Minimization of Food Cost on 2000-Calorie Diabetic Diet

J D Urrutia\(^1\), J Mercado\(^2\) and R L Tampis\(^3\)

\(^1\)Director, Intellectual Property Management Office  
Chief, Center for Statistical Studies, Institute for Data and Statistical Analysis  
Office of the Vice President for Research, Extension, Planning and Development  
Polytechnic University of the Philippines – Sta. Mesa, Manila, Philippines  
\(^2\)Vice President for Research, Extension, Planning and Development  
Polytechnic University of the Philippines – Philippines  
\(^3\)Polytechnic University of the Philippines – Parañaque Campus, Philippines

E-mail: jackieurrutia20@gmail.com, math_urrutia@yahoo.com.ph, jdurrutia@pup.edu.ph, jmercado@pup.edu.ph, razzcelletampis@gmail.com

Abstract. This study focuses on minimization of food cost that satisfies the daily nutrients required based on 2000-calorie diet for a diabetic person. This paper attempts to provide a food combination that satisfies the daily nutrient requirements of a diabetic person and its lowest possible dietary food cost. A linear programming diet model is used to determine the cheapest combination of food items that satisfy the recommended daily nutritional requirements of the diabetic persons. According to the findings, a 50 year old and above diabetic male need to spend a minimum of 72.22 pesos for foods that satisfy the daily nutrients they need. In order to attain the minimum spending, the foods must consist of 60.49 grams of anchovy, 91.24 grams of carrot, 121.92 grams of durian, 121.41 grams of chicken egg, 70.82 grams of pork (lean), and 369.70 grams of rice (well-milled). For a 50 year old and above diabetic female, the minimum spending is 64.65 pesos per day and the food must consist of 75.87 grams of anchovy, 43.38 grams of carrot, 160.46 grams of durian, 69.66 grams of chicken egg, 23.16 grams of pork (lean) and 416.19 grams of rice (well-milled).

1. Introduction
During the last twenty years the prevalence of diabetes has increased dramatically in many parts of the world and the disease is now a worldwide public health problem. Diabetes is a metabolic disease that is diagnosed on the basis of sustained high concentration of glucose in the blood. This high blood sugar produces the symptoms of frequent urination, increased thirst, and increased hunger. Untreated diabetes can cause many complications. Serious long-term complication includes heart disease, stroke, kidney failure, foot ulcers and damage to the eyes [1].

Diabetes in the Philippines affects the lives of 9.7% of the adult population; one out of every five Filipino adults has either diabetes or is at risk with impaired glucose tolerance [2]. Worldwide, there are 371 million people living with diabetes and another 280 million are at high risk, posing a global problem. The total number of people with diabetes is projected to rise from 171 million (11% increase from the previous 154 million) from the year 2000 to 366 million in the year 2030 [3]. Despite all the publicity surrounding new research and new nutrition guidelines, some people with diabetes still
believe that there is something called a "diabetic diet." For some, this so-called diet consists of avoiding sugar, while others believe it to be a strict way of eating that controls glucose. Unfortunately, based on dieticians, neither is quite right. This paper mainly focuses on solving the diet problem for persons with diabetes which minimized cost but still satisfies daily nutrients required [4].

1.1. Statement of the Problem
Diabetes is a chronic disease for which control of the condition demands patient self-management. Self-management behaviours include monitoring blood glucose levels, taking medications, maintaining a healthy diet and regular exercise. This paper attempts to look at a research that addresses the diabetic diet at lowest cost with the given food combination which satisfies the daily nutrient requirements. These nutrients are also based on the different age of a diabetic person, both male and female. This paper will attempt to answer the question: what is the food combination that satisfies the daily nutrient requirements of a diabetic person and its lowest possible dietary food cost?

2. Methodology
A linear programming model is used to find the cheapest combination of food items that satisfies the most important daily nutritional requirements of a diabetic person. Whereas linear programming is a technique for the optimization of a linear objective function, subject to linear equality and linear inequality constraints. Given a polytope and a real-valued affine function defined on this polytope, a linear programming method will find a point on the polytope where this function has the smallest (or largest) value if such point exists, by searching through the polytope vertices [5].

2.1. Excel Solver Function
Solvers, or optimizers, are software tools that help users find the best way to allocate scarce resources. The resources may be raw materials, machine time or people time, money, or anything else in limited supply. The best or optimal solution may mean maximizing profits, minimizing costs, or achieving the best possible quality. To use a solver, you must build a model that specifies: the resources to be used, using decision variables; the limits on resource usage, called constraints, and the measure to optimize, called the objective. The solver will find values for the decision variables that satisfy the constraints while optimizing (maximizing or minimizing) the objective [6].

2.2. Simplex Method
A method is described for the minimization of a function of n variables, which depends on the comparison of function values at the (n + 1) vertices of a general simplex, followed by the replacement of the vertex with the highest value by another point. The simplex adapts itself to the local landscape, and contracts on to the final minimum. The method is shown to be effective and computationally compact. A procedure is given for the estimation of the Hessian matrix in the neighborhood of the minimum, needed in statistical estimation problems. As the new data sets were entered into spreadsheets, it was convenient to use the linear-programming spreadsheet solver add-in to solve our modified diet problems [7]. The basic mathematical structure is given by the following linear programming model. The objective function is written in minimize z and is subjected to the following nutrients.

\[
\begin{align*}
\text{Minimize } Z &= 11.31x_1 + 6.9x_2 + 4.2x_3 + 26.21x_4 + 4.82x_5 + 2.66x_6 + 5.44x_7 + 5.08x_8 + 14.07x_9 + 2.44x_{10} \\
&+ 13.98x_{11} + 5.24x_{12} + 4.76x_{13} + 15.3x_{14} + 10.14x_{15} + 29.63x_{16} + 4.54x_{17} + 17.09x_{18} + 10.91x_{19} + 5.28x_{20} \\
&+ 11x_{21} + 13.64x_{22} + 19.61x_{23} + 3.98x_{24} + 19.83x_{25} + 7.64x_{26} + 4.36x_{27} + 5.25x_{28} + 7.67x_{29} + 13.3x_{30} \\
&- 35.46x_{31} + 24.6x_{32} + 3.97x_{33} + 10.09x_{34} \\
\end{align*}
\]
Calories: 77x₁ + 100x₂ + 105x₃ + 137x₄ + 25x₅ + 18x₆ + 23x₇ + 52x₈ + 80x₉ + 21x₁₀ + 110x₁₁ + 21x₁₂ + 16x₁₃ + 163x₁₄ + 166x₁₅ + 63x₁₆ + 93x₁₇ + 108x₁₈ + 70x₁₉ + 21x₂₀ + 136x₂₁ + 99x₂₂ + 90x₂₃ + 53x₂₄ + 278x₂₅ + 67x₂₆ + 55x₂₇ + 67x₂₈ + 121x₂₉ + 100x₃₀ + 91x₃₁ + 91x₃₂ + 28x₃₃ + 107x₃₄ = 2000

Protein: 14.1x₁ + 0.9x₂ + 1.2x₃ + 23.1x₄ + 0.9x₅ + 0.5x₆ + 1x₇ + 4.1x₈ + 18.7x₉ + 0.4x₁₀ + 20.6x₁₁ + 1.7x₁₂ + 0.6x₁₃ + 2x₁₄ + 12.4x₁₅ + 14.9x₁₆ + 2.5x₁₇ + 21.6x₁₈ + 0.6x₁₉ + 0.3x₂₀ + 19.8x₂₁ + 21.2x₂₂ + 19x₂₃ + 0.5x₂₄ + 17.3x₂₅ + 1.2x₂₆ + 7.4x₂₇ + 0.7x₂₈ + 19.5x₂₉ + 20.4x₃₀ + 19x₃₁ + 182x₃₂ + 0.6x₃₃ + 18.1x₃₄ ≥ 67

Protein: 14.1x₁ + 0.9x₂ + 1.2x₃ + 23.1x₄ + 0.9x₅ + 0.5x₆ + 1x₇ + 4.1x₈ + 18.7x₉ + 0.4x₁₀ + 20.5x₁₁ + 1.7x₁₂ + 0.6x₁₃ + 2x₁₄ + 12.4x₁₅ + 14.9x₁₆ + 2.5x₁₇ + 21.6x₁₈ + 0.6x₁₉ + 0.3x₂₀ + 19.8x₂₁ + 21.2x₂₂ + 19x₂₃ + 0.5x₂₄ + 17.3x₂₅ + 1.2x₂₆ + 7.4x₂₇ + 0.7x₂₈ + 19.5x₂₉ + 20.4x₃₀ + 19x₃₁ + 182x₃₂ + 0.6x₃₃ + 18.1x₃₄ ≥ 58

Fats: 4.7x₁ + 6.2x₂ + 7.3x₃ + 4.6x₄ + 0.4x₅ + 0.1x₆ + 0.3x₇ + 0.4x₈ + 0.6x₉ + 0.1x₁₀ + 3.1x₁₁ + 0.3x₁₂ + 0.2x₁₃ + 1.2x₁₄ + 11x₁₅ + 0.4x₁₆ + 0.4x₁₇ + 2.4x₁₈ + 0.2x₁₉ + 0.1x₂₀ + 6.4x₂₁ + 16x₂₂ + 1.5x₂₃ + 1.5x₂₄ + 23.2x₂₅ + 0.9x₂₆ + 0.5x₂₇ + 1x₂₈ + 4.7x₂₉ + 2.1x₃₀ + 2x₃₁ + 4x₃₂ + 0.2x₃₃ + 3.8x₃₄ ≥ 65

Fats: 4.7x₁ + 6.2x₂ + 7.3x₃ + 4.6x₄ + 0.4x₅ + 0.1x₆ + 0.3x₇ + 0.4x₈ + 0.6x₉ + 0.1x₁₀ + 3.1x₁₁ + 0.3x₁₂ + 0.2x₁₃ + 1.2x₁₄ + 11x₁₅ + 0.4x₁₆ + 0.4x₁₇ + 2.4x₁₈ + 0.2x₁₉ + 0.1x₂₀ + 6.4x₂₁ + 16x₂₂ + 1.5x₂₃ + 1.5x₂₄ + 23.2x₂₅ + 0.9x₂₆ + 0.5x₂₇ + 1x₂₈ + 4.7x₂₉ + 2.1x₃₀ + 2x₃₁ + 4x₃₂ + 0.2x₃₃ + 3.8x₃₄ ≥ 65

Carbohydrates: 10.5x₁ + 24.5x₂ + 0.7x₃ + 4.5x₄ + 3.8x₅ + 4.8x₆ + 10.5x₇ + 4.6x₈ + 2.9x₉ + 2.9x₁₀ + 36.1x₁₁ + 2.8x₁₂ + 19.9x₁₃ + 164x₁₄ + 5.1x₁₅ + 5x₁₆ + 18.5x₁₇ + 80.4x₁₈ + 13.8x₁₉ + 0.1x₂₀ + 2x₂₁ + 4x₂₂ + 4.7x₂₃ ≥ 300

Carbohydrates: 10.5x₁ + 24.5x₂ + 0.7x₃ + 4.5x₄ + 3.8x₅ + 4.8x₆ + 10.5x₇ + 4.6x₈ + 2.9x₉ + 2.9x₁₀ + 36.1x₁₁ + 2.8x₁₂ + 19.9x₁₃ + 164x₁₄ + 5.1x₁₅ + 5x₁₆ + 18.5x₁₇ + 80.4x₁₈ + 13.8x₁₉ + 0.1x₂₀ + 2x₂₁ + 4x₂₂ + 4.7x₂₃ ≥ 300

Calcium: 752x₁ + 11x₂ + 17x₃ + 50x₄ + 42x₅ + 24x₆ + 74x₇ + 69x₈ + 46x₉ + 24x₁₀ + 86x₁₁ + 120x₁₂ + 22x₁₃ + 18x₁₄ + 74x₁₅ + 55x₁₆ + 41x₁₇ + 78x₁₈ + 10x₁₉ + 26x₂₀ + 44x₂₁ + 65x₂₂ + 81x₂₃ + 34x₂₄ + 29x₂₅ + 32x₂₆ + 27x₂₇ + 12x₂₈ + 121x₂₉ + 51x₃₀ + 146x₃₁ + 57x₃₂ + 19x₃₃ + 74x₃₄ ≥ 700

Calcium: 752x₁ + 11x₂ + 17x₃ + 50x₄ + 42x₅ + 24x₆ + 74x₇ + 69x₈ + 46x₉ + 24x₁₀ + 86x₁₁ + 120x₁₂ + 22x₁₃ + 18x₁₄ + 74x₁₅ + 55x₁₆ + 41x₁₇ + 78x₁₈ + 10x₁₉ + 26x₂₀ + 44x₂₁ + 65x₂₂ + 81x₂₃ + 34x₂₄ + 29x₂₅ + 32x₂₆ + 27x₂₇ + 12x₂₈ + 121x₂₉ + 51x₃₀ + 146x₃₁ + 57x₃₂ + 19x₃₃ + 74x₃₄ ≥ 700

Phosphorus: 482x₁ + 27x₂ + 34x₃ + 192x₄ + 38x₅ + 16x₆ + 28x₇ + 38x₈ + 166x₉ + 10x₁₀ + 188x₁₁ + 33x₁₂ + 17x₁₃ + 56x₁₄ + 180x₁₅ + 173x₁₆ + 51x₁₇ + 246x₁₈ + 19x₁₉ + 15x₂₀ + 194x₂₁ + 202x₂₂ + 185x₂₃ + 11x₂₄ + 142x₂₅ + 16x₂₆ + 155x₂₇ + 21x₂₈ + 28x₂₉ + 212x₃₀ + 210x₃₁ + 148x₃₂ + 24x₃₃ + 184x₃₄ ≥ 4000
where $x_1$ is anchovy; $x_2$ is red avocado, $x_3$ is banana (latundan), $x_4$ is beef lean meat, $x_5$ is bitter gourd, $x_6$ is bottle gourd, $x_7$ is green cabbage, $x_8$ is carrot, $x_9$ is catfish, $x_{10}$ is chayote, $x_{11}$ is white meat chicken, $x_{12}$ is Chinese cabbage, $x_{13}$ is cucumber, $x_{14}$ is durian, $x_{15}$ is chicken egg, $x_{16}$ is spotted...
grouper, \( x_{17} \) is horseradish tree pod, \( x_{18} \) is short bodied mackerel, \( x_{19} \) is mango (Carabao), \( x_{20} \) is musk melon, \( x_{21} \) is milkfish, \( x_{22} \) is striated mudfish/murrel, \( x_{23} \) is ribbed-finned nemipterid, \( x_{24} \) is papaya, \( x_{25} \) is lean pork Boston butt, \( x_{26} \) is rambutan, \( x_{27} \) is well-milled rice, \( x_{28} \) is santol, \( x_{29} \) is Indian sardines, \( x_{30} \) is round scad, \( x_{31} \) is white shrimp, \( x_{32} \) = common slipmouth, \( x_{33} \) is sponge gourd, and \( x_{34} \) is tilapia.

2.3. Sensitivity Analysis
A technique used to determine how different values of an independent variable will impact a particular dependent variable under a given set of assumptions. This technique is used within specific boundaries that will depend on one or more input variables, such as the effect that changes in interest rates will have on a bond's price. Sensitivity analysis is a way to predict the outcome of a decision if a situation turns out to be different compared to the key prediction(s).

The objective of the model is to minimize food expenditure; \( Z \). Constraints in the model include the nutritional requirements: energy, protein, fats, carbohydrates, calcium, phosphorus, iron, total vitamin A, thiamine and niacin. The Food and Agriculture Organization and the World Health Organization have documented the harmful effects that may arise from excess consumption of some nutrients. Vitamin D and excess calcium are associated with kidney stone formation. High levels of vitamin A are associated with hair loss, bone pain and dry skin. Nutrients including calcium, phosphorus, iron, vitamin A, and niacin have allowable maximum intake levels based on internationally accepted dietary recommended intake.

2.4. Data
The researchers gathered the cheapest combination of foods for a diabetic person and its prices as shown in table 1. These data are gathered from the Philippine Statistic Authority (Bureau of Agricultural Statistics) [8]. The Energy and Nutritional requirement is based on Required Energy and Nutrient Intake (RENI). The nutritional value of each food is based on the Philippine Food Composition Tables (FCT) of Food and Nutrition Research Institute (FNRI) [9].

| Table 1. Nutritional content of food items and its cost. |
|---------------------------------------------------------|
| Food and Description | Energy (kcal) | Protein (g) | Fats (g) | Carbohydrates (g) | Calcium (mg) | Phosphorus (mg) | Iron (mg) | Total Vit. A (RE) (\( \mu \)g) | Thiamine (mg) | Riboflavin (mg) | Niacin (mg) | Price |
|----------------------|--------------|-------------|---------|-------------------|-------------|----------------|-----------|-----------------------------|--------------|----------------|-----------|-------|
| Anchovy              | 77           | 14.1        | 4.7     | 0                 | 752         | 482            | 1.2       | 68                          | 0            | 0.12           | 1.9       | 11.3  |
| Avocado, red         | 100          | 0.9         | 6.2     | 10.5              | 11          | 27             | 0.8       | 8                           | 0.04         | 0.04          | 0.39      | 6.9   |
| Banana, latundan     | 105          | 1.2         | 7.3     | 24.5              | 17          | 34             | 0.7       | 5                           | 0.02         | 0.02          | 0.6       | 4.2   |
| Beef lean meat       | 137          | 23.1        | 4.6     | 0.7               | 50          | 192            | 2.8       | 16                          | 0.11         | 0.2           | 5.5       | 26.21 |
| Bitter Gourd         | 25           | 0.9         | 0.4     | 4.5               | 42          | 38             | 0.8       | 33                          | 0.05         | 0.04          | 0.2       | 4.82  |
| Bottle gourd         | 18           | 0.5         | 0.1     | 3.8               | 24          | 16             | 0.4       | 2                           | 0.04         | 0.02          | 0.4       | 2.66  |
| Cabbage, green       | 28           | 1.4         | 0.3     | 4.8               | 74          | 28             | 0.8       | 3                           | 0.04         | 0.07          | 0.3       | 5.44  |
| Carrot               | 52           | 1.5         | 0.4     | 10.5              | 69          | 38             | 2.1       | 1668                        | 0.04         | 0.04          | 0.8       | 5.08  |
| Catfish              | 80           | 18.7        | 0.6     | 0                 | 46          | 166            | 0.3       | 196                         | 0.01         | 0.05          | 2.5       | 14.07 |
| Chayote              | 21           | 0.4         | 1.1     | 4.6               | 24          | 10             | 0.4       | 6                           | 0.02         | 0.02          | 0.4       | 2.44  |
| Chicken, white meat  | 110          | 20.6        | 3.1     | 0                 | 86          | 188            | 1.5       | 20                          | 0.02         | 0.06          | 6.6       | 13.98 |
| Chinese cabbage      | 21           | 1.7         | 0.3     | 2.9               | 120         | 33             | 0.5       | 90                          | 0.06         | 0.09          | 0.8       | 5.24  |
| cucumber             | 16           | 0.6         | 0.2     | 2.9               | 22          | 17             | 0.4       | 0                           | 0.02         | 0.02          | 0.1       | 4.76  |
| Durian               | 163          | 2           | 1.2     | 36.1              | 18          | 56             | 1.1       | 0                           | 0.32         | 0.28          | 1.1       | 15    |
| Egg, chicken         | 160          | 12.4        | 1.1     | 2.8               | 74          | 180            | 2.8       | 302                         | 0.07         | 0.39          | 0.1       | 10.14 |
| Grouper, spotted     | 63           | 14.9        | 0.4     | 55                | 173         | 0.6            | 20        | 0.04                        | 0.04         | 0.4           | 4.3       | 29.63 |
| Horseradish tree pod | 93           | 2.5         | 0.4     | 19.9              | 41          | 51             | 0.8       | 10                          | 0.04         | 0.09          | 0.8       | 4.54  |
| Mackerel, short bodied | 108      | 21.6        | 2.4     | 0                 | 78          | 246            | 1.3       | 110                         | 0.09         | 0.13          | 8.4       | 17.09 |
REQUIRED NUTRIENTS: |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Max Res (g)     | Max Req (g)     | Max Res (mg)    | Max Req (mg)    |
|-----------------|-----------------|-----------------|-----------------|
| 320             | 1000            | 150             | 2500            |
| 500             | 2000            | 100             | 4000            |
| 10              | 2500            | 50              | 4500            |
| 12              | 3500            | 20              | 5000            |

3. Results and Discussion

According to the findings, a 50 year old and above diabetic male needs to spend a minimum of 72.22 pesos for foods that satisfy all the nutrients needed per day. In order to attain the minimum cost, the food must consist of 60.49 g of anchovy, 91.24 g of carrot, 121.92 g of durian, 121.41 g of chicken (lean) and 416.19 g of rice (well-milled) as shown in table 2. Furthermore, for ages 50 and above, diabetic female’s minimum spending for foods is 64.65 pesos per day consisting of 75.87 g of anchovy, 43.38 g of carrot, 160.46 g of durian, 69.66 g of chicken egg, 23.16 g of pork (lean) and 416.19 g of rice (well-milled) as shown in table 3.

In addition, in every 100 g consumption of avocado will have a 4.06 pesos increase in the minimum cost, consumption of beef will increase by 16.36 per 100 g, for a 100 g consumption of bitter gourd, catfish and chicken will increase the cost by 1.25 pesos, 12.25 pesos and 9.81 pesos respectively. A 100 g consumption of any meat or poultry product: beef, chicken would increase food cost by at least 10 pesos to 16 pesos, for a 100 g consumption of other vegetables will increase the cost from 0.50 pesos to 2.00 pesos. Obviously, the consumption of any of the above food items will increase food cost because they are relatively more expensive than the components of the food items suggested by the model.

**Table 2. Optimal values of food items for males.**

| Name                | Final Value | Reduced Cost | Objective Coefficient | Allowable Increase | Allowable Decrease |
|---------------------|-------------|--------------|-----------------------|--------------------|--------------------|
| Anchovy             | 0.604925777 | 0            | 11.313                | 1.952737368        | 8.245277361        |
| Avocado, red        | 0           | 4.061649992  | 6.9                   | 1E+30              | 4.061649992        |
| Banana, latundan    | 0           | 2.607837089  | 4.1999999999         | 1E+30              | 2.607837089        |
| Beef lean meat      | 0           | 16.35540355  | 26.21                 | 1E+30              | 16.35540355        |
| Bitter Gourd        | 0           | 1.248238915  | 4.82                  | 1E+30              | 1.248238915        |
| Bottle gourd        | 0           | 0.32528019   | 2.66                  | 1E+30              | 0.32528019         |
| Cabbage, green      | 0           | 1.578952684  | 5.44                  | 1E+30              | 1.578952684        |
| Carrot              | 0.912381187 | 0            | 5.08                  | 1.511165648        | 2.32140067         |
| Catfish             | 0           | 12.25130867  | 14.07                 | 1E+30              | 12.25130867        |
| Chayote             | 0           | 0.832436811  | 2.44                  | 1E+30              | 0.832436811        |
| Chicken, white meat | 0           | 9.807756198  | 13.98                 | 1E+30              | 9.807756198        |
Chinese cabbage 0 0.295638773 5.239999999 1E+30 0.295638773
Cucumber 0 3.151441943 4.76 1E+30 3.151441943
Durian 1.219183293 0 15 0.259597939 2.234035492
Egg, chicken 1.214058829 0 10.14 3.349175752 1.009256568
Grouper, spotted 0 26.36521256 29.63 1E+30 26.36521256
Horseradish tree pod 0 1.108040065 4.54 1E+30 1.108040065
Mackerel, short bodied 0 10.09060649 17.09 1E+30 10.09060649
Mango, carabao 0 6.441651033 10.91 1E+30 6.441651033
Melon, musk 0 3.655461493 5.28 1E+30 3.655461493
Milkfish 0 7.442842668 11 1E+30 7.442842668
Mudfish/Murrel, striated 0 11.60291878 18.64 1E+30 11.60291878
Nemipterid, ribbon-finned 0 16.8859393 19.61 1E+30 16.8859393
Papaya 0 1.079688659 3.98 1E+30 1.079688659
Pork Boston butt, lean 0.708186743 0 19.8 3.474837913 0.354966758
Rambutan 0 5.443741097 7.64 1E+30 5.443741097
Rice, well-milled 3.696979465 0 4.36 1.283083203 3.772623586
Santol 0 2.25971609 5.28 1E+30 2.25971609
Sardines, Indian 0 2.373586482 7.669999999 1E+30 2.373586482
Scad, round 0 4.488145104 13.3 1E+30 4.488145104
Shrimp, White 0 30.08335815 36.46 1E+30 30.08335815
Slipmouth, common 0 21.98212 24.6 1E+30 21.98212
Sponge gourd 0 1.203899137 3.97 1E+30 1.203899137
Tilapia 0 4.264337665 10.09 1E+30 4.264337665

Table 3. Optimal values of food items for females.

| Name                  | Final Value | Reduced Cost | Objective Coefficient | Allowable Increase | Allowable Decrease |
|-----------------------|-------------|--------------|-----------------------|--------------------|--------------------|
| Anchovy               | 0.758707454 | 0            | 11.31                 | 1.952737372        | 8.245273736       |
| Avocado, red          | 0           | 4.061649992  | 6.9                   | 1E+30              | 4.061649992       |
| Banana, latundan      | 0           | 2.60783709   | 4.200000001           | 1E+30              | 2.60783709        |
| Beef lean meat        | 0           | 16.35540355  | 26.21                 | 1E+30              | 16.35540355       |
| Bitter Gourd          | 0           | 1.248238915  | 4.82                  | 1E+30              | 1.248238915       |
| Bottle gourd          | 0           | 0.32528019   | 2.66                  | 1E+30              | 0.32528019        |
| Cabbage, green        | 0           | 1.578952684  | 5.44                  | 1E+30              | 1.578952684       |
| Carrot                | 0.43379878  | 0            | 5.08                  | 1.511165659        | 2.321400671       |
| Catfish               | 0           | 12.25130867  | 14.07                 | 1E+30              | 12.25130867       |
| Chayote               | 0           | 0.832436811  | 2.44                  | 1E+30              | 0.832436811       |
| Chicken, white meat   | 0           | 9.807756197  | 13.98                 | 1E+30              | 9.807756197       |
| Chinese cabbage       | 0           | 0.295638774  | 5.239999999           | 1E+30              | 0.295638774       |
| Cucumber              | 0           | 3.151441943  | 4.76                  | 1E+30              | 3.151441943       |
| Durian                | 1.604649335 | 0            | 15                    | 2.509597939        | 2.234035492       |
| Egg, chicken          | 0.696620418 | 0            | 10.14                 | 3.349175753        | 1.009256568       |
| Grouper, spotted      | 0           | 26.36521256  | 29.63                 | 1E+30              | 26.36521256       |
| Horseradish tree pod  | 0           | 1.108040065  | 4.54                  | 1E+30              | 1.108040065       |
| Mackerel, short bodied| 0           | 10.09060649  | 17.09                 | 1E+30              | 10.09060649       |
| Mango, carabao        | 0           | 6.441651033  | 10.91                 | 1E+30              | 6.441651033       |
| Melon, musk           | 0           | 3.655461493  | 5.28                  | 1E+30              | 3.655461493       |
| Milkfish QUANTITY     | 0           | 7.442842668  | 11                    | 1E+30              | 7.442842668       |
| Mudfish/Murrel, striated| 0         | 11.60291878  | 18.64                 | 1E+30              | 11.60291878       |
| Nemipterid, ribbon-finned| 0       | 16.8859393  | 19.61                 | 1E+30              | 16.8859393        |
| Papaya                | 0           | 1.079688659  | 3.98                  | 1E+30              | 1.079688659       |
| Pork Boston butt, lean| 0.23157692 | 0            | 19.8                  | 3.474837912        | 0.354966758       |
| Rambutan              | 0           | 5.443741098  | 7.64                  | 1E+30              | 5.443741098       |
| Rice, well-milled     | 4.161872183 | 0            | 4.36                  | 1.283083203        | 3.772623596       |
| Santol                | 0           | 2.25971609   | 5.28                  | 1E+30              | 2.25971609        |
| Sardines, Indian      | 0           | 2.373586482  | 7.669999999           | 1E+30              | 2.373586482       |
Scad, round    0    4.488145104    13.3    1E+30    4.488145104
Shrimp, White   0    30.08335815    36.46    1E+30    30.08335815
Slipmouth, common 0    21.98212    24.6    1E+30    21.98212
Sponge gourd    0    1.203899137    3.97    1E+30    1.203899137
Tilapia           0    4.264337666    10.09    1E+30    4.264337666

Table 4. Nutrient constraint sensitivity for males.

| Name               | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|--------------------|-------------|--------------|----------------------|--------------------|--------------------|
| minreq: Energy     | 2000        | -0.003951458 | 2000                 | 462.4217828        | 165.8061758        |
| minreq: Protein    | 67          | 0.021643521  | 67                   | 12.16898951        | 7.036338438        |
| minreq: Fats       | 36.30419287 | 0            | 65                   | 1E+30              | 28.69580713        |
| minreq: Carbohydrates | 354.229033 | 0            | 300                  | 54.22903303        | 1E+30              |
| minreq: Calcium    | 750         | 0.011545564  | 750                  | 936.6761509        | 432.0084098        |
| maxreq: Calcium    | 750         | 0            | 2500                 | 1E+30              | 1750               |
| maxreq: Phosphorus | 1286.643898 | 0            | 4000                 | 1E+30              | 2713.356102        |
| minreq: Phosphorus | 1286.643898 | 0            | 700                  | 586.6438979        | 1E+30              |
| minreq: Iron       | 12          | 0            | 45                   | 1E+30              | 33                 |
| minreq: Iron       | 12          | 1.266754534  | 12                   | 1.05705968         | 1.629062317        |
| maxreq: Total Vit A | 2035.86055  | 0            | 3000                 | 1E+30              | 964.1394496        |
| minreq: Total Vit A | 2035.86055  | 0            | 550                  | 1485.86055         | 1E+30              |
| minreq: Thiamine   | 1.2         | 35.65689469  | 1.2                  | 0.391624655        | 0.124390224        |
| minreq: Riboflavin | 1.3         | 9.247657976  | 1.3                  | 0.109035298        | 0.194866467        |
| maxreq: Niacin     | 16.88015428 | 0            | 35                   | 1E+30              | 18.11984572        |
| minreq: Niacin     | 16.88015428 | 0            | 16                   | 0.880154276        | 1E+30              |

Table 5. Nutrient constraint sensitivity for females.

| Name               | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|--------------------|-------------|--------------|----------------------|--------------------|--------------------|
| minreq: Energy     | 2000        | -0.003951458 | 2000                 | 151.2118285        | 302.8402717        |
| minreq: Protein    | 58          | 0.021643521  | 58                   | 19.24657535        | 3.798000706        |
| minreq: Fats       | 20.78136898 | 0            | 65                   | 1E+30              | 44.21863101        |
| minreq: Carbohydrates | 399.0477889 | 0            | 300                  | 99.0477889         | 1E+30              |
| minreq: Calcium    | 800         | 0.011545564  | 800                  | 306.2929099        | 541.8317639        |
| maxreq: Calcium    | 800         | 0            | 2500                 | 1E+30              | 1700               |
| maxreq: Phosphorus | 1275.407496 | 0            | 700                  | 575.4074956        | 1E+30              |
| maxreq: Phosphorus | 1275.407496 | 0            | 4000                 | 1E+30              | 2724.592504        |
| minreq: Iron       | 10          | 0            | 45                   | 1E+30              | 35                 |
| minreq: Iron       | 10          | 1.266754534  | 10                   | 2.170513324        | 0.570427467        |
| maxreq: Total Vit A | 1020.284376 | 0            | 500                  | 520.2843758        | 1E+30              |
| minreq: Total Vit A | 1020.284376 | 0            | 3000                 | 1E+30              | 1979.715624        |
| minreq: Thiamine   | 1.1         | 35.65689469  | 1.1                  | 0.322787609        | 0.129530511        |
| minreq: Riboflavin | 1.1         | 9.247657972  | 1.1                  | 0.105221721        | 0.288866681        |
| minreq: Niacin     | 16.31869775 | 0            | 14                   | 2.318697751        | 1E+30              |
| maxreq: Niacin     | 16.31869775 | 0            | 35                   | 1E+30              | 18.68130225        |

As shown in table 4 and 5, all the maximum constraints and the energy, fats, carbohydrate, phosphorus, total vitamin A and niacin minimum requirement are not binding in the model. The binding constraints in the model are minimum protein, calcium, iron, thiamine and riboflavin requirements. According to Table 4 and 5 (Shadow Price column), although these constraints are binding, a unit increase in the right hand side of any of them will not increase food expenditure significantly. A unit increase in the minimum protein, calcium, iron, thiamine, and riboflavin constraints will increase food expenditure by 0.021643521 pesos, 0.011545564 pesos, 1.266754534 pesos, 35.65689469 pesos and 9.247657976 pesos respectively. A unit increase in the right hand side of the minimum Energy, on the other hand, will decrease the food expenditure by 0.003951458 pesos.
As long as the Right Hand Side Constraint increases or decreases within the allowable ranges (allowable increases and decreases column) we can use shadow price to find out the new objective function value.

4. Conclusion and Recommendations
People with diabetes have specific calorie need based on the recommendation of the dietitian for support in the daily responsibility of managing the rules of conduct regarding diet. A diabetic male need to spend a minimum of 72.22 pesos for a 60.49 g of anchovy, 91.24 g of carrot, 121.92 g of durian, 121.41 g of chicken egg, 70.82 g of pork (lean), and 369.70 g of rice (well-milled), for female, it cost 64.65 pesos for 75.87 g of anchovy, 43.38 g of carrot, 160.46 g of durian, 69.66 g of chicken egg, 23.16 g of pork (lean) and 416.19 g of rice (well-milled). The foods needed by a diabetic male to satisfy the nutrient requirement are the same as a diabetic female based on 2000-calorie diet. The only difference is the quantity required that results to a higher cost for male. Although diabetes is not a curable disease, a healthy diet is important and can control the disease. We have come up to a combination that is consistent in Calorie and fats, carbohydrates, and proteins have been evenly distributed throughout the day. On the other hand, other patients require insulin injections to control the disease. A good understanding of how to meet the individual’s needs regarding nutrients is necessary in the development of diabetic diet strategies to ensure a sustainable health. Further research is needed to explore how diet options can be differentiated to meet the diverse needs of the diabetic patient group (50-64 years old, male and female and 65 years old above male and female).

References
[1] Diabetes: Symptoms, Causes and Treatments. Diabetes Cases Rise From 30 Million to 230 Million in 20 Years Retrieved from http://www.medicalnewstoday.com/info/diabetes
[2] Philippine Diabetes Statistics 2012 Retrieved from http://allaboutdiabetes.net/Philippine-diabetes-statistics/
[3] Wild S 2004 Global Prevalence of Diabetes Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/15111519
[4] The Truth about the So-Called Diabetes Diet Retrieved from http://www.joslin.org/info/the-truth-about-the-so-called-diabetes-diet.html
[5] Linear Programming: An Essential Optimization Technique Retrieved from http://www-01.ibm.com/software/commerce/optimization/linear-programming/
[6] Excel Solver Retrieved from www.cc.memphis.edu/1112/notes/excel/Excel_solver.pdf
[7] Mead R & Nelder J A Simplex Method for Function Minimization Retrieved from http://comjnl.oxfordjournals.org/content/7/4/308.short?rss=1&ssource=mfc
[8] Country Stat Philippines Retrieved from http://www.countrystat.gov
[9] Food and Nutrition Research Institute 1997 The Philippine Food Composition.
[10] Required Energy and Nutrient Intakes (RENI)