Optimization of Nutritional-Menu Planning for Toddlers by Goal Programming Model

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ABSTRACT

Food or nutrient intake is required to increase human resources. However, there are several problems that arise such as difficulties in preparing a nutritious menu for toddlers and lack of public understanding of nutritional fulfillment despite governmental efforts. Apparently, good quality nutrient is not always costly. Nutritionists often use the material exchange method in calculating the amount of nutrients contained in food as recommended in the standard menu for a toddler. However, this method can cause deviations above or below the expected amount of nutrition. The problem is a multi-objective one because it involves many goals to optimize simultaneously. The targets in preparing this menu are to meet the number of calories and nutritional content and to minimize the expenses. One model for solving this multi-objective problem is goal programming. This model aims to minimize deviations of calorie and nutrient content at optimal costs. The study resulted in the model and solution minimizing the total deviation from the target in accordance with the nutritional requirements set for toddlers.

Keywords: nutrient, menu, toddlers, multiobjective, Goal Programming.

1. INTRODUCTION

A nutrition issue is a necessary topic to discuss since it involves human resources. Nutrition problems that occur in the community include macro and micro nutrition. Macro nutrients usually measured in grams are needed by the body in large quantities, consisting of carbohydrates, proteins and fats. They are defined to provide calories or energy and are needed in large quantities to maintain bodily functions and carry out daily life activities. Meanwhile, micronutrients, as the name implies, are needed in small quantities. They include vitamins and minerals, for example vitamins A, B, C, D, E and K and minerals, such as iron, zinc, potassium and magnesium. The optimal amount of nutritional content which is energy, carbohydrate, fat, protein, iron, and vitamin C intake should be observed. Preparing a toddler menu based on food exchangers can sometimes cause deviations above or below the recommended amount. Therefore, it is necessary to compose a toddler menu whose deviation is as small as possible from the recommendation. The mathematical model that can be used to solve such a problem is the Goal Programming model.

Goal programming is derived from linear programming to achieve the desired goals or objectives. Its basic approaches are to set a goal expressed by a certain number for each goal, formulate an objective function, and find a solution by minimizing the number of deviations from the goal function [1]. This mathematical method solves problems to be optimal with multi objectives. Mathematically, in this method the decision variable must be defined first. Expected objectives must be specified based on their level of importance. Then the optimal solution is sought to minimize the total deviations of goals from the specified target.
Reference [2] discussed to minimize the amount of cost for toddler consumption every day in poor fishermen families, to analyze toddler food consumption habits as well as lower and upper limits of the weight of food consumed, and to get menu planning for toddlers as an effort to improve nutrition. In [3] the research discussed about to get the optimal solution in the selection of food intake. By using the goal programming model this research can minimize deviations from the objectives to be achieved. In 2007 Anis et al. conducted a study using goal programming without priority target", succeeding in forming a more profitable product combination by prioritizing company profits.[4]

See in [5] and [6], Dhoruri et al managed to determine food variations for patients with diabetes mellitus optimally. Based on the description above, the Goal programming model has the potential to be used because of its ability to solve the problem optimally with more than one objective (multi objective). Furthermore, many literatures about goal programming can be seen in [7], [8], [9], and [10]. In this research, both of the weighted and lexicographic goal programming are used in the model.

2. NUTRITION PLANNING FOR TODDLERS

The nutritional needs of toddlers are greater than those of adults, especially energy and protein needs because toddlers are in a phase of growth and development. Guidelines or references for food consumption as nutritional intake for toddlers use the Nutrition Adequacy Rate (NAR). Nutrition Adequacy Rate is a value that shows the amount of nutrients needed by the body to stay healthy every day for almost all populations according to age groups, sex, and certain physiological conditions such as pregnancy and breastfeeding [11]. This is useful to prevent the body from deficient or excessive intake of nutrients. The amount of nutrients needed by the body refers to the Table 1.

| Age (in year) | Energy (calories) | Protein (gram) | Fats (gram) | Carbohydrates (gram) | Iron (Mg) | Vitamin C (Mg) |
|--------------|-------------------|----------------|-------------|----------------------|-----------|----------------|
| 4 – 6        | 1400              | 25             | 50          | 220                  | 10        | 45             |

3. MATHEMATICAL MODEL

3.1. Assumption

The following is the assumptions needed in the formation of mathematical models according to nutritionists at regional public hospital:

a. Toddlers are considered to have no allergies to certain foods.
b. Toddlers have normal weight at birth and are not premature.
c. Toddlers to be the respondents aged 4-6 years.
d. Toddlers are not sick, so they do not need special care.
e. Calculation of the analysis of the amount of costs used for food is in terms of average income of middle class families.
f. Food for the menu is always available as needed.
g. Prices of types of food do not change during the study.
h. Prices of types of food are prices of raw food.
i. Cooking costs (operational) are ignored.

3.2. Data

In this study the data obtained was in the form of eating habits per day from toddlers 4-6 years old attached. The data was taken from toddlers in Pasuruhan, Mertooyudan, Magelang. The sample is toddlers at Healthcare Centre in Pasuruhan. From these data the upper and lower quartiles were counted as limits on the amount of food consumed per day by toddlers. The data were obtained by conducting interviews with respondents assisted by Integrated Healthcare Center officers in Pasuruhan. The data obtained included the condition of the child at birth, weight at birth, whether they had been hospitalized in the last 3 months, whether they had suffered from tuberculosis, and the amount of the habitual food consumption of the child. Based on the interview results, data were obtained from 35 child respondents aged 4 - 6 years at Healthcare Centre in Pasuruhan. All of the respondents were healthy so that they met the model assumptions. Furthermore, Table 2 shows the lower and upper quartiles of the food consumption habits of toddlers.
Table 2 Toddlers’ food consumption habits

| No | Food Type       | Q₁ (gr) | Q₂ (gr) | No | Food Type       | Q₁ (gr) | Q₂ (gr) |
|----|----------------|---------|---------|----|----------------|---------|---------|
| 1  | Rice           | 150     | 250     | 16 | Mustard Greens | 20      | 60      |
| 2  | Vermicelli     | 35      | 70      | 17 | Carrot         | 20      | 60      |
| 3  | Bread          | 20      | 50      | 18 | Potato         | 50      | 150     |
| 4  | Biscuit        | 50      | 100     | 19 | Water Spinach  | 25      | 75      |
| 5  | Cassava        | 75      | 150     | 20 | Spinach        | 25      | 100     |
| 6  | Chicken Meat   | 50      | 200     | 21 | Vegetable Soup | 50      | 100     |
| 7  | Beef           | 50      | 100     | 22 | Beans          | 25      | 50      |
| 8  | Chicken Egg    | 30      | 120     | 23 | Cauliflower    | 25      | 50      |
| 9  | Milkfish       | 25      | 50      | 24 | Orange         | 30      | 100     |
| 10 | Shrimp         | 25      | 50      | 25 | Banana         | 20      | 60      |
| 11 | Sweetened Condensed Milk | 42 | 100 | 26 | Papaya        | 50      | 100     |
| 12 | Soybean Cake   | 25      | 75      | 27 | Jelly          | 45      | 95      |
| 13 | Tofu           | 25      | 75      | 28 | Milk Powder    | 10      | 30      |
| 14 | Green Beans    | 50      | 100     | 29 | Oil            | 2.5     | 5       |
| 15 | Sayur Asam     | 50      | 100     |     |                |         |         |

Table 3 is the nutritional content in each of the consumed food type. The value in Table 3 will be the technology coefficient \((a_{ij})\) of the decision variable \((x_j)\). Adequacy rates for nutrients needed by toddlers \((b_i)\) are taken from Table 1. Meantime, food prices adjusted for data collection areas data \((c_j)\) are presented in Table 4.

### 3.3. Weighted Goal Programming Model (Non-Preemptive Goal Programming)

Weighted goal programming is a model used to minimize more than one objective function using weighting techniques. In this model each variable deviation in the objective function can be given different weights according to interests. The most important goal has the highest weight value. The notation \(w_i\) is a positive weight that reflects the decision makers’ preferences regarding the relative importance of each objective function [14].

Thus, the general form of weighted goal programming is as follows:

Minimize:

\[
Z = \sum_{i=1}^{m} w_i (d_i^+ + d_i^-) \tag{1}
\]

And

\[
X_j, d_i^+, d_i^- \geq 0 \tag{3}
\]

Where,

\[
w_i : \text{the weight given to the deviation from the goal } b_i (w_i \geq 0). \text{ This value based on the nutritionist}
\]

\[
d_i^+ : \text{the number of deviation units used is greater than the value } b_i
\]

\[
d_i^- : \text{the number of deviation units used is less than the value } b_i
\]

### 3.4. Goal Programming Model with priority goals (Preemptive / Lexicographic Goal Programming)

Lexicographic Goal Programming is a goal programming model that has goals each of which has an order of priority level. The notation used to mark the priority of goals is \(P_i (i = 1, 2, 3, \ldots, m)\). Priority factors have the following relationships:

\[
P_1 \gg P_2 \gg \cdots \gg P_m \tag{4}
\]

According to [1], the general form of lexicographic goal programming is as follows:

Minimize

\[
Z = [P_1(d_1^+, d_1^-), P_2(d_2^+, d_2^-), \ldots, P_m(d_m^+, d_m^-)] \tag{5}
\]

With constraints

\[
\sum_{j=1}^{n} a_{ij}X_j + d_i^- - d_i^+ = b_i \tag{2}
\]

For \(i = 1, 2, \ldots, m\) and \(j = 1, 2, \ldots, n\)
The constraint function based on the target
\[ \sum_{i=1}^{m} a_{ij} x_j + d_i^- - d_i^+ = b_i \]
for \( i = 1,2,\ldots,m \) and \( j = 1,2,\ldots,n \) \( \ldots \) (6)
Non negative constraints
\[ x_j, d_i^-, d_i^+ \geq 0 \] \( \ldots \) (7)
Information:
\[ d_i^- = \text{The number of deviation units lacking (-) the goal } b_i \]
\[ d_i^+ = \text{The number of deviation units excess (+) goal } b_i \]

**Table 3.** Nutrient content in each of the food types [13]

| No | Food Type                  | Energy (kcal) | Protein (g) | Fat (g) | Carbohydrate (g) | Iron (mg) | Vit.C (mg) |
|----|---------------------------|--------------|-------------|---------|-----------------|-----------|----------|
| 1  | Rice                      | 180          | 3           | 0.3     | 39.8            | 1.8       | 0        |
| 2  | Vermicelli                | 348          | 4.7         | 0.1     | 82.1            | 1.8       | 0        |
| 3  | Bread                     | 248          | 8           | 1.2     | 50              | 1.5       | 0        |
| 4  | Biscuit                   | 458          | 6.9         | 14.4    | 75.1            | 2.7       | 0        |
| 5  | Cassava                   | 154          | 1           | 0.3     | 36.8            | 1.1       | 31       |
| 6  | Chicken Meat (fresh)      | 298          | 18.2        | 25      | 0               | 1.5       | 0        |
| 7  | Beef (floss)              | 358          | 14.6        | 16.1    | 38.6            | 14.6      | 0        |
| 8  | Chicken Egg               | 154          | 12.4        | 10.8    | 0.7             | 3         | 0        |
| 9  | Presto Milkfish           | 296          | 17.1        | 20.3    | 11.3            | 1.9       | 69       |
| 10 | Shrimp                    | 91           | 21          | 0.2     | 0.1             | 8         | 0        |
| 11 | Sweetened Condensed Milk  | 343          | 8.2         | 10      | 55              | 0.2       | 1        |
| 12 | Soybean Cake              | 201          | 20.8        | 8.8     | 13.5            | 4         | 0        |
| 13 | Tofu                      | 80           | 10.9        | 4.7     | 0.8             | 3.4       | 0        |
| 14 | Green Bean (boiled)       | 109          | 8.7         | 0.5     | 18.3            | 1.5       | 3        |
| 15 | Sayur Asam                | 29           | 0.7         | 0.6     | 5               | 3.1       | 0        |
| 16 | Fresh Mustard Greens      | 28           | 2.3         | 0.3     | 4               | 2.9       | 102      |
| 17 | Carrot                    | 36           | 1           | 0.6     | 7.9             | 1         | 18       |
| 18 | Potato                    | 62           | 2.1         | 0.2     | 13.5            | 0.7       | 21       |
| 19 | Water Spinach             | 28           | 3.4         | 0.7     | 3.9             | 2.3       | 13       |
| 20 | Spinach                   | 16           | 0.9         | 0.4     | 2.9             | 3.5       | 41       |
| 21 | Vegetable Soup            | 27           | 1.3         | 2       | 1               | 1.8       | 0        |
| 22 | Bean                      | 34           | 2.4         | 0.3     | 7.2             | 0.7       | 11       |
| 23 | Cauliflower               | 25           | 2.4         | 0.2     | 4.9             | 1.1       | 69       |
| 24 | Orange                    | 45           | 0.9         | 0.2     | 11.2            | 0.4       | 49       |
| 25 | Banana                    | 108          | 1           | 0.8     | 24.3            | 0.2       | 9        |
| 26 | Papaya                    | 46           | 0.5         | 12      | 12.2            | 1.7       | 7.8      |
| 27 | Jelly                     | 0            | 0           | 0.2     | 0               | 5         | 0        |
| 28 | Milk Powder               | 513          | 24.6        | 30      | 36.2            | 0.6       | 6        |
| 29 | Oil                       | 884          | 0           | 100     | 0               | 0         | 0        |
Table 4. Food prices

| No | Food Type      | Price per 100gr (rupiah) | No | Food Type       | Price per 100gr (rupiah) |
|----|----------------|--------------------------|----|----------------|--------------------------|
| 1  | Rice           | 1500                     | 16 | Sawi           | 500                      |
| 2  | Vermicelli     | 1000                     | 17 | Carrot         | 700                      |
| 3  | Bread          | 3000                     | 18 | Potato         | 1200                     |
| 4  | Biscuit        | 4000                     | 19 | Water Spinach  | 600                      |
| 5  | Cassava        | 500                      | 20 | Spinach        | 800                      |
| 6  | Chicken Meat   | 3000                     | 21 | Vegetable Soup | 1000                     |
| 7  | Beef (floss)   | 20000                    | 22 | Bean           | 400                      |
| 8  | Chicken Egg    | 2500                     | 23 | Cauliflower    | 700                      |
| 9  | Milkfish       | 3000                     | 24 | Orange         | 2500                     |
| 10 | Shrimp         | 8000                     | 25 | Banana         | 1500                     |
| 11 | Sweetened Condensed Milk | 3000 | 26 | Papaya         | 900                      |
| 12 | Soybean Cake  | 1500                     | 27 | Jelly          | 1300                     |
| 13 | Tofu           | 1700                     | 28 | Milk Powder    | 9000                     |
| 14 | Green Bean     | 1500                     | 29 | Oil            | 2000                     |
| 15 | Sayur Asam     | 1000                     |    |                |                           |

Assume that each goal function is optimal. The first step is completing first priority,

Priority 1. Minimize $d_1^+ + d_1^-$

With constraints: Goal equation

Constraint Function

$\sum d_1^+ + \sum d_1^- = v_1$

Non negative constraints

Suppose the solution obtained is the value of the goal function, $v_1$. Thus, the Lexicographic Goal Programming model for the second priority is as follows:

Priority 2. Minimize $d_2^+ + d_2^-$

With Constraints: Goal equation

Constraint Function

$\sum d_1^+ + \sum d_1^- = v_1$

Non negative constraints

$\vdots$

Priority n. Minimize $d_n^+ + d_n^-$

With Constraints: Goal equation

Constraint Function

$\sum d_{n-1}^+ + \sum d_{n-1}^- = v_{n-1}$

Non negative Constraints

4. RESULT AND DISCUSSION

In previous, researcher uses goal programming without target priority. In this study, two methods were used, namely a weighted goal programming and a lexicographic goal programming. In the first method, objective functions are given equal weight based on nutritionist opinion. Then the second method, the first priority are meet energy and protein needs. So, that the deviation from the objective function with the first priority is minimized first. Then, the deviation from the results obtained is entered into the constraint function in the model with the second priority (meet carbohydrate and fat needs). At last, this is done for the model with the third priority (meet iron and vitamin C needs, also minimize expense). The result is the solution of the lexicographic model. Both of the model with those method are done by using A simplex method. The calculation is helped by LINGO program. The following is an example of a menu design served.
### Tabel 5. Menu design

| No | Food Type       | No | Food Type      |
|----|-----------------|----|----------------|
| 1  | Rice            | 8  | Tofu           |
| 2  | Bread           | 9  | Carrot         |
| 3  | Cassava         | 10 | Vegetable Soup |
| 4  | Chicken Meat    | 11 | Orange         |
| 5  | Chicken Egg     | 12 | Banana         |
| 6  | Sweetened       | 13 | Oil            |
| 7  | Soybean Cake    | 14 | Milk Powder    |

The variables and parameters used are as follows:

- \( a_{ij} \): the nutrient content to-i in 100 grams of food type \( x_j \)
- \( x_j \): the amount of the food to-j per 100 grams
- \( y \): food consumption expenditure for toddlers every day

i = nutrient content:
1(Energy), 2(Protein), 3(Fat), 4(Carbohydrate), 5(Iron), 6(Vitamin C) and 7(food price)

\( j = 1, 2, 3, ..., p \)

- \( a_p \): food price to-p in 100 grams
- \( b_i \): Recommended Nutritional Adequacy Rate to-i
- \( d_i^- \): negative deviation of nutritional elements i
- \( d_i^+ \): positive deviation of nutritional elements i
- \( b_{1j} \): the lower quartile of food types \( x_j \) in 100 grams
- \( b_{2j} \): the higher quartile of food types \( x_j \) in 100 grams

**Formulation of menu constraints for day -1:**

Meet the needs of macro nutrients (energy, protein, fat and carbohydrates),

- Energy: \[ 180x_1 + 248x_3 + 154x_5 + 298x_6 + 154x_8 + 343x_{11} + 201x_{12} + 80x_{13} + 36x_{14} + 27x_{21} + 45x_{24} + 108x_{25} + 513x_{28} + 884x_{29} + d_1^- - d_1^+ = 1400 \]
- Protein: \[ 3x_1 + 8x_3 + 1x_5 + 18.2x_6 + 12.4x_8 + 8.2x_{11} + 20.8x_{12} + 10.9x_{13} + 1x_{17} + 1.3x_{21} + 0.9x_{24} + 1x_{25} + 24.6x_{28} + 0x_{29} + d_2^- - d_2^+ = 25 \]
- Fat: \[ 0.3x_1 + 1.2x_3 + 0.3x_5 + 25x_8 + 10.8x_{10} + 10x_{11} + 8.8x_{12} + 4.7x_{13} + 0.6x_{17} + 2x_{21} + 0.2x_{24} + 0.8x_{25} + 30x_{28} + 100x_{29} + d_3^- - d_3^+ = 50 \]
- Carbohydrate: \[ 39.8x_1 + 50x_3 + 36.8x_5 + 0x_6 + 0.7x_8 + 55x_{11} + 13.5x_{12} + 0.8x_{13} + 7.9x_{17} + 1x_{21} + 11.2x_{24} + 24.3x_{25} + 36.2x_{28} + 0x_{29} + d_4^- - d_4^+ = 220 \]

Meet micronutrients (iron and vitamin C)

- Iron: \[ 1.8x_1 + 1.5x_3 + 1.1x_5 + 1.5x_6 + 3x_8 + 0.2x_{11} + 4x_{12} + 3.4x_{13} + 1x_{17} + 1.8x_{21} + 0.4x_{24} + 0.2x_{25} + 0.6x_{28} + 0x_{29} + d_6^- - d_6^+ = 45 \]
- Vitamin C: \[ 0x_1 + 0x_3 + 31x_5 + 0x_6 + 0x_8 + 1x_{11} + 0x_{12} + 0x_{13} + 18x_{17} + 0x_{21} + 49x_{24} + 9x_{25} + 6x_{28} + 0x_{29} + d_5^- - d_5^+ = 25 \]

Minimize costs spent.

- Cost: \[ 1500x_1 + 3000x_3 + 500x_5 + 3000x_6 + 2500x_8 + 3000x_{11} + 1500x_{12} + 1700x_{13} + 700x_{17} + 1000x_{21} + 2500x_{24} + 1500x_{25} + 9000x_{28} + 2000x_{29} + d_7^- - d_7^+ - F = 0 \]

Mathematical model of day 1 menu formed:

**Weighted Goal Programming:**

- Minimize: \[ d_1^- + d_2^- + d_3^- + d_4^- + d_5^- + d_6^- + d_7^- + d_7^+ \] (12)

Toward equality constraints in Equation 8 – 10.

**Lexicographic Goal Programming:**

According to the results of discussions with nutritionists, the priority order of goals to be achieved is obtained, namely

- P1: meet energy and protein needs
- P2: meet the needs of fat and carbohydrates
- P3: meet the needs of iron and vitamin C and minimize costs.

Mathematical model that is formed:

- Minimize: \[ P1(d_1^- + d_2^-) + P2(d_3^- + d_4^-) + P3(d_5^- + d_6^- + d_7^- + d_7^+) \] (13)

Toward equality constraints in Equation 8 – 10.

The results of calculations with the LINGO program that using a simplex method are as follows.
| Time      | Food Type          | Weight (g) | URT  | Energy (kcal) | Protein (g) | Fat (g) | Carbohydrate (g) | Iron (mg) | Vit.C (mg) | Price |
|-----------|--------------------|------------|------|---------------|-------------|---------|--------------------|-----------|------------|--------|
| **Breakfast** |                    |            |      |               |             |         |                    |           |            |        |
| Rice      | 37.5               | $\frac{1}{4}$ cup | 67.5 | 1.12          | 0.11        | 14.92   | 0.67               | 0         | 562.5      |
| Vegetable Soup | 25            | $\frac{1}{4}$ cup | 6.75 | 0.325         | 0.5         | 0.25    | 0.45               | 0         | 250        |
| Chicken Egg | 30                | 1 with small size | 46.2 | 3.72          | 3.24        | 0.21    | 0.9                | 0         | 750        |
| Soybean Cake | 25                | 1 slice with medium size | 50.25 | 5.2         | 2.2        | 3.37    | 1                  | 0         | 375        |
| Orange    | 100                | 1 with medium size | 45   | 0.9          | 0.2        | 11.2    | 0.4                | 49        | 2500       |
| Milk powder | 14.62              | 2 tablespoons | 75   | 3.59         | 4.38       | 5.29    | 0.08               | 0.87      | 1315.8     |
| Oil       | 1.67               | 2 tablespoons | 14.73 | 0         | 1.67       | 0       | 0                  | 0         | 33.34      |
| **Snack**   |                    |            |      |               |             |         |                    |           |            |        |
| Bread     | 10                 | 1 slice    | 24.8 | 0.8          | 0.12       | 5       | 0.15               | 0         | 300        |
| Cassava   | 75                 | $\frac{3}{4}$ slice | 45.5 | 0.75        | 0.23       | 27.6    | 0.82               | 23.25     | 250        |
| **Lunch**  |                    |            |      |               |             |         |                    |           |            |        |
| Rice      | 56.25              | $\frac{1}{2}$ cup | 101.25 | 1.68      | 0.16       | 22.38   | 1.01               | 0         | 843.75     |
| Vegetable Soup | 25          | $\frac{1}{4}$ cup | 6.75 | 0.325       | 0.5        | 0.25    | 0.45               | 0         | 250        |
| Chicken Meat | 41.63            | 1 slice with medium size | 124.05 | 7.57     | 10.4      | 0       | 0.62               | 0         | 1248.9     |
| Tofu      | 25                 | $\frac{1}{2}$ slice with big size | 20   | 2.72        | 1.27      | 0.2     | 0.85               | 0         | 425        |
| Oil       | 1.67               | 2 tablespoons | 14.73 | 0         | 1.67       | 0       | 0                  | 0         | 33.34      |
| Sweetened Condensed Milk | 50            | $\frac{1}{2}$ cup | 171.5 | 4.1        | 5         | 27.5    | 0.1                | 0.5       | 1500       |
| Banana    | 60                 | 1 with medium size | 64.8 | 0.6        | 0.48      | 14.58   | 0.12               | 5.4       | 900        |
| **Snack**   |                    |            |      |               |             |         |                    |           |            |        |
| Cassava   | 75                 | $\frac{3}{4}$ slice | 45.5 | 0.75        | 0.23       | 27.6    | 0.82               | 23.25     | 250        |
| Bread     | 10                 | 1 slice    | 24.8 | 0.8          | 0.12       | 5       | 0.15               | 0         | 300        |
| **Dinner** |                    |            |      |               |             |         |                    |           |            |        |
| Rice      | 56.25              | $\frac{1}{2}$ cup | 101.25 | 1.68      | 0.16       | 22.38   | 1.01               | 0         | 843.75     |
| Chicken Meat | 41.63            | 1 slice with medium size | 124.05 | 7.57     | 10.4      | 0       | 0.62               | 0         | 1248.9     |
| Carrot    | 60                 | $\frac{1}{2}$ with medium size | 21.6 | 0.6        | 0.36      | 4.74    | 0.6                | 10.8      | 420        |
| Oil       | 1.67               | 2 tablespoons | 14.73 | 0         | 1.67       | 0       | 0                  | 0         | 33.34      |
| Sweetened Condensed Milk | 50            | $\frac{1}{2}$ cup | 171.5 | 4.1        | 5         | 27.5    | 0.1                | 0.5       | 1500       |
| **Total**  |                    |            |      | 1522.27      | 48.94      | 49.27   | 219.99             | 10.95     | 113.57     |
| Ratio (%) |                   |            |      | 108.73       | 195.76     | 98.54   | 99.99              | 109.5     | 252.37     |

Table 6. The results of weighted Goal Programming
Table 7. The results of Lexicographic Goal Programming

| Time   | Food Type    | Weight (g) | URT       | Energy (kcal) | Protein (g) | Fat (g) | Carbohydrate (g) | Iron (mg) | Vit.C (mg) | Price    |
|--------|--------------|------------|-----------|---------------|-------------|---------|------------------|-----------|------------|----------|
| Breakfast | Rice        | 53.25      | 1 1/2 cup | 104.85        | 1.74        | 0.17    | 23.18            | 1.04      | 0          | 873.75   |
|         | Vegetable Soup | 25         | 1 1/4 cup | 6.75          | 0.32        | 0.5     | 0.25             | 0.45      | 0          | 250      |
|         | Soybean Cake  | 25         | 1 slice with medium size | 50.25 | 5.2 | 2.2 | 3.37 | 1 | 0 | 375 |
|         | Milk Powder  | 30         | 3 tablespoons | 153.9 | 7.38 | 9 | 10.86 | 0.18 | 1.8 | 2700   |
|         | Oil          | 1.67       | 2 tablespoons | 14.73 | 0 | 1.67 | 0 | 0 | 0 | 33.34   |
| Snack    | Cassava      | 37.5       | 1 1/2 slice | 57.75 | 0.37 | 0.11 | 13.8 | 0.41 | 11.62 | 187.5   |
|         | Bread        | 10         | 1 slice    | 24.8         | 0.8         | 0.12   | 5    | 0.15 | 0 | 300      |
|         | Banana       | 60         | 1 with medium size | 64.8 | 0.6 | 0.48 | 14.58 | 0.12 | 5.4 | 900     |
| Lunch    | Rice         | 87.37      | 3 1/4 cup  | 153.27        | 2.62        | 0.26   | 34.77 | 1.57 | 0 | 1310.62  |
|         | Vegetable Soup | 25         | 1 1/4 cup | 6.75          | 0.32        | 0.5    | 0.25             | 0.45      | 0          | 250      |
|         | Chicken Meat | 33.12      | 1 slice with medium size | 98.69 | 6.02 | 8.28 | 0 | 0.49 | 0 | 993.6   |
|         | Tofu         | 25         | 1 1/2 slice with big size | 20 | 2.72 | 1.17 | 0.2 | 0.85 | 0 | 425     |
|         | Oil          | 1.67       | 2 tablespoons | 14.73 | 0 | 1.67 | 0 | 0 | 0 | 33.34   |
|         | Sweetened Condensed Milk | 50 | 1 1/2 cup | 171.5 | 4.1 | 5 | 27.5 | 0.1 | 0.5 | 1500   |
| Snack    | Cassava      | 37.5       | 1 1/2 slice | 57.75 | 0.37 | 0.11 | 13.8 | 0.41 | 11.62 | 187.5   |
|         | Bread        | 10         | 1 slice    | 24.8         | 0.8         | 0.12   | 5    | 0.15 | 0 | 300      |
|         | Orange       | 30         | 1 1/2 with medium size | 13.5 | 0.27 | 0.06 | 3.36 | 0.12 | 14.7 | 750     |
| Dinner   | Rice         | 87.37      | 3 1/4 cup  | 153.27        | 2.62        | 0.26   | 34.77 | 1.57 | 0 | 1310.62  |
|         | Chicken Meat | 33.12      | 1 slice with medium size | 98.69 | 6.02 | 8.28 | 0 | 0.49 | 0 | 993.6   |
|         | Carrot       | 20         | 1 1/2 with small size | 7.2 | 0.2 | 0.12 | 1.58 | 0.2 | 3.6 | 140     |
|         | Oil          | 1.67       | 2 tablespoons | 14.73 | 0 | 1.67 | 0 | 0 | 0 | 33.34   |
|         | Sweetened Condensed Milk | 50 | 1 1/2 cup | 171.5 | 4.1 | 5 | 27.5 | 0.1 | 0.5 | 1500   |
|         | Chicken egg  | 30         | 1 with small size | 46.2 | 3.72 | 3.24 | 0.21 | 0.9 | 0 | 750     |
|         | Total        |            |            | 1538.44      | 50.34       | 49.99  | 219.99 | 10.78 | 49.75 | 16097   |
|         | Ratio (%)    |            |            | 109.88       | 201.36      | 99.98  | 99.99  | 107.8 | 110.5 |          |
Table 6 shows the objective function of fulfilling energy, fat, carbohydrate and iron needs is achieved. It can be seen from the last row in column 5, 7, 8, and 9 the percentage of tolerance for achieving nutritional needs, namely 90-110% of the expected. Meanwhile, from the last row in column 6 and 10 the need of protein and vitamin C is not achieved because it is above the target. This can be overcome by reducing a number of the types of food that have a big influence on these nutrients but do not reduce the need for other nutrients. Besides, the variation of food types can be changed. The expense for this menu is IDR 16,383.00.

Table 7 describes all of the objective function of fulfilling a nutritional needs is achieved except a protein need. It can be seen from the percentage of protein needs, more than 110% of the expected value. Meanwhile the expense for this menu is IDR 16,097.00. It can be seen from Table 6 and Table 7, in this case The Lexicographic Goal Programming has many advantages than The Weighted Goal Programming in terms of achieving its goals.

5. CONCLUSIONS

Mathematical model for menu planning for toddlers is in the form of a linear program with several (multi-objective) functions. The objective functions to be achieved are to meet the need for macronutrients (energy, protein, fat, and carbohydrates), to meet micronutrients (iron and vitamin C), and to minimize expenses. The approach used to complete the Goal Programming Model includes Weighted Goal Programming and Lexicographic Goal Programming. Weighted Goal Programming with the same weighted objective function resulted in a given menu variation the objective function of fulfilling energy, fat, carbohydrate and iron needs is achieved. The need of protein and vitamin C is not achieved because it is above the target. This can be overcome by reducing the types of food that have a big influence on these nutrients but do not reduce the need for other nutrients. The expense for this menu is IDR 16,383.00. Meanwhile, Lexicographic Goal Programming is a model with an order of priority. According to nutritionists, the first priority is to meet energy and protein needs, the second priority is to meet the needs of fat and carbohydrates, and the third priorities are to meet iron and vitamin C needs and to minimize expenditure costs. The result are the objective function of fulfilling a nutritional needs is achieved except a protein need. The expense for this menu is IDR 16,097.00. It can be seen that The Lexicographic Goal Programming more advantages than The Weighted Goal Programming in terms of achieving its goals based on the expense.

AUTHORS’ CONTRIBUTIONS

DL forms mathematical models and simulates computer programs. AMA and AD analyze data. AIT and EH compile an interpretation of the results. all authors also compile the article as a whole

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