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Abstract

Purpose:

The purpose of the study is to investigate blue zones lifestyle on Indian diet management system through optimized diet plans. The study explores menu planning with plant-based, animal and dairy-based recipes promoting longevity and reduction of chronic diseases in India.

Design/Methodology/Approach:

The macro and micro nutrients data is collected for the regionally available food items in India. The study proposed linear programming problems to maximize the calories with 66 food items, satisfying the Required Nutrient Intake (RNI) for normal individuals living in rural and urban areas of India.

Findings:

Three optimization models such as Linear Programming Problem (LPP), Integer Linear Programming (ILP) and Stigler's diet programming (SDP) were proposed for selecting menus with varying calorie ranges(1900kcal-3100kcal). The percentage of nutrients contained in the diet plans were close to blue zones food guidelines adoptable to Indian population.

Originality/Value:

The revised Stigler Diet Problem (SDP) have well optimized objective function with highest accommodation of recipes in optimal menus. This approach is helpful to nutritionists and dieticians for preparing the affordable diet plans for distinct income groups. Also, the study provides insights to policy makers working on improving the health conditions of people by adopting the blue zone diet.

Keywords: Bluezones lifestyle; Indian diet; Nutritional management; Menu planning; Optimization models.

1. Introduction:

Blue Zones are geographical regions containing more centenarians without disease or other unhealthy conditions such as obesity, cancer, diabetes, and heart problems. The blue zones concept rooted in meticulous scientific research emphasizes the balanced nutrition with a sense of purpose. Proper diet improves cognitive function, whereas individuals with greater depressive symptoms often have lower diet quality, indicating the connection between diet and mental health. The intersection of nutritious diets and the blue zones concept offers a profound insight into living a long, healthy and purposeful life. These two pillars of well-being when harmoniously integrated will provide a holistic framework for optimizing health outcomes. This evolution signifies that a prolonged, fulfilling life is the result of inherited traits and nurturing environments characterized by health-conscious and stress alleviating experiences (Mishra et al., 2009).

One of the main principles behind the blue zones is to consume food which comprises of 95% plant-based and 5% animal-based diets which combinedly consists of 65% carbohydrates, 15% proteins and 20% fats. Also, caloric moderation is a key facet of blue zone nutrition which is consistent with complementing the dietary practices. Blue zones commonalities like access to natural spaces encourages regular physical activity, consumption of fruits and vegetables found positive improvements. Recent scientific explorations in blue zones have shown some basic factors behind a long lifespan which enriches the future research motives. The global average life expectancy of individuals is approximately 73.4 years which can be gradually increased with simultaneous implementation of the optimized diet plans and blue zone's principles (World Health Organization's (WHO) report 2019-20). One such study shown the pioneering exploration into the convergence of the WHO's age-friendly communities and the blue zones checklist (Marston et al., 2021).

The longevity phenomenon is declining due to euphoria of modern-day health achievements falling in the epidemiological cross roads. The average life expectancy of Indian population is 70.8 years (WHO report 2019-20), which is lower than the global average. The concept of healthy living of blue zones is worth exploring with the Indian context, as the country is world capital of several chronic illnesses. Diabetes, Cancer and cardiovascular diseases are the main causes of comparatively lower lifespan, increasing the burden of disease in Indian population. The dietary intake of Indian households has been reported to be deviating from recommendations of healthy eating. Until now, researchers have focused predominantly on the effects of individual nutrients and sometimes foods, but studies on dietary patterns are limited. According to the recent report, the Recommended Dietary Allowances (RDA) and the Estimated Average Requirements (EAR) summarized the recommended energy requirement for Indians to be as follows: 1660 – 2720 Kcal for women and 2110 – 3470 Kcal for men (ICMR - NIN, 2020).

Approaching nutrition with a comparable perspective, applying diet principles leads in preventing and managing various health conditions. The number of calories a person consume should align with their energy expenditure based on the metabolism rate. Regular meal equivalence in particular time intervals can help to maintain blood pressure, sugar levels and sustain energy throughout the day. Having a little awareness on meal planning and advantages of nutrients excels the life expectancy of a person and increases the standard of living. This helps many individuals to increase capacity and make it well into the early 90s without any chronic diseases. Neglecting the nutritious diet may lead to lose out the hard caught health benefits and the risk of developing the modern diseases such as increased blood glucose levels, obesity and its associated non- communicable diseases.

2. Review of Literature:

The prominent studies were dealt with the importance of nutrition and its allied areas shown the directions of awareness in understanding the essentiality of nutrients, minerals role in function of body. The study provided a critical perspective on intersection of nutritional research, food choices and their collective impact on promoting a healthy life span (Ohlhorst et al., 2013). The comprehensive review meticulously assessed the impact of nutrition interventions and knowledge on diet quality within military populations. The results hold critical implications for public health initiatives, advocating for the implementation of evidence- based nutrition for promoting optimal health (Kullen et al., 2022). A systematic study conducted to understand the relationship between dietary magnesium intake and risk of developing type 2 diabetes mellitus in middle school students. Specifically, the study revealed an increase in magnesium intake was linked with a reduced risk of developing the metabolic disorder (Naseeb et al., 2021).

The study illuminated a well- balanced and optimizing nutritional status plays a crucial role in bolstering the human immune system. It could be an essential component of preventative measures and treatment approaches for diseases like covid-19 (James et al., 2021). Another study delved into associations between whole and refined grains consumption and serum C-reactive protein (CRP) levels. The intersection between diet and inflammation, highlighted the knowledge on the potential health benefits associated with whole grain consumption contributes significantly to the growing body (Taskinen et al., 2022). The study presented systematic review on a comprehensive examination of the role of nutrition in relation to covid-19 susceptibility and disease severity. The intensive study identified a critical gap in the literature by providing a comprehensive assessment of current concepts surrounding plant-based diets and proposing a standardized checklist for dietary interventions (Storz et al., 2022). A recent study specially focused on consuming healthy foods from plant and animal protein resources emphasizing the importance of considering personal preferences in plant-based diets for healthier food (Lambert-De Francesh et al., 2023).

The study focused solely on nutrients and aligns with the evolving of nutrition and health by recognizing the complexity of foods, the significance of dietary patterns and the individuality of dietary preferences (Fanzo et al. 2020). The significant study here aimed for optimizing diet quality to mitigate health risks in diverse populations and how dietary patterns may impact age-related shifts in visceral adiposity and metabolic health (Panizza et al., 2020). The study explored the critical aspect in developing the nutrient-dense mixes, creating formulations that provide specialized nutritional support to individuals who rely on enteral feeding in India (Preetika et al., 2004). The adolescent nutrition in Urban India revealed the concerning trends in dietary behaviours and unhealthy dietary practices, initiates significant implications for the overall health and well-being (Rathi et al., 2018). The study developed optimization models for selection of affordable raw food items with energy as objectives function to meet sufficient nutritional intake for survival of the common population in rural villages of India with low to moderate economic conditions Paidipati et al., (2021).

Optimization models are playing vital role in the area of nutrition and diet management to select recipes which includes all necessary nutrients in meal planning. Linear programming is a mathematical optimization technique that has been widely employed in various studies to predict cost-conscious food choices, meeting energy (in cal) requirements while ensuring nutritional adequacy. One such study focused on replicating the dietary patterns observed in low socioeconomic groups by introducing cost constraints and minimizing deviation from the average French diet (Darmon et al., 2002). In the context of infant nutrition, linear programming was utilized to design optimized diets for 9- to 11-month-old Indian infants based on the latest recommendations from the World Health Organization (Briend et al., 2003). The objective was to meet the infants' nutritional requirements while ensuring a minimum energy value using Excel Solver. Another study focused on developing population-specific Food-Based Dietary Guidelines (FBDGs) for Malawian children with linear programming problems. The aim was to ensure nutrient adequacy, diet palatability, and alignment with current dietary practices for high-risk populations (Ferguson et al., 2004).

The concept of nutrient profiling was validated in a study that demonstrated the feasibility of modelling diets that meet nutrient recommendations using foods categorized by their nutrient contents (Darmon et al., 2009). This approach has the potential to predict the impact of food selection on fulfilling multiple nutrient constraints. In the context of developing low-cost, nutritious diets for Malay households, researchers suggested a two-stage linear programming models. The first stage involved formulating a model to meet the diverse nutrient needs of pre-defined age-gender groups, while the second stage focused on optimizing diet plans for the entire household while minimizing daily costs (Shuib et al., 2011). Linear programming, including the "Cost of the Diet" tool, has been widely employed to determine cost-effective fortification strategies in countries like Mozambique. It has also been used to analyse complementary feeding diets, optimize nutrient adequacy, and assess the affordability of meeting nutrient requirements (Frega et al., 2012).

In New Zealand, linear programming and scenario development were employed to optimize daily diets for the population, considering factors such as nutrient content, food prices, food wastage, and greenhouse gas (GHG) emissions. The findings highlighted the potential health benefits and environmental sustainability of optimized dietary patterns (Wilson et al., 2013). The use of linear programming has also extended to develop optimized meal plans for managing diabetes (Abdul Karim et al., 2015). By integrating standard dietitian practices and available guidelines, researchers created linear programming models that help identify the most price effective combinations of food items to fulfil nutritional needs. Studies have also utilized linear programming diet optimization models to develop practical and cost-implicit diet plans for specific populations. For instance, researchers proposed diet plans for pregnant women in Malaysia using locally available food options (Sawal et al., 2019), as well as menus for diabetic patients in Malaysia that align with their preferences and nutrition guidelines (Asni et al., 2022).

A computer program was developed to plan menus for diabetic patients based on their diet prescription, meal pattern, and food preferences. Using algorithms, it selects suitable foods, various menus, and determines portion sizes while ensuring dietary requirements fulfilled. The output includes personalized menus, nutrient summaries, and a shopping list (Madelyn and Lawrence, 1980). A study focused on eczema patients emphasized the need for a specialized menu to control their condition and meet nutritional requirements. It utilized integer programming techniques and considered 426 food items across 10 food groups to create tailored menus (Sheng et al., 2018). Another study explored mathematical programming methods for designing a healthy and cost-effective meal plan for breast cancer patients, comparing integer programming and binary integer programming techniques using different sets of food items (Lee et al., 2020). Additionally, a study developed a mathematical model using linear and integer programming techniques to create cost-effective diet menus for high blood pressure patients, considering factors such as food prices, nutrient compositions, and Recommended Nutrient Intake (Hui et al., 2021).

3. Collection of Data:

Nutritionally adequate diet should be consumed through wide variety of food choices. The data of food recipes quantified with 100gms each and the dietary intake allowances of nutrients for food items are provided by "National Institution of Nutrition (NIN) authorized by Indian Council of Medical Research (ICMR), India.

Table 1: Food recipes considered for various Menus

Menu1	Menu 2	Menu 3	Menu 4	Menu 5
Idli	Plain Dosa	Poha	Puri	Oatmeal
Groundnut chutney	Tomato Chutney	Coriander chutney	Peas and potato curry	Boiled egg
coffee	Green Tea	Orange juice	Green tea	Tea
Papaya	Caramelized Custard	Processed Dates	Banana	Apple
Black tea	Strawberry	Lime soda	Sweet Biscuits	Doughnut
Cooked rice	Brown rice	Cooked rice	Brown rice	Cooked rice
Bengal Gram Dhal	Lentil Dhal	Spinach Green Gram Dhal	Black Gram Dhal	Veg Bengal Gram Dhal
Prawns Masala Curry	Mutton ball curry	Lady's finger curry	Mix Veg curry	Chicken curry
Kovai curry	Veg kofta curry	Chicken curry	Stew	Aamarnath curry
Rasam	Rasam	Bengal Gram Chutney	Rasam	Rasam
Curd	Curd	Curd	Curd	Curd
Murukulu	Basin-ki-Burfi	Bakery biscuits	Cashew Cutlet	Fruit cake
Mixed fruit juice	Guava	Tea	Lemon Juice	Chocolate Ice cream
Brown rice	Cooked rice	Foxtail Millet	Cooked rice	Veg Pulao
Chapathi	Roti	Phulka	Parota	Pulka
Carrot & cauliflower curry	Ridge gourd curry	Cabbage Curry	Chole curry	Paneer butter masala
Keera	Skimmed milk	Buttermilk	Skimmed milk	Keera

4. Methodology:

The present study focused on daily diet obtained through available food items in Indian region. All recipes considered from the optimized diets together contributes 88.38% plant-based foods and 11.62% of animal & dairy-based foods displayed in figure 1. The study here comprises of optimization techniques such as Linear Programming Problem (LPP), Integer Programming Problem (ILP) and Stigler's Diet Problem (SDP), produced exceptional results by making certain that all nutrients necessary for a body on 24-hour cycle are consumed with different ranges of calorie counts. The daily servings commonly available and often consumed by all types of economic categories of Indian Population are described in figure 2.

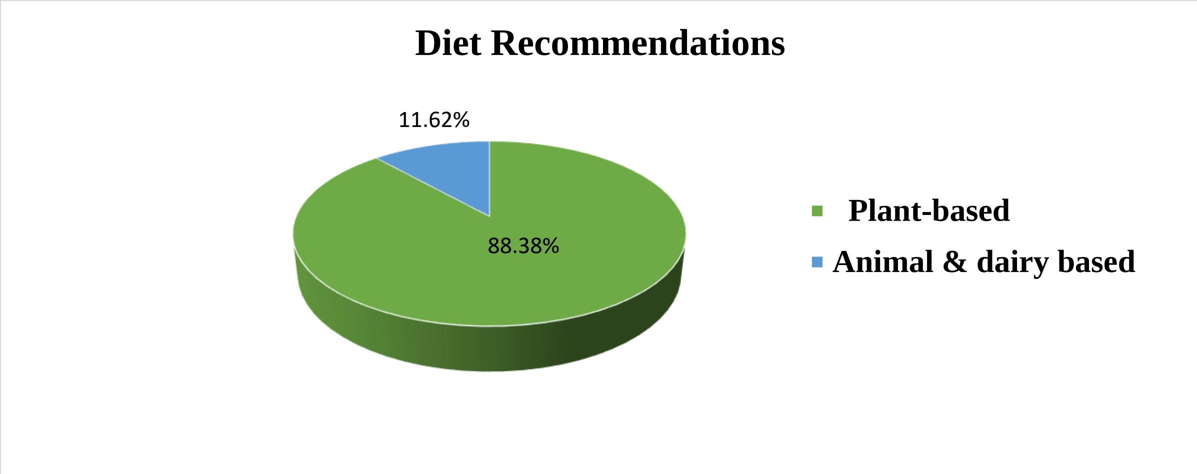

Figure – 1: Percentage of Plant, Dairy & Animal based products considered in the study

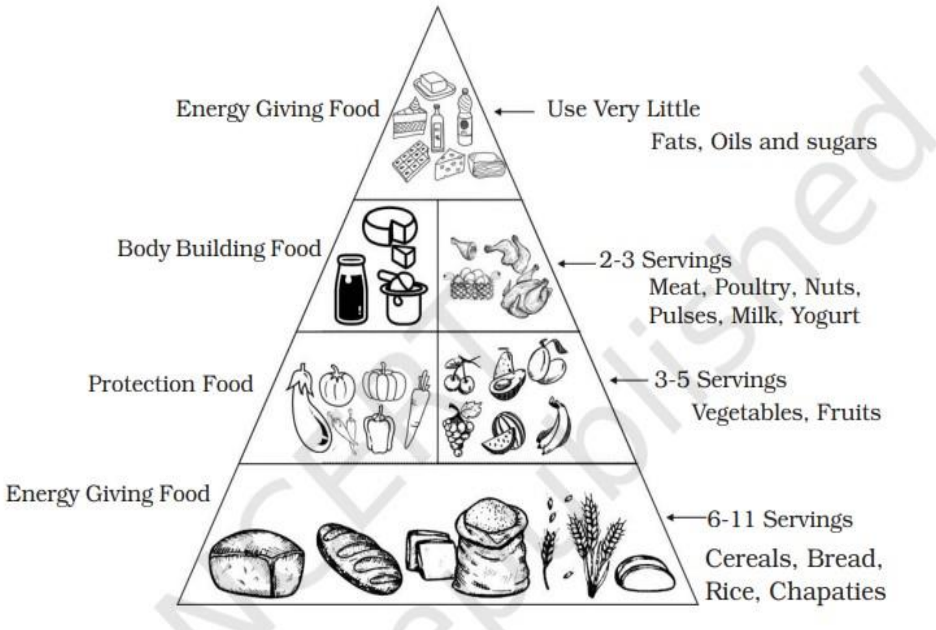

Figure – 2: Food Pyramid

Table 3: Nutrient Metrics

Macro nutrients are required in large quantities, carbohydrates provide energy, proteins aid in tissue repair whereas fats support various bodily functions. Micro nutrients are essential in smaller amounts but are equally important, vitamins and minerals like B2, B6, iron, zinc, potassium, sodium, calcium, and carotenoids play vital role in physiological processes.

Macro – Nutrients	**Micro – Nutrients**
Carbohydrate (g)	Vitamin B2 (mg)
Protein (g)	Vitamin B6 (mg)
Fiber (g)	Iron (mg)
Fat (g)	Zinc (mg)
Saturated Fat (g)	Potassium (mg)
	Sodium (mg)
	Carotenoids (µg)
	Calcium (mg)

5. Mathematical Formulation:

The increasing significance of optimization models for personalized diet plans emphasizes the ability to meet Required Nutrient Intake (RNI) by incorporating locally available food recipes. LPPs are crucial in the development of optimized diet plans which are helpful to meet the nutritional needs within a specific framework. Numerous researchers have developed different optimized techniques to minimize cost- effects on food recipes in various countries worldwide. The present study mainly focuses on ensuring that the individuals receive sufficient nutrients with few food items to enhance the energy levels. The diet management models based on Linear Programming Problems (LPP), Integer Linear Programming (ILP), Stigler's Diet Problems (SDP) are proposed and discussed with specific requirements of calories. The objective of the proposed models is to maximize the available energy (calories) levels with minimal recipes in the menu plans.

5.1 Linear Programming Problem (LPP):

The existing models (Lee et al., 2020, Hui et al., 2021, Wilson et al., 2013, Garille, S. G & Gass, S. I. 2001) were focused on minimizing the cost function subject to nutrients and identified quantities in food items as decision variables. The mathematical model of the problem is formulated as a linear program where the objective function corresponds to total amount of calories as Energy. Decision variables are based on the type of recipes considered under study. The constraints to be satisfied regarding the nutrient amounts as per the food recipes considered in various menus with stipulated upper limits. The models aimed for maximizing the calories with few regionally available recipes to satisfy the nutritional requirements of the individuals.

$$Max\ Z = \sum_{j=1}^{n} E_{jR}$$

$$Subject\ to\ Constraints$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij}\, x_{jR} \le b_{iNu}$$

$$x_{jR}, b_{iNu} \ge 0 \quad \ldots\ldots\ldots (1)$$

where,

E_{jR} = Energy values for j number of recipes from various menus.

m = Number of nutrients considered in the study (m=13).

n = Number of recipes as per diet plans.

a_{ij} = Amount of i^{th} nutrient from j^{th} recipe.

b_{iNu}= Recommended upper level of i^{th} nutrient intake.

x_{jR} = Decision variables that represent the type of recipes.

5.2 Integer Linear Programming (ILP):

The theoretical model considered for Integer Linear Programming resembles the Linear Programming Problem, the results are not anticipated in fractions.

$$Max\ Z = \sum_{j=1}^{n} E_{jR}$$

$$Subject\ to\ Constraints$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij}\, x_{jR} \leq b_{iNu}$$

$$x_{jR}, b_{iNu} \geq 0 \ldots\ldots\ldots (2)$$

where,

E_{jR} = Energy values (integer) for j number of recipes from various menus.

m = Number of nutrients considered in the study (m=13).

n = Number of recipes as per diet plans.

a_{ij} = Amount of ith nutrient from jth recipe in integers.

b_{iNu}= Recommended upper level (integers) of ith nutrient intake.

x_{jR} = Decision variables that represent the type of recipes.

5.3 Stigler Diet Problem (SDP):

The Stigler's diet problem is an extension of Linear Programming Problem where lower limit added to the required nutrients in the constraints.

$$Max\ Z = \sum_{j=1}^{n} E_{jR}$$

$$Subject\ to\ Constraints$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij}\, x_{jR} \leq b_{iNu}$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij}\, x_{jR} \geq b_{iNl}$$

$$x_{jR}, b_{iNu}, b_{iNl} \geq 0 \ldots\ldots\ldots (3)$$

where,

E_{jR} = Energy values for j number of recipes from various menus.

m = Number of nutrients considered in the study (m=13).

n = Number of recipes as per diabetes diet plans.

a_{ij} = Amount of ith nutrient from jth recipe.

b_{iNu}= Recommended upper level of ith nutrient intake.

b_{iNl}= Recommended lower level of ith nutrient intake.

x_{jR} = Decision variables that represent the type of recipes.

6. Results and discussion:

The formulated problems have optimized the required calories approximately ranging from 1900 – 3100 kcal with adjusted quantities of recipes in various menus. The optimized results reduced few recipes from the originally considered, conveying that minimal recipes are enough to meet the daily nutritional requirements. The study achieved preparing 9 diet plans from 5 menus (Table-1) with a limit of 8 to 13 recipes for a diet plan. The detailed information about the diets is described, possible recipes are identified, nutrients sharing percentage is calculated and represented in figures. The recipes suggested under different food intervals per day is the important factor with possible mix of plant and animal-based products which is close to the blue zone practices.

Table 4: Optimized recipes in diet plan-1 from menu-4 through LPP

Diet-1/ Menu-4

Breakfast
Puri (222g)
Peas & Potato Curry (17g)

Morning snack
Sweet biscuits (136g)

Lunch
Cooked rice (350g)
Stew (170.52g)

Evening Snack
Cashew Cutlet (138g)

Dinner
Cooked rice (338g)
Black gram Dhal (170g)

Total Calories: 2069
Optimized Calories: 2854

Description: The diet plan–1 provides a diverse assortment of dishes that collectively provide 2854 calories with 8 recipes through Linear Programming Problem (LPP). The combination of puri with peas & potato curry is a satisfying breakfast for the day. Sweet biscuits are crunchy treat as snack. Cooked rice and stew are well-rounded mix of carbohydrates and protein. Evening snack, cashew cutlet is a protein-rich option. Dinner menu returns to the base of cooked rice by addition of black gram dhal which is a complex blend of carbohydrates and plant- based protein. Overall, this menu also consists little amount of animal meat which helps in muscle nourishing. From figure -3 we can observe the percentage of nutrients presenting 70.03% of carbohydrate, 11.19% of protein, 9.40% of healthy fats and 9.36% of vitamins and minerals.

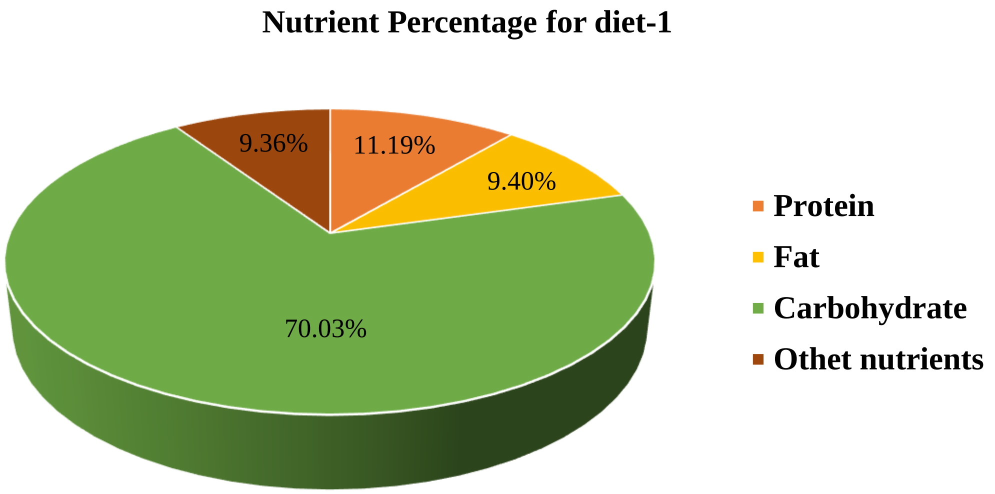

Figure-4: Nutrient share of diet-1 derived from menu-4

Table 5: Optimized recipes in diet plan-2 from menu-5 through LPP

Diet-2/Menu-5

Breakfast
Oatmeal (232g)
Apple (296g)

Morning snack

Fruit cake (240g)

Lunch
Phulka (50g)
Amarnath curry (275g)

Evening Snack

Apple (400g)

Dinner
Phulka (44g)
Veg Bengal Gram Dhal (232g)

Total Calories: 2602
Optimized Calories: 2911

Description: The diet plan -2 offers a well-balanced and wholesome meal providing approximately 2911 optimized calories with 8 recipes through Linear Programming Problem (LPP). Oatmeal with apple, combines slow-releasing carbohydrates with fiber and vitamins. Fruit cake is a delightful treat without compromising on nutrition. The lunch menu ensures a good balance of carbohydrates, protein, fiber and essential nutrients. Recipes in dinner are delivering a complex combination of whole grain-based protein. The diet plan is nutritious and calorie-conscious, individuals with higher energy needs may consider adjusting portion sizes. Also, the diet provides a more robust caloric intake and the percentage of nutrients obtained are in figure-4 shows 64.32% of carbohydrates, 9.92% of protein, 10.36% of fat and 15.39% of other nutrients for better understanding.

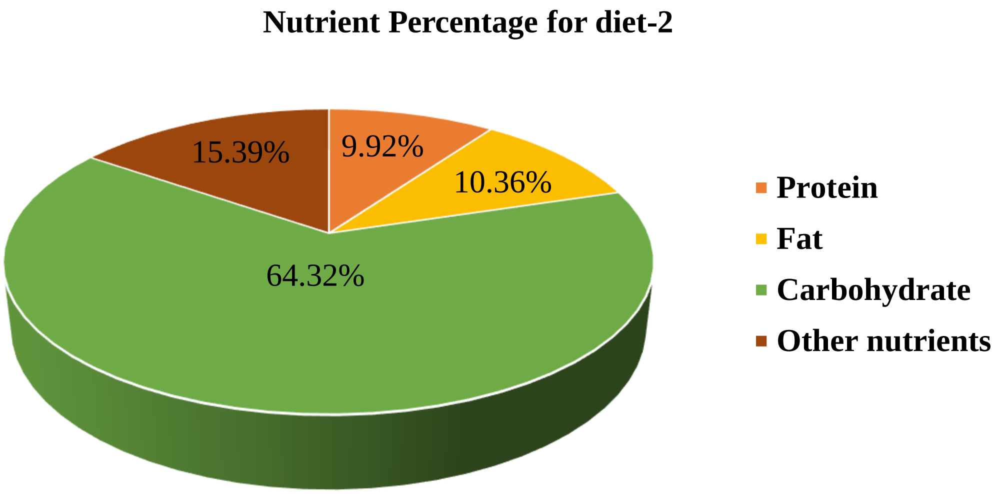

Figure-4: Nutrient share of diet-2 derived from menu-5

Table 6: Optimized recipes in diet plan-3 from menu-1 through ILP

Diet-3/Menu-1 **Breakfast** Papaya (100g) Mixed Fruit juice (200g) **Morning snack** Coffee (100g) **Lunch** Cooked rice (250g) Bengal Gram dhal (100g) Groundnut Chutney (100g) **Evening Snack** Keera (100g) **Dinner** Cooked rice (250g) Carrot & Cauliflower Curry (100g) **Total Calories: 2042** **Optimized Calories:2237**	**Description:** The diet provides a balance and nutritious meal plan designed to provide around 2237 calories with 9 recipes through Integer Linear Programming (ILP). Papaya and mixed fruit juice is a vitamin rich breakfast. Coffee as morning snack is a slight booster for our busy and stressed lives. Bengal gram dhal and groundnut chutney offers a good balanced amount of protein and healthy fats which ensures sustained energy throughout the day. The portion size of keera yields a preferable dose of fiber and vitamins. Finally, cooked rice, carrot and cauliflower curry in dinner are blend of complex carbohydrates and essential nutrients. The percentage of nutrients obtained through this diet are 64.86% of carbohydrate, 12.69% of protein, 13.52% of fat and 8.92% other nutrients represented in figure-5. Comparatively, Integer linear programming slightly maximized the energy levels with satisfying all nutrients.

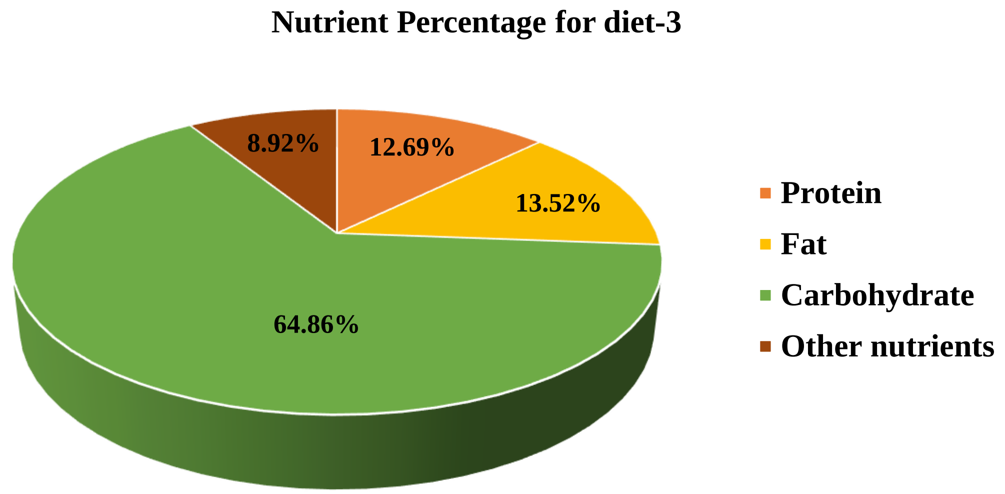

Figure-4: Nutrient share of diet-3 derived from menu-1

Table 7: Optimized recipes in diet plan-4 from menu-3 through ILP

Diet-4/Menu-3

Breakfast
Poha (200g)
Bengal gram chutney (100g).

Morning snack
Processed dates (300g)
Tea (100g)

Lunch
Foxtail Millet (100g)
Spinach Green Gram Dhal (300g)

Evening Snack
Bakery Biscuits (100g)
Lime soda (100g)

Dinner
Foxtail Millet (100g)
Cabbage Curry (100g)

Total Calories: 2379
Optimized Calories: 3036

Description: The diet-4 optimized 3036 calories with 10 recipes which indicates that energy is sustainably maximized by Integer Linear Programming (ILP). The combination of Poha and roasted Bengal gram chutney is a very lite beginning of the day. Processed dates and tea are natural sources of energy and contains fiber. The foxtail millet and green gram dhal in lunch are rich sources of protein, fiber and carbohydrates. Evening snack includes bakery biscuits and fresh lime soda are a quick refreshment. The cabbage curry in dinner also provides good amounts of calcium along with other nutrients. Overall portion sizes in the diet plan are commendable as they are considered on plant- based foods and nutrients from millets. Figure-6 shows the largest share is attributed to carbohydrates with 69.46%, next comes healthy fats with 11.41% whereas protein and other nutrients approximated near with 9.39% and 9.72% respectively.

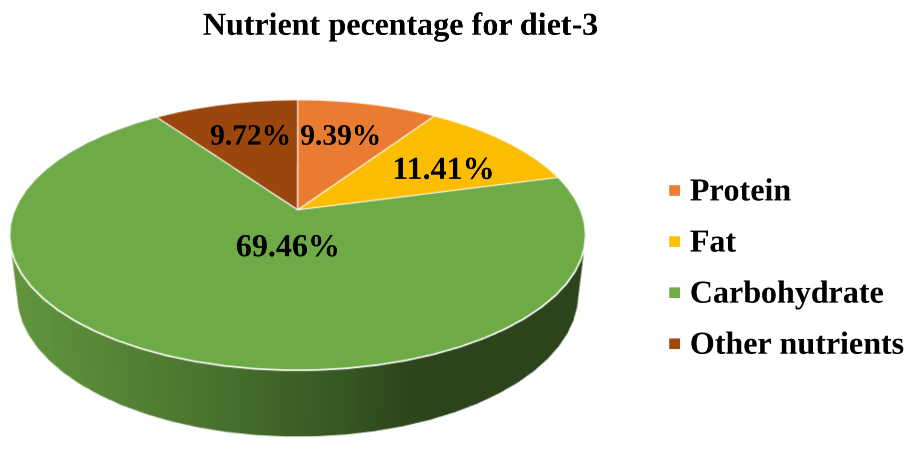

Figure-4: Nutrient share of diet-4 derived from menu-3

Table 8: Optimized recipes in diet plan-5 from menu-2 through ILP

Diet-5/Menu-2

Breakfast
Plain Dosa (400g)
Tomato Chutney (100g)

Morning snack
Strawberry (300g)

Lunch
Cooked rice (200g)
Mutton ball curry (100g)

Evening Snack
Basin-ki-Burfi (100g)
Skimmed milk (300g)

Dinner
Cooked rice (100g)
Veg Kofta curry (100g)
Caramelized custard (200g)

Total Calories: 2189
Optimized Calories: 2766

Description: The diet-5 optimized 2766 calories with 10 recipes which indicates that energy is sustainably maximized by Integer Linear Programming (ILP). Plain dosa with tomato chutney provides a balanced start to the day. The generous portion of strawberry is a natural & nutritional source of sweetness. Cooked rice with mutton ball curry and veg kofta curry in two intervals enriches the essential carbohydrates Basin-ki-Burfi and skimmed milk as evening snack are combination of calcium. In addition, caramelized custard is a delightful dessert option. In summary, the diet plan offers a wide variety i.e., various tastes and preferences. This diet plan includes plant- based and little amount of meat which enhances the protein-rich option. The figure-6 shows 63.63% of carbohydrate, 13.24% protein, 11.62% of fat and 11.49% other nutrients obtained through this diet.

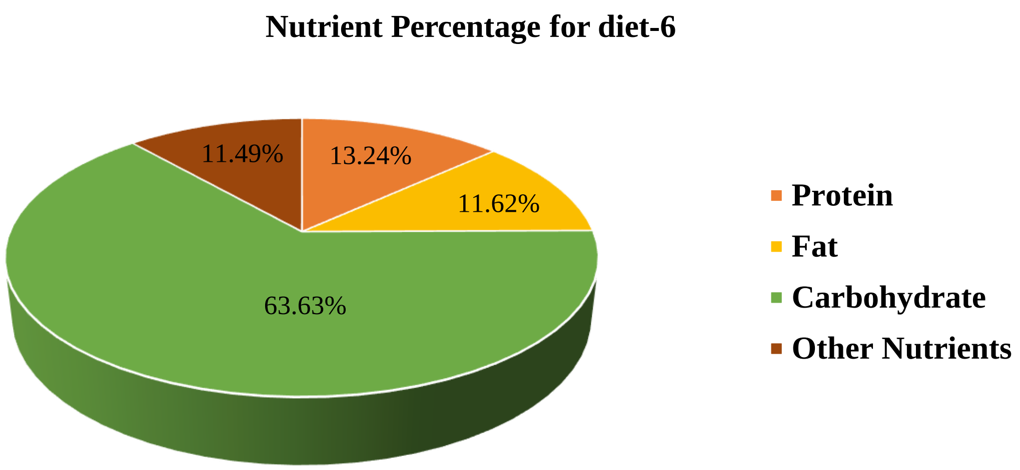

Figure-4: Nutrient share of diet-5 derived from Menu-2

Table 9: Optimized recipes in diet plan-6 from menu-1 through SDP

Diet-6/Menu-1

Breakfast
Chapati (55g)
Bengal gram dhal (125g)

Morning snack
Coffee (105g)

Lunch
Cooked rice (338g)
Groundnut chutney (43g)
Rasam (325g)

Evening Snack
Mixed fruit juice (111g)

Dinner
Cooked rice (300g)
Kovai Curry (300g)

Total Calories: 2042
Optimized Calories:1973

Description: The diet-6 optimized 1973 calories with 9 recipes through Stigler diet problem (SDP) which indicates the plan is well defined. The breakfast and morning snacks are like providing mild energy boost with protein and fiber mix. Cooked rice is essential source of carbohydrate, groundnut chutney serves sufficient protein and rasam balances the sodium levels. Mixed fruit juice is a refreshment choice providing a natural source of hydration. In conclusion the plan offers a diverse range of foods in lunch and dinner offering a balanced mix of nutrients and vitamins. Figure-7 shows 59.92% of carbohydrates converted to energy produces required number of calories and 10.40% of protein, 11.81 % of fat, 17.85% of other nutrient composition are useful for providing enough strength to the body for a whole single day.

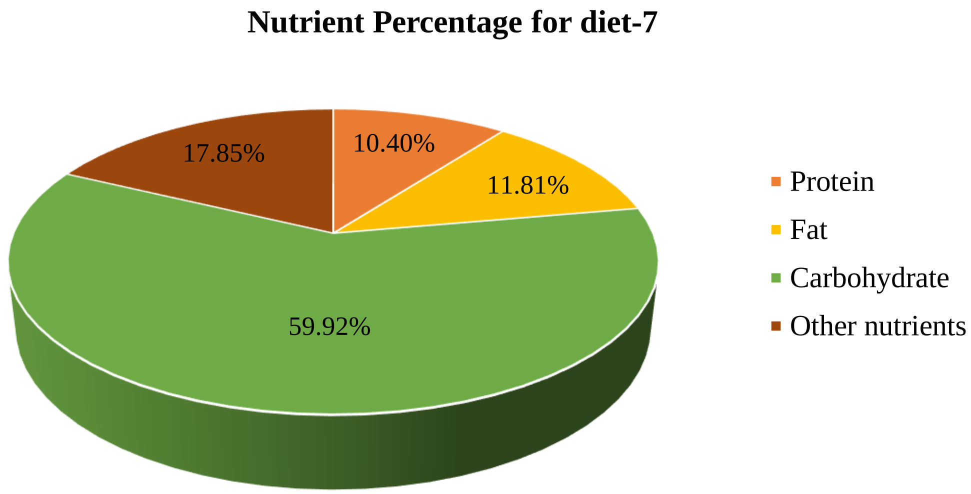

Figure-4: Nutrient share of diet-6 derived from Menu-1

Table 10: Optimized recipes in diet plan-7 from menu-3 through SDP

Diet-7/Menu-3 **Breakfast** Pulka (117g) Spinach Green Gram Dal (136g) Coriander Chutney (99g) **Morning snack** Processed Dates (252g) **Lunch** Cooked rice (235g) Foxtail Millet (91g) Cabbage Curry (190g) Coriander Chutney (99g) **Evening Snack** Bakery Biscuits (95g) Tea (125g) **Dinner** Cooked rice (500g) Bengal Gram Chutney (198g) Lady’s Finger Curry (54g) **Total Calories: 2379** **Optimized Calories:3040**	**Description:** The diet plan-7 optimized 3040 calories with 13 recipes through Stigler diet problem (SDP) meets the energy levels. The diet plan is a well-structured dietary regulation that aims to provide a balanced daily nutrient intake. Beginning with the breakfast and continuing with morning snack processed dates provides natural source of sweetness, more nutritious and boost of energy. Both food intervals are mix of carbohydrate, protein and essential vitamins. The combination of recipes in lunch are well rounded and satisfying meal with substantial intake of fiber as we included foxtail millet. The evening snack and dinner together are worth considering with more nutritional content. The diet plan incorporating variety of foods resulted in different nutrient levels, 64.98% of carbohydrate, 9.34 % of protein, 13.25% of fat and 12.42% of other nutrients shown in figure-8 provides a balanced approach to the nutrition.

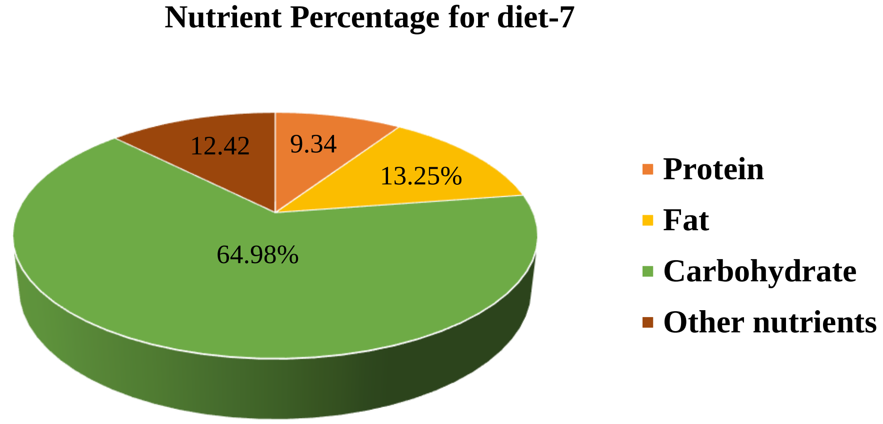

Figure-4: Nutrient share of diet-7 derived from Menu-3

Table 11: Optimized recipes in diet plan-8 from menu-4 through SDP

Diet-8/Menu-4

Breakfast

Cashew Cutlet (168g)
Peas & Potato curry (17g)

Morning snack

Sweet biscuits (118.01g)

Lunch

Cooked rice (164g)
Black Gram dhal (130g)
Mixed vegetable curry (306g)
Rasam (100g)

Evening Snack

Skimmed milk (131.11g)

Dinner
Puri (179g)
Stew (134.44g)
Curd (105g)

TotalCalories:2070
Optimized Calories:2407

Description: The diet plan-8 optimized 2407 calories with 11 recipes through Stigler's diet problem (SDP) which indicates it is well-balanced. Starting with a breakfast the cashew cutlet and peas & potato curry offers a good combination of protein, healthy fats and carbohydrates. The morning snack, sweet biscuits provide a quick energy boost whereas the recipes in lunch provides a substantial source of well-rounded meal. Black gram dhal is rich source of protein and fiber. Skimmed milk, evening snack is a nutritious choice as it provides good amount of protein and calcium. Overall, the diet plan provides essential combination of vital nutrients with 10.62% of protein, 13.08% of fats, 64.09% of carbohydrates and 12.20% of the remaining other nutrients are represented in figure-6.

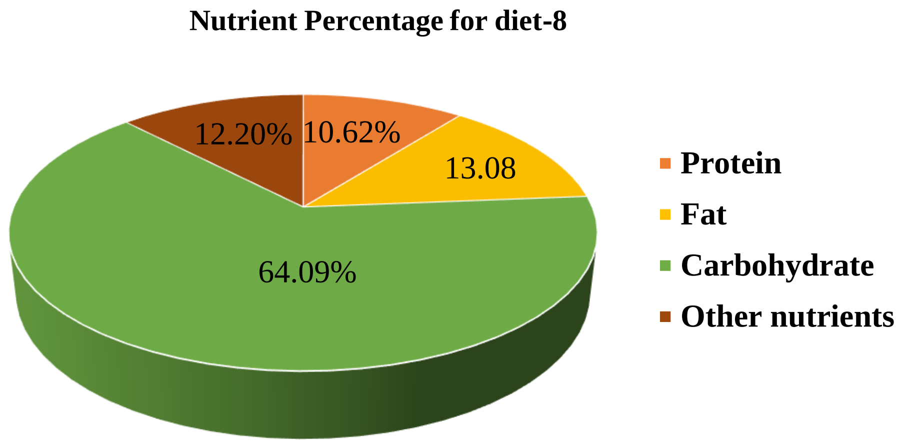

Figure-4: Nutrient share of diet-8 derived from Menu-4

Table 12: Optimized recipes in diet plan-9 from menu-5 through SDP

Diet-9/Menu-5 **Breakfast** Oatmeal(184g) Keera(38g) **Morning snack** Apple (189g) **Lunch** Phulka (80g) Veg Bengal ram dhal (183g) Amarnath curry (232g) Curd (200g) **Evening Snack** Fruit cake (193g) Ice cream (123g) **Dinner** Phulka (80g) Paneer butter masala (87g) Curd (200g) **Total Calories-2602** **Optimized Calories:2696**	**Description:** The diet plan-9 optimized 2696 calories with 12 recipes through Stigler's diet problem (SDP) and appears to offer a good mixture of nutrients throughout the day. The nutritious breakfast, includes oatmeal and keera, provides a good source of fiber and essential vitamins. The morning snack of an apple adds natural sweetness and additional fiber. The recipes included in lunch offers a variety of proteins, carbohydrates and important micronutrients. Evening snack and dinner together contribute to the overall calorie intake and also provides healthy fats. The diet plan is a mix of foods like fruits, vegetables and grains along with protein sources. The percentage of protein is 12.07%, fat is 11.50%, carbohydrate is 67.43% and other nutrients is 12.07% obtained through this diet are represented in figure-10 which helps in easy calorie counting.

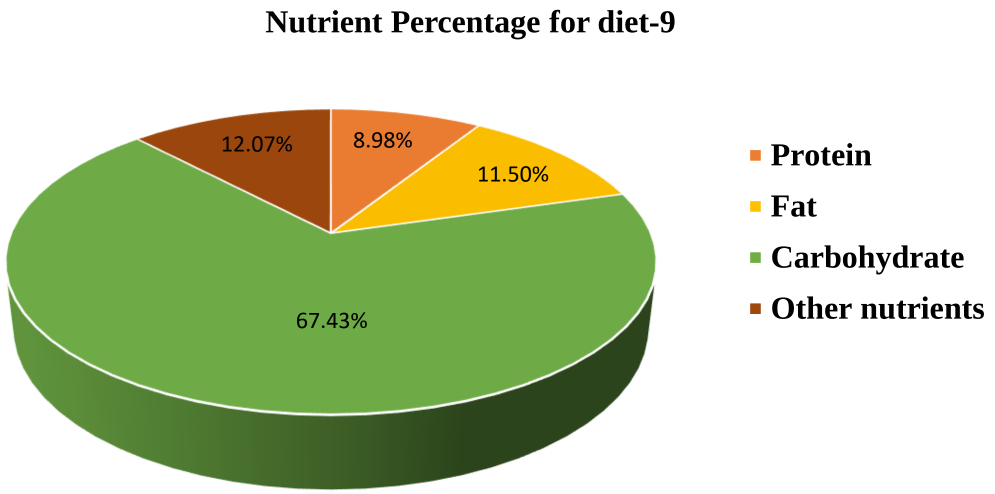

Figure-4: Nutrient share of diet-9 derived from Menu-5

Menu planning with diet-1 and diet-2 combinedly produced 8 recipes in each with 2800-3000 caloric range optimized through LPP. The diet-3, diet-4 and diet-5 maximized by ILP resulted producing between 2100-3100 caloric range with 10 recipes in each diet plan. The SDP has produced 9, 13, 11, 12 number of recipes for diet-6, diet-7, diet-8 and diet-9 within 1900-3100 caloric range respectively. The recipes optimized by mathematical models are regionally available and economically stable. The study also paid attention to the importance of millets and included foxtail millet, contains 12% of protein per 100g of millet and is mineral-rich in phosphorous. The two diet plans from ILP and SDP containing foxtail millet have produced highest amount of calorie intake. The presence of macro-nutrients in higher levels made energy maximization possible through considered recipes in the diet plans. The study observes (60% - 70%) of carbohydrate, (9% - 13%) of Protein, (9% -13%) of Fats and (8%-15%) of other nutrients. Therefore, the study demonstrates that the personalized forms Integer Linear Programming (ILP), Stigler Diet Problem (SDP) has yielded better results than Linear Programming Problem.

6.1 Implications of the study:

The study inferences towards subsequent research in the optimization techniques and helps in developing theoretical contributions in area of nutritional management. The proposed diet plans are easily habitable, economically adaptable as they contain regionally available food items. Based on the prevalence of chronic diseases, the study has much potential for making diet management policies and implementing in rural and urban areas through the National Nutrition Mission (NNM) initiated by the Poshan Abhiyan, the Ministry of Women and Child Development, India. These significant accomplishments states that the possible approach for enhancing successful living is viable through following a diet with optimized food items and recipes. Indian food culture for centuries together with blue zone diet enhances a person for possessing exceptional longevity, health, and happiness.

6.2 Limitations:

The study is limited in considering few recipes producing energy in required limits and constrained with 13 nutrients. There is a possibility of including more recipes without effecting the Required Dietary Allowance (RDA) and balancing the nutrient intake levels. Linear programming problems are considered to the diet management studies which rises scope for adopting advanced mathematical models in future. To advance the knowledge on this topic, more research is deemed necessary to explore diet patterns in diversified cuisines in India.

7. Conclusion:

Blue Zones started as a way of discovering the healthiest lifestyles that lead to longevity prioritizes in making healthier choice not only easy but also the unavoidable choice. Indians can gain back an extra decade of good life by adopting one of the nine principles recommended by bluezones and following nutritionally optimal diets. The diet plans optimized in the study have targeted 14 essential nutrients by demonstrating the nutritional potential of the recipes. Lifestyle changes as suggested in blue zones lifestyle and diet plans obtained through optimization techniques might prove very effective in reducing the burden of diseases in India. The study ultimately contributing to have noteworthy levels of dietary recommendations, interventions, various micro and macro nutrients. Indian food recipes are naturally plant-based diets which contains more macro nutrients like protein, fiber, fat and carbohydrates respectively.

Linear programming problem (LPP) has proven as basic powerful tool for optimizing various range of nutrient resources for calorie allocations by formulating constraints and objectives in a linear mathematical framework. Integer linear Programming (ILP) extends the capabilities of linear programming by allowing decision variables only to integer values. The ability to work with integer programming adds a practical dimension to optimization modelling. Stigler diet problem serves as pioneering example of applied linear programming demonstrates optimization techniques provide practical solutions to complex dietary planning to real-world nutrition. The awareness on food guidelines in bluezones could be used as advice for health practitioners, nutritionists and dieticians in improving overall health and quality of life.

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