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A New Binary Programming and Mathematical Approach for Serving Healthy and Palatable Menu

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Abstract: School children need to eat a well balance nutritious food that provides enough nutrients for development, preservation and restoration of the human body. Moreover, with proper nutrient, it can prevent any undesirable diseases and infections. Recently, medical discovery shows that by consuming well balanced nutritious food, it can help to prevent and diminish the risks of cancer and heart failure. Dietitians, nutritionist and menu planners confronted with incredible tasks and complications in order to expand human wellbeing. Serving healthier meals is a major step towards achieving one of the objectives for this study but assembling a well balance and nutritious menu by hand is complex, ineffective and takes time. Therefore, the objective of this study is to develop a mathematical method for menu scheduling that satisfy the entire nutrient requirement for school children, reducing the processing time of optimal solution, minimize cost and also serve variety type of food every day. The data was obtained from the Ministry of Health Malaysian and also school authorities. Binary Programming along with optimization method was used to solve this problem. In future, this model can be implemented to other menu problems such as for sports, chronic illness patients, militaries, universities, hospitals and nursing homes.

Key words: Binary programming, mathematical modeling, menu scheduling, decision making, optimization

INTRODUCTION

The goal of this study is to find a well balance menu by minimizing the cost while maximizes the variety type of food and reducing the process time to find optimal solution. The caterer in the secondary schools normally provides 6 meals per day within a restricted budget but with a lack of variety. Menu scheduling was first formulated by Stigler in 1945 in order to learn the complications which relates to human nutrition (Stigler, 1945) and this problem has attracted many further research until now (Balintfy, 1975; Dantzig, 2002; Florencio, 2001; Leung *et al*., 1995; Sufahani and Ismail, 2014). In this study, the awareness of menu scheduling was expanded with the application of Malaysian food and Malaysian school children aged 13-18. We used the mathematical approach to solve the problem. We used binary programming through MATLAB with LPSolve programming language in order to produce optimal solutions.

Data: The data for nutrient's requirement, nutrient's values, nutrient's boundaries and meal list for school children aged 13-18 years old was obtained from the nutritionist of the Ministry of Health Malaysia and also in the Nutrient Composition of Malaysian Foods Handbook (Tee *et al*., 2010). An interview session was held with the school authorities, caterers and Ministry of Malaysian Education in order to get the daily budget which is USD 3.99 per day per student for each secondary school in Malaysia.

MATERIALS AND METHODS

Model formulation: The objective of this study is to develop a menu scheduling mathematical model that minimizes the cost, meets the nutrient's (RDA) requirement and food group's requirement and serve variety type of food in a day. There were 11 nutrients considered as listed in Table 1 with specific value of boundaries. We also considered 10 types of food groups as listed in Table 2 with different number of

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requirement. A binary programming model was developed through the given data and planned to produce a healthy menu for 1 day. Through this development, the program can extend the list until 1 week menu just with a single run and within seconds. In total there are 426 type of food in this study or 426 variables (x_i) where i = 1, 2, …, 426 and divided into 10 types of food groups. There are specific numbers of requirement from each food group as shown in Table 2 and the total number of food needed per day is 18 foods. The goal is to minimize the total cost Z:

$$Z = \sum_{i=1}^{426} c_i x_i \qquad (1)$$

where, c_i is the cost of each food x_i. The daily budget is USD 3.62. The daily constraints:

$$LB \le \sum_{i=1}^{426} n_j x_i \le UB;\ j = 1, 2, ..., 11 \qquad (2)$$

where, LB (Lower Bound) and UB (Upper Bound) are the vector values for each nutrient, n_j. Each nutrient has its lower and upper bound values apart from Thiamin (B1), Riboflavin (B2) and Protein where it only have lower bound values (Table 1). By referring to Table 2, the constraints for food requirements can be written as follows:

$$\sum_{i=1}^{426} x_i = f_k;\ k = 1, 2, ..., 10 \qquad (3)$$

and the total food requirement per day is 18 dishes. Each food groups has different number of requirement per day. The 426 parameters are in binary or zero one forms:

$$x_i = \{0, 1\} \qquad (4)$$

Table 1: Boundaries values for the 11 nutrients

Type of nutrients	Lowest value	Highest value
Proteins	54 g	-
Thiamin (B1)	1.1 mg	-
Riboflavin (B2)	1.0 mg	-
Niacin	16 mg	30 mg
Calcium	1000 g	2500 g
Carbohydrate	180 g	330 g
Irons	15 mg	45 mg
Fats	46 g	86 g
Re (A)	600 μg	2800 μg
Ascorbic Acid (C)	65 mg	1800 mg
Energy	2050 kcal	2840 kcal

Table 2: Number of food requirement in 1 day

Food groups	Requirement in 1 day
Cereal based meals	Two including one plain rice
Beverages	Six including two plain water
Fruits, vegetables	Two each
Rice flour based, cereal flour based, miscellaneous, fish and seafood, chicken and meat, wheat flour based	One each

Each food can only be serve once (1 is chosen and 0 is otherwise) in a day or in a week except for except for plain rice and plain water. If the user prefers a week, the program will consider different available variables each time running for each day. This research is a NP-hard problem where it involves >400 variables, >40 constraints and >400 parameters. Binary programming along with MATLAB with LPSolve was used to build up the model. By using a 2.26 GHz personal computer, optimal feasible solution was obtained within less a second. The solution was fast generated compared to other techniques would have taken more processing time (Dantzig, 2002; Sufahani and Ismail, 2014, 2015; Ali *et al*., 2015a, b).

RESULTS AND DISCUSSION

Table 3 shows the result for 1 day menu that covers the entire nutrient's requirement, food group's requirement, maximizes the variety of food to be served in a day and the most important element is minimizing the cost. The total cost is USD1.33 which is less than USD3.99. The result in Table 3, it shows the differences between generated nutrients and range of requirement. While result in Table 4 follows the food requirement as stated in Table 2 which covers six meals per day.

Table 3: The 1 day generated nutrient values

Nutrients	Values
Generated	
Proteins	91.0 g
Thiamin (B1)	1.53 mg
Riboflavin (B2)	2.03 mg
Niacin	23.5 mg
Calcium	1037 g
Carbohydrate	318.5 g
Irons	20.3 mg
Fats	55.5 g
Re (A)	1010 μg
Ascorbic Acid (C)	270.1 mg
Energy	2399 kcal

Table 4: The 1 day cost; USD 1.33

No.	A	B	C	D	E	F
1	-	-	Chicken rice	-	Plain rice	-
2	Orange	Coco-nut water	Plain water	Sugar-cane	Plain water	Hot choco-late
3	-	-	-	Guava	Jack-fruit	-
4	-	-	-	Celery	Morin-da	-
5	-	Kasui	-	-	-	-
6	-	-	Bis-cuit	-	-	-
7	-	-	-	-	-	Coco-nut
	-	-	-	-	-	candy
8	-	-	--	-	Salted	-
	-	-	-	-	dried fish	-
9	-	-	--	Chicken	-	-
	-	-	-	satay	-	-
10	-	-	-	-	Doug-hnut	-

where 1 = cereal meal based, 2 = beverages, 3 = fruits, 4 = vegetables, 5 = rice flour based, 6 = cereal flour based, 7 = miscellaneous, 8 = seafood, 9 = chicken and meat, 10 = wheat flour based, A = breakfast, B = morning tea, C = lunch, D = evening tea, E = dinner, F = supper

CONCLUSION

The model was solved using binary programming through MATLAB with LPSolve programming languages and focused on school children aged on 13-18 years old. It met all the nutrients and food groups constraints which set by the researchers in the beginning of the research and gives a better solution. The total cost for 1 day is less than USD 3.92. Healthier and variety foods can be served as the cost has been minimized. This model can also be implemented for other menu planning problems for instance sports, chronic illness patients, militaries, universities, hospitals and nursing homes.

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