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Diet Problem and Nutrient Requirement using Fuzzy Linear Programming Approach

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ABSTRACT

In recent years, according to Malaysian Medical Association, there has been a dramatic increase in the prevalence of obesity in Malaysia as well as in other regions of the world. Obesity is the commonest nutritional disorders. Therefore, this research aims to suggest people to have healthy foods with the lowest cost as possible. Fuzzy Linear Programming Approach has been employed to solve the dietary problem giving science, computerized advice on food and physical activity.

Key words: Human balance diet, chronic diseases, fuzzy linear programming, health diet system, multi-objective

INTRODUCTION

Childhood obesity is a precursor for adult obesity (Gonzalez-Suareez *et al*., 2009). Obesity and overweight are major risk factors for a number of chronic diseases, including diabetes, cancer and cardiovascular disease (WHO, 2010). Obesity and overweight are now dramatically on the rise in low and middle-income countries, particularly in urban settings.

Most Malaysian people eat based on their appetite without considering the calories, fat, and all other nutrients in the food. This unhealthy eating habit is responsible for at least 300,000 deaths each year (Afoakwah and Owusu, 2011). Beside the unhealthy eating habits, people also do not concern about the price of the foods with the nutrient requirement. To avoid these problems, people should minimize the cost of buying foods. They should spend less money but have sufficient nutrients requirement. By minimizing the cost, they still can fulfill their nutrient requirement everyday (Mamat *et al*., 2011). Raffensperger (2008) has conducted a research about the minimum cost of low-carbohydrate diet. The research found that the least-cost of low-carbohydrate diet is expensive than the least-cost of low-fat diet. The study identifies which nutrients had the greatest effect on cost for a low-carbohydrate and low-fat diet.

Cadenas *et al*. (2004) has done a research about diet problem in Argentina farms using an application of fuzzy optimization. Usually, the livestock is not confined. Therefore it is impossible

to assess the amount of food each animal will eat. Then it makes no sense to design diets verifying the nutritional requirements exactly. Consequently, a Decision Support Systems (DSS) named SACRA (a Spanish acronym for support system for the construction of cattle diets) have been used in order to solve the problem. Karlsson *et al.* (2010) has done a research about diet-induced obesity in mice and has found that Diet-Induced Obese (DIO) mice have increased morbidity and mortality following secondary influenza infection compared with lean mice.

Therefore, this research concentrates on the human diet problem using Fuzzy Linear Programming approach (FLP). Lack of energy balance in human most often causes overweight and obesity. Overweight and obesity happen over time when the calorie taken is higher than the body needs. There are many types of food that is high in calories. For example Malay pancake (roti canai), bread, eggs, fried chicken, fried noodles and others. People unrecognized the amount of calories in the foods. It shows that people consume food that contains high calories but not enough requirement of nutrient for their body. It leads them to get obesity, overweight and other diseases. Therefore, people need to be extra concern about the food that they eat. They must choose the right food with the right nutrient requirement.

In Malaysia, the trend now that fast food had become part and parcel of our lifestyle. People rely on fast food such as burger, KFC chicken, pizza and others for breakfast, lunch or dinner. Although the price for the food are expensive compared to rice-based food, they still interested to eat fast food because it as a way out or a symbol of modern living. Unfortunately, fast food contain high amount of fat, sugar and salt. Therefore, if taken continuously, it can shorten our lives.

Besides, poverty is a historical fact of life especially in rural areas. Lack of job opportunities in the rural areas is the main cause for the problem. Increasing in food price makes them unable to buy healthy food. Therefore, they need to choose the food that is low price but specify the nutrient requirement for their body.

There are two objectives in this research. First is to help people in choosing the right food with the right nutrient requirement. The second one is to minimize cost in buying healthy food.

MATERIALS AND METHODS

The method used in this research is Fuzzy Linear Programming Approach (FLP). FLP is known as multi-objective.

Raffensperger (2008) has proposed the model of Minimum Cost Diet Problem (MCDP) which is:

$$\text{Minimize: } \sum_{j=1}^{n} c_j x_j$$

$$\text{Subject to } \sum_{j=1}^{n} a_{ij} x_j \geq b_i \sum_{j=1}^{n} a_{ij} x_j \leq d_i,\ i = 1,2,\ldots,m,\ x_j \geq 0 \quad (1)$$

where, j is a food eaten per day, c_j is the price of food j, x_j is 100 g of food j eaten per day, a_{ij} is the amount of nutrient i in 100 g of food j, b_i is the required daily amount of nutrient i, d_i is the maximum daily amount of nutrient i, m is the number of nutrients and n is the number of food.

In this study, the price for the food is uncertain and it is assume as fuzzy numbers. Therefore, this fuzzy price is approached by linear programming with fuzzy objective coefficients. Formula (2) is the model of Minimum Cost Diet Problem (MCDP) with fuzzy objective coefficient (MCDP-FOC):

$$\text{Minimize}: \sum_{j=1}^{n} \bar{c}_j x_j$$

$$\text{Subject to} \sum_{j=1}^{n} a_{ij} x_j \geq b_i, \sum_{j=1}^{n} a_{ij} x_j \leq d_i, i = 1,2,...,m, x_j \geq 0 \tag{2}$$

where, $\bar{c}_j$ is the uncertain price of food j per 100 g. $\bar{c}_j = (c_j^-/c_j/c_j^+)$ are triangular fuzzy numbers that assign the uncertain price of foods.

Since, the uncertain prices of MCDP-FOC in Formula (2) are assigned by triangular fuzzy number $\bar{c}_j = (c_j^-/c_j/c_j^+)$, the objective will become multi-objective Linear Programming.

MULTI OBJECTIVE APPROACH

One of Fuzzy Linear Programming Approach is known as multi-objective. Multi-objective linear programming problems can be found in various fields. This formula focuses on minimizing cost of buying healthy food. Definition 1 shows the membership function of triangular fuzzy number.

Definition 1: The membership function of triangular fuzzy number $\bar{c}_j = (c_j^-/c_j/c_j^+)$ is:

$$\mu_{\bar{c}_j}(x) = \begin{cases} (x - c_j^-)/(c_j - c_j^-) & , c_j^- < x < c_j \\ (c_j^+ - x)/(c_j^+ - c_j) & , c_j \leq x < c_j^+ \\ 0 & , x \geq c_j^+ \quad \text{or} \quad x \leq c_j^- \end{cases} \tag{3}$$

where, $\mu_{\bar{c}_j}(x)$ is the membership function for uncertain price of food *j* per 100 g.

Equation 4 show the formula of multi-objective Linear Programming:

$$\min \sum_{j=1}^{n} c_j^- x_j, \min \sum_{j=1}^{n} c_j x_j, \text{ and } \min \sum_{j=1}^{n} c_j^+ x_j \tag{4}$$

The objectives also can be written as:

$$\max\ z_1 = \sum_{j=1}^{n} (c_j - c_j^-) x_j,\ \min\ z_2 = \sum_{j=1}^{n} c_j x_j,\ \text{and}\ z_3 = \sum_{j=1}^{n} (c_j^+ - c_j) x_j \tag{5}$$

When there are constraints, the maximum and minimum value for each objective can be found. It is show as below:

$$z_i^{max} = \max z_i \text{ and } z_i^{min} = \min z_i,\ i = 1, 2, 3$$

$$\text{Subject to } \sum_{j=1}^{n} a_{ij}x_j \geq b_i, \sum_{j=1}^{n} a_{ij}x_j \leq d_i, i = 1,2,...,m, \; x_j \geq 0 \tag{6}$$

Based on Eq. 6, the membership function of each objective is defined as:

$$\mu_{z_1}(x) = \begin{cases} 1 & , z_1 > z_1^{max} \\ (z_1 - z_1^{min}) / (z_1^{max} - z_1^{min}) & , z_1^{min} < z_1 \leq z_1^{max} \\ 0 & , z_1 \leq z_1^{min} \end{cases} \tag{7}$$

$$\mu_{z_2}(x) = \begin{cases} 1 & , z_2 < z_2^{min} \\ (z_2^{max} - z_2) / (z_2^{max} - z_2^{min}) & , z_2^{min} \leq z_2 < z_2^{max} \\ 0 & , z_2 \geq z_2^{max} \end{cases} \tag{8}$$

$$\mu_{z_3}(x) = \begin{cases} 1 & , z_3 < z_3^{min} \\ (z_3^{max} - z_3) / (z_3^{max} - z_3^{min}) & , z_3^{min} \leq z_3 < z_3^{max} \\ 0 & , z_3 \geq z_3^{max} \end{cases} \tag{9}$$

Based on fuzzy decision making proposed by Bellman and Zadeh (1970), let:

$$\beta = \min_x \left\{ \mu_{z_1}(x), \mu_{z_2}(x), \mu_{z_3}(x) \right\}$$

From Eq. 7-9, the model in problem 2 becomes the following optimization problem:

Maximize: β

$$\text{Subject to} \left(\sum_{j=1}^{n} (c_j^{\,0} - c_j^{\,-}) x_j \right) + \beta \left(z_1^{max} - z_1^{min} \right) \leq z_1^{max}, \left(\sum_{j=1}^{n} c_j^{\,0} x_j \right) - \beta \left(z_2^{max} - z_2^{min} \right) \geq z_2^{min}$$

$$\left(\sum_{j=1}^{n} (c_j^{\,+} - c_j^{\,0}) x_j \right) - \beta \left(z_3^{max} - z_3^{min} \right) \leq z_3^{min} \tag{10}$$

where, $x_j \geq 0$, $0 \leq \beta \leq 1$

DATA ANALYSIS

The number of chosen food is 40 and the number of nutrients is 27. The prices of foods (in RM) were collected from local grocery stores in March 2009, Terengganu, Malaysia. Nutrients requirements were for those of a 30 years-old-sedentary woman. The Acceptable Macronutrient Distribution Range (AMDR) for carbohydrate, fat and protein is 45 to 65%, 20 to 35% and 10 to 35% of calories, respectively. For 1982 kcal of energy, at 4 kcal g^{-1} of calories correspond to a maximum of 322 g of carbohydrate, 35% of calories correspondto maximum of 77.078 of fat.

Table 1: Nutrient requirement per day (Female, 30 years old, sedentary, BMI 24.99 kg m^{-2})

			Actual nutrient in the solution	
Nutrient	Minimum	Maximum	Crisp	Multi-objective
Energy (kcal d^{-1})	1982	ND	2223.12	1991.31
sugar (g d^{-1})	ND	124	100.75	124
Carbohydrate (g d^{-1})	130	322	322	195.99
Total fiber (g d^{-1})	25	ND	30.54	30.97
Fat (g d^{-1})	ND	77.078	77.0036	77.0005
Protein (g d^{-1})	46	173.425	78.36	114.7
Vitamin A (IU)	2333	ND	10000.13	10000.02
Vitamin C (mg d^{-1})	75	2000	565.68	811.39
Vitamin E (mg d^{-1})	15	1000	15	15
Thiamin (mg d^{-1})	1.1	ND	1.1.4	1.1
Riboflavin (mg d^{-1})	1.1	ND	2.62	2.28
Niacin (mg d^{-1})	14	35	15.16	26.74
Vitamin B6 (mg d^{-1})	1.3	100	2.16	2.24
Folate (µg d^{-1})	400	1000	504.55	604.83
Vitamin B12 (µg d^{-1})	2.4	ND	10.84	17.66
Panto-thenic Acid (mg d^{-1})	5	ND	8.21	9.67
Calcium (mg d^{-1})	1000	2500	999.56	999.93
Copper (mg d^{-1})	0.9	10	2.53	1.76
Iron (mg d^{-1})	18	45	18.49	18
Magnesium (mg d^{-1})	320	350	320	350
Manganese (mg d^{-1})	1.8	11	3.23	1.02
Phosphorus (mg d^{-1})	700	4000	1413.89	1713.06
Selenium (µg d^{-1})	55	400	149.6	263.06
Zinc (mg d^{-1})	8	40	8	8.08
Pottasium (mg d^{-1})	4700	ND	4700	4700
Sodium (mg d^{-1})	1500	2300	1500	1500

Table 1 shows the minimum maximum and actual nutrient requirements. Entering the price of food, nutrient requirements and amount of nutrients in food to the crisp and fuzzy model, the solutions as in Table 1 can be obtained.

THE HEALTH DIET SYSTEM

It is difficult for people to calculate the amount of nutrient in foods that they consume. Thus, a system to calculate it automatically is presented. The system is known as Health Diet System.

Figure 1 show the login page of the system, Fig. 2 show the homepage of the of the system, Fig. 3 show a page to calculate the Body Mass Index (BMI), Fig. 4 show the food taken by people and Fig. 5 show the final result based on the food and the amount of food taken.

The Health Diet System is functioning to calculate the amount of nutrient based on the food taken. People can choose how many times to eat daily. For example, minimum is one time and maximum is six time. After choosing the how many times to eat, the next step is to choose the type of food to be taken. After that, it will automatically generate the value of nutrients for particular foods. For example if they take coconut rice (nasi lemak) for breakfast, beriyani rice (nasi beriyani) for lunch and satay for dinner, it will calculate the amount of energy, protein, calcium, iron,

Fig. 1: Health diet system login page

Fig. 2: Health diet system homepage

vitamin and other nutrients based on the food that have been taken. Therefore, based on the amount of nutrients, the Health Diet System will determine the level of nutrients. Then, a graph is plotted to show all the amounts and types of nutrients taken. The Health Diet System will also help them to choose the healthy food with minimum cost. For example, if they have RM5, system will suggest healthy food based on the costs that have been keyed-in. The Health Diet System also help people in minimizing cost diet problem, manage them to get a healthy diet and would definitely boost the practice of a healthy lifestylein the Malaysian society.

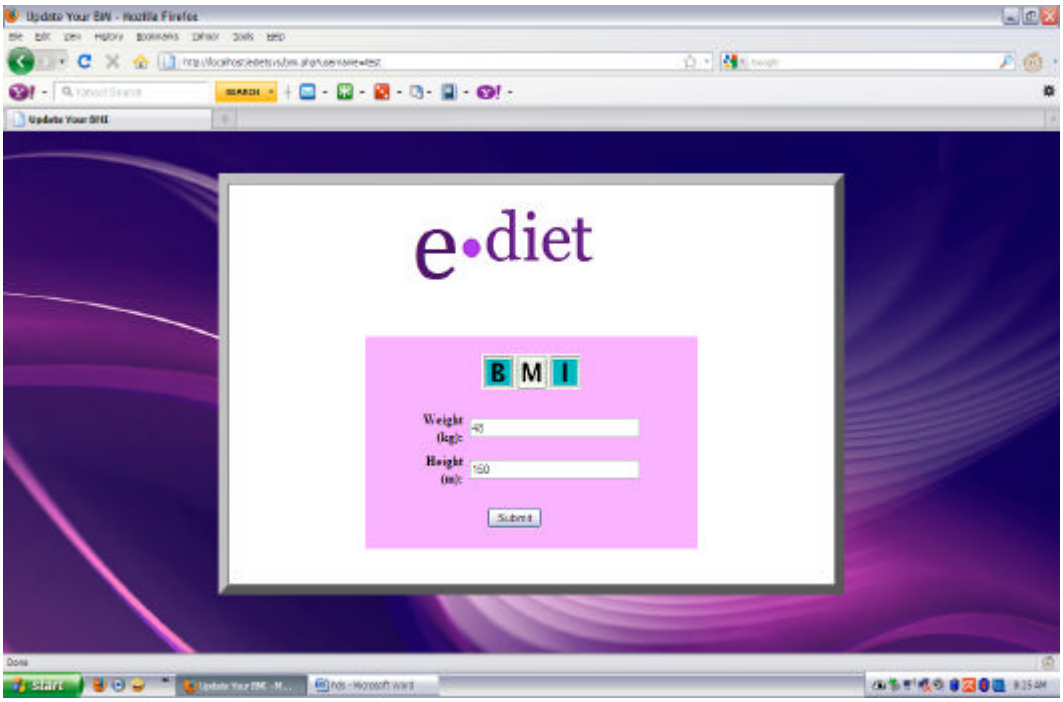

Fig. 3: Body mass index page

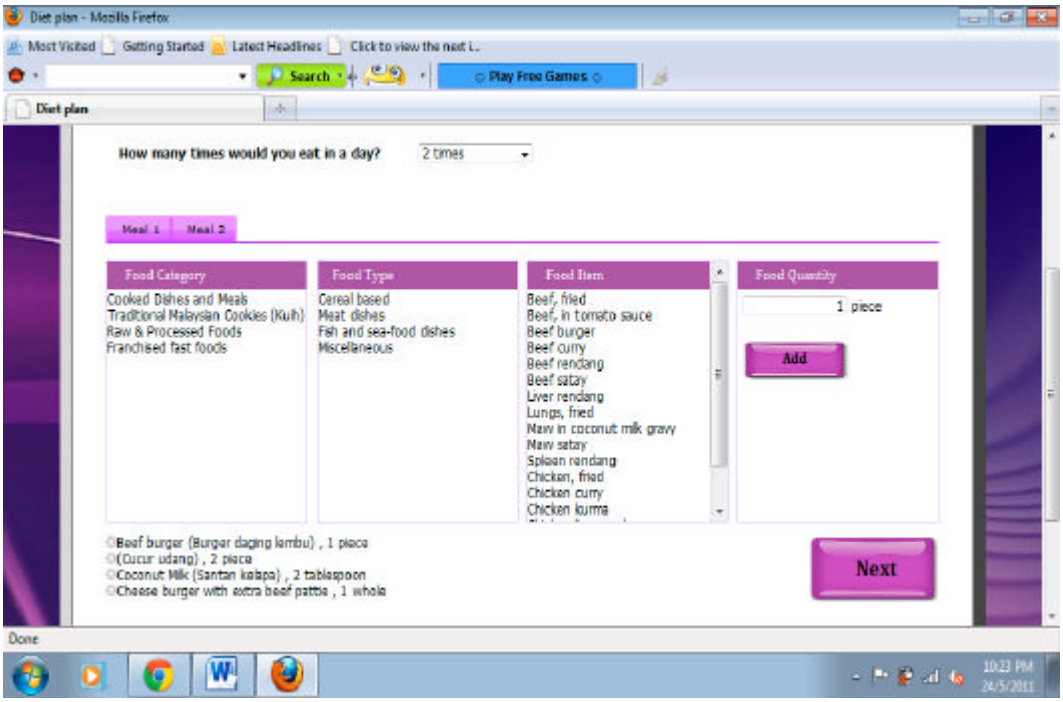

Fig. 4: Food taken page

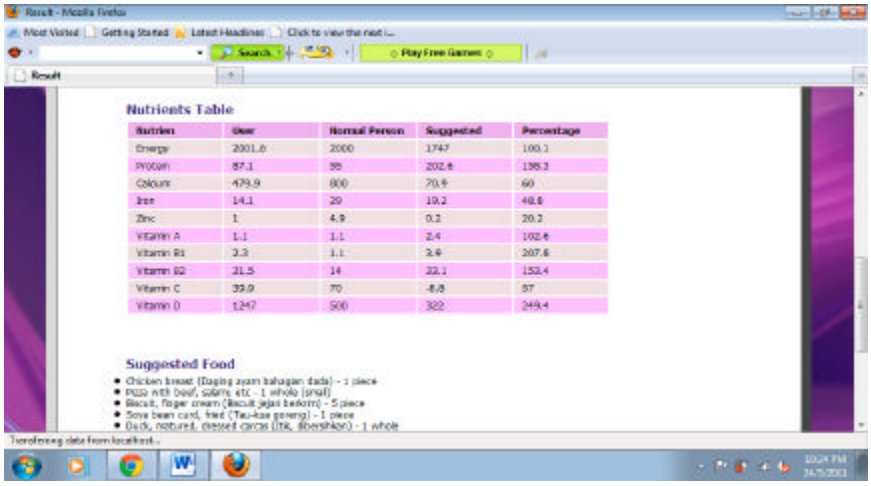

Fig. 5: Final result page of health diet system

CONCLUSION

Fuzzy linear programming approach is used to calculate the amount of nutrient in food. Thus, the balance diet and nutrient requirement can be determined. It is very important because mostly people just eat without considering the amount of nutrient in the food. Nowadays, mostly Malaysian people eat foods that contain high amount of sugar, fat and calories. This problem will lead them to get diabetes and cardiovascular disease. They need to prevent it from happen by taking healthy food. Besides that, when buying food, the price of food with the nutrient requirement need to be considered. It means that, if they just have RM5, they need to buy foods that will give them enough nutrients. It not just helps them to get balance diet but it also prevents them from getting any chronic diseases and obesity. Therefore, people need to concern about the food that they take so that they can prevent themselves from getting any disease. It is because preventing is better than cure.

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