Application of Goal Programming Method for Optimizing Complementary Feeding (MP-ASI) Menu Composition in Stunting Prevention Efforts

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Publication Date: 2026/07/02

Abstract: This study aims to optimize the composition of complementary feeding (CF) menus using the goal programming method by considering the fulfillment of macronutrient and micronutrient requirements, as well as cost constraints. The model was solved using LINGO software. The results indicate that the optimal menu composition consists of 130 g of sweet potato, 125 g of beef, 60 g of spinach, and 105 g of tofu, with a total cost of IDR 19,210. Sensitivity analysis revealed that an increase in the price of beef has the most significant impact on changes in the optimal solution, whereas changes in the prices of sweet potato and tofu have no substantial effect.

Keyword: *Complementary Feeding, Goal Programming, Sensitivity Analysis, Stunting.*

How to Cite: Aidawayati Rangkuti; Ghefira (2026) Application of Goal Programming Method for Optimizing Complementary Feeding (MP-ASI) Menu Composition in Stunting Prevention Efforts. *International Journal of Innovative Science and Research Technology*, 11(6), 2034-2040. https://doi.org/10.38124/ijisrt/26jun795

I. INTRODUCTION

Stunting remains a major global and national nutritional problem. It is a growth and developmental disorder in children caused by chronic undernutrition and recurrent infections, characterized by height-for-age measurements below established standards. Beyond impaired physical growth, stunting can negatively affect cognitive development, immune function, and increase the risk of non-communicable diseases later in life (Asra Laily & Indarjo, 2023).

One of the primary factors contributing to stunting is inadequate nutrient intake required to support child growth and development. The age period of 6–12 months is considered a critical window for stunting prevention because infants begin receiving complementary feeding during this stage to meet nutritional requirements that can no longer be fulfilled solely by breast milk (Shobah & Rokhaidah, 2021). Therefore, appropriate complementary feeding practices are essential to bridge nutritional gaps and serve as an effective strategy for stunting prevention

However, formulating complementary feeding menus presents challenges because food ingredients vary considerably in their nutrient content. Inappropriate combinations of food ingredients may result in nutritional requirements not being met optimally. Consequently, a systematic menu-planning approach is needed to determine food compositions capable of satisfying both macronutrient and micronutrient requirements according to recommended standards.

One approach that can be applied to address this problem is goal programming. Goal programming is a multi-objective optimization technique designed to solve problems involving multiple, potentially conflicting objectives by minimizing deviations from predefined goals (Sharma, 2016). Therefore, this study aims to optimize the composition of complementary feeding menus using goal programming to obtain a cost-effective combination of food ingredients that adequately fulfills the nutritional requirements of infants.

II. LITERATURE REVIEW

➢ *Stunting*

Stunting is a condition resulting from chronic undernutrition and recurrent infections in children, typically characterized by a height-for-age measurement below the standard growth reference for young children (Fauziah et al., 2023). One of the primary causes of stunting is inadequate intake of both macronutrients and micronutrients, which play essential roles in supporting child growth and development (Ashari et al., 2023).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun795

In the short term, stunting can lead to impaired brain development and cognitive function, metabolic disorders, restricted physical growth, and increased healthcare costs. In the long term, it may result in suboptimal cognitive and physical development, reduced immune function that increases susceptibility to disease, and a higher risk of developing degenerative diseases later in life (Asra Laily & Indarjo, 2023).

- *Complementary Feeding*

Complementary feeding refers to foods and beverages provided to infants from the age of six months in addition to breast milk. It is intended to complement, rather than replace, breast milk by supplying additional nutrients required to support the increasing nutritional demands of growing infants. Although complementary feeding is introduced at six months of age, breastfeeding should continue until the child reaches two years of age or beyond (Shobah & Rokhaidah, 2021). The practice of complementary feeding aims not only to meet the nutritional requirements of infants but also to facilitate their gradual adaptation to the family diet and eating patterns (Kementrian Kesehatan RI, 2024).

- *Goal Programming*

Goal programming is a multi-objective optimization technique used to solve decision-making problems involving multiple, and often conflicting, objectives. The method aims to achieve a satisfactory level of attainment for each predefined goal by considering their relative priorities. A key characteristic of goal programming is that goals are expressed as specific numerical targets and are satisfied according to a hierarchical priority structure. Higher-priority goals are addressed first before lower-priority goals are considered (Sharma, 2016).

The general form of a goal programming model can be expressed as follows(Rangkuti, 2023):

Minimize

$$Z = \sum_{i=1}^{m} (\rho + \eta)$$

Subject to,

$$\sum_{j=1}^{n} a_{ij} x_j - (\rho - \eta) = b_i \text{for} \qquad i = 1,2,3, \cdots m$$

$$x_j, \eta, \rho \geq 0 \text{for} \qquad j = 1,2,3, \cdots n$$

Where:

Z: objective function representing the total deviation to be minimized;

x_j: decision variable representing activity level (j);

a_{ij}: coefficient of decision variable (j) in constraint (i);

b_i: target value or resource capacity associated with goal (i);

η: negative deviation variable indicating underachievement of the target;

ρ: positive deviation variable indicating overachievement of the target.

The main steps involved in solving a goal programming problem are as follows:

- Define the decision variables.
- Identify the goals or objectives to be achieved.
- Formulate goal constraints for each objective.
- Construct the objective function based on deviation variables.
- Develop the complete goal programming model.
- Solve the model using an appropriate optimization method or software

- *Sensitivity Analysis*

Sensitivity analysis is a technique used to examine the potential changes in an optimal solution resulting from modifications to the parameters of the original optimization model. Changes in model parameters may occur either discretely or continuously. The study of how discrete changes in model parameters affect the optimal solution is commonly referred to as sensitivity analysis or post-optimality analysis. In contrast, the investigation of the effects of continuous parameter changes is known as parametric programming (Natarajan et al., 2014).

III. RESULT AND DISCUSSION

- *Data*

The nutritional requirements used in this study were based on the Recommended Dietary Allowances (RDA) for infants aged 6–11 months as stipulated in the Regulation of the Minister of Health of the Republic of Indonesia No. 28 of 2019. The nutritional components considered in the optimization model include energy, protein, fat, vitamin A, calcium, iron, and zinc. The recommended intake levels for these nutrients are presented in Table 1.

Table 1 Recommended Dietary Allowances (RDA) for Infants Aged 6–11 Months

Nutrient	**RDA**	**Unit**
Energy	800	kcal
Protein	15	g
Fat	35	g
Vitamin A	400	µg
Calcium	270	mg
Iron	11	mg
Zinc	3	mg

Source: Regulation of the Minister of Health of the Republic of Indonesia No. 28 of 2019.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun795

Since breast milk continues to contribute substantially to the nutritional intake of infants aged 6–11 months, part of their nutrient requirements is assumed to be fulfilled through breastfeeding. In this study, the nutritional contribution of breast milk was estimated based on an average daily breast milk consumption of 600 mL. The daily contribution of breast milk to the nutrient intake of infants is presented in Table 2.

Table 2 Nutritional Contribution of Breast Milk

Nutrient	Nutrient Content per 100 mL of Breast Milk	Daily Contribution (600 mL)	Unit
Energy	67,5	402	kcal
Protein	0,75	4,5	g
Fat	3	18	g
Vitamin A	25,47	152,82	µg
Calcium	26,2	157,2	mg
Iron	0,05	0,3	mg
Zinc	0,257	1,542	mg

Source: Authors' Calculation (2026)

The nutrient requirements to be fulfilled through complementary feeding were calculated as the difference between the Recommended Dietary Allowances (RDA) and the estimated nutrient contribution provided by breast milk. The resulting nutrient targets for complementary feeding are presented in Table 3.

Table 3 Nutrient Targets for Complementary Feeding

Nutrient	RDA	Contribution from Breast Milk	Nutrient Target
Energy	800 kkal	405 kkal	395 kcal
Protein	15 g	4,5 g	10,5 g
Fat	35 g	18 g	17 g
Vitamin A	400 µg	152,82 µg	247,18 mcg
Calcium	270 mg	157,2 mg	112,8 mg
Iron	11 mg	0,3 mg	10,7 mg
Zinc	3 mg	1,542 mg	1,458 mg

Source: Authors' Calculation (2026)

This study considered 17 food ingredients classified into four categories: carbohydrate sources, animal-based protein sources, plant-based protein sources, and fiber sources. Nutrient composition data for each food ingredient were obtained from the NutriSurvey database, while food price data were collected through a market survey. To ensure consistency with the decision variables used in the goal programming model, all nutrient and price data were converted to a per-gram basis. The nutritional composition and prices of the selected food ingredients are presented in Table 4.

Table 4 Nutrient Composition and Prices of Food Ingredients

Food Ingredient	Category	Nutrient Content							Price (Rp)
		Energy (kcal)	Protein (g)	Fat (g)	Vitamin A (µg)	Calcium (mg)	Iron (mg)	Zinc (mg)	
Rice	Carbohydrate Source	3,609	0,067	0,006	0	0,08	0,006	0,011	15
Yellow Sweet Potato	Carbohydrate Source	1,021	0,021	0,001	1,91	0,11	0,008	0,005	20
Potato	Carbohydrate Source	0,93	0,02	0,001	0	0,005	0,004	0,003	15
Mung Bean	Plant-Based Protein Source	1,159	0,077	0,005	0,02	0,24	0,025	0,013	25
Chicken	Animal-Based Protein Source	2,849	0,269	0,189	0,39	0,13	0,014	0,018	40
Beef	Animal-Based Protein Source	2,689	0,249	0,18	0	0,004	0,017	0,041	120
Indian Mackerel	Animal-Based Protein Source	1,121	0,214	0,023	0,43	0,48	0,009	0,004	30
Tuna	Animal-Based Protein Source	1,109	0,24	0,01	0,16	0,17	0,007	0,006	40
Chicken Egg	Animal-Based Protein Source	1,551	0,126	0,106	1,9	0,5	0,012	0,011	30
Spinach	Fiber Source	0,37	0,037	0,002	5,19	2,11	0,031	0,004	10
Moringa Leaves	Fiber Source	0,6	0,053	0,009	7,01	1,51	0,023	0,005	10

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun795

Carrot	Fiber Source	0,258	0,01	0,002	15,74	0,41	0,021	0,006	10
Pumpkin	Fiber Source	0,39	0,009	0,006	4,01	0,14	0,003	0,003	20
Tempeh	Plant-Based Protein Source	1,991	0,19	0,077	0,01	0,93	0,023	0,018	15
Tofu	Plant-Based Protein Source	0,76	0,081	0,048	0	1,05	0,054	0,008	10
Kepok Banana	Carbohydrate Source	1,559	0,008	0,002	0,91	0,02	0,006	0,001	20
Papaya	Fiber Source	0,39	0,006	0,001	1,35	0,24	0,001	0,001	10

Source: Authors' Calculation (2026)

➢ *Goal Programming Model Formulation*

- *Model Assumption*

The following assumptions were adopted in the development of the goal programming model:

✓ Infants are assumed to consume 600 mL of breast milk per day.
✓ The nutrient requirements to be fulfilled through complementary feeding are calculated as the difference between the Recommended Dietary Allowances (RDA) and the nutrient contribution provided by breast milk.
✓ The nutrient content of each food ingredient is assumed to remain unchanged during food preparation and processing.
✓ All selected food ingredients are assumed to be readily available in local markets.
✓ Food prices are assumed to remain constant throughout the study period.
✓ The formulated complementary feeding menu is assumed to be consumed in three meals per day.

- *Notation*

x_j : Amount of food ingredient j used in the formulation (g)
a_{ij} : Content of nutrient (i) in food ingredient (j)
b_i : Target requirement for nutrient (i)
c_j : Price of food ingredient (j) (IDR/g)
η_i : negative deviation from nutrient target (i) (underachievement)
ρ_i : Positive deviation from nutrient target (i)
i : Index of nutrient goal, $(i = 1,2,\cdots,7)$
j : Index of food ingredients, $(j = 1,2,\cdots 17)$

- *Decision Variables*

The decision variables are defined as (x_j), representing the amount (g) of food ingredient (j) included in the complementary feeding formulation, where $(j = 1,2,\cdots,17)$. These variables determine the quantity of each food ingredient selected to satisfy the nutritional requirements of infants aged 6–11 months while considering the established goals and constraints.

- *Goal Definition*

The optimization model was developed based on three hierarchical priorities:

✓ Priority 1: Minimize deficiencies in macronutrients, including energy, protein, and fat.
✓ Priority 2: Minimize deficiencies in micronutrients, including vitamin A, calcium, iron, and zinc.
✓ Priority 3: Minimize food cost to achieve the most economical complementary feeding formulation.

- *Constraint Formulation*

The constraints used in this study are as follows:

✓ *Macronutrient Goal Constraints*

$$\sum_{j=1}^{17} a_{ij}x_j + \eta_i - \rho_i = b_i$$

The macronutrient constraints are given by:

Energy:

$$\sum_{j=1}^{17} a_{1j}x_j + \eta_1 - \rho_1 = 395$$

Protein:

$$\sum_{j=1}^{17} a_{2j}x_j + \eta_2 - \rho_2 = 10{,}5$$

Fat:

$$\sum_{j=1}^{17} a_{3j}x_j + \eta_3 - \rho_3 = 17$$

✓ *Micronutrient Goal Constraints*

$$\sum_{j=1}^{17} a_{ij}x_j + \eta_i - \rho_i = b_i$$

The macronutrient constraints are given by:

Vitamin A:

$$\sum_{j=1}^{17} a_{4j}x_j + \eta_4 - \rho_4 = 247{,}18$$

Calcium:

$$\sum_{j=1}^{17} a_{5j}x_j + \eta_5 - \rho_5 112{,}8$$

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun795

Iron:

$$\sum_{j=1}^{17} a_{6j}x_j + \eta_6 - \rho_6 10{,}7$$

Zinc:

$$\sum_{j=1}^{17} a_{7j}x_j + \eta_7 - \rho_7 = 1{,}458$$

✓ *Cost Minimization Goal*

$$\sum_{j=1}^{17} c_j x_j + \eta_8 - \rho_8 = 20000$$

✓ *Consumption Capacity Constraint*

The consumption capacity constraint ensures that the total amount of food ingredients included in the complementary feeding menu is consistent with the daily consumption capacity of infants. The constraint is formulated as:

$$250 \le \sum_{j=1}^{17} x_j \le 420$$

✓ *Food Group Proportion Constraints*

The food group proportion constraints were incorporated to maintain a balanced complementary feeding composition based on four food categories: carbohydrate sources, animal-based protein sources, plant-based protein sources, and fiber sources. The constraints are expressed as follows:

Carbohydrate Sources:

$$75 \le x_1 + x_2 + x_3 + x_{16} \le 210$$

Animal-Based Protein Sources:

$$50 \le x_5 + x_6 + x_7 + x_8 + x_9 \le 147$$

Plant-Based Protein Sources:

$$25 \le x_4 + x_{14} + x_{15} \le 105$$

Fiber Sources:

$$25 \le x_{10} + x_{11} + x_{12} + x_{13} + x_{17} \le 63$$

- *Objective Function*

The objective function was formulated according to the hierarchical priority structure of the goal programming model.

✓ *Minimizing Macronutrient Deficiencies*

$$Min\ Z = \sum_{i=1}^{3} (\eta_i)$$

✓ *Minimizing Micronutrient Deficiencies*

$$Min\ Z = \sum_{i=4}^{7} (\eta_i)$$

✓ *Minimizing Food Cost*

$$Min\ Z = \rho_8$$

Accordingly, the objective function can be expressed as:

$$Min\ Z = \sum_{i=1}^{3} (\eta_i) + \sum_{i=4}^{7} (\eta_i) + \rho_8$$

or equivalently:

$$Min\ Z = \eta_1 + \eta_2 + \eta_3 + \eta_4 + \eta_5 + \eta_6 + \eta_7 + \rho_8$$

➢ *Results and Discussion*

The goal programming model was implemented and solved using LINGO optimization software. The obtained solution represents the optimal combination of food ingredients that meets the nutritional requirements of infants aged 6–11 months while satisfying all model constraints, including nutrient targets, budget limitations, consumption capacity, and food-group proportion requirements. The resulting optimal food composition is presented in Table 5.

Table 5 Optimal Complementary Feeding Composition

Decision Variable	Food Ingredients	Amount (g)
x_2	Yellow Sweet Potato	130
x_6	Beef	125
x_{10}	Spinach	60
x_{15}	Tofu	105
Total Menu Weight (g)		420
Total Cost (IDR)		Rp19.210

Sumber: Authors' calculation (2026)

Following the determination of the optimal food composition, the negative deviation (η_i) and positive deviation (ρ_i) values were analyzed to evaluate the achievement of each goal in the goal programming model. The results are presented in Table 6.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun795

Table 6 Goal Achievement Analysis of the Goal Programming Model

Goal	Target	Optimization Result	η_i	ρ_i	Status
Energy	395 kkal	520,027 kcal	0	175,027 kcal	Achieved
Protein	10,5 g	44,304 g	0	34,004 g	Achieved
Fat	17 g	27,726 g	0	10,726 g	Achieved
Vitamin A	247,18 µg	561,554 mcg	0	314,374 mcg	Achieved
Calcium	112,8 mg	252,402 mg	0	139,602 mg	Achieved
Iron	10,7 mg	10,7 mg	0	0	Achieved
Zinc	1,458 mg	6,842 mg	0	5,384 mg	Achieved
Cost	≤ Rp 20.000	Rp19.210	Rp790	0	Achieved

Sumber: Authors' calculation (2026)

As shown in Table 6, all macronutrient and micronutrient targets were successfully achieved, as indicated by the absence of negative deviations (η_i) for all nutritional goals. Several goals exhibited positive deviations (ρ_i), indicating that the corresponding nutrient levels exceeded the minimum target requirements. Furthermore, the total cost of the optimized menu was IDR 19,210, which remained below the budget limit of IDR 20,000. These results demonstrate that the proposed goal programming model is capable of satisfying the nutritional requirements of infants aged 6–11 months while maintaining cost efficiency.

➢ *Sensitivity Analysis*

Sensitivity analysis was conducted to evaluate the robustness of the model with respect to changes in food prices. The analysis focused on yellow sweet potato, beef, and tofu, as these ingredients constituted the optimal solution. Price increase scenarios of 10% and 20% were applied to each ingredient while all other parameters were held constant. The results of the sensitivity analysis are presented in Table 7.

Table 7 Sensitivity Analysis Results for Changes in Food Ingredient Prices

Price Change	**Optimal Composition (g)**	**Total Cost**	**Status**
Baseline	Yellow Sweet Potato (130) Beef (125) Spinach (60) Tofu (105)	Rp19.210	Achieved $(\eta_i = 0, i = 1,2, \dots, 7, \rho_8 = 0)$
Yellow Sweet Potato (+10%)	Yellow Sweet Potato (130) Beef (125) Spinach (60) Tofu (105)	Rp19.470	Achieved $(\eta_i = 0, i = 1,2, \dots, 7, \rho_8 = 0)$
Yellow Sweet Potato (+20%)	Yellow Sweet Potato (130) Beef (125) Spinach (60) Tofu (105)	Rp19.730	Achieved $(\eta_i = 0, i = 1,2, \dots, 7, \rho_8 = 0)$
Beef (+10%)	Yellow Sweet Potato (130) Chicken (6) Beef (117) Spinach (62) Tofu (105)	Rp20.000	Achieved $(\eta_i = 0, i = 1,2, \dots, 7, \rho_8 = 0)$
Beef (+20%)	Yellow Sweet Potato (130) Chicken (18) Beef (104) Spinach (63) Tofu (105)	Rp20.000	Not Achieved $(\eta_6 = 0{,}163)$
Tofu (+10%)	Yellow Sweet Potato (130) Beef (125) Spinach (60) Tofu (105)	Rp19.270	Achieved $(\eta_i = 0, i = 1,2, \dots, 7, \rho_8 = 0)$
Tofu (+20%)	Yellow Sweet Potato (130) Beef (125) Spinach (60) Tofu (105)	Rp19.330	Achieved $(\eta_i = 0, i = 1,2, \dots, 7, \rho_8 = 0)$

Sumber: Authors' calculation (2026)

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jun795

Based on Table 7, changes in beef prices had the most significant impact on the optimal menu composition. When the beef price increased by 10%, the amount of beef in the formulation decreased and was partially substituted with chicken while maintaining the achievement of all nutritional targets. However, a 20% increase in beef price resulted in more substantial adjustments to the food composition and generated a negative deviation for the iron target ($\eta_6 = 0{,}163$), indicating that the target could no longer be fully satisfied.

In contrast, increases in the prices of yellow sweet potato and tofu did not lead to changes in the optimal food composition. These price increases only affected the total menu cost while all nutritional goals remained achievable. Overall, the sensitivity analysis indicates that beef is the most price-sensitive ingredient in the optimized formulation. Nevertheless, the model demonstrates the ability to substitute food ingredients in order to maintain the achievement of most nutritional goals under changing price conditions.

IV. CONCLUSION

This study developed a goal programming model to optimize complementary feeding (CF) formulations by considering macronutrient requirements, micronutrient requirements, and budget constraints. The optimal solution consisted of 130 g of yellow sweet potato, 125 g of beef, 60 g of spinach, and 105 g of tofu, resulting in a total menu weight of 420 g and a total cost of IDR 19,210. The optimized formulation successfully met the nutritional requirements of infants aged 6–11 months while remaining within the specified budget limit.

Furthermore, the sensitivity analysis revealed that beef was the most influential ingredient with respect to price changes. While increases in the prices of yellow sweet potato and tofu had minimal impact on the optimal solution, substantial increases in beef prices altered the food composition and reduced the model's ability to satisfy all nutritional targets. These findings demonstrate the effectiveness of goal programming as a decision-support tool for designing nutritionally adequate and cost-efficient complementary feeding menus.

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