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Development of Cost Effective Nutritive Diet for Children using Linear Programming Problem

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***Abstract*—** In this paper authors presents a case based on utilisation of widely known, simple and yet interesting LPP technique for Diet problems i.e. focusing on to optimized product mix with minimum resources. It focuses on developing an innovative product for 12-16 years old children by mixing five different ingredients to formulate a single product that would serve them with the major nutrients needed per day. The objective of work is to minimize the cost of raw material subject to fulfilment of recommended dietary allowance (RDA) values of children. The formulated problem was analysed using LINDO software and gives an optimum solution to minimize the cost for developed product mix. The solution of formulated problem suggests the combination of five ingredients i.e. Milk (200g); Green Beans (200g); Peas (310g); White Rice (200g); Wheat Grains (504g) to achieve the optimum product mix with the minimum cost of INR 64.16 per day or serving.

***Keywords*—** *Linear programing, product mix, Recommended dietry allowance (RDA)*

I. INTRODUCTION

In this small journey of 1000's years over the geographical clock, human species had witnessed many changes. May it be the discovery of wheel to the present giant automobile industry; the discovery of electric bulb to semiconductors and IC's; or the introduction of zero by Aryabhatta to the development of today's number system.

Similarly, the way we consume food nowadays has too evolved many folds. Earlier different types of food mix were eaten, mainly for its associated health benefits as described by a classical writer of Ayurveda: Vagbhata "85% of diseases can be cured without a doctor; only 15% of diseases require a doctor". Then various cooking techniques and spices were introduced to improve the palatability which now has developed into today's wholesome food processing industry. With the passage of time and advancement of technology and changes in the lifestyle, the consumers are demanding more innovative and nutrition rich products. The consumer is aware of their daily nutrition requirement, but their demand to stay fit and healthy inspires them to "eat less but gain more". Therefore the demand and supply of multivitamins and multi-minerals supplement tablets is constantly increasing. Such supplement tablets are used to prevent vitamin deficiency due to poor diet, certain illnesses or due to poor absorption of the body [1]. Some researchers have proven these tablets to use full in increasing energy levels; improve mood; improve lipid profile; reduce stress and anxiety; reduce body weight in obese; improve short-term memory and maintain muscle strength[2-4].

The use of such tablets is not only limited to developed nations but developing and under developed nations have more requirements of such products to enrich their large populations with the good amount of nutrients. In this paper, we tried to identify the optimum proportion in which different ingredients should be mixed so that a high nutrient product mix similar to the multi-nutrient tablets can be formulated for underdeveloped and developing nations. The underlined problem aims at developing a product mix to provide maximum value to the user at minimum cost. The optimum ratio is calculated using Linear programming problem (LPP).

II. RELATED WORK

We want to develop a new product similar to the vitamin and mineral supplement tablets for the children in the developing or under developed countries, where hunger is a prevailing long-term problem.

In order to make the project feasible in terms of its shelf life, economics and to provide children not only with vitamins and minerals but also improve their protein, calcium and

energy uptake, researchers advice to use dried mixture of natural products to meet all the basic nutritional requirement of a day per serving of a single product. We plan to grind pre-treated ingredients i.e. green beans, peas, white rice, wheat to powder and mix it all in milk followed by vacuum spray drying of the entire mixture to get a very fine powder product that could be directly dissolved in water for its consumption. This kind of product is expected to be a better option because:

- Its distribution cost would be very less, due to its low volume,
- Shelf life would be high because of low moisture content and
- Easy to consume as no prior treatment is required

But the product mix should be optimized such that it meet's recommended dietary allowance (RDA) of the children. The nutrient content (per 100 gms of serving) of all the selected ingredients in the product mix and the RDA values for children in the age group of 12 -16 years are given in table-1. The secondary data related to RDA and nutritive values in table-1 is taken from a book titled 'Nutritive Value of Indian Foods (NVIF)' [5] and the cost of different ingredients are collected online from Delhi Milk Scheme, Ministry of Agriculture and Farmer welfare, GOI and AGMARKET Portal, GOI. The nutrients that are tabulated here are shortlisted on the basis of importance for children. Protein is important for proper growth and muscle development [6]. It is also important for proper functioning of hormones and enzymes. Calcium and iron are macronutrients that help in the development of bones and functioning of haemoglobin respectively [7, 8]. Vitamin C (ascorbic acid) and vitamin B-12 (riboflavin) are anti-oxidants that play an important role in energy metabolism. Vitamin C is water soluble and may be lost during washing and cooking, its deficiency may cause scurvy [9]. Fat is the break up source of energy in the body and is used when carbohydrates are used. Having said that carbohydrates, other minerals and vitamins are also important for the holistic development and their deficiency will have ill effects on children. But for the ease of understanding and simplification, we only considered some of these nutrients. As in our diet we should have different ingredients, so this product mix is assumed to have at least of 200g of each of ingredients. By doing this, product will be balanced and will not be dominated by any single ingredient. As the data in table 1 is in per 100 g of ingredients i.e. we should have at least 2 units of each ingredient per child per day in the optimized solution.

Table 1: Nutrient content of various ingredients in the product mix and RDA values for children (12-16 years)

Ingredient	Nutrient (per 100 g)							Cost (Per 100g in rupees)
	Energy (kcal)	Protein (g)	Calcium (mg)	Iron (mg)	Vitamin C (mg)	Fat (g)	Vitamin B-12 (mg)	
Milk	117	4.2	210	0.2	2	6.5	0.10	5
Green Beans	347	24.9	60	3.2	0	0.8	0.16	8
Peas	93	7.2	20	1.5	10	0.1	0.01	5
White Rice (Milled)	345	6.8	10	0.9	0	0.5	0.06	2.5
Wheat Grains	346	11.8	41	5.3	0	1.5	0.17	3.5
Requirement per day for child (12-16 years)	2400-2700	65-75	500-600	30-50	30-40	22	1.0-1.2	
Avg Requirement per day for child (12-16 years)	2550	70	550	40	35	22	1.1	

Linear programming problem is utilized to find the appropriate product mix.

Assumptions as per the Linear Programming Problem

- The cost of all the ingredients in the mix is considered to be fixed and it will not vary with time.
- RDA values are assumed to remain constant for all five ingredients which can actually fluctuate depending on Varity and production quality.
- An adequate and constant supply of all the ingredients is assumed irrespective of seasonal availabilities.

In the above stated problem, we aim to find the optimum product mix such that the required nutrients can be supplied to children by using less material in minimum cost of raw material. Similar type of studies was conducted by researchers [10, 11].

III. METHODOLOGY

The problem is stated as follow:

Minimize: the cost of raw material

Subject to: the requirements as stated in recommended dietary allowance (RDA) for children must be fulfilled and there should be contribution of all the ingredients in the mix.

The objective function is to minimize the cost of raw material, and can be expressed in mathematical equation for LPP as:

Minimize $Z= 5X_1+ 8X_2+5X_3+ 2.5X_4+ 3.5X_5$

Where, X_1= Amount of Milk
X_2= Amount of Green Beans
X_3= Amount of Peas
X_4= Amount of White Rice (Milled)
X_5= Amount of Wheat Grains

In achieving the above objective the following constrains related to recommended dietary allowance (RDA) must be considered:

$117X_1 + 347X_2 + 93X_3 + 345X_4 + 346X_5 \geq 2550$
$4.2X_1 + 24.9X_2 + 7.2X_3 + 6.8X_4 + 11.8X_5 \geq 70$
$210X_1 + 60X_2 + 20X_3 + 10X_4 + 41X_5 \geq 550$
$0.2X_1 + 3.2X_2 + 1.5X_3 + 0.9X_4 + 5.3X_5 \geq 40$
$2X_1 + 0X_2 + 10X_3 + 0X_4 + 0X_5 \geq 35$
$6.5X_1 + 0.8X_2 + 0.1X_3 + 0.5X_4 + 1.5X_5 \geq 22$
$0.10X_1 + 0.16X_2 + 0.01X_3 + 0.06X_4 + 0.17X_5 \geq 1.1$
$X_1; X_2; X_3; X_4; X_5 \geq 2$

SIMPLEX METHOD TO SOLVE THE PROBLEM

The inequalities from all the above constrains are removed by introducing a surplus variable as follow:

$117X_1 + 347X_2 + 93X_3 + 345X_4 + 346X_5 - S_1 = 2550$
$4.2X_1 + 24.9X_2 + 7.2X_3 + 6.8X_4 + 11.8X_5 - S_2 = 70$
$210X_1 + 60X_2 + 20X_3 + 10X_4 + 41X_5 - S_3 = 550$
$0.2X_1 + 3.2X_2 + 1.5X_3 + 0.9X_4 + 5.3X_5 - S_4 = 40$
$2X_1 + 0X_2 + 10X_3 + 0X_4 + 0X_5 - S_5 = 35$

$6.5X_1+0.8X_2+0.1X_3+0.5X_4+1.5X_5 - S_6 = 22$
$0.10X_1+0.16X_2+0.01X_3+0.06X_4+0.17X_5 - S_7 = 1.1$

Now, the same surplus variable must be introduced in the objective function without producing any effect on it.

Therefore,
Minimize $Z= 5X_1+ 8X_2+ 5X_3+ 2.5X_4+ 3.5X_5 -0S_1 -0S_2 -0S_3 -0S_4 -0S_5 -0S_6 -0S_7$

From the above equations the simplex table 2 can be obtained in the straight forward manner.

Table 2: Simplex Table

C_{ij}			5	8	5	2.5	3.5	0	0	0	0	0	0	0
	Basic	Quant	X_1	X_2	X_3	X_4	X_5	S_1	S_2	S_3	S_4	S_5	S_6	S_7
0	S_1	-2550	117	347	93	345	346	-1	0	0	0	0	0	0
0	S_2	-70	4.2	24.	7.2	6.8	11.	0	-1	0	0	0	0	0
0	S_3	-550	210	60	20	10	41	0	0	-1	0	0	0	0
0	S_4	-40	0.2	3.2	1.5	0.9	5.3	0	0	0	-1	0	0	0
0	S_5	-35	2	0	10	0	0	0	0	0	0	-1	0	0
0	S_6	-22	6.5	0.8	0.1	0.5	1.5	0	0	0	0	0	-1	0
0	S_7	-1.1	0.10	0.16	0.01	0.06	0.17	0	0	0	0	0	0	-1

In the above table since identity matrix is not formed so artificial variables are introduced in all the equation such that

it doesn't make any change in objective function. To solve the LPP LINDO software is utilized, which is simple and user friendly.

To operate LINDO, the objective function and constrains are typed in the workspace provided followed by clicking "Solve" provided in the bar above (Figure 1) and then in no time results to the problem is displayed (Figure 2).

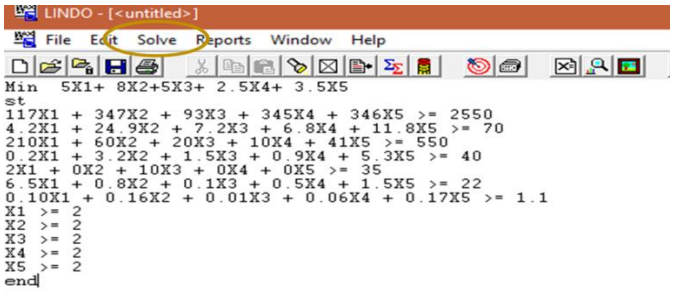

Figure 1: Snapshot of LPP simulation formation using LINDO

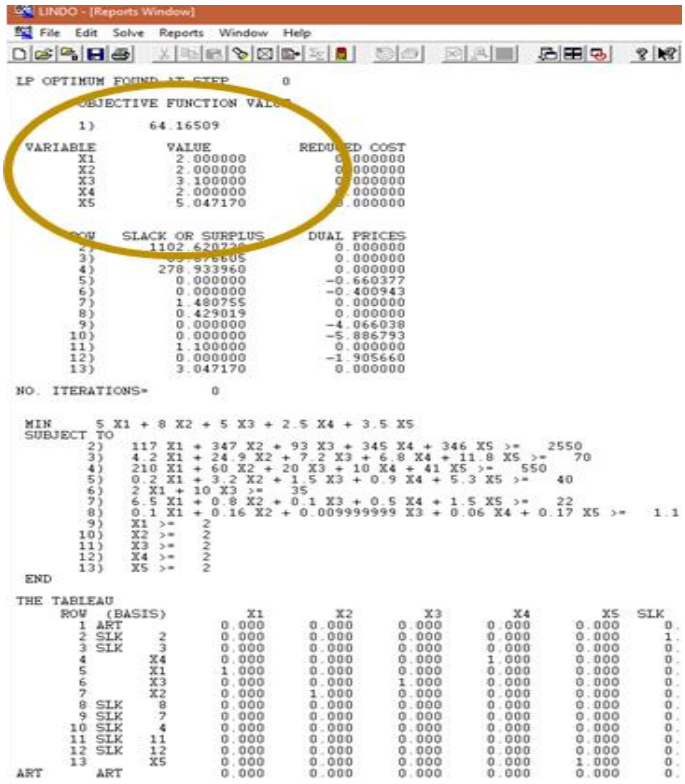

Figure 2: Snapshot of LPP stimulated results for the given problem on product mix

To solve the problem and to reach the optimum solution no iteration is required (Figure 2). It also provides the proportion in which all the material must be mixed to achieve the objective (Table 3). The analysis of table 3 shows that we should mix 200g (=2.00*100) of milk, 200g (=2.00*100) of green beans, 310g (=3.10*100) of peas, 200g (=2.00*100) of milled white rice and 504g (=5.04*100) of wheat grains to make it into ready to serve powder product in order to meet the RDA requirements.

Table 3: Optimum proportions to formulate the product mix

S. No	Ingredient	Quantity	Cost (per serving in INR)
1	Milk	2.00	10
2	Green Beans	2.00	16
3	Peas	3.10	15.5
4	White Rice (Milled)	2.00	5
5	Wheat Grains	5.04	17.64

IV. Results and Discussion

We tried to identify the optimum proportion in which different ingredients i.e. milk, green beans, pears, white rice (milled), wheat grains must be mixed to achieve the RDA value of children of 12-16 years age group. The main aim of study includes planning the optimum product mix per individual per day to minimise the cost of material. This product will cost INR 64.16 per day per child. If we extrapolate this study to real life situation like mid-day meal scheme, suppose there are 100 students that fall in the age group of 12-16 years of age in a school, then providing such a product to this population will cost INR 6,416 (=64.16*100) per day.

V. Conclusion & Future Scope

In future also, if some new ingredients will be recommended by food scientists, which can be replaced with the existing ones, then the problem will be formulated again with respect to the new items. Also, the firms/ companies under the head of corporate social responsibility (CSR), plan to distribute this product to needed once and in result would contribute to the improvement of men kind.

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Dr. Vijay Kumar pursed Bachelor's degree from Hindu College, Sonepat, Haryana, India in 2001 and Master of Science and Ph.D. from Department of Statistics and Operations Reseach, Kurukshetra University Kurukshetra in 2003 and 2009 respectively. He is currently working as Assistant Professor in the Department of Basic and Applied Sciences, NIFTEM, Kundli, Soenpat, Haryana, Indiasince 2012. He is a life member of OPSEARCH, The Indian Science Congress, International Association of Computer Science and Information Technology, International Indian Statistical Association. He has published more than 14 research papers in reputed international, national journals and conferences. His main research work focuses Optimization Techniques.. He has 9.5 years of teaching experience and 12 years of Research Experience.

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