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Dietary Optimization For College-Aged Women In Chhattisgarh: A Linear Programming Approach To Millets And Local Foods.

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Abstract: This research delves into addressing the crucial nutritional requirements of young female college students aged 17-21, emphasizing the vital role of calories in their diet. The study highlights the significance of incorporating millets and locally sourced foods to fulfill these dietary needs. Against the backdrop of the 'Year of Millets' declared in 2023, recognizing the nutritional richness of these grains, the research focuses on the development of a mathematical model. This model is designed to optimize the diet by considering proper nutrition as constraints while aiming to minimize overall costs. A numerical illustration is then presented to validate the effectiveness of the proposed model.

Key words –LPP, diet decision, health care, Millets, Local food.

Introduction:

Young female college students aged 17-21 constitute a demographic with distinct dietary needs, necessitating a targeted approach to ensure optimal nutrition. Recognizing the importance of calories in supporting their active lifestyles and overall well-being, this research underscores the potential of millets and locally sourced foods as valuable contributors to meeting these nutritional requirements.

In alignment with the global initiative declaring 2023 as the 'Year of Millets,' this study aims to develop a mathematical model that addresses the challenge of formulating a cost-effective and nutritionally balanced diet for this specific demographic. By incorporating millets and local foods into the dietary plan, the research seeks to not only provide the required caloric intake but also harness the nutritional benefits associated with these sustainable and locally available resources.

The mathematical model proposed in this research is constructed with a meticulous consideration of various nutritional components and constraints. The primary goal is to minimize the overall cost of the dietary plan while ensuring that the nutritional requirements are met. The subsequent numerical illustration serves as a practical demonstration of the model's efficacy, providing tangible evidence of its validity and potential application in addressing the dietary needs of young female college students.

Literature Review:

Linear Programming (LP) stands out as a versatile mathematical model with applications spanning management decision improvement [1, 2]. This methodology involves the meticulous consideration of an objective function for optimization, utilizing decision variables as constraints [3]. Building upon this foundation, LP has been extended to optimize dietary programs, addressing specific health concerns and nutritional needs.

One notable application is the development of an LP optimization model for a diet program, specifically tailored to treat hypertension in men aged 31-50 [4]. The model, encompassing variables such as low fat, potassium, calcium, iron, and vitamins, incorporates 8 variables and 7 constraints. The optimal solution not only reduces daily costs but also demonstrates improvements in hypertension and harmful cholesterol percentages.

A parallel study employs a similar LP approach for optimal diet decisions, focusing on essential nutritional ingredients for individuals aged 40-45 [6]. This research identifies key nutrients, including calcium, iron, protein, and vitamins A, B, C, and E, utilizing an 8-variable model. The Lips solver is employed to find solutions, shedding light on major human body requirements in the 40-45 age bracket and showcasing the utility of LP in crafting optimal diets.

Expanding the scope further, LP is applied to address diet problems faced by sedentary and moderate working women in India [7]. This study considers various food items as decision variables, crafting constraints corresponding to different nutrients. The objective is to find the optimum solution—determining the quantity of food items that should be consumed to minimize diet costs while meeting the minimum nutrient requirements for these specific demographic groups.

Additionally, LP finds application in solving students' diet problems, relying on survey data and Microsoft Excel Solver software with the simplex method [8]. This application extends the reach of LP to address dietary concerns in student populations, showcasing its adaptability across diverse contexts.

Furthermore, the literature includes a study by Hykamen et al., exploring nutritionally optimized, culturally acceptable, cost-minimized diets for low-income Ghanaian families using LP [10]. This research emphasizes the broader societal impact of LP, contributing to the understanding of dietary challenges and solutions in economically disadvantaged communities.

In summary, the literature underscores the wide-ranging applications of Linear Programming in optimizing dietary choices, from addressing specific health concerns to catering to diverse demographic groups and socioeconomic contexts.

Model Description and Methodology: The model is constructed with 8 decision variables (x_1-x_8) representing the quantity of each food item as shown in Table 1. The objective function minimizes the total cost of these food items subject to nutritional constraints that ensure the diet meets the daily recommended intake for various nutrients essential for college-aged women.

- **Objective Function:** The objective function represents the total cost of the diet, formulated as the sum of the costs of individual food items multiplied by their respective quantities.
- **Constraints:** The constraints include the nutritional requirements specific to the target demographic, such as minimum daily intake levels of calcium, iron, protein, carbohydrates, fiber, vitamins, and potassium. The total quantity of Calcium in this diet should be equal or greater than1000 mg. Iron content should be equal or greater than 18 mg, Protein 46 mg, Carbohydrates 130 mg, Fiber 21 mg ,Vitamin B_1 1.1 mg, Vitamin A 700mcg Vitamin C 75 mg, Potassium 2600 mg. For the feasible solution, non-negative constraints have been added also added. Mathematically, the diet problem can be

$$\text{Min } Z = \sum_{j=1}^{n} c_j x_j \quad (1)$$

Subject to the constraints

$$\sum_{j=1}^{n} a_{ij} x_j \geq b_i \text{ ; } i = 1, 2, \ldots m \quad (2)$$

$$x_j \geq 0; \ j = 1, 2, \ldots., n \quad (3)$$

where x_j 's are the quantities of food items ,c_j 's are the cost of food items per 100 grams, a_{ij}'s are amount of nutrients per 100 grams and b_i's are daily minimum nutritional requirement. Our diet problem is to minimize the function (1) subject to constraints (2) and non negative restriction (3) for the diet problem j = 1, 2, …., 8 and i = 1, 2, …., 9

$$\sum_{j=1}^{8} a_{ij} x_j \geq b_i$$

i.e.

$$a_{11}x_1 + a_{12}x_2 + \text{---} + a_{18}x_8 \geq b_1$$

$a_{21}x_1 + a_{22}x_2 + --- + a_{28}x_8 \geq b_2$

$a_{31}x_1 + a_{32}x_2 + --- + a_{38}x_8 \geq b_3$

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$a_{91}x_1 + a_{92}x_2 + --- + a_{98}x_8 \geq b_9$

$x_1, x_2, --------, x_8 \geq 0$ where b_i's are presented in last column of table 1.

Table 1. Amount of various nutrients contained in different food items and costs ICMR recommended dietary allowances per day for the college going girls.

	Orange 1ps	Ragi 100 gm	Beans (green) 100 gm	Drum-stick 100 gm	Milk 100 ml	Banana	Guava 100 gm	Tomato/ potato 100 gm	Minimum Daily req-uirement
Var. →	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	
Calcium	52 mg	344 mg	37 mg	185 mg	307 mg	10 mg	18 mg	105 mg	1000 mg
Iron	.13 mg	3.9 mg	1.03 mg	0.8 mg	0.07 mg	0.4 mg	0.26 mg	4.55 mg	18 mg
Protein	1.23 g	11 g	1.83 g	9.4 g	8.03 g	1.25 g	2.69 g	17.71 g	46 gm
Carbohyd rates	11 g	72 g	6.97 gm	8.28 gm	11.49 g	27 g	14 gm	5.96 gm	130 gm
Fiber	2.3 g	11 g	2.7 gm	2 gm	-	3 g	5 gm	11.44 gm	21 gm
Vitamin B_1	.114 g	0.42 g	.082 mg	0.257 mg	0.112 mg	0.04 mg	0.067 mg	1.51	1.1 mg
Vitamin A	295 µg	-	35 µg	378 µg	395 µg	350 µg	31 µg	614 IU 15.35 µg	700 mcg
Vitamin C	69.7 g	-	12.2 mg	51.7 mg	-	20 mg	228.3mg	36.6.mg	75mg
Potassiu m	173.8 mg	195 mg	211 mg	3371 mg	361 mg	450 mg	417 mg	403 mg	2600 g
Rate	7 Rs/ps	Rs 8/- 100 gm	Rs 9/-	Rs 6/-	Rs 6/-	Rs 5 /-	Rs 8/-	Rs 2/-	

Thus using all the collected data from the table 1., the formulated diet problem is as follows:

Minimize $z = 7x_1 + 8x_2 + 9x_3 + 6x_4 + 6x_5 + 5x_6 + 8x_7 + 2x_8$ subject to constraints

$52x_1 + 344x_2 + 37x_3 + 185x_4 + 307x_5 + 10x_6 + 18x_7 + 105x_8 \geq 1000$ (calcium) (4)

$0.13x_1 + 3.9x_2 + 1.03x_3 + 0.8x_4 + 0.07x_5 + 0.4x_6 + 0.26x_7 + 4.55x_8 \geq 18$ (iron) (5)

$1.23x_1 + 11x_2 + 1.83x_3 + 9.4x_4 + 8.03x_5 + 1.25x_6 + 2.69x_7 + 17.71x_8 \geq 46$ (protein) (6)

$11x_1 + 72x_2 + 6.97x_3 + 8.28x_4 + 11.49x_5 + 27x_6 + 14x_7 + 5.96x_8 \geq 130$ (carbohydrates) (7)

$2.3x_1 + 11x_2 + 2.7x_3 + 2x_4 + 0x_5 + 3x_6 + 5x_7 + 11.44x_8 \geq 21$ (fiber) (8)

$0.114x_1 + 0.42x_2 + 0.82\, x_3 + 0.257x_4 + 0.115x_5 + 0.04x_6 + 0.067x_7 + 1.51x_8 \geq 1.1$ (vitamin B_1) (9)

$295x_1 + 0x_2 + 35x_3 + 378x_4 + 395x_5 + 350x_6 + 31x_7 + 15.35x_8 \geq 700$ (vitamin A) (10)

$69.7x_1 + 0x_2 + 12.2x_3 + 51.7x_4 + 0x_5 + 20x_6 + 228.3x_7 + 36.6x_8 \geq 75$ (vitamin C) (11)

$173x_1 + 195x_2 + 211x_3 + 337x_4 + 361x_5 + 450x_6 + 417x_7 + 403x_8 \geq 2600$ (potassium) (12)

Model Solving

LPP are usually solved by simplex method. Since the problem is of minimization type it can be solved by Big-m METHOD. In this paper we have used MS- Excel to solve the problem. This model has eight variables and nine constraints.

Results and Discussion: The solution to the linear model indicates the optimal quantities of each food item to minimize costs while meeting nutritional requirements. The daily diet plan at the minimum cost of approximately units

	X1	X2	X3	X4	X5	X6	X7	X8	Z		
Solution	0	1.144152	0	0.174843	0.86559	0.708463	0	2.869002	24.67613		
obj. Coeff	7	8	9	6	6	5	8	2			
									L.H.S		R.H.S
constraint 1	52	344	37	185	307	10	18	105	1000	>=	1000
constraint 2	0.13	3.9	1.03	0.8	0.07	0.4	0.26	4.55	18	>=	18
constraint 3	1.23	11	1.83	9.4	8.03	1.25	2.69	17.71	72.87548	>=	46
constraint 4	11	72	6.97	8.28	11.49	27	14	5.96	130	>=	130
constraint 5	2.3	11	2.7	2	0	3	5	11.44	47.88212	>=	21
constraint 6	0.114	0.42	0.082	0.257	0.112	0.04	0.067	1.51	4.982956	>=	1.1
constraint 7	295	0	35	378	395	350	31	15.35	700	>=	700
constraint 8	69.7	0	12.2	51.7	0	20	228.3	36.6	128.2141	>=	75
constraint 9	173.8	195	211	3371	361	450	417	403	2600	>=	2600

Solution of the given problem is $x_2 = 1.144$, $x_4 = 0.174$, $x_5 = 0.865$, $x_6 = 0.708$, $x_8 = 2.86$ and the

Min z = 24.69 Rs.

Where: x_2, x_4, x_5, x_6 and x_8 indicates Ragi , drumstick , milk, , banana, tomato/potato respectively.

This solution emphasizes the importance of certain local foods and millets in providing a cost-effective, nutritionally rich diet. The absence of certain foods in the optimal diet suggests their replacement or lesser importance compared to other more cost-effective and nutritious options available locally.

Conclusion: The study successfully applies Linear Programming to develop an optimized diet for college-aged women in Chhattisgarh, emphasizing the nutritional and economic benefits of millets and local foods. The research demonstrates the practical application of operations research techniques in public health and nutrition, offering a model that can be adapted to various populations and dietary requirements. The findings encourage the adoption of locally sourced, nutrient-rich foods to promote health, well-being, and economic sustainability.

Scope for Future Work: Future research can expand this study to include a wider range of food items, consider other demographic groups, or apply the model to different geographical or cultural contexts. It could also explore the impacts of seasonal variations, market fluctuations, and changing dietary guidelines on the optimization model. Additionally, further studies might integrate more sophisticated models or data, such as stochastic programming to account for uncertainty in prices and availability of food items, or multi-objective optimization to balance cost, nutrition, and other factors like environmental impact.

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