Ingredients Formulation of Analogue Rice Based on Location Spesific Flour, Case Studies in the Purworejo District

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Abstract. The determined of rice as staple food of Indonesians people will increase with increased of population growth. One of the efforts to meet basic food demand can be done through food diversification perform by using non-rice carbohydrate sources. Purworejo Regency is one of the regions that has a source of carbohydrate in addition to rice, which has not been further processed to be an alternative to meeting calorie needs other than rice. The purpose of this study is to obtain an optimal analog rice composition formulation in the form of a goal programming model by mixing non-rice base ingredients for analog rice production to produce analog rice that has nutritional characteristics determined with Ciherang rice. Conducting the results of making analog rice formulations with non-rice materials available in Purworejo District using a linear objective programming model. The linear goal programming optimization model uses a solver program with an objective function of the nutrient content of protein, amylose, and amylpectin to approach Ciherang rice. Analog rice optimization results were tested using similarity percentage values to determine the proximity of nutrient content with Ciherang rice. Based on the analysis of calculations from the solver program produces a mixture of white corn (94.674%) and taro beneng (5.326%) with a similarity of 98.381%. While the results of the optimization of the availability of carbohydrate sources in Purworejo District produced a mixture of taro beneng (19.462%), sago starch (20.668%) and breadfruit (59.851%) with the similar nutritional content of Ciherang rice of 89.717%.

1. Introduction
Rice is a staple food that is consumed as a source of calories by the people of Indonesia [1]. The high level rice consumption in Indonesia which is comparable to the increase in population rate is due to the routine or consumption patterns of Indonesia people in rice and it is difficult to switch to food other than rice. This is because that most people in Indonesia assume that the main source of carbohydrate is rice. In fact, Indonesia has diverse sources of carbohydrates such as corn, cassava, sorghum, cassava, sago, and other tubers. However, these ingredients are still not enough to replace rice as a staple containing carbohydrates. Analog rice is artificial rice made from flour other than rice and flour [2]. Making anlog rice can be an alternative in developing food diversification that can be a solution for the community to meet carbohydrate needsbeside rice. So that rice consumption is not always a solution in meeting the needs of carbohydrate sources. Besides consuming too much
carbohydrate will cause other effects, such as diabetes and obesity. Analog rice can also be one of the solutions to meet the source of carbohydrates for people with certain diseases by adjusting the nutritional content to be achieved. Like diabetics who consume foods with low sugar so that the design of making analog rice can adjust the desired content.

However, there are obstacles in the development of analog rice production at this time, namely the availability of basic ingredients for local flour to make analog rice that is different in each region. It is necessary to develop an analog rice-making formulation that can provide information on the formulation of the composition by the availability of basic non-rice ingredients locally owned by an area. So that the formulation of this composition can support local food diversification efforts by utilizing carbohydrate-based raw materials for making analog rice. With the nutrient content that is owned by analog rice is expected to have a nutrient content that is close to or even has more nutritional content by the expected target content.

2. Materials and methods

2.1. Data Collection

Data collection of nutrient content from several non-rice carbohydrate source materials and the availability of non-rice ingredients available in Purworejo Regency. Data on nutrient content from a number of non-rice carbohydrate sources were obtained from Hendrawan’s research [3], who had tested at the Laboratory of Food Processing and Agricultural Product Engineering, the Department of Mechanical and Biosystem Engineering, Bogor Agricultural Institute (IPB) and at the Laboratory of Postharvest Research and Development Laboratory, Indonesian Ministry of Agriculture. Ten non-rice ingredients have been studied in terms of nutrition in the form of physicochemical properties. Also, besides analyzing food consumption patterns of rice and non-rice carbohydrate sources in Purworejo Regency, as well as the availability of non-rice ingredients in Purworejo Regency obtained from secondary data at the Department of Food Agriculture and Fisheries Agriculture at Purworejo Regency.

2.2. Optimization Process

The optimization process was done using a solver program with the goal linear programming method. A program solver can provide optimal solutions for several materials that can be made with various requirements that provide and provide advantages or disadvantages of the composition. Optimization was carried out using nutrient data from ten non-rice ingredients and Ciherang rice data to obtain analog rice formulations with expected nutritional content. the content of the combination of non-rice ingredients must contain protein, amylase, and amylopectin which can be close to or equal to the nutritional content of Ciherang rice. The nutrient content approach is used because the protein and amylase content determine the physicochemical properties, especially the quality of the cooking. Besides the ratio of amylase content and amylopectin is a very important factor in determining the quality of rice cookers, both in a state that is still warm or has cooled to room temperature [3]. The various carbohydrate ingredients in the form of flour are formulated in making analog rice compositions using simplex linear programming contained in the solver application.

2.3. Evaluate the Value of Optimization

The evaluation will be carried out by calculating the similarity value on the results of the optimization formulation of analog rice composition. The similarity value is used to determine the percentage value of the proximity of the nutritional content of analog rice formulations with Ciherang rice. The testing of similarity values was calculated based on the average value difference between the nutritional content of analog rice formulations with Ciherang rice. When the desired nutritional value cannot be fulfilled, it is necessary to repeat the preparation of analog rice optimization to obtain a composition that has the expected nutritional content.
2.4. **Research Procedure**
Optimization of analog rice making formulations from non-rice materials concerning the nutrient content of ten starches that have been tested for nutritional content. The research procedure to be carried out can be seen in figure 1.

![Flowchart of the research stage](image)

**Figure 1.** Flowchart of the research stage

*Model Execution Process Using Linear Goal Programming*

The nutrient content approach to the composition of rice is analogous to the nutrient content of Ciherang rice with the aim of minimizing the content of protein, amylose and amylopectin. The nutrient content approach is used because the protein and amylose content determine the physicochemical properties, especially the quality of the cooking. Besides the ratio of amylose content and amylopectin is a very important factor in determining the quality of rice cookers, both in a state that is still warm or has cooled to room temperature [6]. The various carbohydrate ingredients in the
form of flour are formulated in making analog rice compositions using simplex linear programming contained in the solver application. The content which is owned by Ciherang rice (Xst) is used as a limiting factor for constraints. Here is a formulation optimization model using linear programming methods.

Decision variable:
\[ X_1 \quad : \text{Arrowroot starch} \quad X_6 \quad : \text{White corn flour} \]
\[ X_2 \quad : \text{Canna starch} \quad X_7 \quad : \text{Sago starch} \]
\[ X_3 \quad : \text{Talas beneng flour} \quad X_8 \quad : \text{Aren starch} \]
\[ X_4 \quad : \text{Sweet potato flour} \quad X_9 \quad : \text{Sorghum flour} \]
\[ X_5 \quad : \text{Tapioca flour} \quad X_{10} \quad : \text{Breadfruit flour} \]

\[ \sum_{i=1}^{10} \alpha X_i \geq \alpha_{st} \quad (1) \]
\[ \sum_{i=1}^{10} \beta X_i \geq \beta_{st} \quad (2) \]
\[ \sum_{i=1}^{10} \gamma X_i \geq \gamma_{st} \quad (3) \]

Objective Function:
Minimum
\[ Z = W_\alpha (\sum_{i=1}^{10} \alpha X_i - \alpha_{st}) + W_\beta (\sum_{i=1}^{10} \beta X_i - \beta_{st}) + W_\gamma (\sum_{i=1}^{10} \gamma X_i - \gamma_{st}) \]
\[ = W_\alpha (\sum_{i=1}^{10} \alpha X_i + \alpha_{st})^- + W_\alpha (\sum_{i=1}^{10} \alpha X_i - \alpha_{st})^+ + \]
\[ W_\beta (\sum_{i=1}^{10} \beta X_i + \beta_{st})^- + W_\beta (\sum_{i=1}^{10} \beta X_i - \beta_{st})^+ + W_\gamma (\sum_{i=1}^{10} \gamma X_i + \gamma_{st})^- + \]
\[ W_\gamma (\sum_{i=1}^{10} \gamma X_i - \gamma_{st})^+ \quad (4) \]

Constraint Function:
\[ \sum_{i=1}^{10} \alpha X_i = \alpha_{st} \quad (5) \]
\[ \sum_{i=1}^{10} \beta X_i = \beta_{st} \quad (6) \]
\[ \sum_{i=1}^{10} \gamma X_i = \gamma_{st} \quad (7) \]
\[ X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 + X_{10} = 1 \quad (8) \]
\[ X_1 \geq 0; X_2 \geq 0; X_3 \geq 0; X_4 \geq 0; X_5 \geq 0; X_6 \geq 0; X_7 \geq 0; X_8 \geq 0; X_9 \geq 0; X_{10} \geq 0 \quad (9) \]

Equations 1 to 3 is developed based on the desired properties of the content. Equation 4 is an objective function that will be minimized based on priority and penalty weight to produce the goal that is closest to the nutritional content of Ciherang rice. The constraint function equation consists of Equation 5 (protein), Equation 6 (amylose), Equation 7 (amylopectin), Equation 8 where the total percentage of the total addition of the composition must be equal to 1, Equation 9 is a non-negative constraint. These functions will be optimized using Solver found in Microsoft Excel. The number contained in the excel worksheet is the value of the results of laboratory testing which is the value of the nutritional content of each rice and non-rice material.
3. Result and Discussion

3.1. The General Condition of Purworejo Regency

The population of Purworejo Regency according to the projection on May 8, 2018, is 716,477 people with a male population composition of 353,289 and a female population of 363,179 people [4]. While the rate of population growth based on the Central Statistics Agency of Central Java Province in Purworejo Regency in 2010-2016 was 0.36%. Increasing the number of populations that is increasing every year will have an impact on the amount of staple food needs that are increasing. The staple food in meeting the calorie sources that are commonly consumed by the people in Purworejo Regency is a commodity of rice. Based on an average calculation of rice consumption per capita per year is 129.91 kg. Based on data from the population and the amount of consumption per year, the amount of rice needed can be calculated each year. Based on data of production per year and consumption per capita, can be estimated when rice production in Purwojero no longer sufficient for consumption (figure 2). It is obtained from the regression equation that in 2081 the total rice demand in Purworejo Regency is the same as the rice production produced which is 130.58 thousand tons.

3.2. Food Consumption Patterns

The consumption pattern is a picture of the population of a region in consuming food types as a composition of types and amount of food consumed by a person or group at a certain time [5] (Suyastiri 2008). Carbohydrate food sources in Purworejo Regency there are various kinds ranging from grains and tubers. Rice is the most widely grown crop in Purworejo District (57,764 ha) [6], therefore the most dominant staple food consumed in Purworejo Regency is rice. Cassava and corn are other important staple food sources in Purworejo. Rice became the most dominant food consumer in 2012-2017 which reached 72.7% of the total carbohydrate food sources. Yet in meeting basic food needs not only from rice, but other carbohydrates can be used to meet calorie needs or commonly referred to as food diversification. One of the efforts to diversify the food that has been running in Purworejo Regency since the past until now is processed cassava which is commonly called Oyek. But the processed nutritional content is still far from the nutritional content of rice that is commonly consumed by the public. Therefore, with processed carbohydrate sources which are still minimal, it is necessary to develop non-rice or analog rice carbohydrate sources. So that the consumption of carbohydrate sources can have equivalent nutritional content or close to rice that can be consumed by the community (Ciherang rice). Table 1 shows data on the nutritional content of various types of carbohydrate sources that can be optimized in analog rice preparation.

![Figure 2. Prediction of production and consumption of rice in Purworejo Regency](image-url)

\[
y = 0.5849x - 1085.8 \\
R^2 = 0.9995
\]

\[
y = -2.8283x + 6015.7 \\
R^2 = 0.9995
\]
The expected results of the optimization are the same or close to the Ciherang rice content. Function optimization is done using a solver by using the Simplex Linear Programming method. Data input in Excel Solver software in figure 3 shows the writing of the objective function, constraint function, and penalty weight. The Excel Solver Program works to find the value of formulations that are the same or most close to the Ciherang rice content. The penalty weights used to optimize the objective function are the same because all the desired contents can all approach the protein, amylose, and amylopectin content in the Ciherang rice content. The working principle of the solver program will produce the minimum objective function to produce a decision composition that is closest to the Ciherang rice content and its penalties. The values to be achieved from these three objectives are the same or close to the Ciherang rice content, namely, protein ranging from 8.58%, amylose around 23.61%, and amylopectin around 58.69%.

### Table 1. Data on the nutritional value of Ciherang rice and Non-rice

| Nutritional content and physical properties of flour/starch | Arrowroot starch (x1) | Canna starch (x2) | Talas beneng flour (x3) | Sweet potato flour (x4) | Tapioca flour (x5) | White corn flour (x6) | Sago starch (x7) | Aren starch (x8) | Sorghum flour (x9) | Breadfruit flour (x10) | Ciherang rice flour (xst) |
|------------------------------------------------------------|-----------------------|-------------------|------------------------|------------------------|-------------------|----------------------|------------------|-----------------|-------------------|------------------------|-------------------------|
| Water content (%, wd)                                      | 9.9                   | 16.8              | 11.9                   | 7.26                   | 4.62              | 3.6                  | 14.59           | 12.5            | 11.8              | 9.03                   | 11.08                   |
| Ash content (%, db)                                        | 0.27                  | 0.2               | 4.32                   | 1.96                   | 0.06              | 0.49                 | 0.23            | 0.22            | 0.54              | 3.47                   | 0.33                    |
| Fat content (%, db)                                        | 0.36                  | 0.45              | 0.9                    | 0.59                   | 0.29              | 2.03                 | 5.58            | 0.47            | 0.96              | 4.34                   | 0.43                    |
| Protein (%, db)                                            | 0.65                  | 0.69              | 6.86                   | 5.52                   | 0.46              | 8.38                 | 5.36            | 0.66            | 6.39              | 5.83                   | 8.58                    |
| Food fiber (%, db)                                         | 2.67                  | 2.38              | 2.47                   | 2.34                   | 1.52              | 3.16                 | 1.5             | 1.74            | 4.65              | 2.47                   | 6.88                    |
| Rough fiber (%, db)                                        | 0.49                  | 0.57              | 3.24                   | 2.57                   | 0.37              | 0.32                 | 0.41            | 0.48            | 0.8               | 0.54                   | 0.32                    |
| Total Sugar (%, db)                                        | 1.03                  | 1.47              | 2                      | 4.32                   | 1.09              | 0.32                 | 0.32            | 1.33            | 1.1               | 1.69                   | 1.16                    |
| Amylose (%, db)                                            | 28.55                 | 37.3              | 14.9                   | 25.2                   | 29.5              | 24.1                 | 32.99           | 31.99           | 27.5              | 23.2                   | 23.61                   |
| Amylopectin (%, db)                                        | 65.98                 | 56.6              | 65.3                   | 57.4                   | 66.6              | 59.3                 | 53.6            | 63.1            | 58.3              | 58.3                   | 58.69                   |

Source [7]
Figure 3. Example of Optimization Results

The status in the RMS column is the nutritional content owned by Ciherang rice while the column in the LMS is the result of the optimization of analog rice formulation. If one of the results of the formulation produces a value in the negative deviational variable decision column then the resulting value is below the desired value and vice versa when in the positive deviational variable column the value produced is above the desired value. The value of the content produced in figure 4 of the composition shows that the same content value is amylose content, for protein the content is less 0.281 parts of Ciherang rice protein content, and for amylopectin excess 0.930 of the desired content with an average difference of 1.62 %. The value on the decision line which shows the value of 0 means that of the ten flours carried out, the most optimal composition approaching Ciherang rice is the type of taro being and white corn, while for others the optimization does not meet or is less than the desired value so the value is 0.

3.3. Analysis of Optimization Results and Development Potential

Based on the several treatments carried out that have the closest analogue content of rice with Ciherang rice, namely optimization with a combination of white corn and talas beneng where the similarity value is 98.381%. The content of white corn alone is close enough to the nutritional content of Ciherang rice, this can be proven in several optimizations that are carried out when eliminating the type of bending taro material that is produced is only white corn material with a similar value of 98.185%. This value is almost the same as the combination of white corn and beans taro, this shows that the white corn content is enough to replace the Ciherang rice content. The nutritional value of white corn that cannot be fulfilled is protein content less 0.200% from 8.58,% excess amylose content is 0.930% from 23.61%, and amylopectin content is less 0.016% from 58.690%.

Also, from the total optimization that has been carried out the smallest similarity value is equal to 89.0361% which is found in the 47th optimization where the flour combination is done is to remove the white corn material and sago starch. The resulting content values are protein at 5.758%, amylose at 23.61%, and amylopectin at 58.690%. In this optimization, the amylose and amylopectin contents are met or equal to Ciherang rice. However, the value of the lack of protein content is 2.647% of the nutritional content of Ciherang rice which is 8.58%. Calculation of the composition of the combination of the results of several optimizations that have been made can be seen in Table 2 where several conditions occur such as eliminating one or more non-rice base ingredients and producing an optimal combination of 5 combinations. As for the results of the calculation of the similarity evaluation results of analog rice formulations can be seen in Table 3.

The availability of non-rice material in the Purworejo Regency can be a potential development of analog rice with predetermined nutrient content. available flour in Purworejo Regency, namely taro being flour, sweet potato, tapioca, sago starch, sugar palm starch, and breadfruit. Optimization of the
resulting nutritional content obtained protein content of 5.933%, amylose of 23.61%, and amylopectin of 58.690%. The unfulfilled content value is the same as Ciherang rice, which is a protein content that is still less than 2.647% of the expected total of 8.58%. The similarity of the three nutritional contents reached 89.717% with Ciherang rice. The combination produced to obtain the similarity value is talas beneng at 19.462%, sago starch at 20.668%, and breadfruit flour at 59.851%.

Table 2. Results of optimization of analog rice combination formulations

| Material code | Non-rice sources           | Protein (%db) | Amylose (db%) | Amylopectin (db%) | Combination 1 | Combination 2 | Combination 3 | Combination 4 | Combination 5 | Combination of local ingredients |
|---------------|----------------------------|---------------|---------------|-------------------|---------------|---------------|---------------|---------------|---------------|----------------------------------|
| X1            | Arrowroot starch           | 0.650         | 28.550        | 65.980            | 0             | 0             | 0             | 0             | 0             | 0                                |
| X2            | Canna starch               | 0.690         | 37.300        | 56.600            | 0             | 0             | 0             | 0             | 0             | 0                                |
| X3            | Talas beneng flour         | 6.860         | 14.900        | 65.300            | 0             | 0             | 0.056         | 0.160         | 0.053         | 0.195                            |
| X4            | Sweet potato flour         | 5.520         | 25.200        | 57.400            | 0             | 0             | 0             | 0             | 0.813         | 0                                |
| X5            | Tapioca flour              | 0.460         | 29.500        | 66.600            | 0.047         | 0             | 0.000         | 0             | 0             | 0.947                            |
| X6            | White corn flour           | 8.380         | 24.100        | 59.300            | 0             | 1.000         | 0             | 0             | 0             | 0                                |
| X7            | Sago starch                | 5.360         | 32.990        | 53.600            | 0             | 0             | 0.000         | 0             | 0             | 0.207                            |
| X8            | Sago starch                | 0.660         | 31.990        | 63.100            | 0             | 0             | 0             | 0             | 0             | 0                                |
| X9            | Sorghum flour              | 6.390         | 27.500        | 58.300            | 0.027         | 0             | 0.203         | 0.026         | 0             | 0                                |
| X10           | Breadfruit flour           | 5.830         | 23.200        | 58.300            | 0.926         | 0             | 0.741         | 0             | 0             | 0.599                            |

Table 3. Evaluate the differences in the nutritional value of analog rice

| Optimization Results | Nutrient Content from Optimization Results | Average Difference (%) | Material Code |
|----------------------|--------------------------------------------|-------------------------|---------------|
| Combination 1        | Protein (%db) 5.593                        | 11.606%                 | X5, X9, X10   |
| Combinationi 2       | Amylose (db%) 23.610                       | 1.815%                  | X6            |
| Combination 3        | Amylopectin(db%) 58.690                    | 10.02%                  | X3, X9, X10   |
| Combination 4        |                                           | 10.96%                  | X3, X4, X9    |
| Combination 5        |                                           | 1.619%                  | X3, X6        |
| Combination of local |                                           | 10.28%                  | X3, X7, X10   |
| ingredients          |                                           |                         |               |
| Ciherang Rice        |                                           |                         |               | 8.580         | 23.610        | 58.690        |
4. Conclusions and Suggestions

4.1. Conclusions
1. The optimization model was successfully compiled using goal programming with the ten flour starches and formulations of the material specifications from Purworejo Regency. In addition, the optimization formulation can be applied in other districts with a combination of several types of flour can produce a mixture that approaches the nutritional content of Ciherang rice.
2. Optimization simulation carried out produces the formulation that is closest to the nutritional content of protein, amylose, and amylpectin of Ciherang rice, namely a mixture of white corn (94.674%) and talas beneng (5.326%) with a similarity value of 98.381%.
3. The similarity of analog rice content from the combination of the availability of non-rice ingredients in Purworejo Regency with Ciherang rice is 89.717%. The optimal combination obtained is the type of taro being (19.462%), sago starch (20.688%) and breadfruit (59.851%).

4.2 Suggestions
1. Development of other arrangements in the optimization formulation with nutritional content according to the desired target. As well as nuts that contain nutritious protein which is quite high.
2. Purworejo Regency requires the development of other resources such as white corn and sorghum to produce analog rice with the nutrient content needed by Ciherang rice.
3. Development of an analog processing program that is created automatically so that it can produce analogs that can be accessed directly according to the available non-rice material.

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