Using a Linear Programming Approach for Modeling the Optimal Diet Problem to Help Treat Hypertension

Karrar H. Hashim

Department of Mathematics, College of Education for Pure Science, University of Babylon, Hilla, Iraq, teacher89karrar@gmail.com

Mushtak A. K. Shiker*

Department of Mathematics, College of Education for Pure Science, University of Babylon, Hilla, Iraq, Karrar.hashim.pure252@student.uobabylon.edu.iq

Abstract

The mathematical model of linear programming of the diet problem, specifically the diet, was used to reduce hypertension. In this work, we employed this model to reduce hypertension at the age of 31- 50 years for men. In our model, some foods that contain a low percentage of fat and in the same time rich in potassium, calcium, magnesium, iron, and vitamin E were used in addition to fiber and protein, which help in reducing hypertension and high harmful cholesterol percentage, which leads to reduce risks of cardiovascular disease. Therefore the new mathematical model which use the above foods provided us a balanced diet, which reduces the people daily financial cost.

Keywords: *Linear programming. Diet problem. Nutrient requirement. Mathematical model.*

1. Introduction

The linear programming problem is a mathematical model that can be used to solve optimization problems with a linear objective function and a set of linear constraints that can be in the case of equality or inequality, providing optimal solutions that can satisfy the constraints [1, 2].

Many researches have shown that the DASH diet plan to reduce hypertension requires some foods that must be eaten on a daily basis to maintain a healthy heart, and these foods are rich in calcium, potassium, magnesium, protein and fiber, taking into account the reduction of saturated fat and sodium in it [3]. It is known that the linear programming model of the diet has its limits, as is the case in any model, but the important goal remains at the lowest cost to meet the daily nutritional need of people [4, 5]. At the same time, do not forget that there can be negative side effects from excessive intake of nutrients, such as increased fiber, which can cause some health problems such as diarrhea and cramps, as well as excess magnesium can cause tachycardia and slow breathing, in addition to some negatives that can to infect people by increasing the rest of the elements [6].

Hence the need to create a food model that meets the daily human nutritional need at the lowest cost, and it can also be considered a common theoretical method for dealing with multiple objective decision-making problems [7, 8]. To model diet problems, many researchers have introduced a balanced diet plan to reduce eating disorders and meet the nutritional requirements of their bodies as well as help them avoid certain chronic diseases such as diabetes and heart attacks [9]. To find the optimal solution for nonlinear systems and optimization problems, the authors introduced many papers in variety of science fields to discover the best solution including operation research [10- 19] reliability [20- 29] and optimization [30- 55], but in this paper and in order to obtain a balanced diet, a new model is presented for a diet that consisting of eight foods which contains seven nutrients, which in turn can help reduce the risk of developing hypertension for people from 31-50 years old. The best solution was obtained at the lowest cost by developing the model in the form of a linear programming problem and solving it using the big M method.

2. Methodology

The linear programming model of diet problem is given as follows:

$$Min\ z = c_1x_1 + c_2x_2 + \cdots + c_nx_n$$

Subject to the nutritional constraints,

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n &\geq b_1; \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n &\geq b_2; \\ \cdot \qquad\qquad &\quad \cdot \quad \cdot \\ \cdot \qquad\qquad &\quad \cdot \quad \cdot \\ \cdot \qquad\qquad &\quad \cdot \quad \cdot \\ a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n &\geq b_m; \end{aligned}$$

$$x_1, x_2, \ldots, x_n \geq 0$$

where,

c_j = cost of food j, $j = 1,2, \ldots, n$,

x_j = the number of units of food j in the diet,

a_{ij} = amount of i^{th} nutrient in food type j, $i = 1,2, \ldots, m$,

b_i = the required daily amount of nutrient i,

m = the number of nutrients,

n = the number of food items

3. Data analysis of the new model

the new model used eight types of samples and seven nutrients. Food prices were collected from grocery stores and in dollar terms, as dietary requirements were specific to males aged 31-50 years [56].

Table 1 shows the amount of foods in grams, the amount of nutrients per unit of food, and the minimum daily nutritional requirements. The objective is to select the x_j to minimize the total cost of the diet.

Table 1. Nutrient requirement per day (males, 31-50 years old)

Nutritional Requirement									
nutrient	Food Items								daily requirement
	100gms of chicken	100gms of rice	100gms soya beans	100gms wheat	100gms of spinach	1 class milk	100gms of orange	100gms of potato	
Calcium	16	28	37	34	99	350.35	43	8	1000 mg
Potassium	267	115	332	405	558	445.9	166	328	4700 mg

Iron	1.14	0.8	2.57	3.88	2.71	0.15	0.13	0.31	8 mg
Protein	33.44	7.1	13.05	13.7	2.86	9.68	0.91	1.71	56 g
Fiber	0	1.3	0	12.2	2.2	0	2.2	1.8	30.8 g
Magnesium	31	25	130	138	79	36.75	11	20	420 mg
Vitamin E	0.42	0.11	0.9	0.82	2.03	0	0.15	0.01	15 mg
Cost in $	0.25	0.15	0.20	0.15	0.15	0.25	0.20	0.08	minimization

3.1 Objective function

The total formulation of the above problem is:

$$Min\ z = 0.25x_1 + 0.15x_2 + 0.20x_3 + 0.15x_4 + 0.15x_5 + 0.25x_6 + 0.20x_7 + 0.08x_8$$

Subject to,

$$16x_1 + 28x_2 + 37x_3 + 34x_4 + 99x_5 + 350.35x_6 + 43x_7 + 8x_8 \geq 1000;$$

$$267x_1 + 115x_2 + 332x_3 + 405x_4 + 558x_5 + 445.9x_6 + 166x_7 + 328x_8 \geq 4700;$$

$$1.14x_1 + 0.8x_2 + 2.57x_3 + 3.88x_4 + 2.71x_5 + 0.15x_6 + 0.13x_7 + 0.31x_8 \geq 8;$$

$$33.44x_1 + 7.1x_2 + 13.05x_3 + 13.7x_4 + 2.86x_5 + 9.68x_6 + 0.91x_7 + 1.71x_8 \geq 56;$$

$$0x_1 + 1.3x_2 + 0x_3 + 12.2x_4 + 2.2x_5 + 0x_6 + 2.2x_7 + 1.8x_8 \geq 30.8;$$

$$31x_1 + 25x_2 + 130x_3 + 138x_4 + 79x_5 + 36.75x_6 + 11x_7 + 20x_8 \geq 420;$$

$$0.42x_1 + 0.11x_2 + 0.9x_3 + 0.82x_4 + 2.03x_5 + 0x_6 + 0.15x_7 + 0.01x_8 \geq 15;$$

$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8 \geq 0$$

3.2. Results and discussion

The above model contains 8 variables, 7 constraints, and by using the big M method, a solution to the problem was obtained, where the minimum costs involved is 1.495 $ with a balanced diet consisting of:

1. 33 gms of chicken per day.
2. 130 gms of wheat per day.
3. 680 gms of spinach per day.
4. 0.79 class of milk per day.

4. Conclusion

The presented mathematical model, which in turn reduces the daily cost and reduces hypertension and high harmful cholesterol percentage according to the diet problem, was formulated in a linear programming model that was illustrated by using some of the food samples that were used from the DASH food chart.

Through the presented form, we note that the minimum eating plan is obtained, in addition to the main objective of reducing the daily cost of the diet, knowing that it is possible to obtain adjustments in the solution by replacing some foods.

Reference

[1] Dantzig, G. B., & Thapa, M. N. (2006). Linear programming 1: introduction. Springer Science & Business Media.

[2] Gupta, P.K. and Hira, D.S. (2012) Operations Research. S. Chand and Company Ltd., New Delhi.

[3] National Heart, Lung and Blood Institute (2006) Your Guide to Lowering Your Blood Pressure with DASH. NIH Publication.

[4] Iwuji, A.C., Nnanna, M. and Ndulue, N.E.C. (2016) An Optimal DASH Diet Model for People with Hypertension Using Linear Programming Approach. Open Journal of Optimization, 5, 14-21.

[5] Arraut-Berilo, A., Delalic, A. and Huseinbasic (2017) A Nutritional Analysis of the Food Basket of BiH: A Linear Programming Approach. South East European Journal of Economics and Business , 12, 104-113.

[6] Bhargara, A.K., Bansal, D., Chandramouli, A.B. and Kumar, A. (2011) Weighted Goal programming Model Formulation and Calculation of Diet Planning. International Transactions in Mathematical Sciences & Computer , 4, 123-130.

[7] Orumie, U.C. and Ebong, D. (2014) A Glorious Literature on Linear Goal Programming Algorithms. American Journal of Operations Research , 4, 59-71.

[8] Mohamed, N. F., Mohamed, N. A., Mohamed, N. H., & Mohamed, N. A. (2021). An Integer Linear Programming Model For A Diet Problem Of Mcdonald's Sets Menu In Malaysia. European Journal of Molecular & Clinical Medicine, 8(02), 60-67.

[9] Mamat, M., Zulkifli, N.F., Deraman, S.K. and Noor, N.M.M. (2012) Fuzzy Linear Programming Approach in Balance Diet Planning for Eating Disorder and Disease-Related Lifestyle. Applied Mathematical Sciences, 6, 5109-5118.

[10] Hussein, H. A., & Shiker, M. A. K. (2020). A modification to Vogel's approximation method to Solve transportation problems. Journal of Physics: Conference Series (Vol. 1591, No. 1, p. 012029). IOP Publishing.

[11] Hussein, H. A., & Shiker, M. A. K. (2020). Two New Effective Methods to Find the Optimal Solution for the Assignment Problems. press", accepted paper for publication in Journal of Advanced Research in Dynamical and Control Systems.

[12] Hussein, H. A., Shiker, M. A., & Zabiba, M. S. (2020). A new revised efficient of VAM to find the initial solution for the transportation problem. Journal of Physics: Conference Series (Vol. 1591, No. 1, p. 012032). IOP Publishing.

[13] Kadhim, H. J., Shiker, M. A., & Al-Dallal, H. A. (2021). A new technique for finding the optimal solution to assignment

problems with maximization objective function. Journal of Physics: Conference Series (Vol. 1963, No. 1, p. 012104). IOP Publishing.

[14] Kadhim, H. J., Shiker, M. A. K. and Hussein H. A. (2021). New technique for finding the maximization to TPs. Journal of Physics: Conference Series (Vol. 1963, No. 1, p. 012070). IOP Publishing.

[15] Sahib, M. S. A., & Shiker, M. A. Employing the golden ratio to reach the BFS for TP. Transportation, 2, 1-618033988.

[16] Kadhim, H. J., & Shiker, M. A. K. (2021). Solving QAP with large size 10 facilities and 10 locations,". 7th International Conference for Iraqi Al-Khwarizmi Society–Iraq, IOP conference.

[17] Hashim, L. H., Dreeb, N. K., Hashim, K. H., & Shiker, M. A. (2021). An application comparison of two negative binomial models on rainfall count data. Journal of Physics: Conference Series (Vol. 1818, No. 1, p. 012100). IOP Publishing.

[18] Hashim, L. H., Hashim, K. H., & Shiker, M. A. (2021). An application comparison of two Poisson models on zero count data. Journal of Physics: Conference Series (Vol. 1818, No. 1, p. 012165). IOP Publishing.

[19] Abbas, S. A. K., & Hassan, Z. A. H. (2021). Increase the Reliability of Critical Units by Using Redundant Technologies. Journal of Physics: Conference Series (Vol. 1999, No. 1, p. 012107). IOP Publishing.

[20] Abbas, S. A. K., & Hassan, Z. A. H. (2021). Use of ARINC Approach method to evaluate the reliability assignment for mixed system. Journal of Physics: Conference Series (Vol. 1999, No. 1, p. 012102). IOP Publishing.

[21] Abd Alsharify, F. H., & Hassan, Z. A. H. (2021). Computing the reliability of a complex network using two techniques. Journal of Physics: Conference Series (Vol. 1963, No. 1, p. 012016). IOP Publishing.

[22] Abd Alsharify, F. H., Mudhar, G. A., & Hassan, Z. A. H. (2021). A modified technique to compute the minimal path sets for the reliability of complex network. Journal of Physics: Conference Series (Vol. 1999, No. 1, p. 012083). IOP Publishing.

[23] Abdullah, G., & Hassan, Z. A. H. (2020). Using of Genetic Algorithm to Evaluate Reliability Allocation and Optimization of Complex Network. IOP Conference Series: Materials Science and Engineering (Vol. 928, No. 4, p. 042033). IOP Publishing.

[24] Abdullah, G., & Hassan, Z. A. H. (2020). Using of particle swarm optimization (PSO) to addressed reliability allocation of complex network. Journal of Physics: Conference Series (Vol. 1664, No. 1, p. 012125). IOP Publishing.

[25] Abdullah, G., & Hassan, Z. A. H. (2021). A Comparison Between Genetic Algorithm and Practical Swarm to Investigate the Reliability Allocation of Complex Network. Journal of Physics: Conference Series (Vol. 1818, No. 1, p. 012163). IOP Publishing.

[26] Abdullah, G., & Hassan, Z. A. H. (2021). Use of Bees Colony algorithm to allocate and improve reliability of complex network. Journal of Physics: Conference Series (Vol. 1999, No. 1, p. 012081). IOP Publishing.

[27] Hassan, Z. A. H. (2021). Use of a modified Markov models for parallel reliability systems that are subject to maintenance. Journal of Physics: Conference Series

(Vol. 1999, No. 1, p. 012087). IOP Publishing.

[28] Hassan, Z. A. H., & Muter, E. K. (2017). Geometry of reliability models of electrical system used inside spacecraft. 2017 Second Al-Sadiq International Conference on Multidisciplinary in IT and Communication Science and Applications (AIC-MITCSA) (pp. 301-306). IEEE.

[29] Mueen, H. A., & Shiker, M. A. (2021). A new projection technique with gradient property to solve optimization problems. Journal of Physics: Conference Series (Vol. 1963, No. 1, p. 012111). IOP Publishing.

[30] Mueen, H. A., & Shiker, M. A. (2021). Using a new modification of trust region spectral (TRS) approach to solve optimization problems. Journal of Physics: Conference Series (Vol. 1963, No. 1, p. 012090). IOP Publishing.

[31] Shiker, M. A., & Sahib, Z. (2018). A modified trust-region method for solving unconstrained optimization. Journal of Engineering and Applied Sciences, 13(22), 9667-9671.

[32] Dwail, H. H., & Shiker, M. A. (2021). Using trust region method with BFGS technique for solving nonlinear systems of equations. Journal of Physics: Conference Series (Vol. 1818, No. 1, p. 012022). IOP Publishing.

[33] Mahdi, M. M., Dwail, H. H., Wasi, H. A., Hashim, K. H., kahtan Dreeb, N., Hussein, H. A., & Shiker, M. A. (2021). Solving systems of nonlinear monotone equations by using a new projection approach. Journal of Physics: Conference Series (Vol. 1804, No. 1, p. 012107). IOP Publishing.

[34] Mahdi, M. M., & Shiker, M. A. (2020). A new class of three-term double projection approach for solving nonlinear monotone equations. Journal of Physics: Conference Series (Vol. 1664, No. 1, p. 012147). IOP Publishing.

[35] Dwail, H. H., & Shiker, M. A. (2020). Using a trust region method with nonmonotone technique to solve unrestricted optimization problem. Journal of Physics: Conference Series (Vol. 1664, No. 1, p. 012128). IOP Publishing.

[36] Mahdi, M. M., & Shiker, M. A. K. (2020). A new projection technique for developing a Liu-Storey method to solve nonlinear systems of monotone equations. Journal of Physics: Conference Series (Vol. 1591, No. 1, p. 012030). IOP Publishing.

[37] Hashim, K. H., & Shiker, M. A. (2021). Using a new line search method with gradient direction to solve nonlinear systems of equations. Journal of Physics: Conference Series (Vol. 1804, No. 1, p. 012106). IOP Publishing.

[38] Dwail, H. H., & Shiker, M. A. (2020). Reducing the time that TRM requires to solve systems of nonlinear equations. IOP Conference Series: Materials Science and Engineering (Vol. 928, No. 4, p. 042043). IOP Publishing.

[39] Wasi, H. A., & Shiker, M. A. K. (2021). A modified of FR method to solve unconstrained optimization. Journal of Physics: Conference Series (Vol. 1804, No. 1, p. 012023). IOP Publishing.

[40] Mahdi, M. M., & Shiker, M. A. K. (2020). Three terms of derivative free projection technique for solving nonlinear monotone equations. Journal of Physics: Conference Series (Vol. 1591, No. 1, p. 012031). IOP Publishing.

[41] Dwail, H. H., Mahdi, M. M., Wasi, H. A., Hashim, K. H., Hussein, H. A., & Shiker, M. A. (2021). A new modified TR

algorithm with adaptive radius to solve a nonlinear systems of equations. Journal of Physics: Conference Series (Vol. 1804, No. 1, p. 012108). IOP Publishing.

[42] Dreeb, N. K., Hashim, L. H., Hashim, K. H., & Shiker, M. A. (2021). Using a new projection approach to find the optimal solution for nonlinear systems of monotone equation. Journal of Physics: Conference Series (Vol. 1818, No. 1, p. 012101). IOP Publishing.

[43] Hashim, K. H., Hashim, L. H., k Dreeb, N., & Shiker, M. A. (2021). Solving the Nonlinear Monotone Equations by Using a New Line Search Technique. Journal of Physics: Conference Series (Vol. 1818, No. 1, p. 012099). IOP Publishing.

[44] Wasi, H. A., & Shiker, M. A. (2021). Nonlinear conjugate gradient method with modified Armijo condition to solve unconstrained optimization. Journal of Physics: Conference Series (Vol. 1818, No. 1, p. 012021). IOP Publishing.

[45] Wasi, H. A., & Shiker, M. A. (2020). A new hybrid CGM for unconstrained optimization problems. Journal of Physics: Conference Series (Vol. 1664, No. 1, p. 012077). IOP Publishing.

[46] Wasi, H. A., & Shiker, M. A. K. (2021). Proposed CG method to solve unconstrained optimization problems. Journal of Physics: Conference Series (Vol. 1804, No. 1, p. 012024). IOP Publishing.

[47] Mahdi, M. M., & Shiker, M. A. K. (2020). Three-term of new conjugate gradient projection approach under Wolfe condition to solve unconstrained optimization problems,“in press”, accepted paper for publication. Jour of Adv Research in Dynamical & Control Systems, 12(7).

[48] Mahdi, M. M., Dwail, H. H., & Shiker, M. A. (2022). Hybrid spectral algorithm under a convex constrained to solve nonlinear equations. Journal of Interdisciplinary Mathematics, 25(5), 1333-1340.

[49] Dwail, H. H., Mahdi, M. M., & Shiker, M. A. (2022). CG method with modifying βk for solving unconstrained optimization problems. Journal of Interdisciplinary Mathematics, 25(5), 1347-1355.

[50] Hussein Y A and Shiker M A K 2022 Using the largest difference method to find the initial basic feasible solution to the transportation problem, Journal of Interdisciplinary Mathematics, 25 (8), pp. 2511- 2517.

[51] Hussein Y A and Shiker M A K 2023 Using a new method named matrix method to find the optimal solution to transportation problems, AIP Conference Proceedings 2414.

[52] Zabiba M S M, Al- Dallal H A H, Hashim K H, et. al. 2023 A new technique to solve the maximization of the transportation problems, AIP Conference Proceedings 2414, 040042.

[53] Hashim Z K and Shiker M A K 2023 A New technique to solve the assignment problems, AIP Conference Proceedings 2414, 040018.

[54] Hashim Z K, Shiker M A K, and Zabiba M S M 2023 An easy technique to reach the optimal solution to the assignment problems, AIP Conference Proceedings 2414, 040045, https://doi.org/10.1063/5.0114794.

[55] Hashim Z K and Shiker M A K 2023 A new technique for modifying the Hungarian method, AIP Conference Proceedings 2414, 040023, https://doi.org/10.1063/5.0114815.

[56] Dietary Guidelines Advisory Committee. (2015). Dietary guidelines for Americans 2015-2020. Government Printing Office.