# Diet Plan Optimization:
# Minimizing Cost While Getting The Recommended Nutritional Intake

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## Executive Summary

Linear programming was applied to determine the optimal diet plan for one week based on five foods (potatoes, greek yogurt, chicken thigh, Polish sausage, eggs) while meeting nutritional need guidelines (for sodium, energy, protein, Vitamin D, calcium, iron, potassium) and minimizing the cost (in dollars).

The first optimal solution determined the diet plan with the most minimal cost ($94.45) consisted of 0 servings of potatoes, 28.82 servings of greek yogurt, 0 servings of chicken thigh, 44.57 servings of Polish sausage, and 140 servings of eggs. Then, the analysis was rerun to produce at least one serving of each food. This determined an optimal plan with an associated cost of $95.09 and consisted of 1 serving of potatoes, 28.82 servings of greek yogurt, 1 serving of chicken thigh, 42.73 servings of Polish sausage, and 140 servings of eggs. Finally, ChatGPT was utilized to refine the code where the Vitamin D constraint was removed due to only one selected food containing Vitamin D (eggs). This analysis produced an optimal plan with an associated cost of $88.11 and consisted of 39.50 servings of potatoes, 35.87 servings of greek yogurt, 1 serving of chicken thigh, 1 serving of Polish sausage, and 100.06 servings of eggs.

While the solutions are optimal, they all lack variety.

## Method

The goal of this analysis was to minimize the cost associated with a diet plan based on five foods that meet nutritional guidelines. All analyses were conducted in Spyder/Python using the *pulp* package. First, the nutritional values per serving and cost per serving were determined. Then, the objective function was defined from the cost per serving values per each of the five foods. Next, constraints were defined based on the nutritional guidelines provided. Then, the constraints that the objective function was subject to were declared. Finally, the minimization objective was solved and an optimal solution was identified.

Two follow-up analyses were conducted. The first change to this approach included adding a constraint such that at least one serving per food per week was required. The second follow-up analysis removed the Vitamin D requirement and ChatGPT was asked to help with this task. Vitamin D was removed because all selected foods were Vitamin D deficient with the exception of eggs, which had very low Vitamin D. Optimal solutions were determined for both follow-up analyses.

## Results and Discussion

| Variable: | Food Item: | Sodium (mg): | Energy (kcal): | Protein (g): | Vitamin D (mcg): | Calcium (mg): | Iron (mg): | Potassium (mg): | Total Price: | Servings: | Cost Per Serving ($): |
|---|---|---|---|---|---|---|---|---|---|---|---|
| X1 | *Potatoes* | 0 | 0.07 | 2 | 0 | 0 | 0.9 | 440 | 3.29 | 6 | 0.55 |
| X2 | *Greek Yogurt* | 100 | 0.13 | 14 | 0 | 170 | 0 | 220 | 3.49 | 5 | 0.70 |
| X3 | *Chicken Thigh* | 80 | 0.25 | 17 | 0 | 0 | 0.4 | 250 | 6.73 | 8 | 0.84 |
| X4 | *Beef and Pork Polish Sausage* | 400 | 0.17 | 6 | 0 | 0 | 0 | 376 | 2.89 | 7 | 0.41 |
| X5 | *Egg* | 70 | 0.07 | 6 | 1 | 30 | 0.9 | 70 | 4.75 | 12 | 0.40 |

The first step consisted of determining the cost (in dollars) per serving and nutritional information per serving. These values are summarized in Table 1 preceding this paragraph. This exercise suggested that the goal was to minimize cost for the week's meal while meeting nutritional recommendations. Thus the objective function was determined to be:
*Z = 0.55(X1) + 0.70(X2) + 0.84(X3) + 0.41(X4) + 0.40(X5).*

Next, the seven constraints were defined and were the parameters for which the objective function was subjected to. The full data is presented in Table 2, which follows this paragraph. Each constraint corresponded to one nutritional factor and represented how much each food contained of that nutritional factor (see below). In the first follow-up analysis, additional constraints were added such that at least one unit of each food was required (refer to the Github Python code). Then, in the final follow-up analysis the Vitamin D constraint was removed.

1. *Sodium*: 100*Yogurt + 80*Chicken + 400*Sausage + 70*Egg <= 35000
2. *Energy*: 0.07*Potatoes + 0.13*Yogurt + 0.25*Chicken + 0.17*Sausage + 0.07*Egg >= 14
3. *Protein*: 2*Potatoes + 14*Yogurt + 17*Chicken + 6*Sausage + 6*Egg >= 350
4. *Vitamin D*: += 1*Egg >= 140
5. *Calcium*: 170*Yogurt + 30*Egg >= 9100
6. *Iron*: 0.90*Potatoes + 0.40*Chicken + 0.90*Egg >= 126
7. *Potassium*: 440*Potatoes + 220*Yogurt + 250*Chicken + 376*Sausage + 70*Egg >= 32900

| Constraint: | Max/Min: | Daily Amount: | Weekly Amount: | Potatoes | Greek Yogurt | Chicken Thigh | Polish Sausage | Egg |
|---|---|---|---|---|---|---|---|---|
| *Sodium (mg)* | Max | 5000 | 35000 | 0 | 100 | 80 | 400 | 70 |
| *Energy (kcal)* | Min | 2 | 14 | 0.07 | 0.13 | 0.25 | 0.17 | 0.07 |
| *Protein (g)* | Min | 50 | 350 | 2 | 14 | 17 | 6 | 6 |
| *Vitamin D (mcg)* | Min | 20 | 140 | 0 | 0 | 0 | 0 | 1 |
| *Calcium (mg)* | Min | 1300 | 9100 | 0 | 170 | 0 | 0 | 30 |
| *Iron (mg)* | Min | 18 | 126 | 0.90 | 0.00 | 0.40 | 0.00 | 0.90 |
| *Potassium (mg)* | Min | 4700 | 32900 | 440 | 220 | 250 | 376 | 70 |

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Then, the analysis was rerun to produce at least one serving of each food. This determined an optimal plan with an associated cost of $95.09 and consisted of 1 serving of potatoes, 28.82 servings of greek yogurt, 1 serving of chicken thigh, 42.73 servings of Polish sausage, and 140 servings of eggs.

Finally, ChatGPT was utilized to refine the code where the Vitamin D constraint was removed due to only one selected food containing Vitamin D (eggs). This analysis produced an optimal plan with an associated cost of $88.11 and consisted of 39.50 servings of potatoes, 35.87 servings of greek yogurt, 1 serving of chicken thigh, 1 serving of Polish sausage, and 100.06 servings of eggs.