



A mathematical model of healthy diet menu plan for MARA Junior Science College boarding schools

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ABSTRACT

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Adolescents need more attention on eating habits as they go through a critical path period of physical, physiological and psychological changes from children to adult. Therefore, planning a proper healthy diet menu is important to adolescents to have the sufficient nutrients for proper growth. However, manually plan healthy diet menu is complicated, inefficient and time-consuming. The purpose of this study is to develop a mathematical model of healthy diet menu plan that minimizes the daily fat intake and meets the necessary nutrient intake for adolescents aged 13 between 17 years old within the budget provided by Majlis Amanah Rakyat (MARA) for Malaysia adolescent in MARA Junior Science College (MJSC) boarding schools. Optimization approach and binary integer programming method were used to address the diet problem in this study. The finding of the study indicates that the developed mathematical model of healthy diet menu plan for MJSC can generate menu plan that minimizes the total fat intake at minimum level of requirement per day. This menu plan can be used as a guideline for the management of the boarding schools to provide healthy diet meals for their students.

Keywords:

Healthy diet menu plan, optimization, binary integer programming, mathematical model, adolescents, boarding school

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1. Introduction

Adequate nutrients intake is important for the human body to function optimally and stay healthy. However, eating more or less than what our body needs will lead to malnutrition. Malnutrition can be categorized as under-nutrition (severe thinness and thinness) and over-nutrition (overweight and obesity), while body weight status is one of the indicators of malnutrition [1]. According to World Health Organization [1], the prevalence of overweight and obesity of population has been increased in the developing countries.

Obesity and overweight have become a serious public health problem among children and adolescents throughout the developed and developing countries [2]. Many children in developing countries, including Malaysia, are facing obesity problems that are associated with significant

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morbidity and mortality, including cardiovascular, respiratory, gastrointestinal, endocrine and psychosocial morbidities [3]. Obesity can cause the risk of the other chronic disease such as high blood pressure, cancer, diabetes and kidney problems [4-6]. Also noted that obese children and adolescents are likely to be obese into adulthood and increase the likelihood of adult morbidity and mortality [7]. A study conducted by [8] in Tanzania found that the prevalence of overweight and obesity among adolescents staying in boarding school was higher than adolescence staying out of the school. In fact, Malaysian adolescents stay in hostel or boarding school face dual forms of malnutrition with over-nutrition (overweight) being more prevalent than under-nutrition (thinness) [9].

Apart from the physical activity, it is also very important to concern about the eating habit and dietary intake among children in the early of childhood particularly during adolescents for healthy generations in future. Adolescents need more attention on eating habits as they go through a critical path period of physical, physiological and psychological changes from children to adult. The rapid growth and development that involves physical and mental development are occurring during adolescence [10-12]. Planning a healthy diet is important to adolescence in order to have sufficient energy, protein and other nutrients for achieving full growth potential, to promote health and well-being, good cognitive functional and to reduce the risk of chronic disease in adulthood as well.

The pioneer of study on diet planning was George Stigler and his work was called a diet problem. Diet problem is also claimed as one of the first optimization problems which has been studied since the 1930s and is a classic example of the application the linear programming as optimization approach [13]. Diet planning is not a simple process and it is hard to do especially manually [18] due to many consideration must be taking into account which are budget, nutrient intake, the variety of menu items and user preferences [19,22]. Therefore, diet planning is one of the important areas and continues investigated by nutritionist and operational researchers when attempting to prevent malnutrition.

There are various optimization approach been employed by previous researchers to solve diet problem, including linear programming [14-17], mix-integer linear programming [18], binary integer programming [19] and goal programming [20-21]. The study on solving diet problem using optimization approach as the intervention to prevent overweight and obesity among adolescents in the boarding school has been lacking in Malaysia. Thus, the current knowledge about menu planning and diet problems are expanded for MARA Junior Science College (MJSC) boarding school that focusing on Malaysian foods. Therefore, this study aims to develop mathematical model of healthy diet menu plan that minimizes the daily total fat intake, with consideration of recommended nutrient intake (RNI) for Malaysia adolescents aged between 13 and 17 years old, the cost of menu items, the budget provided by MARA for the MRSM boarding school caterers and the variety of menu item groups requirement.

2. Methodology

The menu in MARA Junior Science College (MJSC) boarding schools is planned by the authorities from Majlis Amanah Rakyat (MARA) on monthly basis. There are five meals a day which are breakfast, morning snack, lunch dinner, and supper. The optimization approach was employed as a method to address the healthy diet menu plan for MJSC boarding school, whereby the binary integer programming is selected as a technique to develop a mathematical model for this study.

2.1 Data Collection

There are several types of data needed in order to develop a mathematical model of healthy diet menu for this study. These includes the Malaysian menu items and its nutritional contents, the recommended nutrients intake (RNI) for Malaysian school adolescents aged between 13 and 17 years old, the cost of each Malaysian menu item, and the MARA allocation budget for each adolescent in MRSM boarding school to pay to the caterer [24].

The secondary data for menu items and its nutritional value was collected from the book of Nutrients Composition of Malaysian Foods, compiled by Tee, Mohd Ismail, Mohd Nasir, and Khatijah [23]. There are 170 menu items involved in this study.

Next, 11 of nutrients considered including energy, protein, fat, carbohydrates, vitamin A, vitamin B1, vitamin B2, vitamin B3, vitamin C, iron, and calcium. The secondary data for the RNI requirements for Malaysian adolescents was taken from the book of Recommended Nutrient Intakes for Malaysia [24]. It comprises the upper and lower bound values of each nutrient needed by the adolescents aged between 13 and 17 years old, both male and female. In addition, it also includes the range of recommended intake level for each RNI requirements.

The cost of each menu items was obtained by conducting several interview sessions with the caterer in MJSC boarding schools. The information of the MARA budget allocation was collected from the interview sessions with the MJSC boarding school authorities at Kuala Klawang, Negeri Sembilan.

3. Development of Mathematical Model for Healthy Diet Menu Plan

The aim of the mathematical model for healthy diet menu plan in this study is to minimize the daily total fat intake by the adolescents aged between 13 and 17 years old which fulfils the standard requirement of Malaysian RNI within the budget provided by MARA. As mentioned earlier, 11 nutrients considered which are: energy, carbohydrate, protein, fat, vitamin A, vitamin B1, vitamin B2, vitamin B3, iron, and calcium. The daily value of upper bound and lower bound of the eleven nutrients are shown in Table 1 [24]. Each nutrient has their own lower and upper bound daily intake except for protein, vitamin B1, and vitamin B2, whereby, these sorts of nutrients had the lower bound only.

Table 1
Values of upper bound and lower bound of the 11 nutrients

Nutrients	Lower Bound (LB)	Upper Bound (UB)
Energy (kcal)	2050	2840
Fat (g)	46	86
Carbohydrate (g)	180	330
Protein (g)	54	-
Vitamin A (μg)	600	2800
Vitamin B1 (mg)	1.1	-
Vitamin B2 (mg)	1.0	-
Vitamin B3 (mg)	16	30
Vitamin C (mg)	65	1800
Calcium (g)	1000	2000
Iron (mg)	15	45

170 of menu items including beverages been considered in this study. Apart from that, a variety menu item groups are served in a daily meal in order to optimize multitude of nutrient for the body. This study considered 10 type of menu item groups which are beverages 1, beverages 2, fruits, cereal based, meat dishes, fish and seafood dishes, vegetables, wheat flour based, rice flour based and

miscellaneous. In addition, each of menu item groups contributes different meal that comprising 170 menu items. Each of menu items also has its own available range to be selected in the model. For example, the available range to select beverage 1 to be served in a certain day are from $x_1 - x_{19}$. These available range of selection for each menu item groups and the number of its requirements are shown in Table 2.

Table 2
 The range of selection of the 10 menu item groups

Menu item groups	Available range	Number of requirement per day, n_k
Beverage 1	$x_1 - x_{19}$	3
Beverage 2	$x_{20} - x_{30}$ and x_{170}	3* including 2 plain water, x_{170}
Fruit	$x_{31} - x_{54}$	2
Cereal based	$x_{55} - x_{69}$ and x_{169}	3* including 2 cooked rice, x_{169}
Meat dishes	$x_{70} - x_{84}$	1
Fish and seafood dishes	$x_{85} - x_{105}$	1
Vegetable	$x_{106} - x_{122}$	2
Wheat flour based	$x_{123} - x_{138}$	1
Rice flour based	$x_{139} - x_{153}$	1
Miscellaneous	$x_{154} - x_{168}$	1
Total menu items per day		18

In addition, 18 menu item from 10 types of foods are served in a day. Binary integer programming model is developed according to the data collected. Sufahani and Ismail [19] had proposed the model of diet problem that minimize the total cost for Malaysian Secondary School using binary integer programming. In this study, the model formulation that purposed by Sufahani and Ismail [19] is adapted with minor modification.

3.1 Decision Variables

The decision variables for this study are menu items and 170 menu item considered in this study. Therefore, there are 170 variables (x_i) where $i = 1, 2, 3, \dots, 170$.

3.2 Objective Function

The objective function for this study is to minimize the daily total fat intake, Z , by adolescents. Hence, the objective of this study is given by

$$\text{Minimize, } Z = \sum_{i=1}^{170} c_i x_i \tag{1}$$

where Z refer to daily total fat intake and c_i represent the total fat content in the menu item i .

3.3 Constraints

There are four constraints that involved in this study which are daily RNI constraint, menu item group's requirement per day constraint, budget allocation constraint and binary decision variable constraint.

Based on Table 2, the daily RNI constraint is

$$LB_j \leq \sum_{i=1}^{170} a_{ij} x_i \leq UB_j \quad j = 1, 2, 3, \dots, 11 \quad (2)$$

Where a_{ij} is the amount of nutrient j in the menu item i . Whereas, LB_j is a lower bound for nutrient j and UB_j is an upper bound for nutrient j . These value are needed to ensure that the daily recommended intake by Malaysia guideline are met for the adolescents aged between 13 and 17 years old.

The maximum budget allocation by MARA to each adolescent in MJSC boarding school is RM 16.00 per day. Therefore, the budget allocation constraint is given by

$$\sum_{i=1}^{170} e_i x_i \leq 16 \quad (3)$$

where e_i is the cost of menu item i . This study planned the healthy diet menu within the budget allocated.

Next, the menu item group's requirement per day constraint is

$$\sum_{i=1}^{170} e_i = n_k, k = 1, 2, 3, \dots, 10 \quad (4)$$

where n_k is the number requirement of the menu item group's k per day as show in Table 2.

In order to choose whether the menu item will be chosen to be served or not, binary decision variables constraints considered in this study. Thereby, all 168 variables are in binary values except for cooked rice, x_{169} and plain water, x_{170} ; and it is given by

$$x_i = \begin{cases} 1 & \text{if menu item } i \text{ is chosen} \\ 0 & \text{if menu item } i \text{ is not chosen} \end{cases} \quad i = 1, 2, 3, \dots, 168 \quad (5)$$

Therefore, each menu item can be served once in a day except for cooked rice and plain water. The cooked rice and plain water is not considered as a binary decision due to both of them are served twice a day, which are for lunch and dinner. Microsoft Excel Solver is used to solve the developed binary integer programming model and generate results of the optimization.

4. Results and Discussions

The results of healthy diet menu plan for MJSC boarding school are presented in Table 3.

Table 3
The healthy diet menu plan

Category	Type of Menu Item	Day
Breakfast	Beverages 1	Coffee with milk (1 cup, 250ml)
	Cereal Based	Mee, soup (1 bowl, 450g)
Morning Snack	Beverages 1	Milk UHT full cream (1 cup, 250ml)
	Wheat flour based	Sandwich, sardine (2 piece, 28g)
	Rice and Rice flour based	<i>Kuih buah melaka</i> (3 piece, 45g)
Lunch	Cereal Based	Cooked rice (1 bowl, 159g)
	Meat Dishes	Chicken tomyam (1 bowl, 150g)
	Vegetables	<i>Ulam raja</i> (1 cup, 34 g)
	Fruits	Papaya (1 slice, 76g)
	Beverages 2	Lime flavoured drink (1 cup, 250ml)
Dinner	Beverages 2	Plain water
	Cereal Based	Cooked rice (1 bowl, 159g)
	Fish and Seafood Dishes	Black pomfret, fried (1 piece, 95g)
	Vegetables	<i>Kailan goreng</i> (1 serving, 60g)
	Fruits	Seedless guava (1/2 slice, 85g)
Supper	Beverages 2	Plain water
	Beverage 1	Chocolate, 3 in 1 (1 cup, 250ml)
	Miscellaneous	Biscuit, peanut and coconut (2 round piece, 42g)
Total Fat Content (g)		46
Total Cost (RM)		14.65

There are a variety meals consisting of drinks and foods served each day, which includes five categories of meals: breakfast, morning snack, lunch, dinner and supper. In addition, the diet menu plan for each day consists of beverage 1, beverage 2, fruits, cereal based, meat dishes, fish and seafood dishes, vegetable, wheat flour based, rice flour based and miscellaneous. The value of menu items in the developed healthy diet menu plan for 7 days meet the daily RNI requirement for adolescents aged between 13 years and 17 years old at the minimum total fat consumed in a day within the budget provided. This study also demonstrates the generated menu plan that minimizes the total fat intake at minimum level of requirement per day.

5. Conclusion

This study has developed a mathematical model of healthy diet menu plan for MJSC boarding schools with maximization of menu items to be served. The mathematical model developed in this study also can be a guide to solve diet problem for other organization such as hospital, university and training center.

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