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Developing Optimal Food Menu for Diabetic Patients in Malaysia using Diet Optimization Model

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Abstract

Type 1 diabetes, Type 2 diabetes, and gestational diabetes are the three forms of diabetes. However, Type 2 diabetes is the most frequent diabetes in Malaysia. People with serious disease like diabetes tend to be affected by pandemic Covid-19 since the virus is able to inflict direct injury to the pancreas. Overweight and obesity are also the main contributors to diabetes since it can increase level of fatty acids in blood. In addition, insulin for diabetic individuals nowadays costs between RM500 and RM1000 per month, including injection equipment, medicine, and supplements. Therefore, to reduce the cost, healthy lifestyle such as proper diet and exercise can help diabetic patients to reduce their blood sugar level, boost insulin sensitivity and indirectly can help everyone in Malaysia, including low- and middle-income people. To manage a proper diet, a diet optimization model, based on linear programming with the aid of Microsoft Excel is one of the best techniques to develop menus that are acceptable for Malaysian preferences for diabetic patients at a low cost but at the same time provide adequate nutrition. As a result, we created palatable menus for one day for diabetic patients that require 1400, 1600 and 1800 kcal per day with only cost below RM12 only. However, we can increase the number of decision variables and constraints in the model by include more food items and calorie consumption to get better results. Future researchers should take into account particular parameters including gender, age, blood pressure, and blood lipid

Keyword: Diet optimization; linear programming; diabetes

1. Introduction

Diet optimization using Linear Programming (LP) is one of the mathematical methods for creating a menu plan that adheres to nutrition guidelines. The overall cost of food or the total energy content of the diet might be the objective functions of a diet optimization model, while the constraints ensure that the suggested diet plans match the requisite nutrition and palatability.

Malaysia has the highest obesity and overweight rates in Asia, with 64 percent of men and 65 percent of women being obese or overweight, which can lead to diabetes [33]. Diabetes is a chronic and non-communicable disease caused by the pancreas' failure to produce adequate insulin. Diabetic individuals experience frequent urination, especially at night, as well as a constant sense of hunger and thirst. In April 2022, Malaysia has been declared covid-19 as an endemic in Malaysia. Covid-19 and diabetes have a bidirectional relationship since the virus is able to inflict direct injury to pancreas. Covid-19 infection is more common in the elderly and individuals who have significant illnesses. It might be challenging for diabetic people, in particular, because it involves pulmonary and cardiac [29]. Others than that, adults who live in food-insecure households have a 50% higher risk of diabetes than those who live in food-secure households [13] since deficiency of a dense meal can heighten the risk for diabetes complications and hyperglycemia.

In Malaysia, the overall yearly cost of diabetes was projected to be around USD 600 millionor RM 2,537,100,000 which were associated with age, type of hospital or health provider. This research study can help the government to restore economic recovery by decreasing the usage of insulin by taking proper diet and exercise to reduce blood sugar levels and boost insulin sensitivity.

This research aims to (1) to formulate Linear Programming (LP) to find the minimum cost food for diabetic patients, (2) to find the optimal nutrients in each meal for diabetic patients based on nutrition recommendation and (3) to construct the menus for diabetic patients that is suitable for Malaysia preferences.

2. Literature Review

2.1. Types of Diabetes Mellitus

Diabetes, commonly known as diabetes mellitus (DM), is a serious medical condition in which the amount of sugar in the blood is unusually high due to a lack of insulin production. Diabetes Type 1, Diabetes Type 2, and gestational diabetes are the three basic kinds of diabetes. T2DM (Type 2 Diabetes Mellitus) is the most common type of diabetes in the world. In 2019, 1,614,363 patients were registered, with T2DM being diagnosed in 99.3% of them and the majority of the patients (57.1%) were female and Malay (59.2%) [3]. Type 1 Diabetes Mellitus (T1DM) accounts for around 5% of all diabetes diagnoses, and its global prevalence is increasing at an alarming rate [6]. T1DM occurs because pancreas unable to produce insulin or less insulin because of dysfunction by T cells. Gestational Diabetes Mellitus (GDM) is a medical condition that can develop in women at any stage of pregnancy, even if they do not have diabetes at the start. Pregnant ladies require a sufficient supply of nourishing foods.

2.2. Diet For Diabetic Patients

Coronavirus, also known as covid-19, is a long-term global health problem that has progressed from epidemic to endemic status as the number of cases and deaths has risen rapidly. People with diabetes, hypertension, and excessive obesity (BMI greater than 40 kg/m2) are more likely to develop problems and die [26]. Depending on their preferences, diabetic patients can pick from a variety of healthful diets that are high in protein, high in vegetables and fruits, and low in fat and carbohydrates. A moderate weight loss of 5% to 10% of body weight has been shown to decrease insulin resistance in T2DM patients [19]. Diabetic patients must also limit their sugar intake, which includes carbonated and soft drinks. Fiber plays such an important role in any diet because it can decrease the glycemic index of foods and control our blood glucose level.

2.3. Mathematical Model for Diet Planning

2.3.1 Diet Optimization Model (Linear Programming)

Diet optimization modelling is a strategy for determining the best food combinations to suit a person's nutritional needs. In a range of industries, including banking, petroleum, education, and trucking, LP has been utilised to solve optimization challenges [11]. LP can also be used to resolve concerns about diets matching nutritional constraints with the fewest number of alterations [34].

2.3.2 Robust Optimization Approach

To determine how much food affects our blood glucose level, a robust optimization technique is used to account for uncertainty in dietary Glycemic Load (GL) data. This problem can be solved using mathematical modelling techniques such as Mixed-Integer Programming, Chance-Constrained Programming (CCP), and Linear Programming with a Margin of Safety [5].

2.3.3 Bacterial Foraging Optimization Algorithm

The Bacterial Foraging Optimization Algorithm (BFOA) is a new approach to swarm intelligence. BFOA uses chemo-taxis, swarming, reproduction, and elimination-dispersal processes to address the continuous optimization problem [7]. It was used to build an objective function that adhered to the Laws of Quantity and Quality in order to close the gap between how many calories a person requires and how many calories a healthy food supplies [18].

2.3.4 DASH Diet Model

DASH is a mathematical methodology for creating a menu for hypertension patients who want to lower their blood pressure by following a specific eating plan. DASH diet model can also be used to evaluate the nutrition needs of diabetic individuals because hypertension can lead to diabetes [15].

3. Methodology

3.1. Data Collection

The main data for this study is the varieties of Malaysian foods with nutrition decomposition form Malaysian Food Database Composition (MyFCD).Table 1 indicates the upper and lower limit for each nutrition based on calorie intake while table 2 below shows the assumption of daily nutrition values for 1400, 1600 and 1800 kcal per day which are applicable for all stages of diabetes patients regardless of sex and age to minimize the cost for daily menu in Ringgit Malaysia with enough requirement daily intake of protein (*P*), carbohydrate (*H*), fiber (*B*), iron (*I*), sodium (*S*), vitamin C (*V*) and thiamine (*T*).

Table 1: Upper and lower limit for each nutrition based on calorie intake

	1400 kcal		**1600 kcal**		**1800 kcal**	
	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit
Protein (g)	45	70	53	80	60	90
Fat (g)	33	54	39	62	44	70
Carbohydrate (g)	135	193	158	220	180	248
Fiber (g)	20	30	20	30	20	30
Iron (mg)	29	45	29	45	29	45
Sodium (mg)	500	2300	500	2300	500	2300
Vitamin C (mg)	70	1000	70	1000	70	1000
Thiamin (B1) (mg)	1.1	500	1.1	500	1.1	500

Table 2: Calorie intake per day

Nutrition Composition	**Calorie Intake (kcal)**		
	Model A	**Model B**	**Model C**
	1400 kcal	**1600 kcal**	**1800 kcal**
Protein (g)	≥ 45	≥ 53	≥ 60
Fat (g)	≤ 54	≤ 62	≤ 70
Carbohydrate (g)	≥ 135	≥ 158	≥ 180
Fiber (g)	≥ 20	≥ 20	≥ 20

Iron (mg)	≥ 29	≥ 29	≥ 29
Sodium (mg)	≤ 2300	≤ 2300	≤ 2300
Vitamin C (mg)	≥ 70	≥ 70	≥ 70
Thiamin (B1) (mg)	≥ 1.1	≥ 1.1	≥ 1.1

3.2. Linear Programming Model Formulation

Diet optimization model, formulated by LP will be solved using Microsoft Excel to determine the portion size of all food items that satisfies nutrition recommendation at the possible lowest cost. The formulation of LP is as below:

Objective function: To minimizes cost

$$Min\ C\ =\ \sum_{j=1}^{32} a_j x_j$$

Subjected to constraints

$$\sum_{j=1}^{32} b_{jP} x_j\ \geq\ P\ (Grams\ of\ protein\ per\ serving)\ \ (1)$$

$$\sum_{j=1}^{32} b_{jF} x_j\ \leq\ F\ (Grams\ of\ fat\ per\ serving)\ \ (2)$$

$$\sum_{j=1}^{32} b_{jH} x_j\ \geq\ H\ (Grams\ of\ carbohydrate\ per\ serving)\ \ (3)$$

$$\sum_{j=1}^{32} b_{jB} x_j\ \geq\ B\ (Grams\ of\ fiber\ per\ serving)\ \ (4)$$

$$\sum_{j=1}^{32} b_{jI} x_j\ \geq\ I\ (Grams\ of\ iron\ per\ serving)\ \ (5)$$

$$\sum_{j=1}^{32} b_{jS} x_j\ \leq\ S\ (Grams\ of\ sodium\ per\ serving)\ \ (6)$$

$$\sum_{j=1}^{32} b_{jV} x_j\ \geq\ V\ (Grams\ of\ vitamin\ C\ per\ serving)\ \ (7)$$

$$\sum_{j=1}^{32} b_{jT} x_j\ \geq\ T\ (Grams\ of\ thiamin\ per\ serving)\ \ (8)$$

$$\sum_{j=1}^{32} b_{jL} x_j\ \leq\ L\ (Amount\ of\ calorie\ in\ Kilo\ Calorie)\ \ (9)$$

$$\sum_{j=1}^{32} b_j, \sum_{i=1}^{32} x_j \geq 0$$

The objective function defines the objective of the optimization which is to minimize the total cost for the menu while the constraints are the restriction and limitations on the total amount of all nutrients to get the optimal nutrients at a very minimum cost. The aim for this model is to minimize the cost C where is the cost of food item *j* and is the number of servings of food *j* in gram. Then, is amount of nutrient in each food *j* based on MyFCD while grams of protein per serving (*P*), grams of carbohydrate per serving (*H*), grams of fiber per serving (*B*), milligrams of iron per serving (*I*), milligrams of sodium per serving (*S*), milligrams of vitamin C per serving (*V*) and milligrams of thiamin per serving (*T*) stand for the amount of target value for each daily nutrient.

4. Results and discussion

Table 3, 4 and 5 shows the result of LP technique for diabetes patients that need 1400 (A), 1600 (B) and 1800 (C) kcal per day respectively. As we can see from all outputs below, the lowest price for A, B and C to get enough daily nutrients are only under RM12 per day for three main meals which are breakfast, lunch and dinner.

Table 3: Constraint and outcomes for 1400 kcal calorie intake per day

Objective Cell (Min)

Name	Original Value	Final Value
TOTAL VALUE Cost (RM)	0	9.664410823

Variable Cells

Name	Final Value	Reduced Cost	Coefficient	Allowable Increase	Allowable Decrease
White rice	0	0.818891697	1	1E+30	0.818891697
Fried mee hoon	0	0.993221082	1.5	1E+30	0.993221082
Egg	0	0.799348996	1	1E+30	0.799348996
Whole meal bread	0	0.264542084	0.5	1E+30	0.264542084
Green apple	0	0.725060484	1	1E+30	0.725060484
Tempeh	0	0.208718462	1	1E+30	0.208718462
Ikan kembong kari	0	2.208725817	2.5	1E+30	2.208725817
Ikan pari masak asam pedas	0	2.311817853	2.5	1E+30	2.311817853
Lempeng kelapa	0.069225331	0	1.5	31.10829575	0.788349424
Chicken rice	0	4.753938242	5	1E+30	4.753938242
Nasi dagang	0	3.77053523	5	1E+30	3.77053523
Bubur kacang hijau	0	1.622674807	2.5	1E+30	1.622674807
Sambal sotong kering	2.148947408	0	2.5	0.609999334	2.197539867

Sardine sandwich	0	1.808967655	2	1E+30	1.808967655
Banana	0	1.254055781	1.5	1E+30	1.254055781
Bayam masak air	0	0.035627247	1	1E+30	0.035627247
Fried cabbage	0	0.544581417	1	1E+30	0.544581417
Lettuce	0	0.199197246	0.5	1E+30	0.199197246
Fried kuih teow	0	0.692847118	1.5	1E+30	0.692847118
Fried rice	2.116294975	0	1.5	0.14749819	1.185930024
Nasi lemak	0	0.974622301	1.5	1E+30	0.974622301
mee sup	0	1.824626125	2	1E+30	1.824626125
Ikan tongkol masak lemak	0	2.204219444	2.5	1E+30	2.204219444
Ikan kerisi masak kicap	0	2.265916213	2.5	1E+30	2.265916213
Kuih pau ayam	0	1.750438051	2.5	1E+30	1.750438051
Ayam kurma	0	2.196532543	3	1E+30	2.196532543
Spaghetti with vegetables	0	3.446057887	4	1E+30	3.446057887
Tomato	0	0.260734948	0.5	1E+30	0.260734948
Cucumber	0	0.249852456	0.5	1E+30	0.249852456
Basmathi rice	0.393746798	0	1	1.786907865	0.324820369
Sambal udang	0	2.295771451	2.5	1E+30	2.295771451
papaya	0.620015046	0	1	0.082017102	0.543356256

Constraints

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
TOTAL VALUE Protein (P)	48.5006452	0	45	3.5006452	1E+30
TOTAL VALUE Fat (F)	51.73849553	0	54	1E+30	2.261504466
TOTAL VALUE Carbohydrate (H)	135	0.004819	135	14.41290175	26.54014838
TOTAL VALUE Fiber (B)	20	0.253712024	20	1.239890537	2.275760336
TOTAL VALUE Iron (I)	20	0.176977937	20	1.981373295	10.46974304
TOTAL VALUE Sodium (S)	1205.682594	0	2300	1E+30	1094.317406
TOTAL VALUE vitamin C (V)	70	0.004817108	70	29.8367559	69.93595711
TOTAL VALUE thiamin (T)	1.1	0.057135484	1.1	13.20245723	0.955163869

Table 4: Constraint and outcomes for 1600 kcal calorie intake per day

Objective Cell (Min)

Name	Original Value	Final Value
TOTAL VALUE Cost (RM)	0	11.36804926

Variable Cells

Name	Final Value	Reduced Cost	Coefficient	Allowable Increase	Allowable Decrease
White rice	0	0.818891697	1	1E+30	0.818891697
Fried mee hoon	0	0.993221082	1.5	1E+30	0.993221082
Egg	0	0.799348996	1	1E+30	0.799348996
Whole meal bread	0	0.264542084	0.5	1E+30	0.264542084
Green apple	0	0.725060484	1	1E+30	0.725060484
Tempeh	0	0.208718462	1	1E+30	0.208718462
Ikan kembong kari	0	2.208725817	2.5	1E+30	2.208725817
Ikan pari masak asam pedas	0	2.311817853	2.5	1E+30	2.311817853
Lempeng kelapa	0.064952019	0	1.5	31.10829575	0.788349424
Chicken rice	0	4.753938242	5	1E+30	4.753938242
Nasi dagang	0	3.77053523	5	1E+30	3.77053523
Bubur kacang hijau	0	1.622674807	2.5	1E+30	1.622674807
Sambal sotong kering	2.143990101	0	2.5	0.609999334	2.197539867
Sardine sandwich	0	1.808967655	2	1E+30	1.808967655
Banana	0	1.254055781	1.5	1E+30	1.254055781
Bayam masak air	0	0.035627247	1	1E+30	0.035627247
Fried cabbage	0	0.544581417	1	1E+30	0.544581417
Lettuce	0	0.199197246	0.5	1E+30	0.199197246
Fried kuih teow	0	0.692847118	1.5	1E+30	0.692847118

Fried rice	3.342386925	0	1.5	0.14749819	1.185930024
Nasi lemak	0	0.974622301	1.5	1E+30	0.974622301
mee sup	0	1.824626125	2	1E+30	1.824626125
Ikan tongkol masak lemak	0	2.204219444	2.5	1E+30	2.204219444
Ikan kerisi masak kicap	0	2.265916213	2.5	1E+30	2.265916213
Kuih pau ayam	0	1.750438051	2.5	1E+30	1.750438051
Ayam kurma	0	2.196532543	3	1E+30	2.196532543
Spaghetti with vegetables	0	3.446057887	4	1E+30	3.446057887
Tomato	0	0.260734948	0.5	1E+30	0.260734948
Cucumber	0	0.249852456	0.5	1E+30	0.249852456
Basmathi rice	0.277016447	0	1	1.786907865	0.324820369
Sambal udang	0	2.295771451	2.5	1E+30	2.295771451
papaya	0.620049142	0	1	0.082017102	0.543356256

Constraints

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
TOTAL VALUE Protein P	53.44703212	0	53	0.447032121	1E+30
TOTAL VALUE Fat F	60.90425529	0	62	1E+30	1.095744714
TOTAL VALUE Carbohydrate H	158	0.004819	158	15.97355882	5.307628534
TOTAL VALUE Finer B	20	0.253712024	20	0.600752076	0.290614419
TOTAL VALUE Iron I	29	0.176977937	29	0.960015489	1.336985375
TOTAL VALUE Sodium S	1748.023616	0	2300	1E+30	551.976384
TOTAL VALUE VitaminC V	70	0.004817108	70	33.06753793	60.82952502
TOTAL VALUE Thiamin T	1.1	0.057135484	1.1	2.224229703	0.896201167
TOTAL VALUE Calorie L	1537.289735	0	1600	1E+30	62.7102651

Table 5: Constraint and outcomes for 1800 kcal calorie intake per day

Objective Cell (Min)

Name	Original Value	Final Value
TOTAL VALUE Cost (RM)	0	11.60994858

Variable Cells

Name	Final Value	Reduced Cost	Coefficient	Allowable Increase	Allowable Decrease
White rice	0	0.827263831	1	1E+30	0.827263831
Fried mee hoon	0	0.954162727	1.5	1E+30	0.954162727
Egg	0	0.639133141	1	1E+30	0.639133141
Whole meal bread	0	0.240384066	0.5	1E+30	0.240384066
Green apple	0	0.771499896	1	1E+30	0.771499896
Tempeh	0.651026828	0	1	0.204348506	0.208718462
Ikan kembong kari	0	1.915765496	2.5	1E+30	1.915765496
Ikan pari masak asam pedas	0	1.94113035	2.5	1E+30	1.94113035
Lempeng kelapa	0.062390522	0	1.5	29.09687891	0.869802861
Chicken rice	0	4.611201507	5	1E+30	4.611201507
Nasi dagang	0	3.669715293	5	1E+30	3.669715293
Bubur kacang hijau	0	1.520304486	2.5	1E+30	1.520304486
Sambal sotong kering	1.967756828	0	2.5	0.581608174	1.258448299
Sardine sandwich	0	1.791229345	2	1E+30	1.791229345
Banana	0	1.295265957	1.5	1E+30	1.295265957
Bayam masak air	0	0.030683535	1	1E+30	0.030683535
Fried cabbage	0	0.527602615	1	1E+30	0.527602615
Lettuce	0	0.20440339	0.5	1E+30	0.20440339
Fried kuih teow	0	0.626613657	1.5	1E+30	0.626613657
Fried rice	3.130933809	0	1.5	0.128964815	1.070359581
Nasi lemak	0	0.944829831	1.5	1E+30	0.944829831
mee sup	0	1.752537461	2	1E+30	1.752537461
Ikan tongkol masak lemak	0	1.991478477	2.5	1E+30	1.991478477
Ikan kerisi masak kicap	0	1.816555755	2.5	1E+30	1.816555755
Kuih pau ayam	0	1.586543767	2.5	1E+30	1.586543767

Ayam kurma	0	1.911923604	3	1E+30	1.911923604
Spaghetti with vegetables	0	3.148218949	4	1E+30	3.148218949
Tomato	0	0.25880255	0.5	1E+30	0.25880255
Cucumber	0	0.271929515	0.5	1E+30	0.271929515
Basmathi rice	0.63582227	0	1	1.453003583	0.16724027
Sambal udang	0	2.144019838	2.5	1E+30	2.144019838
papaya	0.613720913	0	1	0.070673699	0.548151102

Constraints

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
TOTAL VALUE Protein P	60	0.028910735	60	39.20451723	4.700029869
TOTAL VALUE Fat F	60.02158781	0	70	1E+30	9.97841219
TOTAL VALUE Carbohydrate H	180	0.002384009	180	43.89108186	44.60347056
TOTAL VALUE Fiber B	20	0.209240634	20	3.055477189	11.8347961
TOTAL VALUE Iron I	29	0.167311393	29	8.839299806	20.02986728
TOTAL VALUE Sodium S	1638.099993	0	2300	1E+30	661.900007
TOTAL VALUE VitaminC V	70	0.004858558	70	82.78014602	69.24107478
TOTAL VALUE Thiamin T	1.1	0.062946047	1.1	39.07756622	0.862126497
TOTAL VALUE Calorie L	1642.53657	0	1800	1E+30	157.4634303

Three different meals were produced from list of food for each calorie intake per day by using LP. For model A, the highest calorie intake is 1343.43 kcal per day with cost RM 9.66, 1537.29 kcal per day for model B with only RM 11.37 while for model C is 1642.54 kcal per day at the lowest cost RM 11.61. For all models, we used the lower limit value for nutrition like protein, carbohydrate, fiber, iron, vitamin C and thiamine because the patients need to take high amounts of these macronutrients in their diet. However, we restricted the value for fat, sodium and calorie intake per day by using upper limit values to control body weight and improve lipid profile. The outcome of excel by using LP does not come out if we use either upper limit or lower limit only for all macronutrients.

'Allowable increase' and 'allowable decrease' for variables and constraints mean the allowable amount of cost for each food items and allowable value for each nutrition composition that can be increase or decrease respectively without changing the optimal serving for each listed foods. Table 6 represents the percentage of increment for each nutrition composition between 1400 & 1600 kcal and 1600 & 1800 kcal.

Table 6: Percentage of increment for each nutrition composition

Nutrition composition	Percentage of increment between 1400 & 1600 kcal (%)	Percentage of increment between 1600 & 1800 kcal (%)
Protein	10.1986	12.2607
Fat	17.7156	-1.4493
Carbohydrate	17.037	13.9241
Fiber	0	0
Iron	45	0
Sodium	44.9821	-6.2885
Vitamin C	0	0
Thiamin	0	0

Based on table 6, the highest percentage of increment of nutrition composition between 1400 and 1600 kcal is iron because it plays a big role in helping hemoglobin to transport oxygen to the blood. However, there is no change increment between 1600 and 1800. This is because too much iron in our body will cause insulin resistance by lowering the liver's ability to extract insulin and blocking glucose uptake in muscle tissues and lipids, resulting in increased hepatic glucose synthesis [8]. Percentage of increment for sodium between 1400 and 1600 kcal is 44.9821% but then, between 1600 and 1800 kcal the percentage of increment becomes -6.2885%. Enough amount of sodium in our body based on calorie intake is good to control our blood pressure however for diabetic patients, they need to restrict the amount of sodium in their daily life since it can raise the blood pressure. That is the reason why the percentage of protein increases between 1600 and 1800 kcal but decreases in fat and sodium. Other than that, the percentage of carbohydrate composition is decreasing from 17.037% (1400 & 1600 kcal) to 13.9341% (1600 & 1800 kcal) because it can raise the blood glucose level and increase risk of diabetes.

<u>Calculation for daily meal portion for model A</u>

i. For basmati rice: 0.39×100g = 39g
ii. For *sambal sotong kering*: 2.15×100g = 215g
iii. For fried rice: 2.12×100g = 212g
iv. For papaya: 0.62×158.9g = 98.52g

<u>Calculation for daily meal portion for model B</u>

i. For basmati rice: 0.28×100g = 28g
ii. For *sambal sotong kering*: 2.14×100g = 214g
iii. For fried rice: 3.34×100g = 334g
iv. For papaya: 0.62×158.9g = 98.52g

<u>Calculation for daily meal portion for model</u>

i. For basmati rice: 0.64×100g = 64g

ii. For *sambal sotong kering*: 1.97×100g = 197g
iii. For fried rice: 3.13×100g = 313g
iv. For papaya: 0.62×158.9g = 98.52g
v. For tempeh: 0.65×70.9g = 46.09g

Calculation above shows the number of portions for each meal that diabetes patients need to take to get enough nutrition per day. Table 7 below represent the schedule of menu for breakfast, lunch and dinner for all models based on the LP outcomes.

Table 7: Optimal Menu for One day

	A (1400 kcal)	**B (1600 kcal)**	**C (1800 kcal)**
Breakfast	Fried rice (212g) Green tea (1 cup)	Fried rice (334 g) Green tea (1 cup)	Fried rice (313 g) Green tea (1 cup)
Lunch	Basmati rice (39 g) Sambal sotong kering (215 g) Papaya (98.52 g)	Basmati rice (28 g) Sambal sotong kering (214 g) Papaya (98.52 g)	Basmati rice (64 g) Sambal sotong kering (197 g) Tempeh (46.09 g) Papaya (98.52 g)
Dinner	Lempeng kelapa (1 pcs) Coffee without sugar (1 cup)	Lempeng kelapa (1 pcs) coffee without sugar (1 cup)	Lempeng kelapa (1 pcs) Coffee without sugar (1 cup)
COST	RM 9.66	RM 11.37	RM 11.61
TOTAL CALORIE	1343.42 kcal	1537.29 kcal	1642.54 kcal

Based on the results above, model A, B and C produces the same type of foods for one day but different values per serving and only tempeh is added in model C because we used the same list foods for each calorie intake. Each model consists of basmati rice which is good for diabetes patients since it has high fiber and lower glycemic index than white rice. *Lempeng kelapa* which its main ingredient is coconut flour also was listed to all models due to rich in nutrient and beneficial fats. Coconut flour has a relatively low glycemic index (GI) of 35, high content of protein, fat, and fiber [30] that can keep blood sugar level stable. Diabetes patients does not need to avoid all fruits that contain sugar such as papaya that contains a lot of vitamin C which is sufficient for diabetes patients that need 70-90 mg/dl dose of vitamin C per day. Besides that, we can add green tea and coffee without sugar in our daily meals since it contains only zero and two calories respectively which can help their diets.

This method only can produce one day meal only for all calorie intake. We tried to construct menu for day 2 and day 3 by removing the meals from the list that already come out in day 1 to avoid repetition. However, the food price per day for all three main meals become higher that already does not meet with our aim which is to construct menu for diabetes patients at minimum cost.

Based on the overall findings from this study, this study has success to create the diet plan for one day where all the food items are widely accessible in Malaysia that contains enough nutrition at a very minimum cost which is less than RM 12. However, this method needs to be improved so that we can construct the menu plan for day 2 and day 3 to be a reference for diabetes patients. No matter how, physical activity like sports, leisure activities or households are still important to improve glycemic control and improve insulin sensitivity.

Conclusion

Based on the overall findings from this study, this study has success to create the diet plan for one day where all the food items are widely accessible in Malaysia that contains enough nutrition at a very minimum cost which is less than RM 12. However, this method needs to be improved so that we can construct the menu plan for day 2 and day 3 to be a reference for diabetes patients. No matter how, physical activity like sports, leisure activities or households are still important to improve glycemic control and improve insulin sensitivity. The lack of variety of foods in MyFCD and the inability to discover adequate nutrition for Malaysian food are both limitations of this study. Future researchers should take into account particular parameters including gender, age, blood pressure, and blood lipid levels.

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