ENHANCED KNOWLEDGE IN SCIENCES AND TECHNOLOGY
e-ISSN: 2773-6385

EKST

Vol. 5 No. 1 (2026) 245-255
https://publisher.uthm.edu.my/periodicals/index.php/ekst

Integer Programming for Solving Hospital Hypertension Patient Menu Planning

Nurul Ain Muhammad[1], Azila Md Sudin[1]*

[1] *Department of Mathematics and Statistics, Faculty of Applied Sciences and Technology, UTHM Kampus Cawangan Pagoh, Hab Pendidikan Tinggi Pagoh, KM 1, Jalan Panchor, 84600 Pagoh, Muar, Johor, MALAYSIA.*

*Corresponding Author: azzila@uthm.edu.my
DOI: https://doi.org/10.30880/ekst.2026.06.01.030

Article Info

Received: 4 January 2026
Accepted: 20 January 2026
Available online: 9 July 2026

Keywords

Integer Programming, Delete-Reshuffle Algorithm, Hypertension, Hospital Menu Planning, Nutritional Optimization, Malaysian Diet

Abstract

The management of hypertension in hospitals has to be an issue of proper dietary planning so that the blood pressure may be controlled and also the diet must be nutritionally adequate. In Malaysia, the present approach to hospital menu planning with hypertension patients is not very systematic, and the menu plan can be nutritionally unbalanced or too expensive. The paper comes up with an Integer Programming (IP) model together with the Delete-Reshuffle Algorithm (DRA) to design an efficient seven-day meal plan among hypertension patients in Malaysian hospitals. The model is based on the database of 426 Malaysian food items in ten categories and minimizes the cost, but it adheres to the Recommended Nutrient Intakes (RNI) 2017 standards of six main nutrients: sodium, protein, potassium, vitamin B2, calcium and vitamin C. The optimization was done with the help of computational techniques whereby emphasis is put on low-cost items yet meet nutritional and food group requirements. The findings indicate a weekly meal plan with a price of RM 109.10 (RM 15.60 per day) with 112 meal components in six eating occasions throughout a day, which will provide full dietary variety. The distribution of all the nutrients was always in compliance with RNI, and the daily sodium consumption was significantly lower than 2000 mg (556-1717 mg variation). The DRA also was able to reduce meal repetitions without compromising cost-effectiveness and nutritional compliance. This framework shows that hypertension management hospital meal plans that are culturally appropriate, economical and produce clinically appropriate results can be obtained by mathematical optimization.

1. Introduction

High blood pressure or hypertension is a worldwide health concern of the population. It is reported as happening when the blood pressure in the vessels is above 140/90 mmHg, as referred to as [1]. The primary causes are elevated cholesterol, bad diet and lack of exercise. The chronic complications that may occur in case of lack of proper nutritional management include diabetes, heart disease, and osteoporosis. This is what is referred to as a silent killer in the sense that the symptoms are not noticed until when they have caused a lot of harm [1].

As nutrition plays a vital role in hypertension treatment, meal planning in hospitals is a necessary factor to recover and further health of patients. Healthy dieting is associated with prevention and management of diseases as well as the reduction of blood pressure as the case of the Dietary Approaches to Stop Hypertension (DASH) dietary program shows [2]. The nutritional condition, recovery of the patients, and their health in general of the hospital patients is greatly determined by the planning of the meal taken daily. The guidelines of standard food services in Malaysian hospitals are generally based on the international health standards of the world that relies on the global health standards established by the World Health Organization and the Malaysian Recommended Nutrient Intakes (RNI) that are published by the Ministry of Health Malaysia (MOH) [3].

Hypertension is a significant non-communicable disease which impacts millions of people across the globe and is closely connected with diet habits. The food provided to the hypertensive patients in the hospitals is not generally very good, even though proper nutrition is crucial in the treatment and recovery of the patients. Nevertheless, menu planning is a complicated process since it must consider several limitations including sodium quantities, calories ratio, nutrient portions, prices, and food supply.

To solve the problem of developing different and at the same time nutritionally compliant meal plans, this work uses the iterative optimization method that is aimed at improving the variety of meals. It leads to less food repetition and a more varied seven-day meal plan that meets all the nutritional requirements. Optimization techniques, specifically designed to solve menu planning problems, offer efficient and dependable menu selections that may be utilized in hospitals [4]-[7].

This study will focus on Integer Programming (IP), among other optimization techniques, as the most suitable technique of dealing with discrete decisions in menu selection with dietary and logistical constraints aimed at ensuring hypertension patients. IP can be applied specifically well to this issue since this will guarantee that meal portions are chosen in whole numbers, which are in accordance with the hospital practice and accepted dietary conventions. Healthcare providers can control the conditions of hypertension patients in a cost-effective and efficient way by devising the best meal plans that will only follow the nutritional demand.

Hypertension is a significant non-communicable disease that reaches millions of patients all over the world and is closely related to diet. The nutrition that hypertension patients receive in hospitals is also substandard, although proper nutrition is one of the crucial factors of treatment and recovery. The menu planning is not a simple process that should consider various limitations such as sodium intake, calorie balance, nutritional balance, cost, and availability of foods. This is in addition to the fact that there is a requirement of offering nutritionally sufficient yet culturally satisfactory and acceptable meals to patients.

The paper also fills in a major gap in the current literature, since the data presented on a seven-day menu is the most practical and is not as a single-day menu planning approach that is observable in the literature. Majority of the literature on diet optimization focuses solely on planning of the daily menu of hypertension patients [8]-[9], which does not suffice in the real hospital settings where the patient may need different types of nutritionally balanced diets over a long duration. It is not possible to ensure dietary variety and avoid redundancy with a one-day menu, and this factor can lead to a decrease in patient satisfaction and adherence to dietary instructions.

The given research makes use of an extensive database of ten food categories and 426 Malaysian foods to represent meals under four meal categories, breakfast, lunch, evening tea, and dinner. An algorithmic strategy is used to make sure that the food varieties are dissimilar and balanced in nutritional value by restricting the frequency of food consumption of a particular food type. This systematic approach guarantees that there is no food repetition in a period of seven days of meals and at the same time, does not provide them with nutrient deficit based on RNI 2017. The outcome is a seven-day meal plan which is diversified and sufficient in nutrition to help in hypertension management.

Consequently, the proposed study will address the issue of hospital menu planning with the use of IP. This methodological option corresponds to the operational activity in hospital food services and can be used to make sure that the menu plans are feasible and practicable. The study aims at enhancing the efficiency of the food service in hospitals, and the patients are provided with food that suits their condition.

The particular aims of the current research project are to develop an IP model to calculate the lowest possible cost of the menu planning of hypertension patients, and to propose a seven-day menu plan of hypertension patients in Malaysia through an IP model with the help of the Delete-Reshuffle Algorithm (DRA) depending on the local food preferences.

2. Research Design

This study uses a quantitative optimization methodology using a mathematical model to design diets. The secondary data used to gather the study on food data is through food databases and nutritional guidelines. This is mathematically formulated and optimized as a methodology, with algorithmic optimization which increases variety and minimizes meals repetition. All the calculations and model implementation are done with computational tools. The study aims to make sure that an appropriate choice of food is made in the proper quantities such that the meals satisfy the medical and nutritional needs regarding the management of hypertension.

2.1 Data Collection

In this research, secondary data were used to come up with and optimize a seven-day hospital meal plan among patients with hypertension. The nutritional data of 426 Malaysian foods was derived in previous studies [8], which classified such products into ten dietary categories. Besides, nutritional advice was formulated based on the RNI 2017 released by the MOH The main idea that can be justified by this data is that optimization techniques are used to make meal plans of hypertension people. The database includes different Malaysian foods and the nutritional contents. Each product has nutritional details on the amount of sodium, protein, calcium, potassium, vitamin B2, and vitamin C. The available comprehensive database allows the choice of culturally suitable foods and satisfies the clinical nutritional needs.

2.2 Model Formulation

The IP model was formulated to minimize total weekly meal cost while satisfying nutritional constraints. The objective function is expressed as:

$$Minimize\ cost, Z = \sum_{i=1}^{426}\sum_{j=1}^{10}\sum_{k=1}^{4} c_i x_{ijk} \tag{1}$$

where x_{ijk} represents decision variables for food item i (1-426), food group j (1-10), and meal occasion k (1-4), and c_i denotes the cost per unit of food item i.
Subject to nutritional constraints:
For each nutrient n (sodium, protein, potassium, vitamin B2, calcium, vitamin C):

$$LB \leq \sum_{i=1}^{426}\sum_{j=1}^{10}\sum_{k=1}^{4} W_i x_{ijk} \leq UB \tag{2}$$

where W_i represents the weight of nutrient for the food, and LB and UB denote the lower and upper bounds based on RNI 2017 guidelines.

The meal structure comprises 16 food items daily distributed across six meal occasions (breakfast, lunch, evening tea, and dinner) over seven consecutive days, totalling 112 meal components. The constraints in this study are expressed as follows for six nutrients, Sodium (mg), Protein (g), Potassium (mg), Vitamin B2 (mg), Calcium (mg), and Vitamin C (mg), each following the general form shown in Equation 2.

Specific nutrient constraints based on RNI 2017:

$$Sodium\ (mg): 460 \leq \sum_{i=1}^{426}\sum_{j=1}^{10}\sum_{k=1}^{4} Na_i x_{ijk} \leq 2000 \tag{3}$$

$$Protein\ (g): 20 \leq \sum_{i=1}^{426}\sum_{j=1}^{10}\sum_{k=1}^{4} P_i x_{ijk} \leq 56 \tag{4}$$

$$Potassium\ (mg): 1500 \leq \sum_{i=1}^{426}\sum_{j=1}^{10}\sum_{k=1}^{4} Po_i x_{ijk} \leq 3500 \tag{5}$$

$$Vitamin\ B2\ (mg): 0.6 \leq \sum_{i=1}^{426}\sum_{j=1}^{10}\sum_{k=1}^{4} Vb2_i x_{ijk} \leq 1.60 \tag{6}$$

$$Calcium\ (mg): 300 \leq \sum_{i=1}^{426}\sum_{j=1}^{10}\sum_{k=1}^{4} Ca_i x_{ijk} \leq 1000 \tag{7}$$

$$Vitamin\ C\ (mg): 65 \leq \sum_{i=1}^{426}\sum_{j=1}^{10}\sum_{k=1}^{4} Vc_i x_{ijk} \leq 500 \tag{8}$$

Where:
$\boldsymbol{Na_i}$ = Sodium content (mg) per unit of food item i
$\boldsymbol{P_i}$ = Protein content (g) per unit of food item i
$\boldsymbol{Ka_i}$ = Potassium content (mg) per unit of food item i
$\boldsymbol{Vb2_i}$ = Vitamin B2 content (mg) per unit of food item i
$\boldsymbol{Ca_i}$ = Calcium content (mg) per unit of food item i

$\boldsymbol{Vc_i}$ = Vitamin C content (mg) per unit of food item i

2.3 Delete-Reshuffle Algorithm

Delete-Reshuffle Algorithm (DRA) is an algorithm that allows post-optimization refinement to remove repetitions in foods without altering the solution feasibility and nutritional compliance [10]. The algorithm was created with the particular purpose of menu planning software where diversity is a key to patient satisfaction and compliance. The procedure of the algorithm is described as follows:

Step 1: Detection Phase
The algorithm starts by scanning systematically the first seven-day menu and pointing at food items that are repeated on two or more days/meal occurrences. The duplicates are all listed down in a list to be processed later.

Step 2: Substitution Phase
On each duplicate identified, the algorithm determines the food category on which the duplicate item belongs. It then picks alternative foodstuff in the same food category with preference to those alternatives that have similar nutritional composition and cost. The replica product is then substituted with the chosen one.

Step 3: Verification Phase
Following every replacement, the algorithm re-calculates the total nutrient content of all six nutrients and ensures all nutritional constraints (Equations 3-8) remain satisfied. Any increase in cost is also checked by the algorithm at reasonable levels. In case any of the constraints are violated, then the algorithm chooses another alternative or replaces the item to ensure feasibility.

Step 4: Iteration
The algorithm repeats Step 1 to 3 until one of the following termination conditions are met: the menu has no food repeats which imply optimal diversity has been achieved, no possible substitutions are possible that satisfy all constraints or the maximum number of iterations is met.

The algorithm focuses on solution feasibility, and every substitution is immediately accompanied by a thoroughness of constraints validation with respect to RNI 2017 constraints. This makes sure that the quest of variety does not affect nutritional adequacy and pushes 1q the costs above the acceptable levels.

The DRA is shown to be useful in several dietary planning cases. [10] successfully used the algorithm to optimize the nutritious menus of Malaysian school children between the age of 13-18 with Binary Integer Programming. In the same light, [11] proved to be effective in the optimal diet planning of patients with eczema. When considering high blood pressure patients and the problem of menu scheduling, [8] combined the algorithm with the IP and obtained nutritional compliance as well as meal variety.

2.4 Solution Approach

The IP is used to construct a seven-day meal plan for patients with hypertension, and the quantitative optimization approach is applied. The IP model also makes sure that the quantity of meal servings to be taken is in whole numbers, as per the standards of the hospital and the established dietary practices. The RNI 2017 published by MOH [3] is used as a guideline to nutritional restrictions. After preliminary rounds of optimization, the DRA is implemented to decrease food repetitions and expand menu acceptability, and this subsequently improves solution feasibility and diversity. The entire model is implemented and solved by using computational software.

The IP model involves the utilization of a database of 426 Malaysian food products classifies into 10 food groups to choose appropriate food items to each of the 4 meal occasions (breakfast, lunch, evening tea and dinner) over 7 days. The objective subject to nutritional constraints minimizes cost but keeps the daily consumption within lower and upper limits based on RNI. All variables of decision are whole food portions representing whole numbers.

The optimization used is a heuristic implementation. The choice procedure puts less emphasis on high-cost foodstuff, although it addresses specific nutritional and food category limitations. In line with the first solution, the DRA enhances the menu diversification in a systematic way by using the iterative cycle outlined in Section 2.3, which guarantees nutritional compliance and menu variety.

3. Results and Discussion

This section reveals the findings of applying IP to the DRA to come up with an ideal seven-day meal plan in hypertension patients within Malaysian hospitals. Values of the objective function, compliance with nutritional guidelines, the selection of the specific food items, and analysis of costs are analysed.

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3.1 Optimal Solution from Integer Programming Model

The formulation of the IP model was effectively executed with the help of the heuristic-based optimization methodology, which allowed us to optimize a seven-day meal plan of hypertension patients. The model took 426 food items of 10 food categories to pick 16 food items per day (a total of 112 food items in seven days) without violating nutritional restrictions and minimizing the overall cost [8]. The heuristic selection program will consider the foods that are of low cost, yet all nutritional needs will be satisfied daily. This simply makes sure that all of the decision variables that denote the food dish selections which are necessary in the operation of the hospital food services assume integer values.

The next tables depict seven-day meal plan generated by IP model using DRA optimization. The daily menu will be divided into six meal events, including breakfast, lunch, evening tea and dinner. Every meal has certain foods of pertinent food categories to be chosen to fulfil nutritional needs as well as kept at its economic and cultural suffering ability.

Table 1 Day 1 Meal Plan (Cost: RM12.80)

Meal	Food Item	Amount	Cost (RM)
Breakfast	Plain water	1	0.80
	Biscuit, cream crackers	1	0.50
	Buah asam jawa	1	0.50
Lunch	Plain water	1	0.80
	Plain rice	1	2.00
	Kuih peneram	1	0.20
	Chicken satay	1	0.80
	Cashew leaves	1	0.50
Evening Tea	Plain water	1	0.80
	Papaya	1	0.80
	Cokodok pisang	1	0.40
Dinner	Plain water	1	0.80
	Plain rice	1	2.00
	Kuih buah melaka	1	0.50
	Cucumber	1	0.50
	Fish, unspecified, dried, salt	1	0.90
Total Daily	16 items	16	12.80

Table 1 shows the meal plan of Day 1 at RM 12.80, the most affordable meal of Day 1 with such staples as cream crackers, plain rice, and local fruits (buah asam jawa, papaya) and traditional types of kuih, making it the most cost-effective day.

Table 2 Day 2 Meal Plan (Cost: RM14.70)

Meal	Food Item	Amount	Cost (RM)
Breakfast	Plain water	1	0.80
	Bread, white	1	0.80
	Binjiai	1	1.00
Lunch	Plain water	1	0.80
	Plain rice	1	2.00
	Bidaran	1	0.50
	Fern shoots	1	0.50
	Anchovy, dried, fried in chilli	1	1.00
Evening Tea	Plain water	1	0.80
	Duku	1	1.00

	Kuih kacang	1	0.70
Dinner	Plain water	1	0.80
	Plain rice	1	2.00
	Chee-pah	1	0.50
	Cucumber, hairy	1	0.50
	Indian mackerel, fried	1	1.00
Total Daily	16 items	16	14.70

Table 2 indicates that the meal plan on Day 2 at RM 14.70 has added variety in terms of the type of food (white bread and new fruits (binjai, duku)) and the type of seafood (anchovy and Indian mackerel) at an affordable price.

Table 3 Day 3 Meal Plan (Cost: RM15.00)

Meal	**Food Item**	**Amount**	**Cost (RM)**
Breakfast	Plain water	1	0.80
	Biscuit, alphabet	1	1.00
	Langsat	1	1.00
Lunch	Plain water	1	0.80
	Plain rice	1	2.00
	Tapai pulut	1	0.50
	Indian Pennywort	1	0.50
	Indian mackerel, fried in chilli	1	1.00
Evening Tea	Plain water	1	0.80
	Water apple	1	1.00
	Kuih kasui	1	0.80
Dinner	Plain water	1	0.80
	Plain rice	1	2.00
	Rempeyek	1	0.60
	Yam stalks	1	0.50
	Sambal udang	1	1.00
Total Daily	16 items	16	15.00

Table 3 presents the meal plan of Day 3 that costs RM 15.00, featuring traditional Malaysian cuisine, such as tapai pulut and rempeyek, as well as local biscuits of the alphabet and other local fruits, that will not disrupt the balance of nutrition and relevance to culture.

Table 4 Day 4 Meal Plan (Cost: RM16.10)

Meal	**Food Item**	**Amount**	**Cost (RM)**
Breakfast	Plain water	1	0.80
	Bread, wholemeal	1	1.10
	Banana (pisang abu)	1	1.10
Lunch	Plain water	1	0.80
	Plain rice	1	2.00
	Tumpi	1	0.60
	Beef satay	1	1.20
	Tomato only	1	0.60

Evening Tea	Plain water	1	0.80
	Banana (pisang berangan)	1	1.10
	Kuih sagu	1	0.70
Dinner	Plain water	1	0.80
	Plain rice	1	2.00
	Wajik	1	0.60
	Quail egg, whole	1	1.20
	Cauliflower	1	0.70
Total Daily	16 items	16	16.10

Table 4 shows that the Day 4 meal plan will start with wholemeal bread, various types of bananas (pisang abu, pisang berangan), beef satay, and even more vegetable options such as cauliflower and tomato.

Table 5 Day 5 Meal Plan (Cost: RM16.50)

Meal	Food Item	Amount	Cost (RM)
Breakfast	Plain water	1	0.80
	Bread ryemeal	1	1.10
	Banana (pisang mas)	1	1.10
Lunch	Plain water	1	0.80
	Plain rice	1	2.00
	Dodol	1	0.70
	Gourd, bitter	1	0.70
	Indian mackerel, in soya sauce	1	1.20
Evening Tea	Plain water	1	0.80
	Banana (pisang nangka)	1	1.10
	Laddu	1	0.70
Dinner	Plain water	1	0.80
	Plain rice	1	2.00
	Dodol durian	1	0.80
	Soya bean sprout	1	0.70
	Red snapper cooked in tamarind	1	1.20
Total Daily	16 items	16	16.50

Table 5 demonstrates the costing of meal plan on Day 5, which is RM 16.50 to cover ryemeal bread, another type of banana (pisang mas, pisang nangka), traditional desserts (dodol, laddu), and various types of foods that are prepared using fish and various kinds of vegetables.

Table 6 Day 6 Meal Plan (Cost: RM16.80)

Meal	Food Item	Amount	Cost (RM)
Breakfast	Plain water	1	0.80
	Biscuit savoury	1	1.20
	Banana (pisang tanduk)	1	1.10
Lunch	Plain water	1	0.80
	Plain rice	1	2.00
	Kuih kasui	1	0.80

	Sweet potato shoots	1	0.70
	Red snapper, fried in chilli	1	1.20
Evening Tea	Plain water	1	0.80
	Lychee	1	1.10
	Kerepek ubi kayu	1	0.80
Dinner	Plain water	1	0.80
	Plain rice	1	2.00
	Kuih koci pulut hitam	1	0.80
	Tapioca shoots	1	0.70
	Tuna, cooked in coconut milk	1	1.20
Total Daily	16 items	16	16.80

The meal plan of Day 6 in Table 6 reflects RM 16.80 meal with savoury biscuits, pisang tanduk, lychee, traditional snacks (kerepek ubi kayu), and different ways of preparing fish and leafy vegetables.

Table 7 Day 7 Meal Plan (Cost: RM17.20)

Meal	Food Item	Amount	Cost (RM)
Breakfast	Plain water	1	0.80
	Oats, processed, tinned	1	1.40
	Mangosteen	1	1.10
Lunch	Plain water	1	0.80
	Plain rice	1	2.00
	Tepung bungkus	1	0.80
	Yam bean	1	0.70
	Yellow-banded travelly, in tamarind	1	1.20
Evening Tea	Plain water	1	0.80
	Candy, coconut	1	0.80
	Salak	1	1.10
Dinner	Plain water	1	0.80
	Plain rice	1	2.00
	Kuih karas	1	0.90
	Carrot	1	0.80
	Cuttlefish crackers	1	1.20
Total Daily	16 items	16	17.20

Table 7 shows the meal plan of Day 7 at RM 17.20, the most expensive one which includes processed oats, high-end fruits (mangosteen, salak), and assorted traditional kuih, which proves that even high-end choices of meals can be afforded by a hospital budget.

3.2 Total Cost Analysis

The IP model minimized the overall weekly meal expense among hypertension patients unsuccessfully. The optimization model generated a seven-day meal plan with total RM 109.10 weekly cost averaging at RM 15.60 per patient per day. There was a gradual rise in the cost on Day 1 (RM 12.80) to Day 7 (RM 17.20), and it shows that the DRA prioritized food variety and nutritional balance but did not compromise the cost.

Table 8 Daily Cost Summary for Seven-Day Meal Plan

Day	Total Cost (RM)
Day 1	12.80
Day 2	14.70
Day 3	15.00
Day 4	16.10
Day 5	16.50
Day 6	16.80
Day 7	17.20
Total Weekly Cost	109.10
Average Daily Cost	15.60

Table 8 has given an average daily cost of RM 15.60, which is a financially viable solution to the meal planning of the hospital. Compared to the current cost of providing food services to the patients of the hospital in Malaysia, this cost means that the nutritionally designed meal plans to the patients who have high blood pressure can be implemented without causing significant financial burden to the health facility. The relative cost changes throughout the week are indicative of the algorithm in generating variety at the same time controlling cost with the least costly day (Day 1) of RM 12.80 and the most varied with RM 17.20 which is only 34% difference and still within reasonable budgetary limits.

3.3 Nutritional Compliance

The nutritional assessment indicates that the optimized meal plan effectively fulfils the RNI 2017 guidelines for adults with hypertension across all monitored nutrients.

Table 9 Daily Nutrient Intake Across Seven Days

Day	Sodium	Protein	Potassium	VitB2	Calcium	VitC
1	1717	55.9	2030	1.17	311	165.3
2	1623	48.1	1650	1.10	324	211.4
3	1580	45.6	1530	0.61	302	80.7
4	1222	55.1	2000	1.51	305	101.6
5	1447	47.2	2280	0.991	344	97.6
6	1433	45.3	2010	1.12	370	191.1
7	1625	30.8	1580	0.72	416	79.1

Table 9 shows the daily changes in nutrients based on the different types of meals. The sodium levels vary between 1222mg (Day 4) and 1717mg (Day 1), protein between 30.8g to 55.9g, and potassium between 1530mg to 2280mg. The differences allow nutritional adequacy and dietary diversity in the week. The fluctuations show that the model has been effective in balancing diversity and a consistent nutritional profile without having to resort to repetitive menus and at the same time maintain all of the nutrients in safe and therapeutic levels.

Table 10 RNI 2017 Requirements vs. Achieved Values

Nutrient	RNI lower bound	RNI upper bound	Minimum Achieved	Maximum Achieved	Compliance Status
Sodium (mg)	460	2000	1222	1717	Compliant
Protein (g)	20	56	30.8	55.9	Compliant
Potassium (mg)	1500	3500	1580	2280	Compliant
Vitamin B2 (mg)	0.6	1.6	0.61	1.51	Compliant
Calcium (mg)	300	1000	305	416	Compliant
Vitamin C (mg)	65	500	79.1	211.40	Compliant

Table 10 proves an overall adherence to all the six nutrients. There was always a large, sustained decrease in sodium levels, which were not great enough to reach the critical threshold of 2000 mg/day [2] and the daily range was 1222 mg to 1717mg. It is especially crucial due to the overall management of hypertension because the overconsumption of sodium is one of the leading risk factors of hypertension. Day 4 had the lowest sodium level of 1222mg, and Day 1 had the highest at 1717 mg, but both were within the acceptable therapeutic range.

In terms of protein consumption, patients were taking between 30.8g and 55.9g of protein daily, which met the nutritional requirements of adult patients and helped to restore tissues and tissue repair, as well as immune system functioning. The difference in protein levels over the days indicates the existence of diverse protein sources such as fish, eggs and plant-based proteins that guarantee a variety of proteins in the diet. The concentration of potassium between 1530 mg and 2280 mg was in the recommended amounts. Sufficient potassium is also especially necessary in case of hypertension since it assists in the overcoming of sodium influence and functioning of healthy blood pressure [12]-[13].

Total micronutrient consumption was adequate to promote major physiological processes. The consumption of vitamin B2 (0.61-1.51 mg) helped in proper energy metabolism and functioning of cells. The calcium consumption (302-416 mg) was beneficial in sustaining bone health and vascular functions which has significance in the cardiovascular health of patients with hypertension. The antioxidant protection with vitamin C intake (79.1-211.4 mg) and improvement of immune work [14] as well as maintenance of vascular health were supported. The level of all micronutrients was not exceeded in their corresponding RNI ranges during the next seven days, thus illustrating the ability of the model to achieve several nutritional goals in a single instance.

The fact that the IP formulation and the DRA are effective in generating clinically appropriate meal plans is proven by the constant compliance of all the nutrients and all the days. The model has managed to strike a balance between competing goals of minimizing costs, increasing variety, and ensuring nutritional adequacy and thereby provide a feasible and practical solution to be used in hospitals.

4. Conclusion

The study has been able to prove that IP and DRA is a viable and practicable solution to the problem of hospital menu planning to hypertensive patients in Malaysia. The RM 109.10 a week (RM 15.60 a day) optimized menu plan will include 112 various meal components but will not exceed all six nutrients in RNI 2017 recommendations. The sodium levels were maintained at a very low level that is below the 2000 mg limit (1222-1717 mg/day) that is essential in the management of hypertension.

The DRA was useful in avoiding food redundancies and still ensuring that it was feasible, nutritionally compliant and cost effective. The 426 genuine Malaysian food items will provide cultural relevancy, and this will be applied immediately within the Malaysian healthcare context. This model shows that mathematical optimization can generate clinically appropriate, cost-effective and culturally sensitive hospital diets.

This method should be piloted in healthcare facilities and feedback collected on patients. The model can be generalized to include more dietary constraints and use the availability of food in the seasons. Hospital information systems integration would allow automated menu generation based on patients. The future studies are supposed to address the preferences of patients and authenticate health outcomes. This framework is an invitation to healthcare administrators to implement it as an aid to decision-making and tailor the food database to the local supply and the limitations of the institution.

Acknowledgement

The authors would also like to thank the Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia for its support.

Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Nurul Ain Muhammad;* ***solve the equations:*** *Nurul Ain Muhammad;* ***analysis and interpretation of results:*** *Nurul Ain Muhammad, Azila Md. Sudin;* ***draft manuscript preparation:*** *Nurul Ain Muhammad, Azila Md. Sudin. All authors reviewed the results and approved the final version of the manuscript.*

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