Least Cost Diet for Children Two to Three Years in Malaysia Using Linear Programming Approach

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ABSTRACT

The early period of life, namely from birth to two years of age is critical for the promotion of optimal growth, brain development as well as health and behavioural development. Thus, attaining the daily required nutrition during this stage of life is very crucial since nutrition is strongly associated with a child's development at a very young age. It is a major challenge for Malaysians to ensure children get a balanced diet, especially children from families of low socioeconomic status. As reported in the Edge Weekly, the review found that 24.9% or nearly one in four children in Malaysia experienced moderate or severe food insecurity due to financial constraints. In this study, a linear programming diet model is used to determine an affordable cheapest food basket that satisfies the daily recommended nutritional requirements for children between two to three years old in Malaysia. POM-QM for Windows Version 5.2 by Howard J. Weiss is used. Initial finding shows that the average costs are RM2.69. This food basket consists of 474g of eggs, 55g of tofu, 29g of papaya, 5g of spinach and 201g of potato. With this food basket and estimated food expenditure, parents can save for 40% of their child's daily food expenditure.

Keywords: *Food Items, Linear Programming Model, Low Cost, Nutrition, Optimization*

INTRODUCTION

Malnutrition is associated with about half of all child deaths worldwide (Eunice et al., 2014). Possible explanations for this as addressed by Schönfeldt et al. (2010) are inefficient education on healthy eating habits and lack of ability to gain the necessary education due to economic constraints.

Socioeconomic background is the main factor for parents ability to buy food with sufficient nutrients or otherwise ("WHO Global Database on Child Growth and Malnutrition 14," 2011). In Malaysia, the prevalence of underweight and stunting persist among young children from poor rural areas (Khor & Sharif, 2003). According to Temim et al. (2010), the problem could be addressed by initiating low cost changes in the health system that would make the entire sector more responsive to the targeted people's requirements.

Linear programming has been utilised in various applications involving diet related problems. Okubo et al., (2015) has used linear programming to determine the pattern of food intake in fulfilling the recommendation of nutrient by Dietary Reference Intake (DRIs). Numerous researches have been done with different purposes such as by Briend et al., (2008) and Van der Merwe et al., (2014).

LP MODEL FORMULATION

This study uses linear programming approach i.e Simplex Method to determine the minimum food budget that satisfies the nutritional requirements for Malaysian children aged two to three years old. The nutrient content was derived from SELF Nutrition Data of Standard Tables Food Composition at nutritiondata.self.com. The Malaysian Dietary Guidelines for Children and Adolescents Summary was used to obtain the caloric, nutrient requirements, and Malaysian favourite food items.

The suggestion by Ministry of Health (2013) was used to identify the food items in the food basket. The collection of food prices was carried out at Giant Hypermarket Kangar on March 26, 2017, and the prices were normal prices without promotion or discount.

Objective function: Minimise cost

$$Z = \sum_{j=1}^{15} c_j X_j$$

where,

X_j = The quantity (100g) of the food item j, c_j = The cost of (100g) of food item j.
The food items are milk(X_1), yoghurt-plain(X_2), chicken(X_3), egg(X_4), mackerel(X_5), tofu(X_6), banana(X_7), papaya(X_8), carrot(X_9), spinach(X_{10}), white rice(X_{11}), white bread(X_{12}), potato(X_{13}), plain biscuits (X_{14}), and noodles(X_{15}).

The above objective function is subjected to the constraints:

$$\sum_{j=1}^{15} A_{ij} X_{ij} \geq B_i \quad ; \quad X_j \geq 0$$

where,

A_{ij}= The amount of nutrient *i* in food item j, and B_i = Minimum daily requirement of nutrient *i*.

The constraints are Carbohydrates ($C_x H_y O_z$), calcium (Ca), iron (Fe), magnesium (Mg), phosphorus (P), potassium (K), sodium (Na), vitamin A (Vit.A), vitamin C (Vit.C), vitamin E (Vit.E), vitamin K (Vit.K), energy, protein, and fats (Refer to Table 1).

Table 1: Price and Nutritional Content of 100 grams of Food Items

	Price (RM)	Energy (kJ)	CxHyOz (g)	Fats (g)	Protein (g)	Vit.A (mg)	Vit.C (mg)	Vit.E (mg)	Vit.K (mcg)	Ca (mg)	Fe (mg)	Mg (mg)	P (mg)	K (mg)	Na (mg)
Milk	0.5	176	5.2	1	3.4	58.8	0	0	0.1	119	0	11	95	150	44
Yoghurt	0.78	255	4.7	3.3	3.5	29.7	0.5	0.1	0.2	121	0.1	12	95	155	46
Chicken	0.72	691	0	3.6	31	6.3	0	0.3	2.8	15	1	29	228	256	74
Egg	0.33	821	0.9	15.3	13.6	218.7	0	1.2	0.3	59	2	13	208	147	204
Mackerel	0.96	1097	0	17.8	23.9	54	0.4	0	0	15	1.6	97	278	401	83
Tofu	0.3	607	4.3	8.7	15.8	49.8	0.2	0	0	683	2.7	58	190	237	14
Banana	0.37	373	22.8	0.3	1.1	19.2	8.7	0.1	0.5	5	0.3	27	22	358	1
Papaya	0.28	163	9.8	0.1	0.6	328.2	61.8	0.7	2.6	24	0.1	10	5	257	3
Carrot	0.3	147	8.2	0.1	0.6	4137	2.6	0	9.4	32	0.9	10	28	237	78
Spinach	1.5	96.3	3.7	0.3	3	3144	9.8	2.1	494	136	3.6	87	56	466	70
Rice	0.23	544	28.6	0.2	2.4	0	0	0	0	3	1.5	13	37	29	0
Bread	0.6	1227	54.4	4	9	0	0	0.2	3.4	119	3.3	26	103	131	592
Potato	0.4	389	21.2	0.1	2.5	3	9.6	0	2	15	1.1	28	70	535	10
Biscuits	1.06	1528	48.5	16.5	6.2	0.6	0	1.3	4.1	49	3.3	17	430	224	1052
Noodles	0.22	1608	71.3	4.4	14.2	18.6	0	0.4	0.5	35	4	58	241	244	21
Constraint		X≥1000	X≥22	X ≥5	X ≥12	X ≥300	X ≥15	X ≥6	X ≥30	X ≥700	X ≥7	X ≥65	X ≥380	X ≥2000	X ≥1000

Prior to using POM-QM software to obtain the optimal solution, the inequality constraints were converted to equality constraints. This was done by introducing the slack and artificial variables. Specifically, in this study all the constraints contain more than inequality ($\geq$).

For example, the energy constraint is shown in equation (1).

$$\begin{pmatrix} 176X_1 + 255X_2 + 691X_3 + 821X_4 + 1097X_5 + \\ 607X_6 + 373X_7 + 163X_8 + 147X_9 + 96.3X_{10} \\ +544X_{11} + 1227X_{12} + 389X_{13} + 1528X_{14} + 1608X_{15} \geq 1000kJ \end{pmatrix} \quad (1)$$

Subtracting the surplus S_1 and adding the artificial variables A_1 in equation (1) results in equation (2).

$$\begin{aligned} &176X_1 + 255X_2 + 691X_3 + 821X_4 + 1097X_5 + \\ &\quad 607X_6 + 373X_7 + 163X_8 + 147X_9 + 96.3X_{10} \\ &\quad +544X_{11} + 1227X_{12} + 389X_{13} + 1528X_{14} + \\ &1608X_{15} - S_1 + A_1 = 1000 \end{aligned} \quad (2)$$

RESULTS AND DISCUSSION

Table 2, 3 and 4 show the linear programming results. The result shows that RM2.68 is the minimum amount that parents need to spend daily on food for children of two to three years old, to meet their necessary nutritional requirements. The food basket must consist of 4.69g of eggs, 0.53g of tofu, 0.05g of spinach, 1.86g of potato and 0.68g of noodle.

Table 2: Optimal Solution of Food Basket

	Milk	Yogurt	Chicken	Egg	Mackerel	Tofu	Banana	Papaya	Carrot	Spinach	Rice	Bread	Potato	Biscuits	Noodles	RHS

Minimize	.5	.78	.72	.33	.96	.3	.37	.28	.3	1.5	.23	.6	.4	1.06	.22		
Energy	176	255	691	821	1097	607	373	163	147	96.3	544	1227	389	1528	1608	>=	1000
$C_xH_yO_z$	5.2	4.7	0	.9	0	4.3	22.8	9.8	8.2	3.7	28.6	54.4	21.2	48.5	71.3	>=	22
Fats	1	3.3	3.6	15.3	17.8	8.7	.3	.1	.1	.3	.2	.4	.1	16.5	4.4	>=	5
Protein	3.4	3.5	31	13.6	23.9	15.8	1.1	.6	.6	3	2.4	9	2.5	6.2	14.2	>=	12
Vit. A	58.8	29.7	6.3	218.7	54	49.8	19.2	328.2	4137	3144.3	0	0	3	.6	18.6	>=	300
Vit. C	0	.5	0	0	.4	.2	8.7	61.8	2.6	9.8	0	0	9.6	0	0	>=	15
Vit E	0	.1	.3	1.2	0	0	.1	.7	0	2.1	0	.2	0	1.3	.4	>=	6
Vit. K	.1	.2	2.8	.3	0	0	.5	2.6	9.4	494	0	3.4	2	4.1	.5	>=	30
Ca	119	121	15	59	15	683	5	24	32	136	3	119	15	49	35	>=	700
Fe	0	.1	1	2	1.6	2.7	.3	.1	.9	3.6	1.5	3.3	1.1	3.3	4	>=	7
Mg	11	12	29	13	97	58	27	10	10	87	13	26	28	17	58	>=	65
P	95	95	228	208	278	190	22	5	28	56	37	103	70	430	241	>=	380
K	150	155	256	147	401	237	358	257	237	466	29	131	535	224	244	>=	2000
Na	44	46	74	204	83	14	1	3	78	70	0	592	10	1052	21	>=	1000
Solution	**0**	**0**	**0**	**4.68722**	**0**	**.534497**	**0**	**0**	**0**	**.4966**	**0**	**0**	**1.86132**	**0**	**.677628**		**2.6752**

If parents wish to add food items other than those suggested in the Model, they need to increase food expenditure that follows the value of the "Reduced" column shown in Table 3. For example, the consumption of 100 grams of milk and yoghurt will increase the costs by RM0.34 and RM0.61, respectively.

Table 3: Optimal Values of Food Items

Food Item	Value	Reduced
Milk, low-fat	0	0.33881
Yoghurt-plain	0	0.607823
Chicken	0	0.457075
Egg	4.68722	0
Mackerel	0	0.607527
Tofu	0.534497	0
Banana	0	0.103634
Papaya	0	0.045367
Carrot	0	0.048009
Spinach	0.04966	0
Rice, white	0	0.208541
Bread, white	0	0.036259
Potato	1.86132	0
Biscuits plain	0	0.045866
Noodles	0.677628	0

Table 4: (i) Constraints Ranging Result (ii) Optimal values of nutrient requirement for the model

	Surplus	Original Val	Lower Bound	Upper Bound
Energy	4991.108	1000	-Infinity	5991.117
CxHyOz	72.47541	22	-Infinity	94.4759
Fats	74.54718	5	-Infinity	79.54719
Protein	74.61584	12	-Infinity	86.61588
Vit.A	926.0453	300	-Infinity	1226.292
Vit.C	3.462236	15	-Infinity	18.46239
Vit.E	0	6	5.793162	6.262717
Vit.K	0	30	5.44136	88.42194
Ca	0	700	337.5239	1203.465
Fe	8.754319	7	-Infinity	15.75437
Mg	122.6744	65	-Infinity	187.675
P	992.8777	380	-Infinity	1372.879
K	0	2000	1792.426	8707.064
Na	0	1000	948.642	1034.537

Nutrient	Original value	Level
Energy	1000	5991.117
CxHyOz	22	94.4759
Fats	5	79.54719
Protein	12	86.61588
Vit.A	300	1226.292
Vit.C	15	18.46239
Vit.E	6	6
Vit.K	30	30
Ca	700	700
Fe	7	15.75437
Mg	65	187.675
P	380	1372.879
K	2000	2000
Na	1000	1000

Table 4 shows that the value of surplus variable are as follows:
S_1 =4991.108, S_2 =72.47541, S_3 =74.54718, $S_4 = 74.61584$, $S_5 = 926.0453$, $S_6 = 3.462236$, $S_7 = 0$, $S_8 = 0$, $S_9 = 0$, $S_{10} = 8.754319$, $S_{11} = 122.6744$, $S_{12} = 992.8777$, $S_{13} = 0$, and $S_{14} = 0$.

Vitamin E, vitamin K, calcium, potassium and sodium have zero value for surplus variable where the resources are fully utilised. Thus, these five nutrients are binding constraints. However, a unit increase in the right-hand side of any of these nutrients will not increase food expenditure significantly.

Meanwhile, the constraints on the energy, carbohydrates, fats, protein, vitamin A, vitamin C, iron, magnesium and phosphorus are not binding in the Model since the value of the surplus is not zero. This indicates that there is an excess amount of resources which are utilised. Therefore, the “level” column as shown in Table 4 are new limitations for the constraints. These values are from the original values plus the surplus values for each constraint.

CONCLUSION AND RECOMMENDATIONS

This study aimed to find the least cost food basket which satisfied nutritional requirements for children between two to three years old in Malaysia. The Simplex method used in this study was successful in providing a systematic tool for designing least cost nutritious food basket. The least cost diet model proposed was also significant for parents from low income households as it provides information on proper balance diet of their children with affordable food items. Furthermore, all the suggested food items such as eggs, tofu, papaya, spinach, potato and noodle are widely available in Malaysia. This study only considered children for low household income from the Malay ethnic in Malaysia; not for any other specific cultural groups or races. It would be interesting if future research works can consider the food consumption patterns of specific cultural groups or races such as Chinese, Indian or other races in Sabah and Sarawak.

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