How to Cite:
Yadav, R., & Sahu, M. (2022). Food intake pattern to achieve nutritional goals for Indian adults by linear programming optimization techniques. *International Journal of Health Sciences*, *6*(S2), 7346–7352. https://doi.org/10.53730/ijhs.v6nS2.6858

Food intake pattern to achieve nutritional goals for Indian adults by linear programming optimization techniques

Dr. Rakesh Yadav
Department of Mathematics, School of Chemical Engineering and Physical Sciences, Lovely Professional University, Phagwara, Punjab
Corresponding author email: rakesh21798@lpu.co.in

Monika Sahu
Department of Mathematics, School of Chemical Engineering and Physical Sciences, Lovely Professional University, Phagwara, Punjab
Email: sahumonika2507@gmail.com

***Abstract*---**This paper discusses about the student diet selection taking some food items to complete the daily needs of nutrition. The objective of the present study was to minimize the cost of per day. To make a mathematical model of diet selection for the students in Indian Institute of Technology, Mumbai. This model is helped in the student's diet problem with minimum possible cost. This model is the application of ILP of the food selection. The ILP model is prepared to pick suitable food items and minimize the cost of the diet taking by the students which makes all students are healthy. The result obtained from the mathematical model disclosed the minimum cost of a balanced diet is Rs 58.05 per day.

***Keywords*---**diet cost, nutrients, optimization, integer linear programming.

Introduction

In this modern life diet plays an important role to balance a healthy lifestyle. Proper intake of nutrients is good for our body functioning properly and preventing our body from all diseases. In the adult age, a lot of health issues like obesity, overweight and also death rate increases due to lack of nutrition [1]. University students facing the problem of malnutrition because they have less money. Due to absence of income source students faced the problem of under nutrition. Now, there are a large amount of students have a big problem of underweight and overweight. This problem also happened among students of all the universities as well as in IIT Mumbai. In some studies, healthy diets were

shown to be more costly than less healthy diet. Such as fish, fruits, lean meat contain high amounts of nutrients but these are very expensive so everyone cannot eat [2].There are many arguments about good and bad foods. Some of them are good and bad diets which are depend upon the total number of different foods taken. Many of foods can appropriate for healthy pattern. Some individual food gives healthy life if that taken in moderate amount. Human focus moves from individual foods to the quality of the total diet because of increasing the variety of food choices [3]. According to the dietary guidelines some points must be taken in daily life to achieve dietary goals like eat a large amount of fruits and vegetables, les use of ghee/butter, exercise regularly, drink plenty of water, minimum use of salt and sugar [4]. One of the objectives describes about the children of low income households and higher income households. There was a big difference in carbohydrates intakes, energy intakes, cholesterol intakes by the children of low income and children of higher income [5]. In India, according to data of some states described that 45% of boys and 61% of girls were eating sufficient amounts of protein and energy while 28% of boys and 22% of girls were eating insufficient amounts of both the nutrients. About 51% of boys and 35% girls were eating insufficient amounts of energy and about 31% of boys and 25% of girls were eating insufficient amounts of proteins [6]. In 2010 Dietary guidelines for sodium investigates the goals which is based on linear programming. With the help of linear programming have some models which showed the sodium levels for all peoples. It advised sodium intake level is less than 2300mg/day in young peoples. The 1500 mg/day sodium levels can be declared insufficient for people aged < 50 years and sufficient for people aged > 50 years [7]. So that, in particular, this study would explore whether students are to know about the healthy diet. This study will help the students in choosing foods which are more important for completing the daily needs of nutrients at lowest cost. By using integer linear programming a mathematical model is formulated. This is very good method which is mostly used for minimization and maximization.

Formulation of the Model

The mathematical model is developed by taking some foods. These foods are totally depending upon accessibility within IIT Mumbai campus. The outsider eating things were not considered in this model. The model defined the values of Calories, Proteins, Fats, Sodium, Calcium, Vitamin C and Carbohydrates contained by those food that are taken in the data. By LINDO, to determine the minimum cost plan for a student. The application of Linear Programming is ILP that needs the description of decision variables in integer values. So that the mathematical model of ILP is same as LP. But only one condition is extra in ILP which is the variables must have integer values. An ILP model includes of three main parts which is the objective function, constraints and decision variables. The normal form of an ILP model contains of either maximizing or minimizing the objective function. In this model, Z is the objective function that was minimized. Z is defined by the sum of multiplication of both C and X where, C denotes the cost of food and X denotes the quantity of food. Equation (2) relates with the constraint coefficients A were related with all food items were subject to a limit B. Equation (4) defines the non negativity and integer constraint for the decision variables which states the pure integer problem.

$$Minimize\ \boldsymbol{Z} = C_1X_1 + C_2X_2 + C_3X_3 + \cdots + C_nX_n \quad (1)$$

Subject to:

$$a11X1 + a12X2 + a13X3 + \ldots + a1nXn \geq b1$$

$$a21X1 + a22X2 + a23X3 + \ldots + a2nXn \geq b2$$

$$\vdots$$

$$am1X1 + am2X2 + am3X3 + \ldots + amnXn \geq b_m \quad (2)$$

$$X1 \geq d1$$

$$X2 \geq d2$$

$$\vdots$$

$$Xn \geq dn \quad (3)$$

$$Xn \geq 0 \text{ and integer} \quad (4)$$

The minimum value of nutrient requirements is defined in table 1. The nutrients which are described in this table are Calories, Proteins, Fats, Sodium, Calcium and Carbohydrates. The breakfast, lunch and dinner are proper explained in table no 2, 3, 4 respectively. All the food items which are given to the students and their cost are properly explained. Total 19 food items are included in the daily diet according to the observation. All the data that were mentioned in these tables were taken from the canteen of IIT Mumbai. Some of the nutrition data that are not obtain was noted from the internet.

Table1. The minimum value of nutrient requirements

Nutrients	Minimum Requirement
Calories (kcal)	1600
Proteins (gm)	120
Fats (gm)	38
Sodium (mg)	152
Calcium (mg)	140
Vitamin C (mg)	65
Carbohydrates (mg)	190

Table2. Ingredients for the breakfast

Food Item	Mix Veg Prantha	Poha	Omlate	Milk	Daliya	Bread	Sambher	Butter
	X1	X2	X3	X4	X5	X6	X7	X8
Per serving	100gm	100gm	1 large	250gm	100gm	2 slices	100 gm	5 gm
Price (Rs)	17	12	17	15	12	6	5	2
Calories (Kcal)	153	110	93	150	152	133	114	36
Proteins (gm)	3.5	2.34	6.48	8.05	5.03	3.82	4.85	0.04
Fats (gm)	4.1	2.87	7.33	8.12	3.41	1.64	4.08	4.06
Sodium (mg)	35.8	201	96	100	143	340	252	1

Calcium (mg)	30.3	15	29	282	35	76	43	1
Vitamin C (mg)	9.1	6.4	0	0	0	0	13.9	0
Carbohydrates (gm)	25.9	18.8	0.42	12.87	27.7	25	15.86	0

Table3. Ingredients for the lunch

Food Item	Roti	Rice	Raita/ Curd	Salad	Rajma (dal)	Chicken biryani
	X9	X10	X11	X12	X13	X14
Per serving	2	100g	100g	1cup	100g	1cup
Price (Rs)	3	10	10	15	10	40
Calories (Kcal)	208	364	61	9	165	348
Proteins (gm)	9.99	3.54	4.1	0.84	7.04	15.9
Fats (gm)	0.8	0.3	3.3	0.13	7.08	9.82
Sodium (mg)	506	1	61	16	286	805
Calcium (mg)	20.8	10	83	26	143	53
Vitamin C (mg)	0	0	0	8.7	4.5	5.1
Carbohydrates(gm)	58.04	28	4.4	11	19.77	48.07

Table4. Ingredients for the dinner

Food Item	Veg pulao	Egg curry	Shahi paneer	Moong dal	Chicken fry
	X15	X16	X17	X18	X19
Per serving	200g	100g	100g	100g	1medium
Price (Rs)	30	25	15	8	30
Calories (Kcal)	198	114	131	347	119
Proteins (gm)	5.08	5.95	6.35	24	13.6
Fats (gm)	2.74	7.11	9.44	1.2	6.79
Sodium (mg)	620	253	311	15	211
Calcium (mg)	34	55	208	132	17
Vitamin C (mg)	10.6	9	4	4.8	0
Carbohydrates (gm)	38.28	7.54	5.98	18.38	0

Total formulation of the problem

$MIN\ Z = 17X_1 + 12X_2 + 17X_3 + 15X_4 + 12X_5 + 6X_6 + 5X_7 + 2X_8 + 3X_9 + 10X_{10} + 10X_{11} + 15X_{12} + 10X_{13} + 40X_{14} + 30X_{15} + 25X_{16} + 15X_{17} + 8X_{18} + 30X_{19}$

Subject to,

$153X_1 + 110X_2 + 93X_3 + 150X_4 + 152X_5 + 133X_6 + 114X_7 + 36X_8 + 208X_9 + 364X_{10} + 61X_{11} + 9X_{12} + 165X_{13} + 348X_{14} + 198X_{15} + 114X_{16} + 131X_{17} + 347X_{18} + 119X_{19} \geq 1600$

$3.5X_1 + 2.34X_2 + 6.48X_3 + 8.05X_4 + 5.03X_5 + 3.82X_6 + 4.85X_7 + 0.04X_8 + 9.99X_9 + 3.54X_{10} + 4.1X_{11} + 0.84X_{12} + 7.04X_{13} + 15.9X_{14} + 5.08X_{15} + 5.95X_{16} + 6.35X_{17} + 24X_{18} + 13.6X_{19} \geq 120$

$4.1X_1 + 2.87X_2 + 7.33X_3 + 8.12X_4 + 3.41X_5 + 1.64X_6 + 4.08X_7 + 4.06X_8 + 0.8X_9 + 0.3X_{10} + 3.3X_{11} + 0.13X_{12} + 7.08X_{13} + 9.82X_{14} + 2.74X_{15} + 7.11X_{16} + 9.44X_{17} + 1.2X_{18} + 6.79X_{19} \geq 38$
$35.8X_1 + 201X_2 + 96X_3 + 100X_4 + 143X_5 + 340X_6 + 252X_7 + 1X_8 + 506X_9 + 1X_{10} + 61X_{11} + 16X_{12} + 286X_{13} + 805X_{14} + 620X_{15} + 253X_{16} + 311X_{17} + 15X_{18} + 211X_{19} \geq 152$
$303X_1 + 15X_2 + 29X_3 + 282X_4 + 35X_5 + 76X_6 + 43X_7 + 1X_8 + 20.8X_9 + 10X_{10} + 83X_{11} + 26X_{12} + 143X_{13} + 53X_{14} + 34X_{15} + 55X_{16} + 208X_{17} + 132X_{18} + 17X_{19} \geq 140$
$9.1X_1 + 6.4X_2 + 13.9X_7 + 8.7X_{12} + 4.5X_{13} + 5.1X_{14} + 10.6X_{15} + 9X_{16} + 4X_{17} + 4.8X_{18} \geq 65$
$25.9X_1 + 18.8X_2 + 0.42X_3 + 12.87X_4 + 27.7X_5 + 25X_6 + 15.86X_7 + 58.04X_9 + 28X_{10} + 4.4X_{11} + 19.77X_{12} + 48.07X_{13} + 38.28X_{14} + 7.54X_{15} + 5.98X_{17} + 18.38X_{18} \geq 190$

Lingo Formulation

$\text{Min}= 17*X_1 + 12*X_2 + 17*X_3 + 15*X_4 + 12*X_5 + 6*X_6 + 5*X_7 + 2*X_8 + 3*X_9 + 10*X_{10} + 10*X_{11} + 15*X_{12} + 10*X_{13} + 40*X_{14} + 30*X_{15} + 25*X_{16} + 15*X_{17} + 8*X_{18} + 30*X_{19};$
$153*X_1 + 110*X_2 + 93*X_3 + 150*X_4 + 152*X_5 + 133*X_6 + 114*X_7 + 36*X_8 + 208*X_9 + 364*X_{10} + 61*X_{11} + 9*X_{12} + 165*X_{13} + 348*X_{14} + 198*X_{15} + 114*X_{16} + 131*X_{17} + 347*X_{18} + 119*X_{19} >=1600;$
$3.5*X_1 + 2.34*X_2 + 6.48*X_3 + 8.05*X_4 + 5.03*X_5 + 3.82*X_6 + 4.85*X_7 + 0.04*X_8 + 9.99*X_9 + 3.54*X_{10} + 4.1*X_{11} + 0.84*X_{12} + 7.04*X_{13} + 15.9*X_{14} + 5.08*X_{15} + 5.95*X_{16} + 6.35*X_{17} + 24*X_{18} + 13.6*X_{19} >=120;$
$4.1*X_1 + 2.87*X_2 + 7.33*X_3 + 8.12*X_4 + 3.41*X_5 + 1.64*X_6 + 4.08*X_7 + 4.06*X_8 + 0.8*X_9 + 0.3*X_{10} + 3.3X_{11} + 0.13*X_{12} + 7.08*X_{13} + 9.82*X_{14} + 2.74*X_{15} + 7.11*X_{16} + 9.44*X_{17} + 1.2*X_{18} + 6.79*X_{19} >=38;$
$35.8*X_1 + 201*X_2 + 96*X_3 + 100*X_4 + 143*X_5 + 340*X_6 + 252*X_7 +1*X_8 + 506*X_9 + 1*X_{10} + 61*X_{11} + 16*X_{12} + 286*X_{13} + 805*X_{14} + 620*X_{15} + 253*X_{16} + 311*X_{17} + 15*X_{18} + 211*X_{19} >=152;$
$303*X_1 + 15*X_2 + 29*X_3 + 282*X_4 + 35*X_5 + 76*X_6 + 43*X_7 + 1*X_8 + 20.8*X_9 + 10*X_{10} + 83*X_{11} + 26*X_{12} + 143*X_{13} + 53*X_{14} + 34*X_{15} + 55*X_{16} + 208*X_{17} + 132*X_{18} + 17*X_{19} >=140;$
$9.1*X_1 + 6.4*X_2 + 13.9*X_7 + 8.7*X_{12} + 4.5*X_{13} + 5.1*X_{14} + 10.6*X_{15} + 9*X_{16} + 4*X_{17} + 4.8*X_{18} >=65;$
$25.9*X_1 + 18.8*X_2 + 0.42*X_3 + 12.87*X_4 + 27.7*X_5 + 25*X_6 + 15.86*X_7 + 58.04*X_9 + 28*X_{10} + 4.4*X_{11} + 19.77*X_{12} + 48.07*X_{13} + 38.28*X_{14} + 7.54*X_{15} + 5.98*X_{17} + 18.38*X_{18} >=190;$

Lingo Solution

Global optimal solution
Objective value: 58.05945
Infeasibilities: 0.000000
Total solver iterations: 4
Elapsed solver seconds: 0.08
Model Class: LP
Total variables: 19
Nonlinear variables: 0
Integer variables: 0
Total constraints: 8

Nonlinear constraints: 0
Total nonzero: 140
Nonlinear nonzero: 0

Variable	Reduced Cost	Value
X_1	12.94160	0.000000
X_2	9.184089	0.000000
X_3	11.71636	0.000000
X_4	8.919368	0.000000
X_5	9.015846	0.000000
X_6	4.199095	0.000000
X_7	0.000000	4.676259
X_8	0.000000	2.742917
X_9	0.000000	9.730773
X_{10}	8.928843	0.000000
X_{11}	7.312534	0.000000
X_{12}	13.63138	0.000000
X_{13}	4.131145	0.000000
X_{14}	30.40059	0.000000
X_{15}	26.00840	0.000000
X_{16}	18.83946	0.000000
X_{17}	8.217176	0.000000
X_{18}	0.5475949	0.000000
X_{19}	23.12225	0.000000

Row	Slack or Surplus	Dual Price
1	58.05945	-1.000000
2	1055.839	0.000000
3	0.000000	-0.2610580
4	0.000000	-0.4900388
5	5952.932	0.000000
6	266.2221	0.000000
7	0.000000	-0.1247849
8	448.9396	0.000000

References

1. World Health Organization, WHO (2015). Obesity and Overweight Fact Sheets. Retrieved on 25th March 2016, from http://www.who.int/mediacentre/factsheets/fs311/en/
2. Maillot, M., Ferguson, E. L., Drewnowski, A., & Dermon, N. (2008). Nutrient profiling can help identify foods of good nutritional quality for their price: a validation study with linear programming. *The Journal of nutrition,* 138(6), 1107-1113.
3. Drewnowski, A., Renderson, S. A., Driscoll, A., & Rolls, B. J. (1997). The Dietary Variety Score: assessing diet quality in healthy young and older adults. *Journal of the American Dietetic Association,* 97(3), 266-271.
4. Misra, A., Sharma, R., Gulati, S., Joshi, S. R., Sharma, V., Ibrahim, A., & Bhardwaj for the National Dietary Guidelines Consensus Group, S. (2011).

Consensus dietary guidelines for healthy living and prevention of obesity, the metabolic syndrome, diabetes, and related disorders in Asian Indians. *Diabetes technology & therapeutics,* 13(6), 683-694.

5. Casey, P. H., Szeto, K., Lensing, S., Bogle, M., & Weber, J. (2001), Children in food-insufficient, low-income families: prevalence, health, and nutrition status. *Archives of pediatrics & adolescent medicine,* 155(4), 508-514.
6. Venkaish, K., Brahman, G. N. V., & Vijayaraghavan, K. (2015). Identification of dietary patterns analysis and study of the relationship with nutritional status of rural adolescents using factor scores. *Journal of Health, Population and Nutrition,* 34(1), 1-8.
7. Maillot, M., & Drenowski, A. (2012). A conflict between nutritionally adequate diets and meeting the 2010 dietary guidelines for sodium. *American journal of preventive medicine,* 42(2), 174-179.
8. Darmon, N., Ferguson, E. L., & Briend, A. (2002). A cost constraint alone has adverse effects on food selection and nutrient density: an analysis of human diets by linear programming. *The Journal of nutrition, 132(12),* 3764-3771.