Optimizing Fruits and Vegetables Intake in Indonesia using Linear Programming

Nurhayati and Sundari Wirasmi
Researcher of Research Center for Preclinical and Clinical Medicine
National Research and Innovation Agency, INDONESIA
nurh038@brin.go.id, sund005@brin.go.id

Aris Yulianto
Student at ASEAN Institute for Health Development
Mahidol University
Nakhon Pathom 73170 THAILAND
Researcher of Research Center for Preclinical and Clinical Medicine
National Research and Innovation Agency, INDONESIA
aris.yul@mahidol.edu, aris.yulianto@brin.go.id

Abstract

World Health Organization recommends consuming vegetables and fruits at least 400 gr or 5 (five) servings of vegetables and fruits a day. According to the results of the analysis of Basic Health Research (Riskesdas) data in 2007, the average portion of vegetable and fruit consumption per day in Indonesians aged 10 years and over, is less than 5 (five) servings per day. This study is to determine the number and type of recommended consumption of vegetables and fruits by the Indonesian population according to age group and gender as well as the adequacy of the needs of vitamin A, vitamin C, potassium, folic acid, and fiber for the body. This study used vegetable and fruit consumption data from Riskesdas data in 2010. The results showed that the 5 (five) types of fruits that are most consumed by the Indonesian population are bananas, oranges, papayas, apples, and watermelons. The five (5) types of vegetables that are most consumed by Indonesians are spinach, spinach water, cassava leaves, tamarind vegetable soup, and soup. The results of linear programming analysis obtained 5 (five) alternatives to vegetables and fruits according to age group and gender**.**

Keywords:
Optimizing, fruits, vegetables, consumption, Indonesia

1. Introduction

Linear programming is a mathematical tool that is useful for optimizing (minimizing or maximizing) a linear function from a set of decision variables (variables x1, x2,...xn). Y function (objective function) is the function that will be optimized with the linear program (Stanimirovic 2022).

The World Health Organization (WHO) recommends consuming at least 400g of fruits and vegetables per day as part of a healthy diet to prevent chronic diseases such as heart disease, stroke, diabetes, and certain types of cancer. This is equivalent to roughly 5 servings of fruits and vegetables per day (WHO 2021). Approximately 16 million (1.0%) DALYs and 1.7 million (2.8%) of deaths worldwide are attributable to low fruit and vegetable consumption. Adequate consumption of fruit and vegetables reduces the risk of cardiovascular diseases, stomach cancer and colorectal cancer. There is convincing evidence that the consumption of high levels of high-energy foods, such as processed foods that are high in fats and sugars, promotes obesity compared to low-energy foods such as fruits and vegetables (WHO 2022).

According to the National Report of Basic Health Research 2018, 95.4% of the Indonesian population consumes fewer fruits and vegetables than the recommended amount, which is 400 grams per day (Ministry of Health, Republic of Indonesia 2018). The low consumption of vegetables and fruits by the Indonesian population is a subject of

contemplation to find out whether the standard consumption of at least 400 grams or 5 servings of vegetables and fruits per day is suitable for the Indonesian population. Additionally, the types of vegetables and fruits that are commonly consumed by the Indonesian population are certainly different from those of other countries. Some countries already have guidelines for the amount and type of vegetable and fruit consumption per day, while in Indonesia, such guidelines do not yet exist. Research on determining the recommended amount and type of vegetable and fruit consumption per day for the Indonesian population has also never been conducted. Therefore, a study will be conducted the determination of the recommended amount and type of vegetable and fruit consumption per day for the Indonesian population using the 2010 Basic Health Research data and a Linear Programming analysis approach.

In this study, the recommended amount of fruit and vegetable consumption is a function that will be optimized with a linear program. Meanwhile, the composition of nutrients in fruits and vegetables, such as vitamin A, vitamin C, potassium, fiber, and folate, is a set of decision variables (x1, x2,...xn).

1.1 Objectives

The aim of this study is to determine the appropriate amount and types of recommended fruit and vegetable consumption for the Indonesian population according to age and gender groups using the linear programming method.

2. Literature Review

Linear Programming was first proposed by a Russian mathematician named L.V. Kantorovich in his book titled "Mathematical Methods in The Organization and Planning of Production". In this book, he formulated the problem of "Linear Programming" for the first time. However, the methods for solving these problems in Russia did not develop well, and it turned out that experts in the West and the US who used this method made good use of it (Bazaraa et al. 2009).

In 1947, an American mathematician named George B. Dantzig found a way to solve linear programming problems. This method was called the "Simplex Method" and was explained in his book "Linear Programming and Extension". Subsequently, this theory developed rapidly, especially in the field of military optimization in war strategies and other fields (Bazaraa et al. 2009).

Linear programming is a mathematical method for allocating limited resources to achieve a goal, such as maximizing profit and minimizing costs. Linear programming is widely applied in economic, industrial, military, social, and other problems. Linear programming is related to explaining a real-world case as a mathematical model consisting of a linear objective function and several linear constraints (Bazaraa et al. 2009).

Linear Programming Characteristics

Linearity of a case can be determined using several methods. Statistically, we can check linearity using scatterplots or hypothesis testing. Technically, linearity is indicated by the presence of proportional, additive, divisible, and certain properties of the objective function and constraints (Bazaraa et al. 2009).

Proportional property is fulfilled if the contribution of each variable in the objective function or the use of limiting resources is proportional to the variable's value level. For example, if the unit price of a product is the same regardless of the quantity purchased, then the proportional property is fulfilled. Or in other words, if purchasing in a large quantity gets a discount, then the proportional property is not fulfilled. If the use of a resource per unit depends on the quantity produced, then the proportional property is not fulfilled. The additive property assumes that there is no cross multiplication between various activities, so there will be no cross multiplication in the model. The additive property applies to both the objective function and the constraints (Bazaraa et al. 2009).

The additive property is fulfilled if the objective function is a direct addition of the contributions of each decision variable. For the constraint function, the additive property is fulfilled if the right-hand value is the total use of each decision variable. If two decision variables represent two substituting products, where an increase in sales volume of one product will reduce the sales volume of another product in the same market, then the additive property is not fulfilled (Bazaraa et al. 2009).

The divisibility property means that activity units can be divided into any fractional level, so that non-integer decision variable values are possible. The certainty property shows that all model parameters are constants. This means that the coefficients of the objective function and constraint functions are certain values, not values with certain probabilities. These four assumptions (properties) are not always fulfilled in the real world. To ensure that these four assumptions are fulfilled, sensitivity analysis of the optimal solution obtained is required in linear programming (Bazaraa et al. 2009).

Problem Formulation

The first step in problem-solving is to study the relevant system and develop a clearly articulated problem statement. This statement should include the goals, limiting resources, possible decision alternatives (activities or actions), decision-making time constraints, relationships between the parts studied and other parts of the company. Proper goal setting is a crucial aspect of problem formulation. To form optimal goals, identification of management members who will actually make the decision and discussing their thoughts on the goals they want to achieve is needed (Bazaraa et al. 2009).

Mathematical Model Formation

The next step to be taken after understanding the optimization problem is to create an appropriate model for analysis. The conventional approach of operations research for modeling is to build a mathematical model that describes the core of the problem. The case of a story form is translated into a mathematical model. The mathematical model represents the quantitative representation of goals and limiting resources as a function of decision variables. The mathematical model of an optimal problem consists of two parts. The first part models the optimization goal. The mathematical model of the objective always uses equation form. Equation form is used because we want to obtain an optimal solution at one point. The objective function to be optimized is only one. It does not mean that the optimization problem is only faced with one goal. The goal of an effort can be more than one. But in this part, we will only be interested in optimization problems with one goal (Bazaraa. et al. 2009).

The second part is a mathematical model that represents limiting resources. The limiting function can be in the form of an equation (=) or an inequality ($\leq$ or $\geq$). The limiting function is also called a constraint. Constants (both as coefficients and right-hand values) in the limiting function as well as the goal are called model parameters. Mathematical models have several advantages over verbal problem descriptions. One of the most obvious advantages is that the mathematical model describes the problem more concisely. This tends to make the overall structure of the problem easier to understand and helps to reveal important cause-and-effect relationships. The mathematical model also facilitates considerations related to the problem and its entirety, and considers all of its interconnections simultaneously. Finally, the mathematical model forms a bridge to the use of high-capacity mathematical and computer techniques to analyze problems (Bazaraa et al. 2009).

On the other hand, mathematical models have their weaknesses. Not all system characteristics can be easily modeled using mathematical functions. Even though they can be modeled with mathematical functions, sometimes the solution is difficult to obtain due to the complexity of the functions and techniques required (Bazaraa et al. 2009).

3. Methods

This research uses data from Riskesdas 2010. The research design used is cross-sectional. This study analyzed data on food consumption of the Indonesian population, along with age and gender data from Riskesdas 2010. The study location covers all Riskesdas 2010 research locations, namely 33 provinces spread over 441 districts/cities from a total of 497 districts/cities in Indonesia.

The study population is the same as the population and sample of Riskesdas 2010, which is all households representing 33 provinces. The sample in this study consisted of respondents aged one year and above in the Riskesdas 2010

sample, totaling 237,053 respondents. The inclusion criteria are respondents who consume vegetables and fruit with vitamin A, vitamin C, and folic acid content below or equal to the recommended upper limit (IOM 2001).

The data source for this study comes from Riskesdas 2010 data, Nutrient Adequacy Ratio 2004 for vitamin A, vitamin C, and folic acid, Dietary Reference Intakes Tables and Application, Institute of Medicine of the National Academy of Sciences 2010 for potassium and fiber.

The data processing for this research was done using the data processing program. The data analysis consists of: a. Descriptive statistics analysis to obtain the quantity and types of vegetables and fruit consumed by the Indonesian population. b. Analysis of data to determine the quantity and types of recommended vegetable and fruit consumption by age and gender groups. The aim of this analysis is to obtain the optimal amount and type of vegetable and fruit consumption nationally and regionally. The recommended nutrient adequacy ratio to be used is the Indonesian Nutrient Adequacy Ratio 2004 and Dietary Reference Intakes Tables and Application, Institute of Medicine of the National Academy of Sciences 2010.

4. Data Collection

The data collection for the 2010 Riskesdas used tools and methods with the following details: 1) Household data collection was done through interview techniques using Household Questionnaires and Guidelines for Filling out Household Questionnaires. 2) Individual data collection across various age groups was done through interview techniques using Individual Questionnaires and Guidelines for Filling out Individual Questionnaires. Respondents for the Individual Questionnaire were every household member. For household members under 15 years of age who were sick, the interview was conducted with their accompanying household members. Food consumption data for each household member was collected in the Riskesdas 2010. In addition to food consumption data, data on age and gender of household members was also collected.

5. Results and Discussion

Description of Vegetable and Fruit Consumption by Age Group

Table 1. The percentage of vegetable types consumed by the Indonesian population based on age groups.

Age Group (years)	Vegetable	n	%	Fruit	n	%
1-3	1. Spinach	858	19,7	1. Banana	524	66,8
	2. Soup	531	12,2	2. Orange	50	6,4
	3. Water spinach	475	10,9	3. Papaya	48	6,1
	4. Cassava leaves	389	8,9	4. Apple	42	5,4
	5. Tamarind vegetable soup	355	8,2	5. Watermelon	28	3,6
4-6	1. Spinach	1280	15,2	1. Banana	815	62,6
	2. Water spinach	1183	14,1	2. Orange	85	6,5
	3. Cassava leaves	988	11,7	3. Papaya	71	5,5
	4. Soup	746	8,9	4. Apple	71	5,5
	5. Tamarind vegetable soup	666	7,9	5. Watermelon	59	4,5
7-9	1. Spinach	1242	14,3	1. Banana	810	62,5
	2. Water spinach	1223	14	2. Orange	101	7,8
	3. Cassava leaves	1013	11,6	3. Apple	64	4,9
	4. Tamarind vegetable soup	710	8,1	4. Watermelon	58	4,5
	5. Soup	704	8,1	5. Papaya	46	3,5
10-12	1. Water spinach	1337	14,6	1. Banana	808	60,8
	2. Spinach	1159	12,7	2. Orange	122	9,2
	3. Cassava leaves	1075	11,8	3. Watermelon	55	4,1
		768	8,4	4. Apple	52	3,9

	4. Tamarind vegetable soup 5. Soup	711	7,8	5. Papaya	48	3,6
13-15	1. Water spinach	1347	14,9	1. Banana	840	65,3
	2. Spinach	1098	12,1	2. Orange	118	9,2
	3. Cassava leaves	976	10,8	3. Papaya	47	3,7
	4. Tamarind	785	8,7	4. Apple	47	3,7
	vegetable soup	644	7,1	5. Watermelon	38	3
	5. Soup					
16-18	1. Water spinach	1155	14,3	1. Banana	707	61,3
	2. Spinach	1006	12,4	2. Orange	130	11,3
	3. Cassava leaves	808	10	3. Papaya	52	4,5
	4. Tamarind	728	9	4. Apple	57	4,9
	vegetable soup	603	7,5	5. Watermelon	33	2,9
	4. Soup					
19-29	1. Water spinach	4105	13,2	1. Banana	2868	63,3
	2. Spinach	4034	12,9	2. Orange	511	11,3
	3. Cassava leaves	3138	10,1	3. Papaya	209	4,6
	4. Tamarind	2613	8,48	4. Apple	196	4,3
	vegetable soup	2531	8,1	5. Watermelon	156	3,4
	4. Soup					
30-49	1. Water spinach	7206	12,8	1. Banana	6311	69
	2. Spinach	7182	12,7	2. Orange	931	10,2
	3. Cassava leaves	5838	10,3	3. Papaya	413	4,5
	4. Tamarind	5045	8,9	4. Apple	366	4
	vegetable soup	4204	7,4	5. Watermelon	205	2,2
	4. Soup					
50-64	1. Spinach	2748	12,1	1. Banana	2963	73,7
	2. Water spinach	2597	11,4	2. Orange	311	7,7
	3. Cassava leaves	2459	10,8	3. Papaya	211	5,3
	4. Tamarind	2114	9,3	4. Apple	164	4,1
	vegetable soup	1464	6,5	5. Watermelon	60	1,5
	4. Soup					
65+ th	1. Spinach	1281	13,3	1. Banana	1310	79,1
	2. Water spinach	1027	10,6	2. Orange	106	6,4
	3. Cassava leaves	1024	10,6	3. Papaya	79	4,8
	4. Tamarind	825	8,5	4. Apple	42	2,5
	vegetable soup	613	6,3	5. Watermelon	28	1,7
	4. Soup					

Based on table 1, the overview of vegetable consumption according to age group shows that for the 1-3 years age group, the first ranking is Spinach, followed by Soup, Water spinach, Cassava leaves, and Tamarind vegetable soup. Meanwhile, for the 4-6 years and 7-9 years age groups, the top three rankings are Spinach, Water spinach, and Cassava leaves. For the age groups of 10-12 years, 13-15 years, 16-18 years, 19-29 years, and 30-49 years, the top three rankings are Water spinach, Spinach, and Cassava leaves, followed by Tamarind vegetable soup and Soup. However, for the age groups of 50-64 years and 65 years and above, the top three rankings are Spinach, Water spinach, and Cassava leaves.

According to table 1, the overview of fruit consumption according to age group shows that for the 7-9 years age group, the top five rankings are Banana, Orange, Apple, Watermelon, and Papaya. Meanwhile, for the 10-12 years age group, the rankings are Banana, Orange, Watermelon, Apple, and Papaya. In general, the top five rankings of fruit consumption are Banana, Orange, Papaya, Apple, and Watermelon.

Optimization of the Amount and Types of Vegetable and Fruit Consumption for the Indonesian Population.
The following are the stages and results of Linear Programming analysis using the QM (Quantitative Method) for Windows program to obtain recommendations for the amount and types of vegetable and fruit consumption for the Indonesian population. The types of vegetables and fruits used in this linear programming analysis are the most commonly consumed types in Indonesia (top 5). The vegetable types used are Spinach, Water spinach, Cassava leaves, Tamarind vegetable soup, and Soup. Meanwhile, the fruit types are Banana, Orange, Papaya, Apple, and Watermelon.

Linear Programming Formulation Model.

Table 2. Decision Variables, Nutrient Composition of Vegetables and Fruits, and Prices of Vegetables and Fruits

Type of Vegetables and Fruits	The required amount.	Vitamin A (µg)	Vitamin C (mg)	Fiber (g)	Potasium (mg)	Tamarind vegetable soup Folat (µg)	Price (Rp)
Spinach	X_1	4,1	0,05	0,01	2,33	0,73	13,3
Water spinach	X_2	1,48	0,12	0,01	0,99	0,36	11,1
Cassava leaves	X_3	2,26	0,15	0,003	2,39	0,45	6,67
Tamarind vegetable	X_4	0,8	0,13	0,01	0,16	0,25	8
Soup	X_5	4,73	0,03	0,03	2,13	0,32	8
Banana	X_6	0,06	0,07	0,02	2,97	0,14	10
Orange	X_7	8,4	0,44	0,04	13,7	2,19	14
Papaya	X_8	1,01	0,46	0,01	1,93	0,28	4
Apple	X_9	0,04	0,05	0,02	1,01	0,03	24
Watermelon	X_{10}	0,17	0,05	0,002	0,53	0,01	4,5

Based on the data from Table 2, a Linear Programming formulation model is developed for each age group. To fulfill the nutrient requirements of vitamin A, vitamin C, fiber, potassium, and Tamarind vegetable soup folate, only 80% is used, as it is estimated that 80% of these nutrients are obtained from vegetables and fruits, while the remaining 20% is obtained from other food sources. The description of the Linear Programming formulation model for each age group can be found in the appendix.

Furthermore, based on the formulation model for each age and gender group, a Linear Programming analysis is performed using the Linear Programming program in QM for Windows software.

Linear Programming Analysis Results: Optimization of Quantity and Type of National Vegetable and Fruit Consumption
The Linear Programming analysis was conducted five times to obtain five alternative results of recommended vegetable and fruit consumption according to age and gender groups. The results of the Linear Programming analysis were then validated based on the percentage of nutrient content (vitamin A, vitamin C, Tamarind vegetable soup folate, fiber, and potassium) according to the 2004 nutrient requirement standards, and the maximum limits for vitamin A, vitamin C, and Tamarind vegetable soup folate were adjusted accordingly. The upper limits for vitamin A, vitamin C, and Tamarind vegetable soup folate can be found in the appendix. The following table shows the recommended amount and type of national vegetable and fruit consumption.

Table 3. Recommended Amount and Type of Vegetable and Fruit Consumption

Age Group (years)	Alternative	Type	Weight (grams)	Portion
Children :	1	Spinach	100	1

1-3		Banana	150	3
		Papaya	50	0,5
	2	Soup	100	1
		Banana	150	3
		Papaya	50	0,5
	3	Water spinach	150	1,5
		Banana	150	3
		Papaya	150	1,5
	4	Spinach	100	1
		Banana	150	3
		Orange	100	1
	5	Soup	100	1
		Banana	100	2
		Orange	150	1,5
Children :	1	Spinach	150	1,5
4-6		Banana	150	3
		Orange	100	1
	2	Water spinach	150	1,5
		Banana	150	3
		Orange	100	1
	3	Soup	150	1,5
		Banana	150	3
		Orange	100	1
	4	Spinach	150	1,5
		Banana	150	3
		Papaya	100	1
	5	Water spinach	150	1,5
		Banana	150	3
		Papaya	100	1
Children :	1	Spinach	200	2
7-9		Banana	100	1
		Papaya	100	1
	2	Water spinach	200	2
		Orange	200	2
		Banana	150	3
	3	Cassava leaves	200	2
		Papaya	100	1
		Banana	100	2
	4	Soup	200	2
		Apple	100	1
		Banana	150	3
	5	Tamarind vegetable soup	200	2
		Watermelon	100	1
		Banana	150	3
Male :	1	Water spinach	300	3
10-12		Banana	100	1
		Papaya	150	3
	2	Spinach	300	3
		Orange	100	1
		Banana	150	3
	3	Cassava leaves	300	3
		Papaya	100	1
		Banana	150	3

	4	Tamarind vegetable soup	300	3
		Apple	100	1
		Banana	150	3
	5	Soup	300	3
		Watermelon	100	1
		Banana	150	3
Male : 13-15	1	Water spinach	300	3
		Banana	150	3
		Papaya	100	1
	2	Spinach	300	3
		Orange	100	1
		Banana	150	3
	3	Cassava leaves	300	3
		Papaya	100	1
		Banana	150	3
	4	Tamarind vegetable soup	300	3
		Apple	100	1
		Banana	150	3
	5	Soup	300	3
		Watermelon	100	1
		Banana	150	3
Male : 16-18	1	Water spinach	300	3
		Banana	150	3
		Papaya	100	1
	2	Spinach	300	3
		Orange	100	1
		Banana	150	3
	3	Cassava leaves	300	3
		Papaya	100	1
		Banana	150	3
	4	Tamarind vegetable soup	300	3
		Apple	100	1
		Banana	150	3
	5	Soup	300	3
		Watermelon	100	1
		Banana	150	3
Male : 19-29	1	Water spinach	300	3
		Banana	150	3
		Papaya	100	1
	2	Spinach	300	3
		Orange	100	1
		Banana	150	3
	3	Cassava leaves	300	3
		Papaya	100	1
		Banana	150	3
	4	Tamarind vegetable soup	300	3
		Apple	100	1
		Banana	150	3
	5	Soup	300	3

		Watermelon	100	1
		Banana	150	3
Male :	1	Water spinach	300	3
30-49		Banana	100	1
		Papaya	150	3
	2	Spinach	300	3
		Orange	100	1
		Banana	150	3
	3	Cassava leaves	300	3
		Papaya	100	1
		Banana	150	3
	4	Tamarind	300	3
		vegetable soup		
		Apple	100	1
		Banana	150	3
	5	Soup	300	3
		Watermelon	100	1
		Banana	150	3
Male :	1	Spinach	300	3
50-64		Banana	100	1
		Papaya	150	3
	2	Water spinach	300	3
		Orange	100	1
		Banana	150	3
	3	Cassava leaves	300	3
		Papaya	100	1
		Banana	150	3
	4	Tamarind	300	3
		vegetable soup		1
		Apple	100	3
		Banana	150	
	5	lodeh	300	3
		Watermelon	100	1
		Banana	150	3
Male :	1	Spinach	300	3
65+		Banana	100	1
		Papaya	150	3
	2	Water spinach	300	3
		Orange	100	1
		Banana	150	3
	3	Cassava leaves	300	3
		Papaya	100	1
		Banana	150	3
	4	lodeh	300	3
		Apple	100	1
		Banana	150	3
	5	Tamarind	300	3
		vegetable soup		
		Watermelon	100	1
		Banana	150	3
Female :	1	Water spinach	300	3
10-12		Banana	100	1
		Papaya	150	3

	2	Spinach	300	3
		Orange	100	1
		Banana	150	3
	3	Cassava leaves	300	3
		Papaya	100	1
		Banana	150	3
	4	Tamarind vegetable soup	300	3
		Apple	100	1
		Banana	150	3
	5	Soup	300	3
		Watermelon	100	1
		Banana	150	3
Female : 13-15	1	Water spinach	300	3
		Banana	100	1
		Papaya	150	3
	2	Spinach	300	3
		Orange	100	1
		Banana	150	3
	3	Cassava leaves	300	3
		Papaya	100	1
		Banana	150	3
	4	Tamarind vegetable soup	300	3
		Apple	100	1
		Banana	150	3
	5	Soup	300	3
		Watermelon	100	1
		Banana	150	3
Female : 16-18	1	Water spinach	300	3
		Banana	100	1
		Papaya	150	3
	2	Spinach	300	3
		Orange	100	1
		Banana	150	3
	3	Cassava leaves	300	3
		Papaya	100	1
		Banana	150	3
	4	Tamarind vegetable soup	300	3
		Apple	100	1
		Banana	150	3
	5	Soup	300	3
		Watermelon	100	1
		Banana	150	3
Female : 19-29	1	Water spinach	300	3
		Banana	100	1
		Papaya	150	3
	2	Spinach	300	3
		Orange	100	1
		Banana	150	3
	3	Cassava leaves	300	3

		Papaya	100	1
		Banana	150	3
	4	Tamarind	300	3
		vegetable soup		
		Apple	100	1
		Banana	150	3
	5	Soup	300	3
		Watermelon	100	1
		Banana	150	3
Female :	1	Water spinach	300	3
30-49		Banana	100	1
		Papaya	150	3
	2	Spinach	300	3
		Orange	100	1
		Banana	150	3
	3	Cassava leaves	300	3
		Papaya	100	1
		Banana	150	3
	4	Tamarind	300	3
		vegetable soup	100	1
		Apple	150	3
		Banana		
	5	Soup	300	3
		Watermelon	100	1
		Banana	150	3
Female :	1	Sayur Spinach	300	3
50-64		Banana	100	1
		Papaya	150	3
	2	Water spinach	300	3
		Orange	100	1
		Banana	150	3
	3	Cassava leaves	300	3
		Papaya	100	1
		Banana	150	3
	4	Tamarind	300	3
		vegetable soup	100	1
		Apple	150	3
		Banana		
	5	lodeh	300	3
		Watermelon	100	1
		Banana	150	3
Female :	1	Spinach	300	3
65+		Banana	100	1
		Papaya	150	3
	2	Water spinach	300	3
		Orange	100	1
		Banana	150	3
	3	Cassava leaves	300	3
		Papaya	100	1
		Banana	150	3
	4	lodeh	300	3
		Apple	100	1
		Banana	150	3

	5	Tamarind vegetable soup	300	3
		Watermelon	100	1
		Banana	150	3

Table 4 . Summary of Recommended Amount and Type of Vegetable and Fruit Consumption

Age Group (years)	Amount and Type of Consumption
Children : 1-3	1-1,5 portion of vegetables, 3–4 portion of fruit
Children : 4-6	1,5-2 portion of vegetables, 3-4 portion of fruit
Children : 7-9	2-3 portion of vegetables, 3 - 4 portion of fruit
Male : 10-12	3 portion of vegetables, 2-4 portion of fruit
Male : 13-15	3 portion of vegetables, 2-4 portion of fruit
Male : 16-18	3 portion of vegetables, 2-4 portion of fruit
Male : 19-29	3 portion of vegetables, 2-4 portion of fruit
Male : 30-49	3 portion of vegetables, 2-4 portion of fruit
Male : 50-64	3 portion of vegetables, 2-4 portion of fruit
Male : 65+	3 portion of vegetables, 2-4 portion of fruit
Female : 10-12	3 portion of vegetables, 2-4 portion of fruit
Female : 13-15	3 portion of vegetables, 2-4 portion of fruit
Female : 16-18	3 portion of vegetables, 2-4 portion of fruit
Female : 19-29	3 portion of vegetables, 2-4 portion of fruit
Female : 30-49	

	3 portion of vegetables,	2-4 portion of fruit
Female : 50-64	3 portion of vegetables,	2-4 portion of fruit
Female : 65+	3 portion of vegetables,	2-4 portion of fruit

Notes:
1 portion of vegetables = 100 grams
1 portion of fruit = 50 – 100 grams

The research limitation is the consumption data used in this study, which was collected using the 24-hour recall method. One of the weaknesses of the 24-hour recall method is that respondents rely on memory to report the amount and types of vegetables and fruits consumed 24 hours ago, which can lead to bias in the information provided by respondents. Another weakness of using the 24-hour recall method is that trained interviewers are required to ask about the amount and types of vegetables and fruits consumed by respondents.

Another limitation of this study is the use of linear programming mathematical analysis method. Mathematical models have weaknesses, including that not all system characteristics can be easily modeled using mathematical functions. Even if they can be modeled with mathematical functions, sometimes their solutions are difficult to obtain due to the complexity of the function and techniques required.

Linear programming is a mathematical method for allocating limited resources to achieve a goal, such as maximizing profit and minimizing cost. Linear programming is widely applied in economic, industrial, military, social, and other problems. Linear programming is related to explaining a real-world case as a mathematical model consisting of a linear objective function with several linear constraints.

The results of the research on the recommendation for the amount and types of vegetable and fruit consumption by the Indonesian population have been summarized in a table of recommended portions of vegetables and fruits for each age group (Table 3). Generally, the recommendation for vegetable and fruit consumption by the Indonesian population is 1-3 portions of vegetables and 2-4 portions of fruit. The recommended types of vegetables and fruits are commonly and widely consumed by the Indonesian population. The recommended types of vegetables are Spinach, Water spinach, Cassava leaves, Tamarind vegetable soup, and Soup. Meanwhile, the recommended types of fruits are Banana, Orange, Papaya, Apple, and Watermelon. These types of vegetables and fruits can also be varied with local varieties in each region. For example, in Sulawesi, the recommended types of vegetables can be added with Moringa leaves, and in Maluku and Papua, the recommended types of fruits can be added with langsat fruit.

Currently, several countries in the world have guidelines for the recommended amount and types of vegetable and fruit consumption per day that are appropriate for their respective countries, including Greece, the Netherlands, the United Kingdom, New Zealand, the United States, Switzerland, Australia, Japan, Spain, Canada, Mexico, Argentina, Brazil, Malaysia, the Philippines, South Africa, and Mauritius.

Compared to the guidelines for vegetable and fruit consumption in other countries, the recommended amount of vegetable and fruit consumption from this research (1-3 portions of vegetables and 2-4 portions of fruit) for the Indonesian population is not significantly different from other countries, especially from New Zealand and Mauritius. In terms of the portion size, Indonesia is still considered moderate (not too large). This can be caused by the diverse eating patterns of the Indonesian population, such as rice, side dishes, vegetables, fruits, and milk (balanced nutrition). Based on the eating patterns that have become a habit for the Indonesian population, the fulfillment of nutrient needs for the body can be met from various types of food consumed, some of which come from animal and plant sources. Therefore, in the recommendation for vegetable and fruit consumption, it is necessary to consider local eating patterns and local varieties to increase the diversity of vegetable and fruit consumption.

6. Conclusion

The types of vegetables commonly consumed by the Indonesian population are Spinach, Water spinach, Cassava leaves, Tamarind vegetable soup, and Soup. The types of fruit commonly consumed by the Indonesian population are Banana, Orange, Papaya, Apple, and Watermelon. The average daily consumption of vegetables for the Indonesian

population is 153.66 grams, while the average daily consumption of fruit is 136.61 grams. The recommended daily intake for vegetables is 1-3 portions, and for fruit is 2-4 portions. The recommended intake of vegetables and fruit may vary depending on age and gender. Regional recommendations for vegetable and fruit intake are adjusted to include local produce.

References

Stanimirovic, I. *Advances in Optimization and Linear Programming*. United Kingdom: Apple Academic Press, 2022.

World Health Organization. *Healthy diet*. Geneva, Switzerland: World Health Organization; 2021 [cited 2022 Feb 14]. Available from: https://www.who.int/news-room/fact-sheets/detail/healthy-diet.

World Health Organization. , *WHO Global Health Observatory (GHO) metadata*: Fruit and vegetable consumption. Geneva: WHO; 2022 [cited 2022 Feb 14]. *Basic Health Research (Riskesdas) 2018*. Jakarta: Ministry of Health of the Republic of Indonesia; 2018.

Bazaraa, M. S., Jarvis, J. J., & Sherali, H. D. *Linear Programming and Network Flows*. John Wiley & Sons; 2009.

Schultz H, et al., Potassium compounds. In: *Ullmann's Encyclopedia of Industrial Chemistry*. A22. Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA; 2006. p. 39-103.

Pressman AH, Buff S. *Vitamin and Minerals*. Ed ke-2. USA: Penguin Group; 2000. Hal. 36-39.

Pucci de Farias D., *The Linear Programming Approach to Approximate Dynamic Programming Theory and Application*. Stanford University; 2002.

AACC (American Association of Cereal Chemist) Report., *The Definition of Dietary Fibre*. Cereal Foods World. 200;46:89-148.\

Burkhardt ER, Schröter B, Weiser H, et al., Potassium and Potassium Alloys. *Ullmann's Encyclopedia of Industrial Chemistry*. 2006;A22:31-38.

Ferguson EL, Briend A, Nicole D. Can Optimal Combinations of Local Foods Achieve the Nutrient Density of the F100 Catch-up Diet for Severe Malnutrition? *J Pediatr Gastroenterol Nutr*. 2008;40:447-452.

Food Security Agency., *Food Balance Sheet 2018-2020*. Jakarta: Ministry of Agriculture; 2020.

Ministry of Health of the Republic of Indonesia. *Regulation of the Minister of Health of the Republic of Indonesia Number 28 Year 2019 Concerning Recommended Dietary Allowances for the Indonesian Population*. Jakarta: Ministry of Health; 2019.

Gibson RS., *Principles of Nutritional Assessment*. 2nd ed. Oxford: Oxford University Press; 2005.

Naidu KA., Vitamin C in human health and disease is still a mystery? An overview. *Nutr J*. 2003 Aug 21;2:7. doi: 10.1186/1475-2891-2-7,2003. PMID: 14498993; PMCID: PMC201008.

Pollard J, Kirk SF, Cade JE., Factors affecting food choice in relation to fruit and vegetable intake: a review. *Nutr Res Rev*. 2002 Dec;15(2):373-87. doi: 10.1079/NRR200244. PMID: 19087412.

Ruel MT, Minot N, Smith L. *Pattern and determinants of fruit and vegetable consumption in Sub-Saharan Africa: a multicountry comparison*. World Health Organization (WHO); 2005.

World Health Organization. *Fruit and vegetables for health: report of the Joint FAO/WHO Workshop on Fruit and Vegetables for Health*, 1-3 September 2004, Kobe, Japan. Geneva: World Health Organization; 2005. Available from: https://apps.who.int/iris/handle/10665/43143

Sattar N, Forouhi NG. More Evidence for 5-a-Day for Fruit and Vegetables and a Greater Need for Translating Dietary Research Evidence to Practice. *Circulation*. 2021;143:1655–1658. Available from: https://doi.org/10.1161/CIRCULATIONAHA.121.053293

Euro WHO., *Linear programming build food-based dietary guidelines*: Romanian food baskets [Internet]. Copenhagen: WHO Regional Office for Europe; 2016 [cited 2023 Feb 14]. Available from: https://www.euro.who.int/__data/assets/pdf_file/0004/317506/Linear-programming-build-food-based-dietary-guidelines-Romanian-food-baskets.pdf

Okubo, H., Sasaki, S., Murakami, K. *et al.,* Designing optimal food intake patterns to achieve nutritional goals for Japanese adults through the use of linear programming optimization models. *Nutr J* **14**, 57 (2015). https://doi.org/10.1186/s12937-015-0047-7.

Biography

Nurhayati is currently employed at the National Research and Innovation Agency as a researcher. From 2000-2021 he worked at the National Institute of Health Research and Development, Indonesian Ministry of Health as a

researcher. He received a Doctor of Health from Indonesia University in 2013. His research interests mainly concern public health, epidemiology, biostatistics, and clinical research.

Sundari Wirasmi is a researcher for the Research Center for Preclinical and Clinical Medicine, National Research and Innovation Agency Republic of Indonesia. Her educational background is in Chemistry, which she obtained from the Bandung Institute of Technology. She is a candidate for the Master of Public Health, at Indonesia University. Her research interests mainly concern public health, traditional health service, and health service management.

Aris Yulianto is a Researcher from National Research and Innovation Agency. Before, he was exposed to health research at the National Institute of Health Research and Development, Ministry of Health, Republic of Indonesia. He studied Chemistry at the Faculty of Mathematics and Natural Sciences, Brawijaya University. He is now a student at the Master of Primary Health Care Management, ASEAN Institute for Health Development, Mahidol University. His passion concerns public health, traditional health service, disease registry, and health information system (HISs).