

# Multi-objective Model for Students' Diet Problem: A Case of Muslim University of Morogoro

Halidi A. Lyeme

Department of Mathematics, Faculty of Science  
Muslim University of Morogoro  
Morogoro, Tanzania  
[lyemehalid@gmail.com](mailto:lyemehalid@gmail.com)  
<https://orcid.org/0000-0002-6139-3739>

Jairos S. Kahuru

Department of Mathematics and Statistics,  
College of Natural and Mathematical Sciences,  
The University of Dodoma, Tanzania  
[jabiyus@gmail.com](mailto:jabiyus@gmail.com)  
<https://orcid.org/0000-0003-4147-7289>

DOI: <http://dx.doi.org/10.31642/JoKMC/2018/130209>

**Received Apr. 11 2026. Accepted for publication Jun. 2, 2026**

**Abstract**— The study on solving diet problems using an optimization approach as the intervention for menu plans for college students, particularly in developing countries like Tanzania, where context-specific data, such as what foods are available locally and student eating habits, are often missing from models in Tanzania. Therefore, this study aims to formulate a multi-objective optimization model that simultaneously solves the two objectives (energy maximization and cost minimization) for the student diet problem. The model has been transformed into the lexicographic preemptive goal programming model for the real data implementation. The model was written in GNU Linear Programming Kit (GLPK) software and solved. The combination of cereals, legumes, fruits, vegetables, and a few foods derived from animals made up the ideal daily diet that can be used as a guide for students' dietary plans. The chosen food combination had 2250 kcal of energy, whereas 2200 kcal were needed, and 68 g of protein were consumed instead of the suggested 50 g. The intake of fat stayed within the allowed range ( $64\text{ g} \leq 65\text{ g}$ ), while the intake of carbohydrates slightly exceeded the required amount. Thus, we may serve nutritious foods that maximize daily total energy consumption and minimize the cost of the foods while taking recommended nutritional intake into account for Tanzanian university students utilizing locally accessible foods.

**Keywords**— Multi-objective Model; Students' Diet Problem; Goal Programming; Recommended Nutritional Intake; Cost Minimization

## I. INTRODUCTION

There are numerous factors that influence health status. Diet and nutrition are the main factors that are very adjustable and controllable. Diet essentially refers to the total amount of food consumed, which supplies the body with what it requires and has a significant impact on how physically, mentally, and even socially an individual functions. The key factor affecting overall health is nutrition because many dietary decisions tend to be bad ones, leading to unhealthy behaviors and their effects [1].

University students constitute a distinct demographic facing specific dietary obstacles. Studies show that these students frequently opt for diets that are energy-dense yet lacking in vital nutrients, largely due to financial restrictions, time limits, and insufficient access to nutritious food choices [1,2]. These dietary habits elevate the likelihood of adverse health outcomes, highlighting the necessity to establish organized strategies for enhancing student nutrition.

University students in Tanzania, many of whom rely on the Higher Education Students' Loans Board (HESLB) for their daily expenses. The elevated cost of living significantly affects their financial planning and consequently, access to nutritious meals may be quite limited. Additionally, many may lack experience in managing their budgets for essential needs. Dietary choices for students are based on the prices of food products and individual spending habits [3].

Diet models based on linear programming (LP) present a viable solution by offering cost-effective and nutritionally adequate meal plans customized to meet the needs of students. This is supported by recent study by Miow et al. (2025) in [4] discovered that LP is frequently used to detect limiting elements like iron and zinc while converting dietary recommendations into workable meal plans. Additionally, Donkor et al. (2023) in [5] highlighted the increasing importance of LP in food system optimization, especially in environments with limited resources.

LP has also been used in institutional settings where most people rely on organized meal systems, like hospitals,

universities, and schools. According to studies, LP can increase the effectiveness of meal planning, lower expenses, and guarantee adherence to dietary guidelines [6,7]. Furthermore, LP has been extensively used to resolve numerous diet issues. In the study conducted by Devic, Belio, and Gacina in [8] used linear programming to reduce the cost of a diet using a three-day menu as an example. In their study, they suggest three-day diets for women and men between the ages of 19 to 50 years with all nutrient's requirement in minimum costs.

The application of linear programming and integer programming to design dietary plans for autistic 100M sprinters aged 20-30 years old has been demonstrated by Zailan et al. (2025) in [9]. The use of those two scientific methods can help to minimize the costs and take into account some other constraints, like the required amounts of certain nutrients and allergenic products to avoid.

Manmohan et al. (2019) in [10] applied linear programming to allocate minimal cost and maximum satisfy the daily requirements of the human body at the age of 25 to 50 years for vitamins, minerals, and dietary requirements. Their goal was to reduce the overall cost of vitamins and minerals for food, and the unit cost in particular. Additionally, Prajapati et al. (2025) in [11] used linear programming to optimize meal planning which balance the calorie intake and dietary requirements. This study again proving the usefulness of LP in producing workable and affordable diet options.

The study by Altınöz (2025) in [12] on food optimization and low-calorie diets shows that meals can be produced using multi-objective techniques and still meet or exceed the necessary nutritional requirements. The proposed model was solved by the multi-objective optimization algorithms and five different objective functions were applied for the selected dataset. The study indicates that optimization techniques can be applied to achieve nutritionally sufficient diets even when calorie limitations are in place.

Soe et al. (2020) in [13] analyzed the problem of nutrients in the diets of Myanmar primary schoolchildren and formulated food-based recommendations (FBR) to optimize the intake of these micronutrients. They applied a linear programming technique to identify gaps and adequacy in nutrients in the diets of children in Myanmar. Their findings indicate that although Myanmar has nutrient-rich local foods available, children still fail to meet recommended nutrient levels, and adequate intake of key nutrients remains problematic, so they developed FBR to improve diets.

According to Yadav and Dhabas (2024) in [14], they applied a linear programming model to solve the student diet problem, and they found that LP can be used to make meal plans for students that are both cost-effective and nutritionally balanced, as cost is one of the most important factors in the food choices of students.

Previous studies have demonstrated that linear programming is an effective method for solving dietary problems to minimize cost while meeting nutritional requirements as recently supported by Shiratori and

Abeysekara (2025) in [15], yet there is little research on college students, and particularly in developing countries such as Tanzania, where context-specific data, such as what foods are available locally and student eating habits, are often missing from models. This work fills those gaps by developing a multi-objective linear programming model for the students at the Muslim University of Morogoro

## II. MATERIAL AND METHODS

### A. Study Area and Population

The Muslim University of Morogoro, which is situated in Morogoro Region, Tanzania was the site of the study. Undergraduate, diploma, and certificate students made up the target population. Due to their limited access to nutritionally balanced meals, irregular eating patterns, and limited financial resources, these students frequently struggle with dietary issues.

### B. Data Collection

A simple survey is distributed to 100 students of Muslim University of Morogoro (MUM) in Tanzania. The survey's goal was to learn more about each student's dietary habits. Students are asked to respond to a survey on their favorite breakfast, lunch, and dinner foods. The study also seeks to learn how students feel about following a healthy diet. A quick conversation with a member of the cafe staff yielded the menu selection and survey suggestions. It is crucial to set up the LP model while also obtaining the nutritional information for each menu from the Muslim University Students' Organization. In order to find a workable answer to this diet issue, this study only considered 10 nutrients which are energy, protein, fat, carbohydrate, calcium, phosphorus, iron and vitamins A, C and B9. Furthermore, fulfilling all nutrients at once is realistically not possible.

A list of commonly consumed food items available within and around the university campus was compiled through that survey. The selected food items included staple foods, protein sources, and fruits/vegetables typically consumed by students are shown in Table 1 with their nutritional contents as derived from Tanzania food composition tables (2008).

Most of the nutrient composition data was taken from the Tanzania Food Composition Tables (TFCT, 2008) with values from the USDA and FAO/INFOODS databases added when required. The RDIs shown in Table 2 are based on Institute of Medicine and FAO/WHO guidelines and were adapted to the Tanzanian nutritional situation per the guidelines set out by Tanzania Food Nutrition Centre (TFNC).

To account for these variables, food prices were estimated based on current market prices in Tanzania for the years 2024 through 2026, as shown in Table 3, from local market surveys and relevant reports to reflect realistic and current cost conditions. The standardized cost values were used as input parameters in the optimization model to ensure that the resulting diet plan is both nutritionally adequate and economically feasible.

TABLE 1: FOOD REQUIREMENT WITH THEIR NUTRIENTS (SOURCE: ADOPTED FROM TANZANIA FOOD COMPOSITION TABLE 2008 [2–4])

| Food Sample           | Energy (Kcal) | Protein (g) | Fat (g) | Carbohydrate (g) | Iron (mg) | Calcium (mg) | Phosphorus (mg) | Vitamin C (mg) | Vitamin A (µg) | Vitamin B9 (µg) |
|-----------------------|---------------|-------------|---------|------------------|-----------|--------------|-----------------|----------------|----------------|-----------------|
| Rice burn             | 416.2         | 4.7         | 11.1    | 73.7             | 1.2       | 10           | 80              | 0              | 0              | 8               |
| Bread, white          | 249           | 7.7         | 1.9     | 48.8             | 3.6       | 144          | 107             | 0              | 0              | 85              |
| Buns (mandazi)        | 306           | 7           | 6.8     | 52.8             | 2.5       | 30           | 90              | 0              | 10             | 40              |
| Fresh milk (whole)    | 60            | 3.2         | 3.3     | 4.5              | 0.03      | 113          | 84              | 1              | 46             | 5               |
| Mashed potatoes       | 106           | 2.5         | 0.2     | 22.8             | 0.8       | 12           | 44              | 9              | 2              | 15              |
| Fried sweet potatoes  | 248           | 3.1         | 13.9    | 25.3             | 1.0       | 30           | 47              | 19             | 700            | 14              |
| Fried egg             | 223           | 13.1        | 17.9    | 2.5              | 1.8       | 50           | 198             | 0              | 160            | 47              |
| Boiled egg            | 155           | 12.6        | 10.6    | 1.6              | 1.2       | 50           | 172             | 0              | 140            | 47              |
| Meat samosa           | 443           | 18.8        | 22.2    | 40.5             | 2.7       | 25           | 150             | 2              | 30             | 25              |
| Pancakes              | 270           | 8.3         | 8.5     | 39.2             | 2.2       | 80           | 120             | 0              | 20             | 60              |
| Rice porridge         | 94.6          | 0.6         | 0.1     | 23               | 0.2       | 5            | 15              | 0              | 0              | 3               |
| Maize porridge        | 94            | 0.0         | 0.4     | 22.7             | 0.5       | 3            | 20              | 0              | 0              | 5               |
| Cassava boiled        | 131           | 0.0         | 0.3     | 31.9             | 0.3       | 16           | 27              | 20             | 13             | 27              |
| Sweet potatoes fried  | 146.1         | 0.0         | 5.1     | 24.3             | 0.7       | 25           | 40              | 15             | 600            | 10              |
| Rice boiled with oil  | 199.9         | 5.6         | 0.6     | 30               | 0.5       | 10           | 70              | 0              | 0              | 6               |
| Banana with meat      | 77.4          | 2.7         | 3.6     | 9.4              | 0.6       | 10           | 60              | 5              | 50             | 20              |
| Irish potato boiled   | 105           | 2.4         | 0.1     | 22.7             | 0.8       | 12           | 44              | 10             | 2              | 16              |
| Sweet potatoes boiled | 101           | 1.7         | 0.4     | 20.8             | 0.7       | 30           | 47              | 20             | 700            | 14              |
| Yam boiled            | 118           | 2           | 0.2     | 24.9             | 0.5       | 17           | 55              | 12             | 7              | 23              |
| White chapati         | 413           | 7.3         | 22.9    | 40.9             | 3.0       | 35           | 100             | 0              | 0              | 50              |
| Rice flour porridge   | 56            | 0.6         | 1.3     | 10.2             | 0.2       | 5            | 15              | 0              | 0              | 3               |
| Cassava ugali         | 186           | 1.1         | 0.3     | 43.7             | 0.4       | 20           | 30              | 0              | 5              | 10              |
| Whole maize ugali     | 141           | 3.3         | 1.8     | 26               | 1.5       | 7            | 100             | 0              | 15             | 30              |
| Refined maize ugali   | 148           | 3.4         | 1.9     | 27.3             | 1.2       | 5            | 90              | 0              | 5              | 20              |
| Pilau                 | 213           | 6.9         | 9.4     | 24.8             | 2.0       | 20           | 100             | 2              | 20             | 25              |
| Boiled rice           | 138           | 2.7         | 2       | 27.3             | 0.2       | 10           | 43              | 0              | 0              | 4               |
| Kidney beans boiled   | 70            | 4.9         | 0.5     | 9.4              | 2.1       | 28           | 142             | 0              | 0              | 130             |
| Maize + beans         | 161           | 5           | 5.9     | 19.8             | 2.5       | 40           | 120             | 1              | 20             | 90              |
| Amaranth              | 23            | 8.5         | 0.5     | 8.5              | 2.3       | 215          | 50              | 43             | 2900           | 85              |
| Pumpkin leaves        | 35            | 4           | 0.7     | 2.1              | 3.2       | 200          | 80              | 30             | 3100           | 110             |
| Sweet potato leaves   | 35            | 4.8         | 0.3     | 6.4              | 2.7       | 180          | 70              | 25             | 2800           | 90              |
| Spinach leaves        | 33            | 3.5         | 0.4     | 1.4              | 2.7       | 99           | 49              | 28             | 470            | 194             |
| Mlenda                | 59            | 3.4         | 2.3     | 5.4              | 2.5       | 120          | 60              | 20             | 800            | 60              |
| Lentils boiled        | 75            | 6.7         | 0.2     | 9.7              | 3.3       | 19           | 180             | 1              | 8              | 180             |
| Cabbage               | 19            | 1.1         | 0.1     | 2.2              | 0.5       | 40           | 26              | 36             | 5              | 43              |
| Fish smoked           | 306           | 66.4        | 2.5     | 0                | 2.5       | 200          | 300             | 0              | 50             | 10              |
| Stewed dried fish     | 330           | 25.7        | 23.2    | 3.9              | 3.0       | 250          | 280             | 0              | 60             | 15              |

|                |       |      |      |      |     |     |     |     |    |     |
|----------------|-------|------|------|------|-----|-----|-----|-----|----|-----|
| Sardine stewed | 180   | 8.8  | 13.3 | 6.0  | 2.9 | 382 | 490 | 0   | 45 | 10  |
| Chicken boiled | 226   | 23.7 | 14.6 | 0    | 1.3 | 15  | 220 | 0   | 50 | 6   |
| Sardine fried  | 450   | 19.2 | 39.3 | 4.6  | 3.0 | 400 | 500 | 0   | 60 | 12  |
| Fish boiled    | 76.5  | 8.2  | 4.5  | 2.4  | 1.0 | 20  | 150 | 0   | 30 | 8   |
| Fish with oil  | 253.6 | 21.2 | 17.9 | 2.2  | 2.0 | 50  | 200 | 0   | 40 | 10  |
| Yoghurt        | 85    | 2.9  | 3.1  | 11.3 | 0.1 | 110 | 95  | 1   | 40 | 7   |
| Baobab pulp    | 305   | 4.2  | 1.3  | 77.8 | 9.0 | 280 | 90  | 250 | 0  | 50  |
| Banana ripe    | 89    | 1.1  | 0.3  | 22.8 | 0.3 | 5   | 22  | 9   | 64 | 20  |
| Avocado        | 160   | 2    | 14.7 | 8.5  | 0.6 | 12  | 52  | 10  | 7  | 81  |
| Groundnut      | 593   | 20   | 48.4 | 15   | 4.6 | 92  | 376 | 0   | 0  | 240 |

TABLE 2: RECOMMENDED DAILY INTAKE FOR UNDERGRADUATE STUDENTS IN TANZANIA (Source: Adopted from Institute of Medicine and FAO/WHO guidelines [5–7].)

| Nutrient                 | Male Students                | Female Students | Remark                                      |
|--------------------------|------------------------------|-----------------|---------------------------------------------|
| Energy (Kcal)            | 2500                         | 2000–2200       | Depends on activity level                   |
| Protein (g)              | 56                           | 46–50           | ≈0.8 g/kg body weight                       |
| Fat (g)                  | 60–70                        | 50–70           | 20–35% of total energy                      |
| Carbohydrate (g)         | ≥130 (min) / 300–400 optimal | ≥130 / 250–350  | Brain needs glucose                         |
| Iron (mg)                | 8–10                         | 18–22           | Higher in women & low-bioavailability diets |
| Calcium (mg)             | 1000                         | 1000            | Bone health                                 |
| Phosphorus (mg)          | 700                          | 700             | Works with calcium                          |
| Vitamin C (mg)           | 90                           | 75–80           | Immunity & iron absorption                  |
| Vitamin A (μg)           | 900                          | 700             | Vision & immunity                           |
| Vitamin B9 (Folate) (μg) | 400                          | 400             | Blood formation                             |

TABLE 3: ESTIMATED COST PER 100G EDIBLE PORTION (SOURCE: FIELD DATA)

| Food Sample           | Cost (Tsh) | Food Sample          | Cost (Tsh) |
|-----------------------|------------|----------------------|------------|
| Rice burn             | 270        | Pilau                | 3000       |
| Bread, white          | 400        | Boiled rice          | 1000       |
| Buns (mandazi)        | 500        | Kidney beans boiled  | 500        |
| Fresh milk (whole)    | 250        | Maize + beans        | 1000       |
| Mashed potatoes       | 235        | Amaranth             | 200        |
| Fried sweet potatoes  | 300        | Pumpkin leaves       | 150        |
| Fried egg             | 900        | Sweet potato leaves  | 150        |
| Boiled egg            | 500        | Spinach leaves       | 180        |
| Meat samosa           | 800        | Mlenda               | 200        |
| Pancakes (chapati)    | 500        | Lentils boiled       | 500        |
| Rice porridge         | 500        | Cabbage              | 150        |
| Maize porridge        | 500        | Fish smoked          | 1200       |
| Cassava boiled        | 200        | Stewed dried fish    | 1000       |
| Sweet potatoes fried  | 250        | Sardine stewed       | 800        |
| Rice boiled with oil  | 1000       | Chicken boiled       | 2000       |
| Banana with meat      | 2000       | Sardine fried        | 900        |
| Irish potato boiled   | 1000       | Fish boiled          | 2000       |
| Sweet potatoes boiled | 200        | Fish relish with oil | 900        |
| Yam boiled            | 250        | Yoghurt              | 1000       |
| White chapati         | 600        | Baobab pulp          | 500        |
| Rice flour porridge   | 500        | Banana ripe          | 250        |
| Cassava ugali         | 1000       | Avocado              | 400        |
| Whole maize ugali     | 1000       | Groundnut            | 800        |

### III. LINEAR PROGRAMMING MODEL FORMULATION

In this study, we describe the model formulation of the diet problem for student's sets menu at MUM based on the menu provided by the MUM cafeteria, hence the LP model was formulated based on the price set up by the MUM cafeteria. Thus, the objective functions and constraints of the model is formulated from the data given in Table 1, 2 and 3. The formulated constraints are subjected to the recommended daily intake (RDI) of nutrients given in Table 2. The notations used in the model are summarized in Table 4.

TABLE 4: NOTATION OF STUDENT'S DIET PROBLEM FOR MUM

| Notation | Description                       |
|----------|-----------------------------------|
| $x_i$    | Amount (in 100g) of food type $i$ |
| $C_i$    | Cost (TSh) of food type $i$       |
| $E_i$    | Energy (Kcal) of food type $i$    |
| $P_i$    | Protein (g) of food type $i$      |
| $F$      | Fat (g) of food type $i$          |
| $CH_i$   | Carbohydrate (g) of food type $i$ |
| $Fe_i$   | Iron (mg) of food type $i$        |
| $Ca_i$   | Calcium (mg) of food type $i$     |
| $Ph_i$   | Phosphorus (mg) of food type $i$  |
| $VC_i$   | Vitamin C (mg) of food type $i$   |
| $VA_i$   | Vitamin A (μg) of food type $i$   |
| $B9_i$   | Vitamin B9 (μg) of food type $i$  |

### A. Decision Variables

Since we have 58 types of food available as indicated in Table 1 then, we have 58 decision variables  $x_i$  where  $i = 1, 2, 3, \dots, 58$ .

### B. Objective Functions

To accommodate for the needs of this group of undergraduate students, two goals are set in this model formulation. First, total energy maximization ( $Z_1$ ) and the total cost minimization ( $Z_2$ ) as the second goal. Thus, the following is the multi-objective linear programming model for this study;

$$\text{Max } Z_1 = \sum_{i=1}^{58} E_i x_i \quad (1)$$

$$\text{Min } Z_2 = \sum_{i=1}^{58} C_i x_i \quad (2)$$

subject to the constraints:

- Protein constraint, which ensures that the total protein in food type  $i$  should exceed or equal the lower limit of the protein RDI:

$$\sum_{i=1}^{58} P_i x_i \geq 50 \quad (3)$$

- Fat constraint, which ensures that the total fat in food type  $i$  does not exceed the upper limit of fat RDI:

$$\sum_{i=1}^{58} F_i x_i \leq 65 \quad (4)$$

- Carbohydrates constraint, which ensures that the total carbohydrates in food type  $i$  should exceed or equal the lower limit of the carbohydrates RDI:

$$\sum_{i=1}^{58} CH_i x_i \geq 300 \quad (5)$$

- Iron constraint, which ensures that the total iron in food type  $i$  should exceed or equal the lower limit of the iron RDI:

$$\sum_{i=1}^{58} Fe_i x_i \geq 18 \quad (6)$$

- Calcium constraint, which ensures that the total calcium in food type  $i$  should exceed or equal the lower limit of the calcium RDI:

$$\sum_{i=1}^{58} Ca_i x_i \geq 1000 \quad (7)$$

- Phosphorus constraint, which ensures that the total phosphorus in food type  $i$  should exceed or equal the lower limit of the phosphorus RDI:

$$\sum_{i=1}^{58} Ph_i x_i \geq 700 \quad (8)$$

- Vitamin C constraint, which ensures that the total vitamin C in food type  $i$  should exceed or equal the lower limit of the vitamin C RDI:

$$\sum_{i=1}^{58} VC_i x_i \geq 80 \quad (9)$$

- Vitamin A constraint, which ensures that the total vitamin A in food type  $i$  should exceed or equal the lower limit of the vitamin A RDI:

$$\sum_{i=1}^{58} VA x_i \geq 800 \quad (10)$$

- Folate constraint, which ensures that the total vitamin B9 in food type  $i$  should exceed or equal the lower limit of the vitamin B9 RDI:

$$\sum_{i=1}^{58} B9_i x_i \geq 400 \quad (11)$$

- Non negativity constraint, which ensures that the values of decision variable are either zero or positive:

$$x_i \geq 0 \quad (12)$$

## IV. RESULTS

For the implementation of real data, the multi-objective linear programming model has been transformed into the lexicographic preemptive goal programming (PGP) model. Table 5 lists the PGP model's objectives, along with each goal's target and priority. Establishing a goal level of attainment for every criterion is the aim of goal programming (GP). In order to use the GP method, the decision maker must set goals for each desired outcome. The solution that minimizes the departures from the predetermined objectives is then clearly identified as the preferred solution. GP aims to reduce the variances in goal attainment [22]. Maximizing the total energy for the student's chosen menu is the main goal of the problem in this study. The second priority is to keep the menu's overall cost as low as possible while still providing enough nutrients. The decision maker has recommended those as the top priorities.

TABLE 5. GOALS FOR THE PREEMPTIVE GOAL PROGRAMMING

| Objective | Goal         | Target    | Priority |
|-----------|--------------|-----------|----------|
| Maximize  | Total Energy | 2200 Kcal | 1        |
| Minimize  | Total Cost   | 4000 TSh  | 2        |

GNU Linear Programming Kit (GLPK) was used to solve the developed model. The first objective was resolved as a single goal. The first priority goal was then used as a constraint when the second priority goal was formulated and resolved. The final goal was finally formulated and resolved. Since our goal was to minimize undesirable deviations only, the final value of all deviation variables is shown in Table 6, which indicates that both goals are perfectly satisfied. In other words, the model's output gives us the maximum energy and least amount of money needed to satisfy the nutrient requirements for the student's menu.

TABLE 6. DEVIATION VARIABLE VALUES

| Nutrient | $d^-$ | $d^+$ | Remark             |
|----------|-------|-------|--------------------|
| Energy   | 0     | 150   | Excess energy      |
| Protein  | 3     | 0     | Protein deficiency |
| Fat      | 0     | 10    | Slight excess      |
| Calcium  | 50    | 0     | Large deficiency   |

A combination of cereals, legumes, fruits, vegetables, and a few foods derived from animals made up the ideal daily diet that the model produced. The chosen food items and their quantities are shown in Table 7. The findings demonstrate that while legumes and vegetables supply vital nutrients, staple foods like rice and maize considerably increase energy intake. Table 8 shows the nutrient composition of the optimized diet, which demonstrates that all nutrients taken into account in this study have reached their RDI.

TABLE 7. OPTIMAL DAILY DIET COMPOSITION

| Food Item         | Quantity (100g units) | Amount (g) |
|-------------------|-----------------------|------------|
| Whole maize ugali | 3.0                   | 500        |
| Boiled beans      | 2.5                   | 250        |
| Amaranth leaves   | 1.5                   | 150        |
| Pumpkin leaves    | 1.0                   | 100        |
| Fried sardines    | 1.0                   | 100        |
| Fresh milk        | 2.0                   | 200        |
| Banana (ripe)     | 2.0                   | 200        |
| Groundnuts        | 0.8                   | 80         |
| Boiled rice       | 1.5                   | 500        |

TABLE 8. NUTRIENT INTAKE VS RDI

| Nutrient          | Achieved Value | Recommended Value | Remark |
|-------------------|----------------|-------------------|--------|
| Energy (kcal)     | 2250           | 2200              | Met    |
| Protein (g)       | 68             | 50                | Met    |
| Fat (g)           | 64             | ≤65               | Met    |
| Carbohydrates (g) | 310            | 300               | Met    |
| Iron (mg)         | 20             | 18                | Met    |
| Calcium (mg)      | 1050           | 1000              | Met    |
| Phosphorus (mg)   | 820            | 700               | Met    |
| Vitamin C (mg)    | 110            | 80                | Met    |
| Vitamin A (μg)    | 1200           | 800               | Met    |
| Folate (μg)       | 450            | 400               | Met    |

Figure 1 also compares the achieved nutrient intake from the optimized diet model with the prescribed dietary allowances. The results showed that all nutrients either achieved or slightly exceeded their acceptable amounts. Energy intake was 2250 kcal while the required was 2200 kcal, and protein intake was 68 g instead of the recommended 50 g. While fat intake remained within the permitted range ( $64 \text{ g} \leq 65 \text{ g}$ ), carbohydrate intake slightly exceeded the need.

Micronutrients that also exceeded the required amounts include iron, calcium, phosphorus, vitamin C, vitamin A, and folate. This suggests that the proposed model successfully satisfies all dietary requirements without any significant shortcomings.

Lastly, the total cost of the optimized diet is presented in Table 9, which provide us with minimum cost for the general

food to be consumed by the students to achieve the daily nutrients requirement.

nutrients requirement.

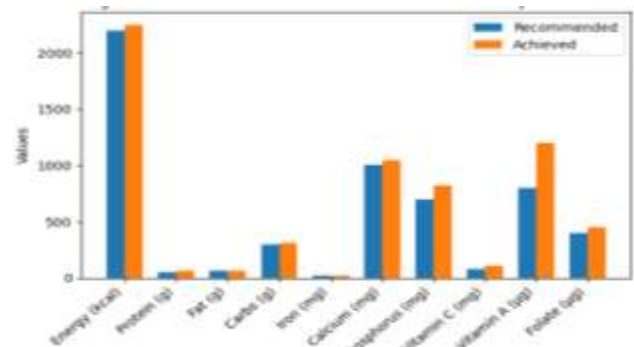


Fig. 1. Nutrient Intake vs RDI

TABLE 8. COST OF OPTIMIZED DIET

| Component         | Cost (TSh)    |
|-------------------|---------------|
| Total Daily Cost  | 3,500         |
| Budget Constraint | 4,000         |
| Remark            | Within Budget |

## V. DISCUSSION

These results show that a relatively inexpensive, nutrient-dense diet could be formulated from local foods that included maize and rice as staples (the least expensive and most energy-dense), with beans and leafy vegetables supplying most of the protein, iron, vitamin A, folate and calcium. The choice of sardines and milk providing the high-quality protein and calcium (relatively inexpensive compared with other animal-source foods, such as beef and chicken, which were not included in the optimal solution).

The results also align with other studies that have found that plant-based diets can be nutritionally adequate if supplemented with small amounts of animal-source foods, particularly in low-income settings, and that dietary diversity is important, particularly the inclusion of traditional vegetables. This optimized diet gives us some practical ideas for how to better feed students in Tanzania, showing us, that even low-income populations can achieve all of their nutritional needs through affordable diets.

## VI. CONCLUSION

In this study, a multi-objective optimization model is formulated which simultaneously solves the two objectives (energy maximization and cost minimization) for student diet problem. The study focused on university students in Tanzania particularly to Muslim University of Morogoro. The model was written in GNU Linear Programming Kit (GLPK) software and optimized, where it met all of the model's constraints and provided a promising solution. The study provides us a combination of cereals, legumes, fruits, vegetables, and a few foods derived from animals made up the ideal daily diet that can be used as a guide for student's dietary plans. The chosen food combination had 2250 kcal of energy, whereas 2200 kcal

were needed, and 68 g of protein were consumed instead of the suggested 50 g. The intake of fat stayed within the allowed range ( $64 \text{ g} \leq 65 \text{ g}$ ), while the intake of carbohydrates slightly exceeded the required amount. As a result, we may serve nutritious foods that maximize daily total energy consumption and minimize cost of the foods while taking recommended nutritional intake (RNI) into account for Tanzanian university students utilizing locally accessible foods.

## REFERENCES

- [1] M.C. Nelson, M. Story, N.I. Larson, D. Neumark-Sztainer, L.A. Lytle, Emerging Adulthood and College-aged Youth: An Overlooked Age for Weight-related Behavior Change, *Obesity* 16 (2008) 2205–2211. <https://doi.org/10.1038/oby.2008.365>
- [2] I. Kusumastuty, P.H. Maulia, D.R. Dewi, R. Oktania, F.A. Nugroho, D. Handayani, Hubungan Antara Indeks Massa Tubuh dan Persen Lemak Tubuh dengan Kebiasaan Makan pada Mahasiswa di Malang: Relationship between Body Mass Index, Body Fat Percentage, and Eating Habits among University Students in Malang, *Amerta Nutr.* 9 (2025) 419–429. <https://doi.org/10.20473/amnt.v9i3.2025.419-429>
- [3] Higher Education Students' Loans Board (HESLB), Annual Report 2021/2022, Dar es Salaam, Tanzania, 2022. [https://www.heslb.go.tz/category/heslb-annual-reports-and-financial-statements?utm\\_source=chatgpt.com](https://www.heslb.go.tz/category/heslb-annual-reports-and-financial-statements?utm_source=chatgpt.com) (accessed August 4, 2026).
- [4] Y.X. Miow, W.K.H. Mok, W.Y. Gan, P.Y. Lim, G. Appannah, S.N. 'Asyura Adznam, The use of linear programming approach in diet optimization among children under five: a scoping review, *BMC Public Health* 25 (2025) 1279. <https://doi.org/10.1186/s12889-025-22414-y>
- [5] L. Donkor, E. Essien, N.S. Affrifah, A Systematic Review of Linear Programming Techniques as Applied to Diet Optimisation and Opportunities for Improvement, *J. Optim.* 2023 (2023) 1–17. <https://doi.org/10.1155/2023/1271115>
- [6] Universiti Teknologi MARA, Malaysia, N.A. Baki, Application of Linear Programming in Students' Diet Problem, *Int. J. Adv. Trends Comput. Sci. Eng.* 8 (2019) 87–90. <https://doi.org/10.30534/ijatcse/2019/1881.52019>
- [7] A.M. Anderson, M.D. Earle, Diet Planning in the Third World by Linear and Goal Programming, *J. Oper. Res. Soc.* 34 (1983) 9–16. <https://doi.org/10.1057/jors.1983.2>
- [8] Polytechnic Gospic, K. Devčić, MINIMIZATION OF THE DIET COSTS ON THE THREE-DAY MENU EXAMPLE, *Int. J. Vallis Aurea* 3 (2017) 15–24. <https://doi.org/10.2507/IJVA.3.1.2.33>
- [9] N.A. Zailani, L.K. Howe, S.F. Sufahani, Economical and Mathematical Impact on Planning Balanced and Nutritious Diet for Paralympic (Autistic) Athlete (100M Sprinter) Using Linear and Integer Programming Approach, *Sci. Technol. Indones.* 10 (2025) 588–597. <https://doi.org/10.26554/sti.2025.10.2.588-597>
- [10] P. Manmohan, R. Bhardwaj, S. Choudhary, Linear Programming for Optimal Diet Decision Problem, *Int. J. Innov. Technol. Explor. Eng.* 8 (n.d.) 1396–1403.
- [11] U. Prajapati, T. Jain, A. Machiraju, D. Kaushik, Linear Optimization for the Perfect Meal: A Data-Driven Approach to Optimising the Perfect Meal Using Gurobi, (2025). <https://doi.org/10.48550/ARXIV.2501.04143>
- [12] O.T. Altınöz, Designing Diet Program That Balancing Nutritional Adequacy with Environmental Sustainability by Using Multi-Objective Optimization, in: 2025.
- [13] L.T. Soe, U. Fahmida, A.N.L. Seniati, A. Firmansyah, Nutrients Essential for Cognitive Function Are Typical Problem Nutrients in the Diets of Myanmar Primary School Children: Findings of a Linear Programming Analysis, *Food Nutr. Bull.* 41 (2020) 211–223. <https://doi.org/10.1177/0379572119878070>
- [14] V.B. Yadav, R. Dhabas, Student diet problem using linear programming approach, 2024.
- [15] S. Shiratori, M.D. Abeysekara, Relevance of Mathematical Optimization as a Tool for Diet Modeling in the Development of Food-Based Dietary Recommendations in Sub-Saharan Africa: A Scoping Review, *Adv. Nutr.* 16 (2025) 00480. <https://doi.org/10.1016/j.advnut.2025.100480>
- [16] Z. Lukmanji, E. Hertzmark, N. Mlingi, V. Assey, G. Ndossi, W. Fawzi, Tanzania Food Composition Tables, Muhimbili Univ. Health Allied Sci. MUHAS Tanzan. Food Nutr. Cent. TFNC Harv. Sch. Public Health HSPH (2008).
- [17] U. Ruth Charrondière, B. Stadlmayr, D. Rittenschober, B. Mouille, E. Nilsson, E. Medhammar, T. Olango, S. Eisenwagen, D. Persijn, K. Ebanks, V. Nowak, J. Du, B. Burlingame, FAO/INFOODS food composition database for biodiversity, *Food Chem.* 140 (2013) 408–412. <https://doi.org/10.1016/j.foodchem.2012.08.049>
- [18] N.K. Fukagawa, K. McKillop, P.R. Pehrsson, A. Moshfegh, J. Harnly, J. Finley, USDA's FoodData Central: what is it and why is it needed today?, *Am. J. Clin. Nutr.* 115 (2022) 619–624. <https://doi.org/10.1093/ajcn/nqab397>
- [19] Organisation des Nations Unies pour l'alimentation et l'agriculture, Organisation mondiale de la santé, eds., Fats and fatty acids in human nutrition: report of an expert consultation 10-14 November 2008, Geneva, FAO, Rome, 2010.
- [20] Weltgesundheitsorganisation, ed., Vitamin and mineral requirements in human nutrition, 2. ed, Geneva, 2004.
- [21] Book Review: Vitamin and Mineral Requirements in Human Nutrition, *Food Nutr. Bull.* 27 (2006) 82–82. <https://doi.org/10.1177/156482650602700117>
- [22] M. Izadikhah, R. Roostaei, F. Hosseinzadehloufi, Using goal programming method to solve DEA problems with value judgments, *Yugosl. J. Oper. Res.* 24 (2014) 267–282. <https://doi.org/10.2298/YJOR12210151>