_min, ';', sep='')
print('')

for i in range(len(data)):
    print('+', data[i][14], 'x_', i, sep='', end='')
print('<=', VitD_max, ';', sep='')
print('')

# Vitamin E requirement
for i in range(len(data)):
    print('+', data[i][15], 'x_', i, sep='', end='')
print('>=', VitE_min, ';', sep='')
print('')

for i in range(len(data)):
    print('+', data[i][15], 'x_', i, sep='', end='')
print('<=', VitE_max, ';', sep='')
print('')

# Vitamin B6 requirement
for i in range(len(data)):
    print('+', data[i][16], 'x_', i, sep='', end='')
print('>=', VitB6_min, ';', sep='')
print('')

for i in range(len(data)):
```

```
        print('+', data[i][16], 'x_', i, sep='', end='')
    print('<=', VitB6_max, ';', sep='')
    print('')

    # Vitamin B12 requirement
    for i in range(len(data)):
        print('+', data[i][17], 'x_', i, sep='', end='')
    print('>=', VitB12_min, ';', sep='')
    print('')

    # Vitamin C requirement
    for i in range(len(data)):
        print('+', data[i][18], 'x_', i, sep='', end='')
    print('>=', VitC_min, ';', sep='')
    print('')

    for i in range(len(data)):
        print('+', data[i][18], 'x_', i, sep='', end='')
    print('<=', VitC_max, ';', sep='')
    print('')

    # Beverages limit
    for i in range(len(data)):
        # if the group name starts with P or Q, which means the item is
        # either the beverage or alcohol, add the variable to the constraint
        if (data[i][1].startswith('P') or data[i][1].startswith('Q')):
            print('+x_', i, sep='', end='')
    print('<=', bev_max, ';', sep='')
    print('')

    # amount of food limit
    for i in range(len(data)):
        print('+x_', i, '<=', amount_max, ';', sep='', end='')
    print('')
```

---

4. Solution

Through lpsolve, we got long outputs. Here is an extraction from `lp_output_female.txt`:

```
Value of objective function: 1639.81681676

Actual values of the variables:
x_0                             0
…
```

and 2834 more lines like above...

In order to give us a better idea of what these outputs suggests about our diet, we wrote `lp_output_process.py` to process our output files by extracting all the non-trivial items from the output with non-zero amount of food, and printing out their corresponding food names, group names, and the lpsolve output. The output from this step, `lp_trimmed_*.txt`, is our final

solution for our question; in another words, it is the suggested diet that maximizes our happiness or satisfaction under specified nutritional constraints.

From the trimmed output, we found that, in order to maximize the happiness, an optimal daily diet for female consisted of chicory, cranberries, fennel, gourd, jackfish, jelly, lemon juice, limes, marrow, mushroom, nutmeg, passion fruit, orange juice, rock salmon and tea, with a maximum happiness score $\mathbf{H}_{max}$= 1639.81681676. An optimal daily diet for male consisted of chicory, cranberries, fennel, duck, gourd, jackfish, jelly, lemon juice, lime juice, marrow, mushroom, nutmeg, passion fruit, orange juice, rock salmon and tea, with a maximum happiness score $\mathbf{H}_{max}$= 1794.33880959. The specific food names and amount of each item to be consumed in 100 grams of food are listed in the trimmed output below.

(output) lp_trimmed_male.txt

```
Value of objective function: 1794.33880959

Actual values of the variables:
```

Food Name	Group Name	Variable	100g of food
Chicory, pale variety, boiled in unsalted water	DG	x_716	30
Cranberries	FA	x_853	30
Duck, raw, meat only, weighed with fat, skin and bone	MCC	x_1049	2.94369
Fennel, Florence, boiled in unsalted water	DG	x_1089	8.29889
Fruit juice drink/squash, no sugar added, diluted	PCC	x_1162	30
Gourd, ridge, raw	DG	x_1199	21.6347
Jackfish, raw	JC	x_1316	0.46012
Jelly, sugar free, made with water	BR	x_1327	30
Lemon juice, fresh, weighed as whole fruit	FC	x_1492	30
Lime juice, fresh	FC	x_1520	15.6523
Marrow, boiled in unsalted water	DG	x_1575	30
Mushrooms, white, raw	DG	x_1699	3.7122
Orange juice, ambient, UHT	FC	x_1760	0.0189024
Passion fruit, flesh and pips, weighed with skin	FA	x_1817	30
Rock Salmon/Dogfish, raw	JA	x_2346	0.990351

(output) lp_trimmed_female.txt

```
Value of objective function: 1639.81681676

Actual values of the variables:
```

Food Name	Group Name	Variable	100g of food
Chicory, pale variety, boiled in unsalted water	DG	x_716	30
Cranberries	FA	x_853	30
Fennel, Florence, boiled in unsalted water	DG	x_1089	9.78434
Gourd, ridge, raw	DG	x_1199	2.39609
Jackfish, raw	JC	x_1316	0.809946
Jelly, sugar free, made with water	BR	x_1327	30
Lemon juice, fresh, weighed as whole fruit	FC	x_1492	30
Limes, flesh only, weighed with peel and pips	FA	x_1522	20.8073
Marrow, boiled in unsalted water	DG	x_1575	30
Mushrooms, white, raw	DG	x_1699	3.72073
Nutmeg, ground	H	x_1731	0.269869
Orange juice, ambient, UHT	FC	x_1760	0.0146341

```
Passion fruit, flesh and pips, weighed with skin            FA            x_1817        25.8045
Rock Salmon/Dogfish, raw                                    JA            x_2346        0.490755
Tea, black, infusion, average                               PAA           x_2647        30
```

(code) lp_output_process.py

```
# The following python code can be run with
# an lpsolve output file as input, like this:
# python lp_output_process.py < lp_output_*.txt > lp_trimmed_*.txt
#
# It will extract the lines giving the non-zero values
# and prints out the corresponding food name, group name, and the lp output

import fileinput
import csv
import re

# open the csv file and extract the necessary data into a list of lists
with open('./NewNew_Data.csv') as f:
    reader = csv.reader(f)
    next(reader) # skip headers
    next(reader)
    next(reader)
    data = [] # stores necessary food data
    for row in reader:
        # stores each item's
        # Food Name, Group Name, male prefrence, female preference, protein(g), fat(g),
        # carb(g), energy(kcal), sat fat (g), trans fat(g), cholesterol(mg), sodium(mg),
        # potassium(mg), calcium(mg), Vitamin D(mcg), Vitamin E(mg), Vitamin B6(mg),
        # Vitamin B12(mcg), Vitamin C(mg)
        item = [row[1], row[3], row[4], row[5], row[11], row[12], row[13], row[14], row[29],
row[47],
                row[48], row[49], row[50], row[51], row[64], row[65], row[72], row[73], row[77]]
        data.append(item)

# get the results from the input file
for line in fileinput.input():
    # deals with the lines that print the actual lp output
    if line.startswith('x'):
        output = line.split() # split into a variable name and an output value
        # find lines that have non-zero values
        if output[1] != '0':
            # extracts the number of the variable name
            var_num = int(re.search(r'\d+', output[0]).group())
            # find the corresponding food name and group name using the variable number
            item = [data[var_num][0], data[var_num][1], output[0], output[1]]
            # align the columns appropriately
            print ('{0[0]:<60}{0[1]:<15}{0[2]:<15}{0[3]:<30}'.format(item))
    else:
        if line.startswith('Actual'):
            print(line)
            # prints out the header
            header = ['Food Name', 'Group Name', 'Variable', '100g of food to consume daily (opt
value)']
            print ('{0[0]:<60}{0[1]:<15}{0[2]:<15}{0[3]:<30}'.format(header))
            print('')
        else:
            print(line, end='')
```

---

5. Commentary on solution

Firstly, from the result of the diet preference optimization for male, we found that the value of objective function is $\mathbf{H}_{max}$= 1794.33880959, which means male in our group reach the highest level of happiness while fulfilling the requirement of nutrition. There are fifteen kinds of food items that male consume. Among these fifteen items, five kinds are vegetables within food group DG, three kinds are fruit juice within FC, two kinds are general fruit within FA, one kind is duck within MCC, one kind is squash and cordials within PCC, one kind is fatty fish within JC, one kind is puddings and chilled desserts within BR, and one type is white fish within JA. From this data, we can know that approximately half items from the recommended food list are vegetables and fruits. These food items are healthy and contain low level of calories and fat.

In order to ensure diversity in our food list, we set that the amount of each type of food can be consumed up to 3000 grams per day. There are seven kinds of foods that reached the maximum amount of consumption: chicory, cranberries, fruit juice drink/squash, jelly, lemon juice, marrow and passion fruit. Most of them are grouped in vegetable (DG) and fruits (FA). That means male in our group feel happier when they eat these seven kinds of foods than eat others. In fact, these two groups were rated by male at 6.5 and 8, which are relatively high. Meanwhile, we found that male consume less on jackfish, orange juice and rock salmon/dogfish, which are less than 100 grams per day. They are grouped in white fish (JC), fruit juices (FC) and fatty fish (JA). This tells us male are less likely to eat them; however, they have to consume some of them per day in order to meet daily requirements of nutrition.

The interesting thing is that male highly prefer to have lemon juice, but dislike drinking orange juice. However, they still need to consume orange juice, although lemon juice and orange juice are both in fruit juices group. The reason is that orange juice contains more energy and water than lemon juice, which are 146 kj and 89.4g separately. Lemon juice contains only 11 kj energy and 32g water. male need to consume orange juice to get enough energy and water. Besides, the result shows that duck, jackfish, mushroom and rock salmon account for relatively small portion of daily consumption for male, which are fewer than 300g. We found that all of them are raw foods, which indicated that male in our group are less likely to eat raw foods.

Second, base on the result we got for female preference maximization, female can reach a happiness score $\mathbf{H}_{max}$= 1639.81681676 with eating fifteen different types of food and meeting the nutrition requirement daily. Out of these fifteen kinds of food, there are five types of general vegetables within group DG, three types of general fruits within group FA, two types of fruit juice within group FC), two kinds of fish and fish products, namely one from fatty fish within group JC and one white fish within group JA, one food of puddings and chilled desserts within group BR, which belongs to milk and milk products group, one food from herbs and spices within group H, and one kind of beverage, powered drinks and essences within group PAA. Obviously, we can see that two-thirds of the recommended food list contains vegetables and fruits. From the nutrition data of these food, we found

that they are low in calories and fat. So we can consume more units of them than other foods that have higher levels of nutrients that we want to restrict below certain amounts. The two vegetables are both rich in Potassium, which female are required to have as much as 4700 mg per day and cranberries, fresh lemon juice, passion fruit, and orange juice are high in Vitamin C. Besides, there are several types of food like fish and nuts that can fulfill the proteins intake requirement for female. And also, black tea does not give any fat, which means it meets the nutrition constraints as well as the preference by female in our group. In addition, jelly should not be good for a diet. But since based on our group survey of preference, the two female members rated highly for the happiness they could get by eating desserts, so the recommendation contains sugar free and also water made jelly to increase their joy while restraining the sugar and calories they take in.

Moreover, from the result we got, six types of food items, namely unsalted water boiled pale chicory, cranberries, water made sugar free jelly, fresh lemon juice weighed as whole fruit, unsalted water boiled marrow, and black tea all have the value of 30. Since we have restricted that we cannot have any types of food more than 30 units of 100 grams, or 3000 grams per day, having a solution of 30 units of these six types of food indicates that the female in our group love consuming vegetables, fruits, desserts, and beverages and the six types of food listed above best fulfill the nutrient requirements. If we do not restrain the units of food consumed, perhaps female will eat even more of those six types. In other words, the female still remain healthy, but the diversity of food eating per day will drop.

Another interesting result is that both of the two female member in our group do not like cranberries, which means that they will not raise happiness level by eating cranberries. However, our solution gives that the recommended consumption of cranberries is 30 units, i.e., 3000 grams. This seems to be unhappy since they would be a lot of food that they dislike. We suppose that the reason for the optimal solution to contain this much of cranberries is that our survey placed preference ratings on each food group, not on each individual food item. Therefore, even if they do not like cranberries, because entire fruit group was rated as highly as 8, the model will consider cranberries as an item that enhances preference optimization. This is one of the drawbacks from rating food groups instead of individual items, though it was impossible to rate each of 2384 items in the first place.

In conclusion, in order to reach a happiness level as high as possible and also meet daily nutritional requirements, both male and female in our group should eat 15 types of certain food. They all prefer to eat vegetables and fruits but are less likely to eat raw food. However, male are less suggested to consume fruit juice than are female.

6. Variations

Variation 1: Unhappy Case -- minimize our satisfaction but in a healthy way

Good. This is an amusing, and quite easy, thing to look at.

(code) lp_diet_unhappy.py

From the original lp_diet.py, we did some modification by changing max to min in line 47.

```
# print out objective function which minimizes the preference rating based on gender
    print('min:', end='')
    for i in range(len(data)):
        print('+' , data[i][gender], 'x_', i, sep='', end='')
    print(';')
    print('')
```

According to our original model, we try to maximize our happiness and meet the nutritional requirement at the same time. There also exists another interesting situation that we may want to punish ourselves when we do worse in the exams and works. We can choose eating unhappy as a form of punishment. Besides, sometimes, one has to be harsh on him/herself, and this is the classy way to do so. Thus, in this variation, we try to minimize our happiness and keep enough daily nutrition. Based on our original model, we changed maximizing happiness to minimizing happiness and kept all constraints unchanged.

From the result of male's and female's preference minimization, we can see the value of objective functions are 8.33620465 and 15.27183148. Compared with maximum happiness scores in the original model, both of the happiness levels in the variation are much lower. This is the result we want to get, which is to minimize our satisfaction in a healthy way. Also, the numbers of food in the optimal food list for male and female are less than original model. In male's recommended food list, there are only seven kinds of food. Female's food list contains nine kinds of food. All types of food in the food list for male are different from the ones we got form the original model except orange juice that belongs to the type of fruit juices. This is because orange juice has a large amount of energy and water is essential to male's body under these two situations. A concrete evidence that indicates this diet indeed punishes male is that it has three different types of breakfast cereal, which was rated by male at 1. In female's food list, there are two types of food that were in the original model: jackfish and orange juice. This is because jackfish and orange juice mainly provide energy for female body. As similar as the unhappy diet for male, the unhappy diet for female contains the types of food they rated very low, such as cheese within group BL at 1.5 unit and processed milk within group BAR at 2.5 unit.

Besides, both value of male' and female' daily consumption are smaller than original model. In the food list for male, the values of five types of food are under 100 grams, one is about 130 grams and one is about 564 grams. Since male in our group are less likely eating these foods, they want to consume less of them naturally. Meanwhile, our model needs to ensure male meet the requirements of

nutrition. So, the consumption of each food is low, while at least meeting minimum daily nutritional requirements. It is the same condition in female' food list.

In conclusion, this variation is an inverse version of our original model with same constraints. Both male and female will consume food that makes them unhappy. As a result, they will eat few types of food and small values of consumption to at least meet the minimum amount of daily nutritional requirements.

(output) lp_trimmed_male_unhappy.txt

```
Value of objective function: 8.33620465

Actual values of the variables:

Food Name
Group Name     Variable       100g of food to consume daily (opt value)

Breakfast cereal, bran type cereal, fortified                AI            x_408          5.64612
Breakfast cereal, honey loops and hoops                      AI            x_416          1.30292
Breakfast cereal, instant hot oat, plain, raw, fortified     AI            x_417
0.0928571
Chervil, dried                                               H             x_635
0.0201999
Creme fraiche, full fat                                      BJC           x_870
0.0115916
Dressing, oil and lemon, homemade                            WC            x_1031         0.30048
Orange juice, ambient, UHT                                   FC            x_1760
0.0184186
```

(output) lp_trimmed_female_unhappy.txt

```
Value of objective function: 15.27183148

Actual values of the variables:

Food Name
Group Name     Variable       100g of food to consume daily (opt value)

Bloater, flesh only, grilled                                 JC            x_352          0.0197297
Cheese, Brie, rind only                                      BL            x_579          0.448212
Cherries, West Indian, flesh only                            FA            x_634          0.0303948
Coffeemate, whitener powder                                  BAR           x_802          0.619319
Courgette, dried                                             DI            x_839          0.151279
Jackfish, raw                                                JC            x_1316         0.913868
Milk, skimmed, dried, fortified                              BAR           x_1635         1.74777
Orange juice, ambient, UHT                                   FC            x_1760         0.0146341
Pizza base, raw                                              AE            x_1991         2.00951
```

Variation 2: Vegetarian Case -- maximize our happiness with a vegeterian diet

---

(code) lp_diet_veg.py

From the original lp_diet.py, we did some modification by adding this constraint in line 282.

```
# vegetarian diet: no meat or fish
    for i in range(len(data)):
```

```
    # the group name starts with M or J, which means the item is
    # either meat or fish
     if (data[i][1].startswith('M') or data[i][1].startswith('J')):
         print('+x_', i, sep='', end='')
print('=0;')  # the sum of meat and fish varaibles is 0
print('')
```

Perhaps there are some days that we do not want to have meat or fish, but we indeed wish to keep on a healthy diet. In our original model, we maximized our happiness score based on restrictions considering every kind of food as a possible choice. Now, we modify our model and add some constraints that set the amount of all the food that made with meat and fish to zero. In this case, we could have a vegetarian diet on the days when we are not willing to eat meat and fish.

The outcome gives optimal happiness scores $\mathbf{H}_{max}$= 1296.64981001 for female and $\mathbf{H}_{max}$= 1454.78168382 for male. The optimal values of our objective function decrease for both male and female. Since our original problem includes meat and fish to maximize our preference and we have raw duck, jackfish, and rock salmon in optimal solution for male, and jackfish and rock salmon in the optimal solution for female, substituting these food will reduce our happiness when we have the same nutrient constraints as before. For both of the results for male and female, the solution also contains a maximum amount of 30 units of sugar free jelly, fresh lemon juice, and marrow. Female do not eat fennel for this new solution, while male increase about 16.4 units of that since they drop about 21.6 units of gourd and have to complement more vegetables. Meanwhile, this solution includes breakfast cereal, reduced fat coconut milk, coffee, and eggs, which we do not have any in the previous result. Although their consumption amounts are less than most of the suggested vegetables and fruits, they are recommend to eat to replenish proteins, carbohydrate, calcium, and cholesterol, which are originally supplied by meat and fish.

In addition, it is interesting that we do not have cranberries for both male and female for fruit in this vegetarian diet. Instead, the solution adds 8.13063 units of fresh lime juice and 10 more units of fresh limes for female. Based on our group survey, since both of the female in our group dislike cranberries and prefer lime juice rather, taking cranberries off the list and add lime juice can actually increase their happiness. However, because we are calculating happiness score based on the group categorization but not on each specific food, our optimal value will not change since cranberries and lime juice are both in one categorization.

Overall, the happiness drops for both male and female if we want to have a vegetarian day. We have to consume more cereals and dairy to fulfill the nutrient need that was provided by meat and fish in our original diet problem.

(output) lp_trimmed_male_veg.txt

```
Value of objective function: 1454.78168382

Actual values of the variables:
```

```
Food Name
Group Name     Variable       100g of food to consume daily (opt value)

Breakfast cereal, Ricicles, Kellogg's                    AI          x_427          1.5107
Chicory, pale variety, boiled in unsalted water          DG          x_716          9.32401
Coconut milk, reduced fat, retail                        GA          x_768          1.28691
Coffee, cappuccino, latte                                P           x_790          9.4863
Eggs, duck, whole, raw                                   CA          x_1077         0.401817
Fennel, Florence, boiled in unsalted water               DG          x_1089         24.6649
Fruit juice drink/squash, no sugar added, diluted        PCC         x_1162         20.5137
Jelly, sugar free, made with water                       BR          x_1327         30
Lemon juice, fresh, weighed as whole fruit               FC          x_1492         30
Lime juice, fresh                                        FC          x_1520         27.4038
Marrow, boiled in unsalted water                         DG          x_1575         30
Mushrooms, white, stewed in unsalted water               DG          x_1700         3.71616
Orange juice, ambient, UHT                               FC          x_1760
0.0169221
Passion fruit, flesh and pips, weighed with skin         FA          x_1817         30
```

(output) lp_trimmed_female_veg.txt

```
Value of objective function: 1296.64981001

Actual values of the variables:

Food Name
Group Name     Variable       100g of food to consume daily (opt value)

Breakfast cereal, Ricicles, Kellogg's                    AI          x_427          1.42263
Chicory, pale variety, boiled in unsalted water          DG          x_716          22.7102
Coconut milk, reduced fat, retail                        GA          x_768          1.2542
Coffee, cappuccino, latte                                P           x_790          10.0323
Dressing, oil and lemon, homemade                        WC          x_1031
0.0131536
Eggs, duck, whole, raw                                   CA          x_1077
0.399646
Jelly, sugar free, made with water                       BR          x_1327         30
Lemon juice, fresh, weighed as whole fruit               FC          x_1492         30
Lime juice, fresh                                        FC          x_1520         8.13063
Limes, flesh only, weighed with peel and pips            FA          x_1522         30
Marrow, boiled in unsalted water                         DG          x_1575         30
Mushrooms, white, stewed in unsalted water               DG          x_1700         3.72489
Orange juice, ambient, UHT                               FC          x_1760
0.0125553
Passion fruit, flesh and pips, weighed with skin         FA          x_1817         12.0148
Tea, black, infusion, average                            PAA         x_2647         19.9677
```

Variation 3: Diverse Case -- maximize our happiness with plenty of diversity of foods

---

(code) lp_diet_grouplim.py

From the original lp_diet.py, we did some modification by adding this constraint in line 289.

```
# amount of group limit
    # create a list containing alphabets in uppercase
    groups = string.ascii_uppercase
    # loops through the list to check each alphabet
    for j in range(len(groups)):
        # binary to check if the alphabet represents one of the groups
```

```
group_bool = 0
for i in range(len(data)):
    # prints out the sum of items on each group
    if (data[i][1].startswith(groups[j])):
        group_bool = 1
        print('+x_', i, sep='', end='')
# only print this if the letter is one of the groups
if group_bool == 1:
    # the sum of items on each group is less than 1000g
    print('<=', group_max, ';', sep='')
    print('')
```

In our daily life, we sometimes want to eat food to make us happy and try as many different types of food as possible within a day. This action can let us taste various types of food as well as ingest different nutritions from varied food. In this variation, we modify the original model to enlarge our possibility to getting more different types of food. That is, originally both male and female eat food from 8 different groups, but after our modification, male can now consume food from 14 kind of groups and female can consume food from 13 different groups.

We set new constraints on each group of food so that no matter what specific food we eat, the total amount of food for each group will be restricted less than a certain amount. In this case, we bound each group with 10 units as an upper limit. Hence, we cannot eat more than 1000 grams of any food for a single day. From the recommended food list for male, we obeserve that the value of consuming coconut, lager, lemon juice, lemon juice that weighed as whole fruit, lollies and marrow reached 10 units. It shows that male are happy to eat these food, but for taking more different types of food, they can only consume 10 units of these food. It is the same situation in the recommended food list for female. The value of cider, coconut, lemon juice, limes and marrow is up to 10 units, which means that the female members in our group prefer to consume them. For sake of having more different food, female can only consume 10 units of each of them. By doing so, we decrease the total amount of vegetables and fruits for every day and add several new food items in the list. For example, we now have low alcohol cider, coconut milk, roast duck, grilled eel, lollies with real fruit juice, fresh oregano, turmeric, homemade carrot and orange soup, and chicken noodle soup for female. This is a big change in the food list since we only have four out of fourteen specific food identical to our original optimal solution. Besides the white fish, fatty fish, puddings and chilled desserts, general fruits, general vegetables, and herbs and spices, female can eat food in the other five groups: ciders, nuts and seeds, duck, juices (which is a different group from the fruit juices group), and ice cream. Ingesting nuts and seeds, juices, and ice cream can increase female happiness in our group, since their rates on these three groups are relatively high. In particular, female have an average rate of 8.5 in juices, 6.5 in nuts and seeds, and 8.5 in ice cream, out of a maximum rate of 10. Similar things happen for male. They can now ingest ten specific new food with nine new groups to the original problem. As female, the male in our group prefer juice at an average rate of 8.5 out of 10 and have a perfect rate of 10 on ice cream. So adding these two groups to the optimal solution will give them more happiness comparing to eating vegetables with a rating of 4.75.

However, with the limitations on the consumption for each group of food, both the male and the female happiness decrease sharply. The maximum happiness score drop from 1639.81681676 to 558.85880275 for female and from 1794.33880959 to 618.16189370 for male. This is basically because with the several constraints on nutrient levels, we can not eat much ice cream, nuts, or beverage juice since all of them are rich in calories. Moreover, limiting the total consumption for each group indeed decreases the total amount of food we consume in the optimal solution, and thus reduces our happiness. In addition, we suppose another reason for the dropping in our joy is that both of male and female in our group like fruits and fruit juice, with an average rating of 8 and 7.5 out of 10. This new solution to the variation on diversity does not give as much the amount of fruit or fruit juice groups as the one we get in the original problem. Hence, our optimal happiness values drop.

(output) lp_trimmed_male_grouplim.txt

```
Value of objective function: 618.16189370

Actual values of the variables:

Food Name                    Group Name     Variable       100g of food to consume daily (opt value)

Cardamom, ground                                           H          x_517
1.12797
Chicken, stir-fried with rice and vegetables, retail, reheated      MR         x_695
0.500352
Coconut milk                                               GA         x_767          10
Duck, roasted, meat only, weighed with fat, skin and bone          MCC        x_1052
9.49965
Eel, conger, flesh only, grilled, weighed with bones and skin      JA         x_1058
8.84615
Jackfish, raw                                              JC         x_1316
1.15385
Lager, alcohol-free                                        QA         x_1360         10
Lemon juice, fresh                                         PE         x_1491         10
Lemon juice, fresh, weighed as whole fruit                 FC         x_1492         10
Lollies, with real fruit juice                             BP         x_1548         10
Marrow, boiled in unsalted water                           DG         x_1575         10
Oregano, fresh                                             H          x_1768
1.59442
Rice, Thai fragrant, boiled in unsalted water              AC         x_2310
2.24167
Soup, carrot and orange, homemade                          WAA        x_2516
0.251388
Soup, low calorie, canned                                  WAC        x_2529
2.68501
Turmeric, ground                                           H          x_2743
4.1343
```

(output) lp_trimmed_female_grouplim.txt

```
Value of objective function: 558.85880275

Actual values of the variables:

Food Name                    Group Name     Variable       100g of food to consume daily (opt
value)

Cider, low alcohol                                         QC         x_753          10
Coconut milk                                               GA         x_767          10
```

Duck, roasted, meat only, weighed with fat, skin and bone	MCC	x_1052	9.48769
Eel, conger, flesh only, grilled, weighed with bones and skin	JA	x_1058	6.35424
Jackfish, raw	JC	x_1316	1.15385
Jelly, sugar free, made with water	BR	x_1327	2.51637
Lemon juice, fresh	PE	x_1491	10
Limes, flesh only, weighed with peel and pips	FA	x_1522	10
Lollies, with real fruit juice	BP	x_1548	7.48363
Marrow, boiled in unsalted water	DG	x_1575	10
Oregano, fresh	H	x_1768	2.74731
Soup, carrot and orange, homemade	WAA	x_2516	0.625
Soup, chicken noodle, dried, as served	WAE	x_2518	2.70183
Turmeric, ground	H	x_2743	2.65146

7. Conclusion

Through this study of exploring the optimal diet based on preference, we concluded that, in order to maximize our happiness, generally a daily diet should consist of mostly fruits and vegetables. For non-vegetarians, fish seems to be the most nutritious meat type in an optimal daily diet. Debatably, from our results, male seem to be more easily satisfied than female, with maximized happiness scores higher than female in every set. From our variation studies, we found that to make oneself unhappy, breakfast cereal and milk/cheese might be good choices for male and female respectively. For vegetarians, with vegetables and fruits they could never be alone and sick. Having a diverse diet can help introducing a more balanced diet while maintaining a high happiness level.

Despite these interesting findings, we have to admit that there are some limitations. First, our preference scores for male and female groups are solely based on the small survey within our group with a sample size of 4. This small sample cannot be representative of the entire male and female populations. Further study can be conducted based on a survey with a much bigger sample size across different populations, and in that case, the generalizability of our model can greatly increase. Second, the survey was inevitably focused on each food group, instead of each individual food item, which resulted in some food item that one actually dislikes being rated highly. This can be fixed with more time and patience of the survey subjects to actually rate each item. Last but not least, we based our model on the dataset by Public Health England, which covers a wide variety of food types but cannot cover every possible food in the world espeically the U.S. we currently live in. This may, in a very rare chance, imply possible better solutions.

Even with limitations due to our small sample size and dataset selection as described above, our model still provides profound insight into diet planning. With our model, not only can the suggested diets be healthy, they can bring satisfaction and happines into people's daily life. Therefore, we feel our efforts into this project are very meaningful and rewarding.

8. References (in the alphabetical order)

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8. US Department of Argriculture, "Estimated Calorie Needs per Day by Age, Gender, and Physical Activity Level" https://www.cnpp.usda.gov/sites/default/files/usda_food_patterns/EstimatedCalorieNeedsPerDayTable.pdf
9. US Food and Drug Administration, "Guidance for Industry: A Food Labeling Guide (14. Appendix F: Calculate the Percent Daily Value for the Appropriate Nutrients)" http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm064928.htm
10. Vegetarian Resource Group, "Veganism in a Nutshell" http://www.vrg.org/nutshell/vegan.htm#what
11. Wikipedia, "Knapsack problem" https://en.wikipedia.org/wiki/Knapsack_problem
12. Wikipedia, "Stigler Diet" https://en.wikipedia.org/wiki/Stigler_diet

9. Appendix: Codes, Inputs and Outputs

- **Data arrangements** https://goo.gl/GnIS24
  - (code) Preference_Switch.sh
  - (code) pref_ind_switch_final.sh
  - (input) FoodGroup.list
  - (input) pref.list
  - (input) prefMF.list
  - (output) new_pref.out
- **Main Solution** https://goo.gl/lhWq0X
  - (code) lp_diet.py
  - (code) lp_output_process.py
  - (out/input) lp_diet_female.txt
  - (out/input) lp_diet_male.txt
  - (out/input) lp_output_female.txt
  - (out/input) lp_output_male.txt
  - (output) lp_trimmed_female.txt
  - (output) lp_trimmed_male.txt
- **Variation 1: Unhappy Case** https://goo.gl/MSypoq
  - (code) lp_diet_unhappy.py
  - (out/input) lp_diet_female_unhappy.txt
  - (out/input) lp_diet_male_unhappy.txt
  - (out/input) lp_output_female_unhappy.txt
  - (out/input) lp_output_male_unhappy.txt
  - (output) lp_trimmed_female_unhappy.txt
  - (output) lp_trimmed_male_unhappy.txt
- **Variation 2: Vegetarian Case** https://goo.gl/MSypoq
  - (code) lp_diet_veg.py
  - (out/input) lp_diet_female_veg.txt
  - (out/input) lp_diet_male_veg.txt
  - (out/input) lp_output_female_veg.txt
  - (out/input) lp_output_male_veg.txt
  - (output) lp_trimmed_female_veg.txt
  - (output) lp_trimmed_male_veg.txt
- **Variation 3: Diverse Case** https://goo.gl/MSypoq
  - (code) lp_diet_grouplim.py
  - (out/input) lp_diet_female_grouplim.txt
  - (out/input) lp_diet_male_grouplim.txt
  - (out/input) lp_output_female_grouplim.txt
  - (out/input) lp_output_male_grouplim.txt
  - (output) lp_trimmed_female_grouplim.txt
  - (output) lp_trimmed_male_grouplim.txt

(code) Preference_Switch.sh

```
#!/usr/local/bin/
# Baihan Lin, October 2016

# The following code was to generate proper data format of
# two columns of preference data for male and female
# corresponding to each food item. These two columns
# are later copied and pasted into Excel sheet of all data.

# Part I: Generate pattern matching arguments
# input file: FoodGroup.list, pref.list, prefMF.list
# output file: pref_ind_switch_final.sh

rm pref*.run*;
rm pref_ind_switch.sh*;
rm pref_ind_switch_final.sh*;
rm new_pref.out*;

cp pref.list pref1.run;
sed -i -e 's/^/elif [[ $j = /' pref1.run;

cp prefMF.list pref2.run;
sed -i -e 's/^/ ]];then echo /' pref2.run;

paste pref1.run pref2.run > pref_ind_switch.sh;
sed -i '' 's#$# >> new_pref.out;#' pref_ind_switch.sh;

cat pref_ind_switch.sh | tr -d '\011' > pref_ind_switch_final.sh;

sed -i '' "s/+/ /" pref_ind_switch_final.sh;
sed -i '' "s/+/ /" pref_ind_switch_final.sh;

# Part II: Generate columns with matched preference data
# input file: pref_ind_switch_final.sh
# output file: new_pref.out

for j in `cat FoodGroup.list`; do
        #sh pref_ind_switch_final.sh
if [[ $j = A ]];then echo A 5 3.5 >> new_pref.out;
elif [[ $j = AA ]];then echo AA 3.5 3.5 >> new_pref.out;
elif [[ $j = AB ]];then echo AB 8 2.5 >> new_pref.out;
elif [[ $j = AC ]];then echo AC 6 3.5 >> new_pref.out;
elif [[ $j = AD ]];then echo AD 4.5 3 >> new_pref.out;
elif [[ $j = AE ]];then echo AE 6.5 1.5 >> new_pref.out;
elif [[ $j = AF ]];then echo AF 2.5 4.5 >> new_pref.out;
elif [[ $j = AG ]];then echo AG 2 4 >> new_pref.out;

...
```

and 128 more rows like that...

```
elif [[ $j = WE ]];then echo WE 4 3.5 >> new_pref.out;
else

        echo $j not found >> new_pref.out;
fi;
done
```

Here is the link to the full file: https://goo.gl/GnIS24

(code) pref_ind_switch_final.sh

```
#!/usr/local/bin/
# Baihan Lin, October 2016

# The following code was generated by Preference_Switch.sh
# in order to be copied and pasted into Part II of
# Preference_Switch.sh.

elif [[ $j = A ]];then echo A 5 3.5 >> new_pref.out;
elif [[ $j = AA ]];then echo AA 3.5 3.5 >> new_pref.out;
elif [[ $j = AB ]];then echo AB 8 2.5 >> new_pref.out;
...
```

and 135 more rows like that...

Here is the link to the full file: https://goo.gl/GnIS24

(input) FoodGroup.list

Too big to display, 2898 rows.

Here is the link to the full file: https://goo.gl/GnIS24

(input) pref.list

A	BJL	IFB
AA	BJP	IFC
AB	BJS	J
AC	BL	JA
AD	BN	JC
AE	BNE	JK
AF	BNH	JM
AG	BNS	JR
AI	BP	M
AK	BR	MA
AM	BV	MAA
AN	C	MAC
AO	CA	MAE
AP	CD	MAG
AS	CDE	MAI
AT	CDH	MC
B	D	MCA
BA	DA	MCC
BAB	DAE	MCE
BAE	DAM	MCG
BAH	DAP	MCI
BAK	DAR	MCK
BAN	DB	MCM
BAR	DF	MCO
BC	DG	ME
BF	DI	MEA
BFD	DR	MEC
BFG	F	MEE
BFJ	FA	MG
BFP	FC	MBG
BH	G	MI
BJ	GA	MIG
BJC	H	MR
BJF	IF	O

OA	Q	SN
OB	QA	SNA
OC	QC	SNB
OE	QE	SNC
OF	QF	W
P	QG	WA
PA	QI	WAA
PAA	QK	WAC
PAC	S	WAE
PC	SC	WC
PCA	SE	WCD
PCC	SEA	WCG
PE	SEC	WCN
		WE

For environment protection (saving trees is saving paper), here we displayed it in 3 columns.

(input) prefMF.list

A	+	5	+	3.5	BR	+	4	+	5.5	MCE	+	5.5	+	4.5
AA	+	3.5	+	3.5	BV	+	3.5	+	3.5	MCG	+	2.5	+	3
AB	+	8	+	2.5	C	+	5.5	+	5.5	MCI	+	2	+	3
AC	+	6	+	3.5	CA	+	5	+	5.5	MCK	+	2	+	3.5
AD	+	4.5	+	3	CD	+	7	+	5.5	MCM	+	3	+	3.5
AE	+	6.5	+	1.5	CDE	+	7	+	5	MCO	+	5	+	6.5
AF	+	2.5	+	4.5	CDH	+	4	+	4.5	ME	+	2	+	4.5
AG	+	2	+	4	D	+	4.5	+	5.5	MEA	+	2.5	+	1.5
AI	+	1	+	4.5	DA	+	3.5	+	7.5	MEC	+	3	+	1.5
AK	+	2	+	2	DAE	+	4	+	4.5	MEE	+	2	+	1.5
AM	+	3.5	+	4.5	DAM	+	4.5	+	5	MG	+	1.5	+	2.5
AN	+	7	+	5.5	DAP	+	4	+	5	MBG	+	7	+	3.5
AO	+	3	+	3.5	DAR	+	4.5	+	5.5	MI	+	7	+	4.5
AP	+	4	+	3.5	DB	+	4	+	5	MIG	+	6	+	4
AS	+	4.5	+	4.5	DF	+	4	+	5.5	MR	+	7	+	4.5
AT	+	2	+	3	DG	+	6.5	+	6.5	O	+	3	+	2
B	+	4	+	4	DI	+	5	+	5	OA	+	2	+	1.5
BA	+	3	+	4	DR	+	7	+	6.5	OB	+	3.5	+	2
BAB	+	3	+	4.5	F	+	6.5	+	7.5	OC	+	2	+	2
BAE	+	2	+	4.5	FA	+	8	+	8	OE	+	4.5	+	2.5
BAH	+	2	+	4.5	FC	+	8	+	7	OF	+	1.5	+	2
BAK	+	5	+	4	G	+	4.5	+	6.5	P	+	5.5	+	4.5
BAN	+	3	+	3.5	GA	+	5	+	6.5	PA	+	5.5	+	4
BAR	+	4.5	+	2.5	H	+	4	+	4	PAA	+	5.5	+	5
BC	+	4	+	3	IF	+	1.5	+	1.5	PAC	+	3	+	4
BF	+	1.5	+	0.5	IFB	+	1.5	+	1.5	PC	+	5	+	4.5
BFD	+	5	+	3	IFC	+	1.5	+	1.5	PCA	+	5	+	3.5
BFG	+	4.5	+	3	J	+	5.5	+	5.5	PCC	+	6.5	+	2.5
BFJ	+	6	+	6.5	JA	+	7	+	7	PE	+	8.5	+	8.5
BFP	+	3.5	+	2.5	JC	+	5	+	5	Q	+	4.5	+	4
BH	+	4.5	+	4	JK	+	5	+	4.5	QA	+	6	+	3.5
BJ	+	1	+	2.5	JM	+	5	+	4	QC	+	4.5	+	4
BJC	+	1	+	3.5	JR	+	7	+	7	QE	+	3	+	5
BJF	+	1	+	2	M	+	6.5	+	5	QF	+	3	+	4.5
BJL	+	1	+	2.5	MA	+	8.5	+	6	QG	+	3	+	2.5
BJP	+	1	+	2.5	MAA	+	6.5	+	3.5	QI	+	4.5	+	2.5
BJS	+	1	+	2.5	MAC	+	8.5	+	5.5	QK	+	7	+	4.5
BL	+	5	+	1.5	MAE	+	7.5	+	4.5	S	+	4.5	+	6.5
BN	+	8	+	6	MAG	+	5.5	+	5.5	SC	+	4	+	7
BNE	+	8	+	5	MAI	+	5	+	6	SE	+	2	+	6.5
BNH	+	7	+	7	MC	+	5	+	5	SEA	+	4.5	+	6
BNS	+	6.5	+	7	MCA	+	5	+	6	SEC	+	4.5	+	6
BP	+	10	+	8.5	MCC	+	5.5	+	6.5	SN	+	5	+	7

```
SNA     +       7       +       7   WA      +       6.5     +       4.5 WC      +       4       +       4
SNB     +       6       +       6   WAA     +       7       +       5.5 WCD     +       5       +       5
SNC     +       4.5     +       6   WAC     +       4.5     +       3   WCG     +       6.5     +       6.5
W       +       5.5     +       4.5 WAE     +       4       +       3.5 WCN     +       4.5     +       5
                                                                        WE      +       4       +       3.5
```

For environment protection (saving trees is saving paper), here we displayed it in 3 columns.

(output) new_pref.out

Too big to display, 2898 rows.

Here is the link to the full file: https://goo.gl/GnIS24

(code) lp_diet.py

This part is already included in the main text.

(code) lp_output_process.py

This part is already included in the main text.

(out/input) lp_diet_female.txt

Too big to display, thus here is only an extraction:

```
max:+6.5x_0+6.5x_1+...+2x_2834;
+151x_016x_1...+211x_2834>=2200;
+151x_016x_1...+211x_2834<=2800;
+2.9x_01.3x_1...+6.7x_28326.8x_2833+6.7x_2834>=55;
+2.9x_01.3x_1...+6.7x_28326.8x_2833+6.7x_2834<=245;
+15.2x_01.2x_1...9.8x_2834>=48.9;
15.2x_01.2x_1...9.8x_2834<=108.9;
+0.8x_0+0.0x_1+...+25.8x_2834>=247.5;
+0.8x_0+0.0x_1+...+25.8x_2834<=455;
+0.0x_0+0.3x_1+...+2.78x_2834<=21.8;
+0x_0+0.0x_1+...+0.09x_2834<=3.1;
+0x_0+0x_1+0x_2+...+57.3x_2834<=300;
....
+x_0<=30;+x_1<=30;...+x_2834<=30;
```

and 53 more lines like above...

Here is the link to the full file: https://goo.gl/lhWq0X

(out/input) lp_diet_male.txt

```
max:+6.5x_0+6.5x_1+...+2x_2834;
....
+x_0<=30;+x_1<=30;...+x_2834<=30;
```

and 53 more lines like above...

Too big to display, similar to female case, but with different constraint values.

Here is the link to the full file: https://goo.gl/lhWq0X

(out/input) lp_output_female.txt

```
Value of objective function: 1639.81681676

Actual values of the variables:
x_0                            0
...
```

and 2834 more lines like above...
Too big to display, thus here is the link to the full file: https://goo.gl/lhWq0X

(out/input) lp_output_male.txt

```
Value of objective function: 1794.33880959

Actual values of the variables:
x_0                            0
…
```

and 2834 more lines like above...
Too big to display, thus here is the link to the full file: https://goo.gl/lhWq0X

(output) lp_trimmed_female.txt

This part is already included in the main text.

(output) lp_trimmed_male.txt

This part is already included in the main text.

(code) lp_diet_unhappy.py

This part is already partly included in the main text.
Here is the link to the full file: https://goo.gl/MSypoq

(out/input) lp_diet_female_unhappy.txt

```
min:+6.5x_0+6.5x_1+...+2x_2834;
....
+x_0<=30;+x_1<=30;...+x_2834<=30;
```

and 53 more lines like above...
Similar to original case, except that we changed the “max” to “min”.
Too big to display, thus here is the link to the full file: https://goo.gl/MSypoq

(out/input) lp_diet_male_unhappy.txt

```
min:+6.5x_0+6.5x_1+...+2x_2834;
....
+x_0<=30;+x_1<=30;...+x_2834<=30;
```

and 53 more lines like above...
Similar to original case, except that we changed the “max” to “min”.
Too big to display, thus here is the link to the full file: https://goo.gl/MSypoq

(out/input) lp_output_female_unhappy.txt

```
Value of objective function:  15.27183148

Actual values of the variables:
x_0                            0
…
```

and 2834 more lines like above...
Too big to display, thus here is the link to the full file: https://goo.gl/MSypoq

(out/input) lp_output_male_unhappy.txt

```
Value of objective function:  8.33620465

Actual values of the variables:
x_0                           0
…
```

and 2834 more lines like above...
Too big to display, thus here is the link to the full file: https://goo.gl/MSypoq

(output) lp_trimmed_female_unhappy.txt
This part is already included in the main text.

(output) lp_trimmed_male_unhappy.txt
This part is already included in the main text.

(code) lp_diet_veg.py
This part is already partly included in the main text.
Here is the link to the full file: https://goo.gl/MSypoq

(out/input) lp_diet_female_veg.txt

```
max:+6.5x_0+6.5x_1+...+2x_2834;
....
+x_0<=30;+x_1<=30;...+x_2834<=30;
```

and 53 more lines like above...
Similar to original case, except that we added a constraint.
Too big to display, thus here is the link to the full file: https://goo.gl/MSypoq

(out/input) lp_diet_male_veg.txt

```
max:+6.5x_0+6.5x_1+...+2x_2834;
....
+x_0<=30;+x_1<=30;...+x_2834<=30;
```

and 53 more lines like above...
Similar to original case, except that we added a constraint.
Too big to display, thus here is the link to the full file: https://goo.gl/MSypoq

(out/input) lp_output_female_veg.txt

```
Value of objective function:  1296.64981001

Actual values of the variables:
x_0                           0
…
```

and 2834 more lines like above...
Too big to display, thus here is the link to the full file: https://goo.gl/MSypoq

(out/input) lp_output_male_veg.txt

```
Value of objective function:  1454.78168382
```

```
Actual values of the variables:
x_0                             0
…
```
and 2835 more lines like above...
Too big to display, thus here is the link to the full file: https://goo.gl/MSypoq

(output) lp_trimmed_female_veg.txt
This part is already included in the main text.

(output) lp_trimmed_male_veg.txt
This part is already included in the main text.

(code) lp_diet_grouplim.py
This part is already partly included in the main text.
Here is the link to the full file: https://goo.gl/MSypoq

(out/input) lp_diet_female_grouplim.txt
```
max:+6.5x_0+6.5x_1+...+2x_2834;
....
+x_0<=30;+x_1<=30;...+x_2834<=30;
```
and 53 more lines like above...
Similar to original case, except that we added a constraint.
Too big to display, thus here is the link to the full file: https://goo.gl/MSypoq

(out/input) lp_diet_male_grouplim.txt
```
max:+6.5x_0+6.5x_1+...+2x_2834;
....
+x_0<=30;+x_1<=30;...+x_2834<=30;
```
and 53 more lines like above...
Similar to original case, except that we added a constraint.
Too big to display, thus here is the link to the full file: https://goo.gl/MSypoq

(out/input) lp_output_female_grouplim.txt
```
Value of objective function:  558.85880275
Actual values of the variables:
x_0                             0
…
```
and 2835 more lines like above...
Too big to display, thus here is the link to the full file: https://goo.gl/MSypoq

(out/input) lp_output_male_grouplim.txt
```
Value of objective function:  618.16189370
Actual values of the variables:
x_0                             0
…
```
and 2834 more lines like above...
Too big to display, thus here is the link to the full file: https://goo.gl/MSypoq

(output) lp_trimmed_female_grouplim.txt
This part is already included in the main text.

(output) lp_trimmed_male_grouplim.txt
This part is already included in the main text.

(Data) Dataset in Excel format
Here is the link to the full file: https://goo.gl/4umRKN

(Folder) link to our google drive
https://drive.google.com/open?id=0B6BZ-0nxfo4YaW5sS1dKWTZMWmc