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Millet Thali (Food Basket) for Transforming Nutrition Intake

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Abstract

Sustainable Development Goals (SDGs) are a set of 17 interrelated goals adopted by the United Nations (UN) for a better and sustainable future for all. One of the SDGs, SDG 2, relates to achieving food security, and improved nutrition and promoting sustainable agriculture. Millets are a group of small seeded grasses rich in different nutrients, micronutrients and minerals. Apart from many types, finger millet, pearl millet, foxtail millet, barnyard millet, proso millet, kodo millet, and sorghum are the most important ones grown worldwide. Millets can contribute to dietary diversity and promote sustainability. The objective of this research has been to identify an optimal combination of intake food items to satisfy the daily nutritional requirements by including millets. This research uses a modified form of the classic Diet problem. Using this mathematical model, an optimal combination of food items to be included in daily meal is found out. Apart from satisfying the nutritional need optimally, this research also takes into consideration to include the dietary preference of people. After solving for multiple scenarios, it has been concluded that that daily Recommended Dietary Allowance (RDA) cannot be fulfilled without including millets in the meal. Millets can have transforming impact on the nutritional intake of people and they can be highly beneficial in combating dietary nutrient deficiency.

Key words
Millets, Food basket, Meal planning, and Operations research

1. Introduction
Millet are small-seeded grasses, which have a usage history spanning thousands of years. Millets are classified into major and minor millets. Sorghum (Sorghum bicolor), pearl millet (Pennisetum glaucum), and finger millet (Eleusine coracana) are the major millets. Besides major millets, there are numerous minor millets available locally in various regions of the world.

Millets have been regarded as a dietary staple in numerous regions across Africa and Asia. They are now gaining widespread acknowledgment globally due to their remarkable health advantages and adaptability in contemporary diets. These grains are nutrient powerhouses, containing vital elements like iron, calcium, magnesium, phosphorus, fiber, and an array of other micronutrients essential for overall well-being. Notably, millets stand out as gluten-free grains, offering a wholesome substitute for individuals with gluten sensitivities or celiac disease. The inclusion of millets in one's diet contributes significantly to holistic health, fostering cardiovascular well-being, facilitating digestion, and fortifying bone strength. As awareness grows about their nutritional richness and versatility, millets are increasingly becoming a focal point in the pursuit of balanced and diverse dietary choices worldwide.

In recent years there is a growing emphasis on sustainable diet choices. The global millet production has been estimated to be 30,802,000 mt. The global millet production is concentrated in a few regions. Out of the total global production only two countries, India and Niger, account for more than 50% of world millet production with 40% and 11% respective contribution. (Millet 2023 World Production, 2024). The reason for this concentrated production is the limited demand for millets from other parts of the world. The inclusion of millets in the daily food basket will lead to demand generation, which will drive higher millet production. To enhance global reach and demand for millets, the year 2023 was declared the International Year of Millets (IYOM) by the United Nations (UN). The inclusion of millets in daily food baskets can have many benefits for consumers as well as producers across the world.

The concept of achieving nutrition through a food basket is centered on curating a well-rounded selection of foods to meet essential dietary needs. This strategy places a strong emphasis on variety in eating choices, guaranteeing a balanced intake of the nutrients required for optimum health. Fruits, vegetables, complete grains, lean proteins, dairy products, and dairy substitutes are only a few of the food groups that are included in the food basket. Through the concept of a food basket, people can obtain a wide range of vitamins, minerals, and macronutrients by including a variety of colors, textures, and nutritional profiles in their diet. An ideal food basket aims to lower the risk of chronic illnesses, prevent dietary shortages, and enhance general well-being.

1.1 Objectives of the research

The objective of this research has been to satisfy the daily nutritional and serving size requirements by including millets in the daily food basket. The research assumes that the daily nutritional requirement can be fulfilled using a linear combination of the number of serving sizes of different food items containing different amounts of nutrients. This research also provides a guideline on how to include consumer preferences while planning the optimal food basket.

2. Literature review

Millets have been consumed historically, in many regional pockets of the world. However, there has been a decline in millet's consumption and production in recent years (Rao & Basavaraj, n.d.). The nutritional content of millets is found to be much better than rice and wheat, due to which they are an excellent choice for improving nutritional security as well as preventing cardiovascular diseases, diabetes mellitus, and others(Jain et al., 2024). The three major millets viz. sorghum, pearl millet, and finger millet have been found to have high nutritional contents. Sorghum has high nutritional values along with various functional compounds such as (phenolic compounds, bran, and 3-deoxyanthianine, which have a positive impact on human health (Istrati et al., 2019). Finger millet is highly valued for its nutrient content. It is rich in carbohydrates, protein, and fat. Its micronutrients include calcium (0.38%), dietary fiber (18%), and phenolic compounds (0.3–3%), such as catechin, epicatechin, as well as ferulic, salicylic, protocatechuic, cinnamic, and hydroxybenzoic acids, etc. (Gaikwad et al., 2024). Pearl millet is an excellent source of micronutrients like iron and zinc. It also has good fat contents of 5-7 g/100 g (Singh et al., 2023). Apart from major millets, minor millets also are full of nutrients and micronutrients. The inclusion of millets in daily food basket has many health benefits, a brief overview of which can be seen in Table 1.

Many government programs, in India, have introduced millets in the schemes targeting poor and malnutrition-affected people and have found positive outcomes. Inclusion of ragi (finger millet), jowar (sorghum), and bajra (pearl millet) based products in Integrated Child Development Services (ICDS's) Anganwadi centres demonstrated a positive impact on weight and BMI for pregnant and nursing women in community setting (Sharat Dhruthi & Gokhale, 2022). Research done by Samal & Mishra (2022) suggests that expanding the PDS to a include nutritionally diverse basket along with other relevant measures is likely to be beneficial for improvement in nutritional levels amongst pregnant mothers.

In addition to their nutritional attributes, millets contribute to fostering sustainable agricultural practices. Millet crops have high resilience to harsh environmental conditions, require minimal water, and exhibiting drought tolerance. Their low ecological footprint makes them an environmentally friendly option for cultivating food. Diversification of crops with millets has been found to have a potential for GHG reductions (Sachdeva et al., 2023). Growing millets can also contribute to increasing farmers' incomes (Tonapi, 2021). Due to all the consumption and production advantages associated with millets, millets are ideal candidates to act as "famine reserves" (Bandyopadhyay et al., 2022).

Table 1. Benefits of including different types of millets in the food basket

Millet	Benefit	Reference
Foxtail millet	Treating and preventing malnutrition	(Kalsi & Bhasin, 2023)
Sorghum	Improving nutrition security	(Ratnavathi & Tonapi, 2022), (Akplo et al., 2023)
Pearl Millet	Prevention of lifestyle diseases	(Ratnavathi & Tonapi, 2022)
Barnyard millet	Prevention of lifestyle diseases	(Ratnavathi & Tonapi, 2022)
Foxtail millet, Sorghum and Pearl Millet	Improving health of pregnant mother	(Sharat Dhruthi & Gokhale, 2022)
Finger millet	Improving child health	(Durairaj et al., 2019)

The diversification of food basket has many advantages such as improving the palatability of diet. Apart from improving the palatability of food, the diversification of food intake can contribute positively to nutritional outcomes (Douyon et al., 2022). As the world looks towards diversification of food intake, millets stand out as a valuable addition to modern diets, offering a delicious and sustainable food alternative.

To diversify food basket, operations research has been used by researchers for optimizing meals for various purposes. Bas (2014) used MILP to optimize daily meals to lower the glycemic index. The authors used a robust optimization approach for identifying daily optimal serving sizes of food choices for a minimum total daily glycemic load. Cakrak & Cimen (2017) used a genetic algorithm for the food supply chain for a military unit of 400 men. They optimized the distribution of 400 dishes over 360 days, such that the cost of raw materials is minimized while maintaining the variety of dishes. Abuabara et al. (2022) used the Parsimonious Analytic Hierarchy Process along with LPP to include the palatability factor while planning meals for an average family of size of four persons. They produced a weekly meal plan while considering the palatability factor. The objective function was to minimize the combination of cost, preference, and handling/preparation time of the food items. Most of the applications of diet problems have used the nutrient contents of food dishes as input parameters for the optimization of nutrient intake. One such attempt to optimize food basket was conceived by (Stigler, 1945) and it has been one of the first optimization problems studied in OR. The objective of this problem is to fulfill the minimum nutritional requirement at the minimum possible cost. Since then, the problem has been utilized by many researchers to produce other diet solutions (van Dooren, 2018).

3. Methodology

In this research, we used a modified version of the Stigler's Diet problem. To accommodate the preference of the target population additional constraints limiting the minimum and maximum food quantity as well as a constraint to limit the total nutrient less than or equal to the Tolerable Upper Limit (TUL) have been included in the model. The parameters associated with the consumption of various food items were taken for the population of a selected region. The problem of food basket has been solved for a family size of four people composed of one adult male, one adult female, and 2 children The following mathematical model was used for this research:

Notations used:

I = set of i food item including millets such as cereals, pulses, edible oil, fortified salt, millets milk & curd, and green vegetables.

J = set of j nutrients such as carbohydrates, protein, fat, calcium, iron, minerals, other nutrients, and calories.

Parameters

a_{ij} = amount of nutrient j in food i, $\forall i \in I$, $\forall j \in J$

c_i = cost per gm of food item i, $\forall i \in I$
$Fmin_i$ = minimum quantity (in gm) of food item $i \in I$ which must be included in daily meal.
$Fmax_i$ = maximum quantity (in gm) of food item in daily meal.
R_j = Recommended Dietary Allowance (RDA) value of nutrient $j \in J$ (i.e, set of nutrients).
$Nmax_j$ = maximum level of nutrient $j \in J$ in daily meal.
x_i = quantity (in gm) of food item i included in the daily meal, $\forall i \in I$ (i.e, set of food items)
Objective Function: Minimize the total cost of the food
Minimize $\sum_i c_i x_i$
Constraint Set 1: For each nutrient j, the minimum required level in daily meal must be more than RDA value.
$\sum_i a_{ij} x_i \geq R_j, \quad \forall j \in J$
Constraint Set 2: For each nutrient j, maximum allowable level in daily meal.
$\sum_i a_{ij} x_i \leq Nmax_j, \quad \forall j \in J$
Constraint Set 3: For each food item i, minimum quantity to be included in daily meal.
$x_i \geq Fmin_i, \quad \forall i \in I$
Constraint Set 4: For each food item i, the maximum allowed quantity in daily meal.
$x_i \leq Fmax_i \quad \forall i \in I$
Constraints for preference of millets
Constraint 4: For each food item i, minimum quantity of total quantity of millets to be included in daily meal.
$\sum_i x_i \geq Fmin_i, \quad \forall i \in I$ Set of millets (Sorghum, finger millet and pearl millet)
Constraint 5: For each food item i, the maximum allowed total quantity of millets in daily meal.
$\sum_i x_i \leq Fmax_i \quad \forall i \in I$ Set of millets (Sorghum, finger millet and pearl millet)
Constraints for preference of pulses:
Constraint 6: For each food item i, minimum quantity of total quantity of pulses to be included in daily meal.
$\sum_i x_i \geq Fmin_i, \quad \forall i \in I$ Set of pulses (Red gram, pigeon pea, black gram and green gram)
Constraint 7: For each food item i, the maximum allowed total quantity of pulses in daily meal.
$\sum_i x_i \leq Fmax_i \quad \forall i \in I$ Set of pulses (Red gram, pigeon pea, black gram and green gram)

Table 2 contains the food items included in the study as well as the daily consumption data for a family of 4.

Table 2. Food items consumed by a family of 4 in the targeted region (*Household Consumption of Various Goods and Services in India 2011-12*, 2014)

Food Category	Food item	Consumption (in g for a family of)	Avg. retail cost in INR per 100 g or ml
Cereal Grains	Wheat	233.33	3.4
	Rice	1173.33	3.7
	Jowar	0	2.5
	Bajra	0	2.35
	Ragi	2	3.65
Cooking oil	Ground nut oil	0.4	17
	Soyabean oil	41.33	15
	Sunflower oil		14.4
	Mustard oil	28.66	16.4
Legumes	Split Pigeon Pea (Red Gram)	48.8	11.2
	Split Green gram	17.86	10.3
	Split Bengal gram	6.26	6.8
	Split Black gram	5.2	10.1
Vegetables	All vegetables available in the region	1064	4
Others	Salt	38.26	2.5
	Milk and Curd	388	6

The constraints for the minimum and maximum quantity of pulses, edible oil, and millets have been included so that the optimal solution must be as close as possible to the present consumption habits of the target population. The idea is that the behavioral change required for implementing the meal with optimal composition must be as minimal as possible. This was done to improve the acceptance of optimal solutions and improve the adoption rate. The nutrition input parameters are given in Table 3

Table 3: Minimum and maximum values of different nutrients and minerals.

Nutrient (unit)	**Recommended Dietary Allowance (RDA)**	**Tolerable upper limit (TUL)**
Calories (kcal)	NA	No Limit
Protein (g)	173.08	650
Fat (g)	146.72	200
Iron (mg)	93	170
Calcium (mg)	3750	10000
Magnesium (mg)	1288.7	No Limit
Zinc (mg)	51.78	127.34
Phosphorus (mg)	4000	No Limit
Sodium (mg)	8000	No Limit
Potassium (mg)	14000	No Limit
Copper (mg)	8	No Limit
Iodine (mg)	585	2900
Chromium (mg)	200	No Limit
Manganese (mg)	16	No Limit
Selenium (mg)	160	No Limit
Vitamin B1 (mg)	6.58	No Limit
Vitamin B2 (mg)	9.2	No Limit
Vitamin B3 (mg)	62.64	140
Vitamin B6 (mcg)	8.48	400
Vitamin B9 (mg)	992.5	3114

4. Results

The mathematical model was used to derive the optimal combination of different food items, to fulfill the RDA values. Apart from optimizing for the lowest cost, different scenarios have been considered to include the local preferences of food consumption. Figure 1, shows the flow of different scenarios for arriving at an optimal food basket. First of all, an optimal food basket has been identified that fulfills the required RDA. As this food basket is identified then attempt is made to modify its composition such that the optimal composition is as close as possible to the present consumption habits and preferences of the population of the region.

4.1 Discussion and Inferences

There have been numerous studies for identifying the optimal combination of food dishes to be include to fulfil the nutritional requirement. However, optimizing the food dishes instead of food items can limit the number of options a person will have. Another aspect that must be considered is that there may be some inconsistency in preparing the same dishes repeatedly. Hence, using food items, used for making the food dishes, is a better way to find an optimal food basket. With this approach, the palatability of the optimal diet can also be addressed partially as the approach is to modify the present dietary pattern as minimum as possible. The outcomes of this study will help governments plan malnutrition fighting strategies (Table 4).

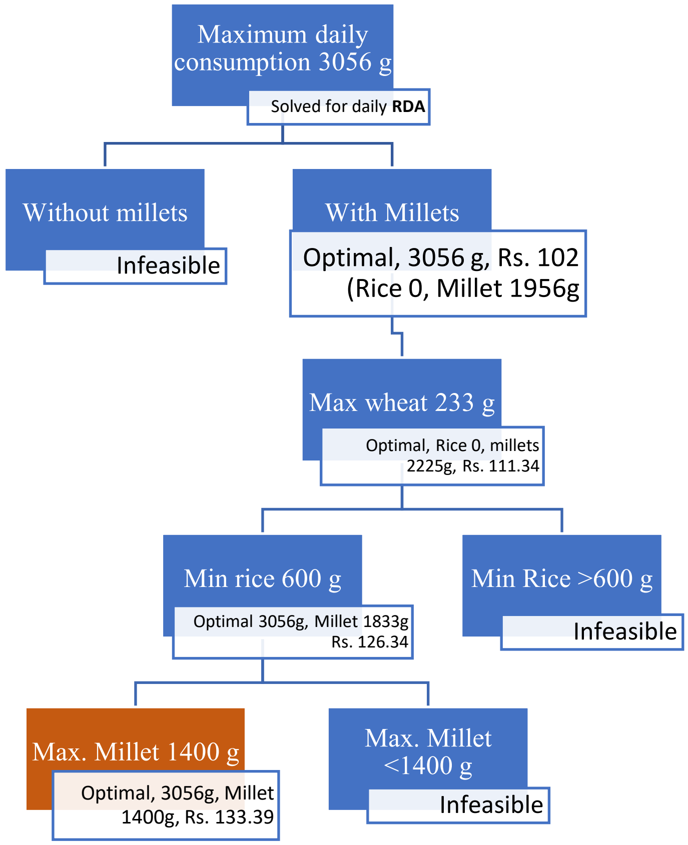

Figure 1: Flow of different scenario for identifying optimal food basket.

Table 4. Composition of food basket in the optimal scenario considering consumer preferences.

Items in food basket	**Quantity (g)**
Rice	600
Wheat	233
Sorghum	777
Pearl millet	0
Finger millet	623
Soyabean oil	00
Mustard oil	00
Groundnut oil	00
Sunflower oil	00
Red Gram	00
Bengal Gram	737
Black gram	64
Green gram	00
Salt	21
Milk and Curd	00
Vegetables	00

Table 5: Quantity of different nutrients in the optimal scenario considering consumer preferences.

Nutrient	Unit of measurement	Resultant value
Calories	kcal	10045.39
Protein	g	367.99
Fat	g	138.12
Iron	mg	160.20
Carbs	g	1939.43
Calcium	mg	3000.00
Magnesium	mg	3330.50
Zinc	mg	73.96
Phosphorus	mg	7382.63
Sodium	mg	8250.01
Potassium	mg	14604.18
Copper	mg	16.65
Manganese	mg	54.26
Selenium	mg	590.38
Iodine	mg	412.00
Chromium	mg	387.12
B1	mg	9.18
B2	mg	7.36
B3	mg	59.32
B6	mcg	21.30
B9	mg	2050.99

From Figure 1, it can be observed that even in the best possible scenario, the amount of millets to be included in the optimal daily basket comes out to be at least 1400 g. If the quantity of millets is reduced further, then the models gives an infeasible solution. Whereas, Table 4 and Table 5 provide an overview of the composition of the food basket, and recommended consumption quantity of food items respectively, in the optimal scenario considering consumer preferences.

5. Conclusion

Millets have huge potential for improving the nutrition quotient of food intake while simultaneously being sustainable to produce. The model was used to identify the optimal combination of food items to be included in daily meals so that RDA values are met successfully. However, with the acceptance of such a combination of food items, it is important to prepare palatable meals using that combination. To be able to do that, more food items as per the availability and preferences of consumers can be added in the model. Consideration of more food items in the food basket can lead to a more acceptable combination. Another possibility is to explore the optimality of the solution for different time frames. There is a possibility to use the results of this research for planning government programs for the eradication of malnutrition and ensuring nutrition amongst vulnerable populations in various parts of the world.

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