Practical Applications of Linear Optimization: Pushing The Limits Of A Student Budget

Graeme Crawley

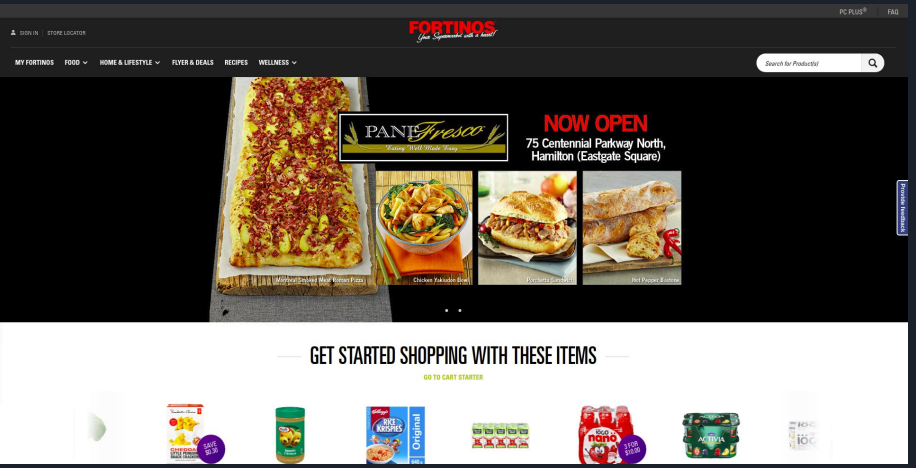
Goal: Create an LP to minimize grocery expenses with constraints ensuring basic nutrition

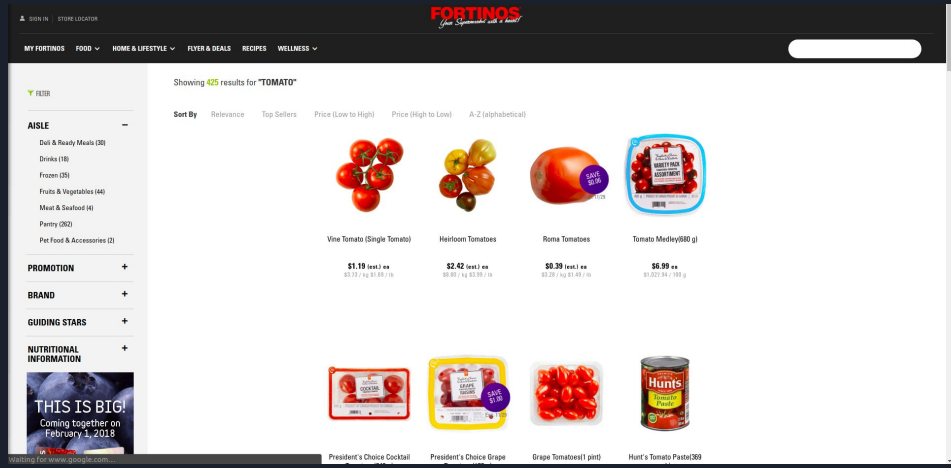
Motivation

- Meal prepped previously
  - Planned meals based on macros, recipes, and taste
- Interested in living “healthy” for less $$$
- Applicable to many classes I’m currently taking

Step 1: Gather Data

- Scrapy





https://www.fortinos.ca/search/page/~item/tomato/~sort/recommended/~selected/true

Step 2: Store Data

- MySQL

```
mysql> select name,
    -> price as Price,
    -> PPG as PricePer100Gram,
    -> prot as Protein,
    -> carb as Carbohydrates,
    -> chol as Cholesterol,
    -> sod as Sodium,
    -> ID
    -> from food where name like '%tomato%' and PPG!=0.00 order by PricePer100Gram asc limit 20;
+-----------------------------------------+-------+----------------+---------+---------------+-------------+--------+----------------+
| name                                    | Price | PricePer100Gram | Protein | Carbohydrates | Cholesterol | Sodium | ID             |
+-----------------------------------------+-------+----------------+---------+---------------+-------------+--------+----------------+
| Tomatoes, Plum                          |  0.99 |           0.12 |    0.80 |          3.20 |        0.00 |   0.24 | 20219574001_EA |
| Tomatoes, Crushed                       |  0.99 |           0.12 |    2.40 |          8.80 |        0.00 |   0.17 | 20219574002_EA |
| Passata Di Pomodori Strained Tomatoes   |  0.88 |           0.13 |    1.60 |          7.20 |        0.00 |   0.20 | 20016661_EA    |
| Mutti Tomato & Basil                    |  0.88 |           0.13 |    1.67 |          5.00 |        0.00 |   0.27 | 20288490002_EA |
| Whole Tomatoes, No Salt Added           |  1.25 |           0.16 |    0.80 |          3.20 |        0.00 |   0.01 | 20314629002_EA |
| Crushed Tomatoes                        |  1.25 |           0.16 |    2.40 |          8.80 |        0.00 |   0.17 | 20314629005_EA |
| Diced Tomatoes, No Salt Added           |  1.25 |           0.16 |    0.80 |          4.80 |        0.00 |   0.00 | 20314629003_EA |
| Crushed Tomatoes. No Salt Added         |  1.25 |           0.16 |    0.00 |          0.00 |        0.00 |   0.00 | 21024447_EA    |
| Whole Tomatoes                          |  1.29 |           0.16 |    0.80 |          4.00 |        0.00 |   0.18 | 20600789_EA    |
| Crushed Tomatoes                        |  1.29 |           0.16 |    2.40 |          8.80 |        0.00 |   0.16 | 20601345_EA    |
| Sliced Stewed Tomatoes                  |  1.29 |           0.16 |    0.80 |          6.40 |        0.00 |   0.16 | 20651741_EA    |
| Diced Tomatoes With Herbs  And Spices   |  1.29 |           0.16 |    0.80 |          5.60 |        0.00 |   0.22 | 20326215005_EA |
| San Marzano Type Tomatoes               |  1.25 |           0.16 |    0.80 |          5.60 |        0.00 |   0.16 | 20066912_EA    |
| Peeled Plum Tomatoes                    |  1.25 |           0.16 |    0.80 |          3.20 |        0.00 |   0.32 | 20314629004_EA |
| Diced Tomatoes, Herbs & Spices          |  1.25 |           0.16 |    0.80 |          5.60 |        0.00 |   0.30 | 20314629006_EA |
| Diced Tomatoes                          |  1.25 |           0.16 |    0.80 |          3.20 |        0.00 |   0.14 | 20314629001_EA |
| Blue Menu Tomato Clam Cocktail, Original |  3.29 |           0.17 |    0.40 |          5.20 |        0.00 |   0.18 | 20506849003_EA |
| Sriracha, Tomato, & Clam Cocktail       |  3.29 |           0.17 |    0.40 |          5.60 |        0.00 |   0.13 | 20975966_EA    |
| Blue Menu Tomato Clam Cocktail, Spicy   |  3.29 |           0.17 |    0.40 |          5.60 |        0.00 |   0.18 | 20506849002_EA |
| Blue Menu Tomatoes, Diced No Salt       |  1.49 |           0.19 |    1.60 |          4.00 |        0.00 |   0.01 | 20034188_EA    |
+-----------------------------------------+-------+----------------+---------+---------------+-------------+--------+----------------+
20 rows in set (0.02 sec)
```

Step 3: Optimize

- IBM CPLEX

```
print minimize[:-3]
print "Subject To"
print "C1: " + subjectToProtein[:-3] + " >= 108000\n"
print "C2: " + subjectToProtein[:-3] + " <= 139400\n"
print "C3: " + subjectToCarbs[:-3] + " >= 391000\n"
print "C4: " + subjectToCarbs[:-3] + " <= 765000\n"
print "C5: " + subjectToFats[:-3] + " >= 66000\n"
print "C6: " + subjectToFats[:-3] + " <= 100000\n"
print "C7: " + subjectToCholesterol[:-3] + " <= 300\n"
print "C8: " + subjectToSodium[:-3] + " <= 200\n"
print "C9: " + subjectToPotassium[:-3] + " <= 4700\n"
print "C10: " + subjectToSugars[:-3] + " <= 25000\n"
print "C11: " + subjectToSatFat[:-3] + " <= 13000\n"
print "C12: " + subjectToDietFiber[:-3] + " <= 25000\n"
print "End"
```

```
Minimize
 Obj: 180 freshpressedsweetapplecider + 1200 creamyhorseradishsauce + 1200
 extralightoliveoil + 1200 oliveoil + 3060 wholeblanchedalmonds + 1610
 almondschocolatecovered + 720 sourcreamregular + 510 tomatopaste + 3560
 canadiancheesegoatsmilkplain + 880 ryebreadwithflaxseeds + 550
 creamyhomestylebuttercream + 550 creamyhomestylevanilla + 550
 creamyhomestylecreamcheese + 1330 liquidhoneybear + 237570
 ricedrinkclassicoriginal + 480 spaghetti + 480 spaghettini + 480 linguine +
 480 capellini + 1450 riceflour + 1450 potatostarch + 1650 medjooldates +
 143630 mellowapplejuice + 3230 bakersdarkchocolatesquares + 570
 organicyogurtplain + 530 canolaoilfirstpressed + 2000 bombayclubmangochutney
 + 1760 acaciahoney + 2060 yearoldroyalcanadianwhitecheddar + 4410
 naturalfilberts + 6590 tangerine + 530 longgrainbrownrice + 810
 honeyroastedpeanuts + 1000 puresemisweetchocolatechips + 140 yellowcornmeal +
 650 creamcrackers + 1330 chickensacchettini + 1860 grillemsoriginalsausage +
 1610 fruitsnackpackcarameldip + 880 spinach + 880 hoisinsauce + 4390 fennel +
 4460 redcurrypaste + 4460 greencurrypaste + 432670 irinigreenolivesgiant +
 5490 chinesebroccoli + 530 creamofmushroomlowsodium + 1330 shepherdspie +
 4390 whiteonion + 2420 pistachiosroasted + 4710 cocktailshrimp + 1330
 muffetsshreddedwheat + 3990 wildskinlessbonelesssockeyesalmon + 920
 instantcoffeemix + 19160 kolbassathinsliced + 390 lightredkidneybeans + 350
 peachjuice + 1400 coconutmilkfrozendessertchocolate + 1400 vanillacoconutmilk
 + 550 broadbeans + 3790 pappadumsplain + 370 dicedtomatoes + 660 romanobeans
 + 900 blackcurrantjuicefromconcentrate + 1860 grillemsoktoberfestsausage +
 600 aseelvegetableghee + 290 wholekernelcorn + 960
 salsaconquesocheesedipmedium + 1000 fruitsnacksclubpack + 610 hotchocolate +
 740 ahcaramel + 1920 saladspringmix + 1760 hummusclassic + 990
 porkandbeefsausageroll + 1000 spaghetti + 570 applecidervinegar + 900
 kalamataolives + 550 wholegrainsbreadancientgrains + 880 pittedpruneslarge +
 5840 originalchickenloafnoporkorbeef + 11600 snackpackliteranch + 500
 brownricevermicelli + 180 bluemenudarkredkidneybeansnosaltadded + 1450
 englishstylechipsfish + 400 pickledmixedvegetablesalad + 400
 pickledcucumbersalad + 3950 papayahalves + 8800 redpeppers + 550
 johnnycakemix + 50 cheese + 3740 bovrilinstantbeefbouillon + 34590
 carvedovenroastedturkeybreastthinsliced + 630 sunfloweroil + 1010
 realmayonnaise + 1010 mayonnaisefat + 1260 jumboveggiedogs + 1500
```

The Math

$$Min \quad \sum_{i=0}^{n} c_i x_i + c_{i+1} x_{i+1} + \ldots + c_n x_n$$

$$Subject\ to \quad C1 : \sum_{i=0}^{n} p_i x_i + p_{i+1} x_{i+1} + \ldots + p_n x_n \geq 108000$$

$$C2 : \sum_{i=0}^{n} p_i x_i + p_{i+1} x_{i+1} + \ldots + p_n x_n \leq 139400$$

$$\vdots$$

$$C12 : \sum_{i=0}^{n} d_i x_i + d_{i+1} x_{i+1} + \ldots + d_n x_n \leq 25000$$

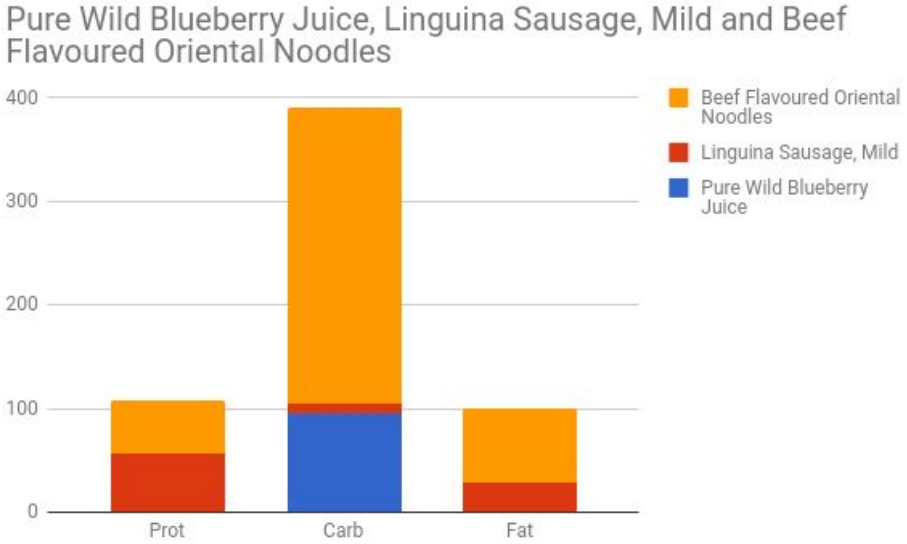
$$c_1, c_2 \ldots c_n > 0$$

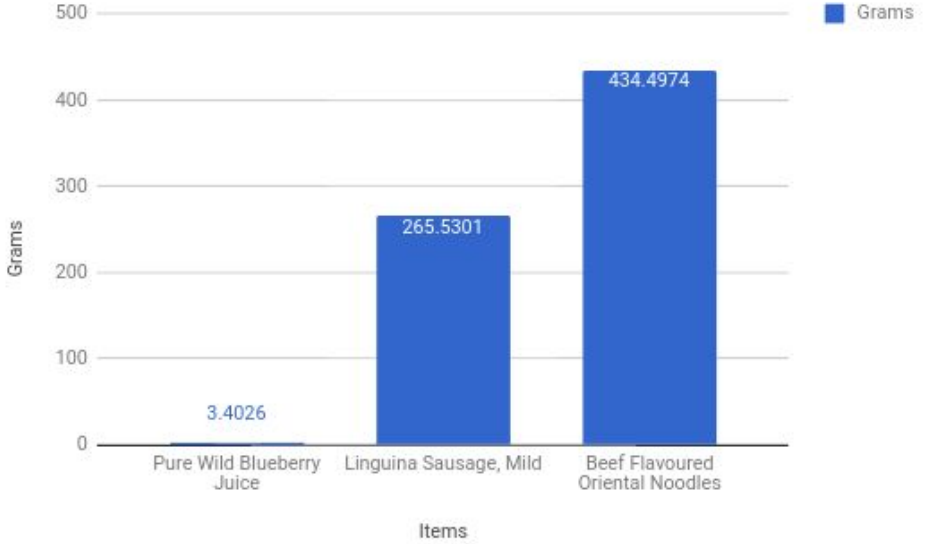
$$p_1, p_2 \ldots p_n \geq 0$$

$$\vdots$$

$$d_1, d_2 \ldots d_n \geq 0$$

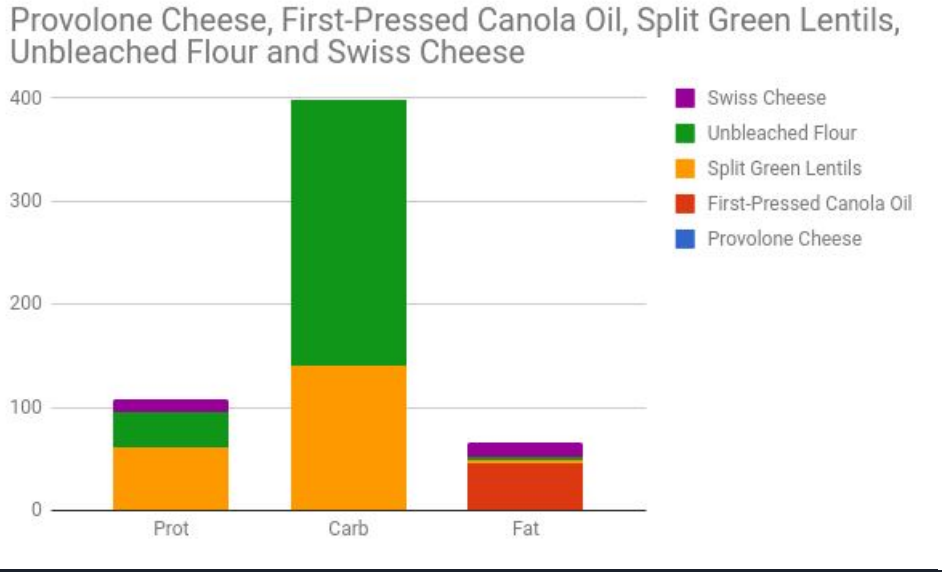
Results 1: Just Macros (Carb, Fat, Protein)

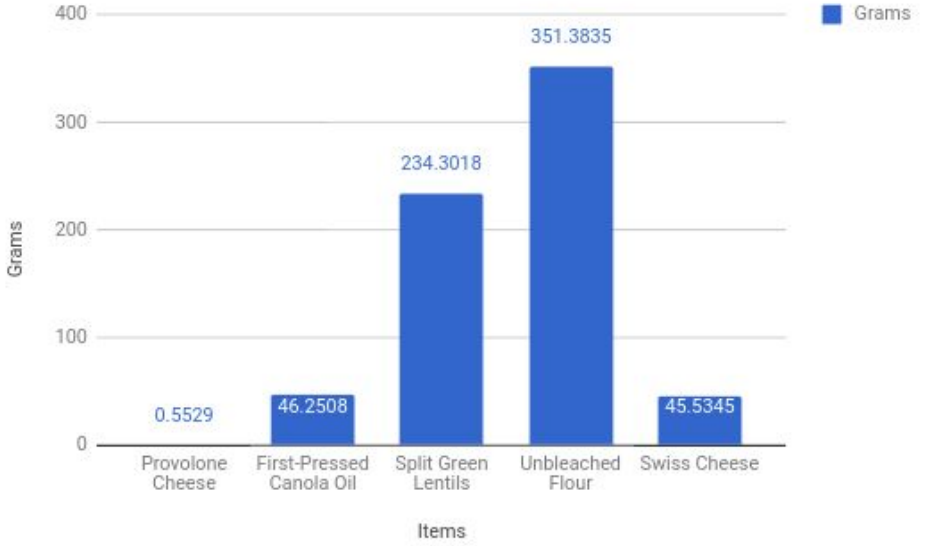




Price: $0.17/day

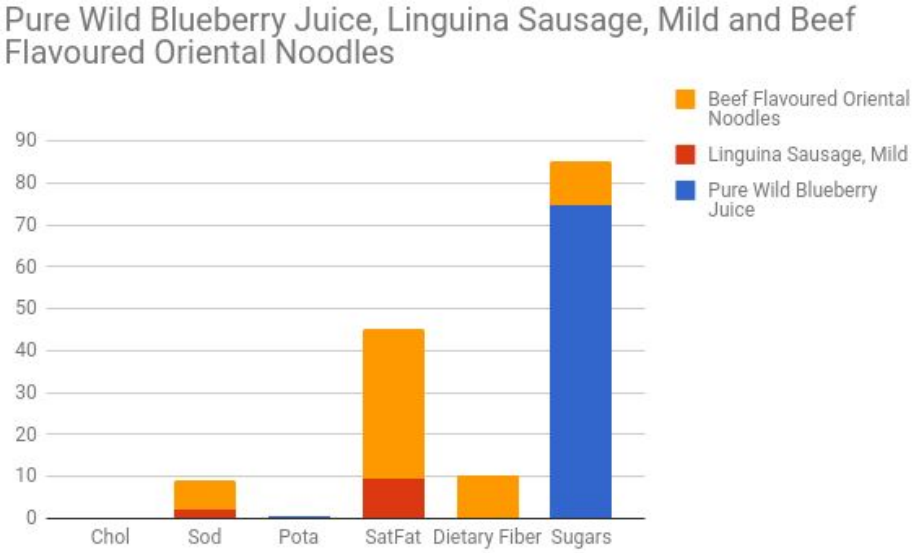
Results 2: All Constraints

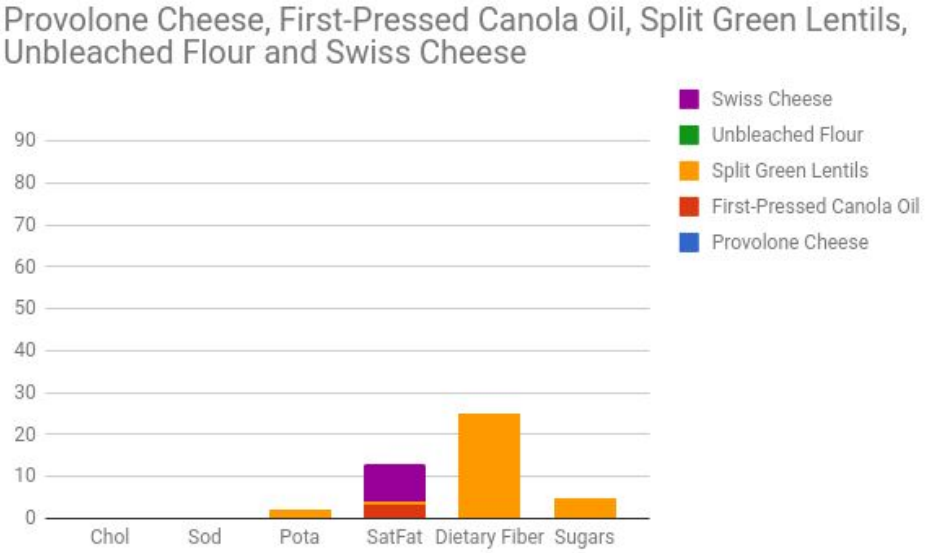




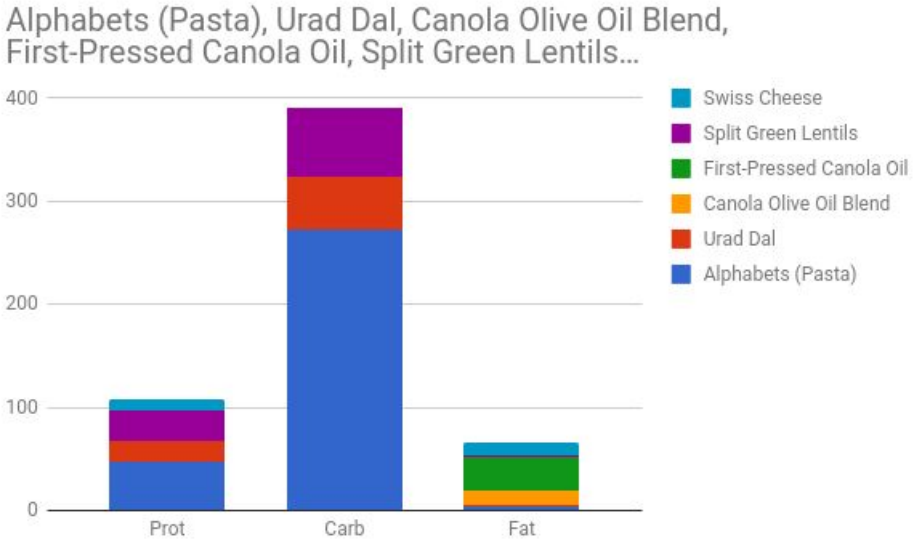
Price: $1.22/day

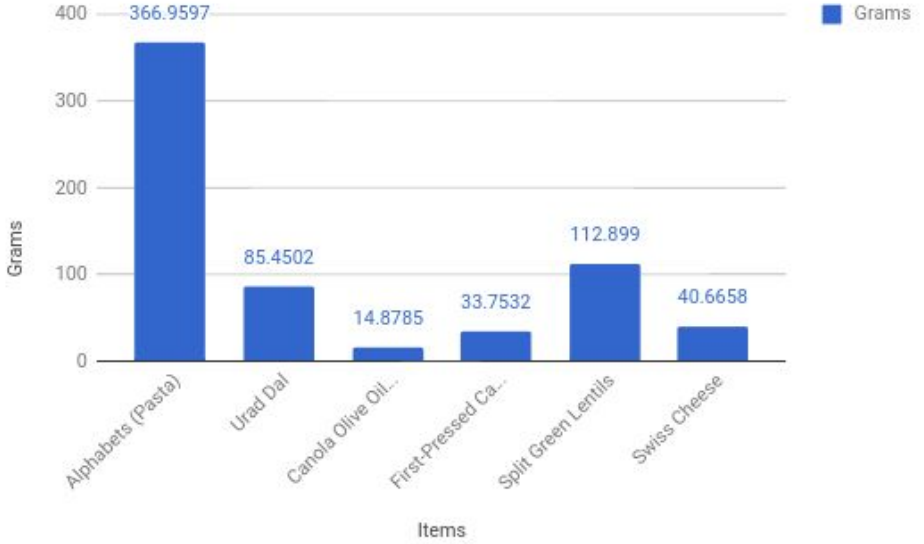
Why the price jump?





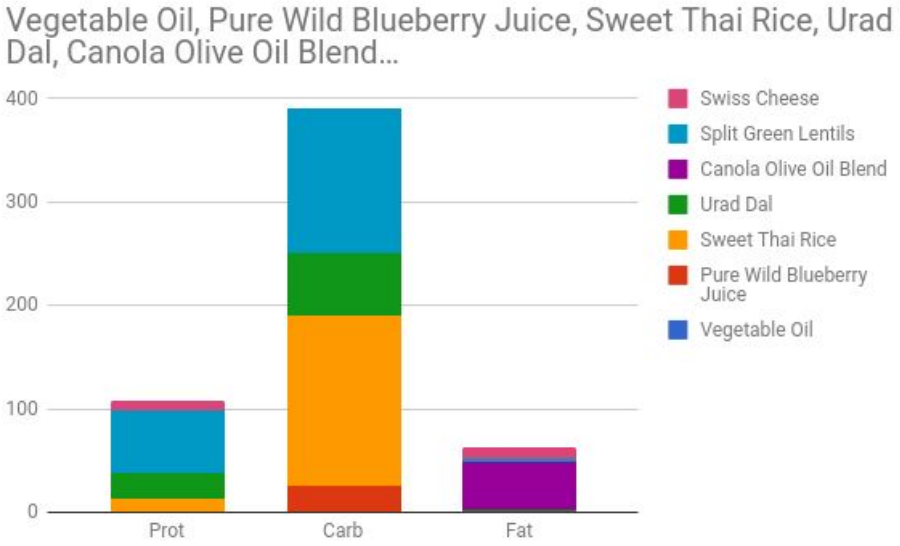
Results 3: Removing Flour

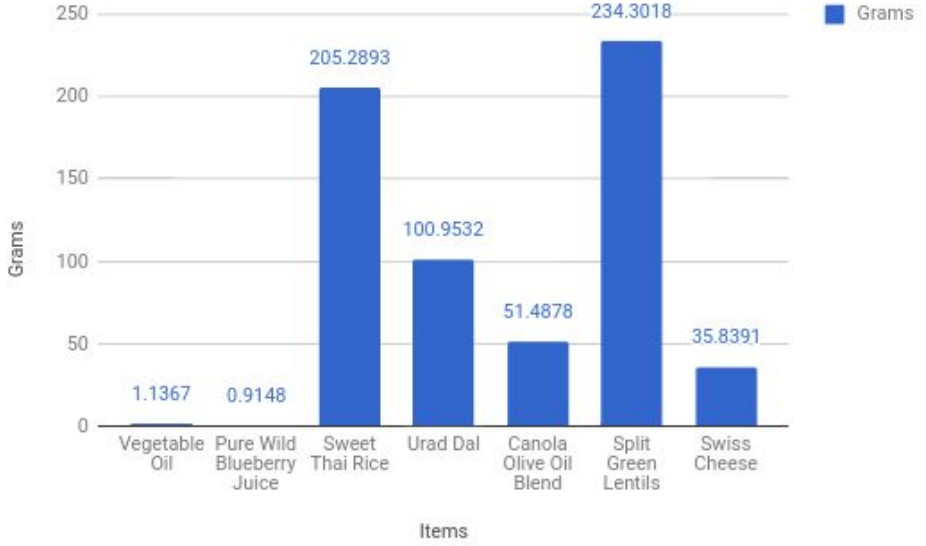




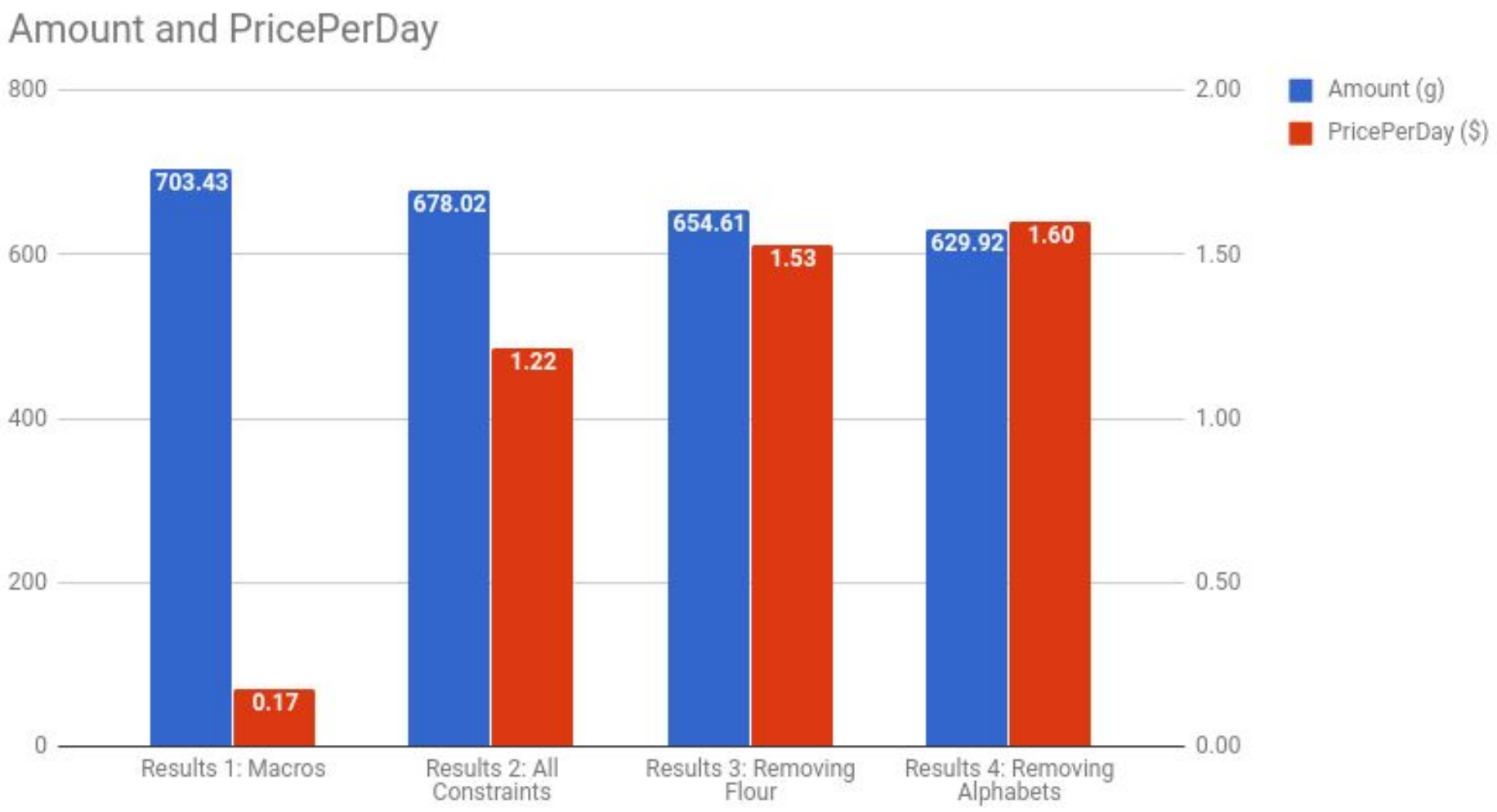
Price: $1.53/day

Results 4: Removing Alphabet Pasta





Price: $1.61/day


Amount and PricePerDay
800
600
400
200
0
2.00
1.50
1.00
0.50
0.00
Amount (g)
PricePerDay ($)
703.43
0.17
678.02
1.22
654.61
1.53
629.92
1.60
Results 1: Macros
Results 2: All Constraints
Results 3: Removing Flour
Results 4: Removing Alphabets

```
mysql> select ID, brand, name, PPG from food where name like '%water%' order by PPG desc limit 20;
+-----------------+--------------------+-------------------------------------------+-------+
| ID              | brand              | name                                      | PPG   |
+-----------------+--------------------+-------------------------------------------+-------+
| 20313917_EA     | PC  Club Pack      | Spring Water                              | 33.28 |
| 20023359_KG     |                    | Fresh Watermelon                          |  8.80 |
| 20021359_KG     |                    | Sliced Seedless Watermelon                |  5.49 |
| 20688857_EA     | GoldSeal           | No Drain White Tuna, Flaked Albacore In Water |  3.52 |
| 20118249_EA     | Clover Leaf        | Tuna, White Solid in Water                |  3.28 |
| 20689179_EA     | GoldSeal           | No Drain White Tuna, Solid In Water       |  2.99 |
| 20021832_EA     | President's Choice | Cooked Peeled Wild Atlantic Cold Water Shrimp |  2.94 |
| 20415010001_EA  | Raincoast Trading  | Wild Pacific Sardines, Spring Water       |  2.91 |
| 20503182_KG     |                    | Watermelon Cuts                           |  2.84 |
| 20889585_EA     | Clover Leaf        | Wild Selections White Tuna, Solid in Water |  2.81 |
| 20889074_EA     | Clover Leaf        | Wild Selections Light Tuna, Solid in Water |  2.81 |
| 20415654001_EA  | Dole               | Lots of Cherries in Water                 |  2.79 |
| 20437509002_EA  | Elco               | Sardine Fillets in Spring Water           |  2.49 |
| 20865062_EA     |                    | Rio Mare Tuna in Water                    |  2.41 |
| 20549546002_EA  | Millionnaires      | Sardines, Skinless Boneless In Water      |  2.41 |
| 20321094_EA     | Carr's             | Table Water Crackers                      |  2.39 |
| 20850959_EA     | Nestle             | FruPops, Watermelon                       |  2.39 |
| 20724562_EA     | Clover Leaf        | Baby Clams, Whole Yellow In Water         |  2.11 |
| 20374262001_C12 | President's Choice | Carbonated Spring Water, Lime             |  1.97 |
| 20966757_EA     | Clover Leaf        | Chunk Light Yellowfin Tuna, In Water      |  1.89 |
+-----------------+--------------------+-------------------------------------------+-------+
20 rows in set (0.02 sec)
```

DRINKS WATER | SPARKLING WATER

PC CLUB PACK

SPRING WATER

(18 L)

$5.99 ea

$33.28/100mL

ADD TO LIST

Product Number: 20313917_EA

- 0.3328/100mL
- $5990.4 ea

Some takeaways

- Data is often used to help make decisions, not to make them alone
  - Industrial optimization
    - Cement kiln at 2500 when rated for 2000
- Some things aren’t able to be represented as data
  - Tastiness
  - Availability/stock
- Data cleaning is important

Future Work

- Put it online
- Expand to include recipes
- Expand to include other data
  - Vitamins, amino acids, etc
- Apply to other grocery stores
  - All loblaws stores use the same format
  - Show cheapest place to get item x

Questions?