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A New Diet scheduling Model for Malaysian School Children Using Zero-One optimization Approach

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Abstract

Humans need to eat a good and balanced nutritious diet that provides calories for energy requirements and nutrients for proper growth, repair and maintenance of the body tissues. Moreover, it is essential for resisting and preventing diseases and infection that may lead to problems such as anemia, scurvy and rickets. In recent studies, medical researchers have discovered that good nutrition can help to reduce the risks of coronary heart disease and certain types of cancer. Menu and diet planners face tremendous challenges and difficulties in order to improve human health. Serving healthier meals is a major step towards achieving that objective. However, constructing and planning a nutritious and balanced menu manually is complicated, inefficient and time-consuming. The aim of this study is to develop a mathematical model for diet planning that meets the necessary nutrient intake for the secondary school student as well as minimizing a budget. The data were collected from various boarding schools and also from the Ministry of Education. Nutrition planning is a well-known optimization problem and the goal is to find the best possible optimal solution. Therefore the model was solved by using optimization method along with Zero One Integer Programming. This model can be adopted to solve other diet planning problems such as for the military, hospitals nursing home and universities.

Keyword: Decision Making, Mathematical Modeling, Optimization, Integer Linear Programming, Menu Planning, Health Management.

Introduction

Institutions and schools provide meals over an extended time period with a restricted budget. Research on this problem is evolving in order to find nutritious meals within the constraints of the cost of the foods. The main purpose of the "diet problem" model formulated by Stigler in 1945 is to study problems relating to human nutrition [6]. This model, as in most operational research models, has been set up on the traditional fundamental assumption that the decision maker seeks to optimize a single objective function. The problem has continued to be investigated by scientists and nutritionists [1,2,3,4,5,7,10,11,12,13,14,15,16,17,18, 20]. Therefore in this paper, we expanded the current knowledge in menu planning and diet problems focusing on Malaysian recipes. We used an optimization approach to solve the problem and a model that was developed for the usage of the Ministry of Education, Malaysia. In this paper we used Integer Programming to determine the most nutritious and palatable meals, while considering the constraints of the RDA for Malaysian children aged 13 to 18 years old, the cost of the menu items, the budget provided by the government and a variety requirement. Matlab with the LP Solve programming language was used to solve the problem.

Malaysian Secondary Schools

In Malaysian boarding schools, nutritionists from the Ministry of Education are responsible for planning menus for school children based on the cost of food items and RDA for children aged between 13 to 18 years. The menu lists are given to caterers in boarding schools who provide six meals per day, breakfast [B], morning tea [M], lunch [L], evening tea [E], dinner [D] and supper [S]. The menu provided is a nonselective menu where the school children do not have the choice to choose the preferred foods. The primary purpose of this research paper is to develop a mathematical model that could lead to the creation of menu lists. We tried to minimize the budget provided by the government and fulfill the requirements of the Malaysian RDA. Furthermore we had hoped to maximize the variety and fulfill the consumers' preferences. Hence, research on menu planning by developing mathematical models, which use operational research and decision science techniques, is important in order to help caterers provide nutritious meals over extended time periods within the limited budget allocation.

Data Collection

There are several types of data needed to build a menu planning model. These include the standardization of prices of each Malaysian menu, the nutritional contents for each menu, RDA for Malaysian school children aged between 13 – 18 years old, and the government budget for caterers. Data is provided in the Nutrient Composition of Malaysian Foods Handbook, compiled and published by the Malaysian Food Composition Database Programs, Institute for Medical Research [19]. It also includes suggestions for RDA for Malaysians comprising the upper and lower bound values of each nutrient needed by children aged 13 to 18 years old, both male and female. For

each nutrient requirement, there is an intake level that specifies the range of adequate intake. The information on the current monthly caterers' budget was collected from the nutritionists of the Ministry of Education and the boarding schools authorities through interview sessions. Cost per serving for each meal was obtained from several interview sessions with the caterers.

Model Formulation

The main aim of this research is to formulate a menu planning model that minimizes the budget provided by the government for boarding school caterers and maximizes the variety of food intake. This model also tried to achieve the maximum nutritional requirement based on the Malaysian RDA requirements. There were 11 nutrients considered: energy, fats, carbohydrate, protein, niacin, vitamin A, vitamin B1, vitamin B2, vitamin C, calcium and iron.

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	-
Calcium (g)	1000	2500
Vitamin A (mg)	600	2800
Vitamin B1 (mg)	1.1	-
Vitamin B2 (mg)	1.0	-
Vitamin C (mg)	65	1800
Niacin (mg)	16	30
Iron (mg)	15	45

Table 2: Food Requirement per Day

Type of food	**No. of requirement per day (n)**
Beverage (x_1-x_{37})	6 * including 2 Plain Water (x_9)
Cereal Flour Based (x_{38}-x_{85})	1
Rice Flour Based (x_{86}-x_{113})	1
Cereal Based Meal (x_{114}-x_{126})	2 * including 1 Plain Rice (x_{104})
Meat Dishes (x_{127}-x_{158})	1
Seafood (x_{287}-x_{324})	1
Vegetable (x_{159}-x_{212})	2
Fruits (x_{213}-x_{261})	2
Wheat Flour Based (x_{262}-x_{286})	1
Miscellaneous (x_{325}-x_{426})	1
Total Dishes Per Day	**18**

We considered 10 types of foods: beverage, cereal flour based, rice flour based, cereal based meal, meat dishes, seafood, vegetables, fruits, wheat flour based and miscellaneous. Each type of food contributed different dishes, so our food data comprised 426 dishes. Based on the data, an integer programming model was developed and discussed. The program should produce a palatable menu for 1 day. As mentioned earlier, we had 426 dishes, therefore we had 426 variables (x_i) where *i=1,2,…,426.* Each type of food had its own available range of selection as presented in Table 2. For example Beverage dishes (x_1-x_{37}), hence we needed 18 dishes (18 variables) from 10 types of food per day. Therefore in a week, we needed 126 dishes that would be suitably selected from the 426 dishes that were available.

Objective function:
We had hoped to minimize the total cost F,

$$F = \sum_{i=1}^{426} \text{Cost}(x_i) = \sum_{i=1}^{426} c_i x_i \quad \textbf{(}4.1)$$

by selecting the dish and providing a palatable daily menu. The maximum budget provided per day by the government was RM15.00 (RM=Ringgit Malaysia and equivalent to USD3.52). Thus, we tried to minimize the cost.

Constraints:
The daily constraints

$$\text{LB} \leq \sum_{i=1}^{426} \text{Nutrients}(x_i) \leq \text{UB} i = 1,2,..,11 \quad (4.2)$$

where LB and UB are the vectors, give different value for each nutrient. This is to ensure that we meet the nutrients requirements. We had 11 constraints of nutrients with lower and upper bound values except for protein, vitamin B1 and B2 as stated in Table 1. These three nutrients only have lower bound values. Based on Table 2, we then specified the food requirements

$$\sum_{i=1}^{10} \text{Type of foods } (x_i) = \text{n}; \; i = 1,2,..,10 \quad (4.3)$$

So that we could serve 18 dishes per day. We had 10 types of food and the number of requirements needed per day. So the variables were all binary values

$$x_i = \{0, 1\} \quad (4.4)$$

Each food can only be serve once (1 chosen and 0 otherwise) in a week except for except for Plain water and Plain Rice. Each time running, the program will consider different available variables. This present study involved many decision variables, constraints and parameters. The model had searched for an optimal solution using an zero one integer programming. The coding was programmed using Matlab with LP Solve and the optimal solution for a one day menu was obtained within 1 second with a 2.26GHz pc. This is really fast comparing to other techniques where it would have taken more than 4 hours or even a day. The efficiency of the methods in solving this menu planning problem has been proven based on past studies [8,20].

Result

The results are presented in Table 3. It shows meals for seven days to be provided by the management of the school to the children aged 13 to 18 years old. Each meal consists of beverages (6), cereal flour based (1), rice flour based (1), cereal meal based (2), meat (1), seafood (1), vegetables (2), fruits (2), wheat flour based (1) and miscellaneous (1).

Table 3: 1 Day Cost: RM 5.50 (equivalent to USD1.29).

Beverages	Orange flavoured drink, powder [B]; Plain water (2 times) [T,L]; Coconut water [E]; Sugar cane juice D]; Milo [S]
Cereal Flour Based	Biscuit soda/plain [S]
Rice Flour Based	Kuihkasui [B]
Cereal Meal Based	Rice, chicken [L], Rice, cooked [D]
Meat	Chicken satay [L]
Seafood	Fish, unspecified, dried, salt [D]
Vegetables	Celery(daunseladeri) [L]; Mengkudu [D]
Fruits	Guava [L], Nangka [D]
Wheat Flour Based	Doughnut [E]
Miscellaneous	Candy, coconut [M]

In Tables 3, we can see that there is a variety of drinks and foods presented in different ways each day, which includes six types of meals from breakfast to supper. While in Table 4, it shows the differences between generated nutrients and range of requirement. All these drinks and foods meet the daily nutritional requirements for the school children at a minimum cost.Therefore, it can be concluded that all the meals chosen are nutritious and are advisable to be served to the school children aged 13 to 18 years old.The value of the total cost is less than the budget provided by the government. This means the management of the school will spend less than RM15.00 per person per day.

Table 4.1 Day Generated Nutrient

	Lower Bound	**Generated Nutrient**	**Upper Bound**
Energy	2050	2399	2840
Carbohydrate	180	318.5	330
Fat	46	55.5	86
Calcium	1000	1037	2500
Niacin	16	23.5	30
Iron	15	20.3	45
Vitamin A	600	1010	2800
Vitamin C	65	270.1	1800
Protein	54	91	-
Vitamin B1	1.1	1.53	-
Vitamin B2	1	2.03	-

Conclusion

The researchers have produced a suitable one day menu plan that can be used as a guide for the management of the school. The model was solved using Matlab with LPSolve. It fulfills all the constraints set by the researchers and gives a better solution compared to other heuristic methods, such as Genetic Algorithms [18]. This research focused on 13 to 18 years old school children at secondary boarding schools. The nutritional requirements required for children below 12 years old and adults will be different from those used here, and they will affect the menu selection and the cost of preparing the meals. The total cost for one day is less than RM15.00. Therefore we can serve slightly expensive and better quality of foods for the children. An approach using post-optimality and sensitivity analysis will be developed in the future based on the changes in the coefficient value (c_i).

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