Formulation and characterization of instant baby complementary food from red sorghum flour *(Sorghum bicolor (L) Moench)* and papaya puree *(Carica papaya Linn.)*

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Abstract. This study aims to obtain the best formulation and conduct physicochemical, organoleptic and microbiological testing of instant baby complementary food products based on red sorghum flour and papaya. The preliminary research was conducted to determine the upper and lower limits of the expert design program using hedonic tests. The main research was carried out to find the best formulation using the expert design program with the D-optimal Mixture Design method. The result of the preliminary research has shown that the chosen formulation was included in the application design expert. There was one optimal formulation out of eight that had been obtained that is the one using 12.25% of red sorghum flour and 5.75% of papaya. Organoleptic test results showed that instant baby complementary food formula could be accepted by panellists.

1. Introduction
Age 0 to 12 months is a period of rapid growth and development until reaching a peak at the age of 24 months. During the first six months after birth, breast milk is recommended as a source of exclusive nutrition that is very necessary for the health and development of the baby [1]. During the period of growth and subsequent development, the baby will experience a physiological shift in nutritional and energy needs that are not obtained only from breast milk [1]. Therefore, to achieve optimal growth and development, the World Health Organization (WHO) recommends infants aged 6 to 24 months to be given additional nutrition from instant baby food as a complementary to breast milk to achieve nutritional adequacy [2].

In general, during the first 6 months of life, babies need energy of about 115-120 kcal/kg/day, which then decreases to around 105-110 kcal/kg/day in the next 6 months [3]. Energy is supplied mainly by carbohydrates and fats. One of the sources of carbohydrates is the sorghum plant [4]. Sorghum *(Sorghum bicolor L. Moench)* is a cereal source of carbohydrates. Sorghum contains carbohydrates reaching 74.63
grams/100gram, higher than wheat which is 71.97 grams/100gram and ranked third after rice is 79.15
grams/100gram, and corn 76.85 grams/100gram [5].

Food products made from cereals can be combined with fruit to have better nutritional value [6]. In
baby food, it is important to present soft textures such as creamy, thick, and tender to develop baby’s
ability to swallow and prevent choking. Papaya (Carica papaya L.). has been considered as one type of
fruit as a source of fibre that can help improve texture to another food product. Papaya also has ideal
consistency as a starting food for babies. Therefore, in this study papaya is used to enrich the instant
baby complementary food made from sorghum flour.

Food formulations are prepared to obtain a composition of food ingredients that contain good
nutrients and in large quantities in a certain ratio which meets the criteria as food ingredients for toddlers
following Indonesian National Standards. Thus the purpose of this research is to obtain an optimal
formulation in the process of making instant baby complementary food made from red sorghum flour
and papaya puree and to conduct physicochemical, organoleptic and microbiological testing of the
product.

2. Materials and Methods

2.1. Materials

The main raw material used in this study is red sorghum flour (Sorghum bicolor L. Moench) obtained
from Ganesha Farmhouse located in Margahayu Utara, Bandung and papaya (california variant). The
supporting materials used include skim milk, sucrose, and water. The chemical used for the analysis of
starch and total sugar content of the luff schoorl method [6] uses H$_2$SO$_4$ 6N, solid KI, 0.1N Na$_2$S2O$_3$,
HCN 9.5N, luff schoorl solution, starch, PP indicator, and 30% NaOH. Analysis of fat content using the
soxhlet extraction method using n-hexane and silica gel solvents. Analysis of crude fiber content using
a gravimetric method using H$_2$SO$_4$ 0.3 N, NaOH, CHCl$_3$. Materials used to identify microbes include
MRS agar, Salmonella Shigella Agar (SSA), Eosyn Metyl Blue Agar (EMBA) and Baird Parker Agar.

2.2. Methods

2.2.1. Preliminary research

The preliminary research was carried out by conducting a Trial and Error determination of instant
porridge instant baby complementary food formulation. After that, the determination of the upper and
lower limits of the Trial and Error results with organoleptic hedonic test methods with assessment
parameters in the form of color, aroma, taste and texture as mentioned in Table 1.

| Table 1. Red sorghum and papaya based instant baby complementary food formulation. |
|---------------------------------------------------------------|
| Materials (%) | Sample Code |
|----------------|------------|
| Red Sorghum Flour | F1 | F2 | F3 |
| Papaya Puree | 14 | 12 | 11 |
| Sucrose | 4 | 6 | 7 |
| Skimmed Milk Powder | 3.38 | 3.38 | 3.38 |
| Water | 8.62 | 8.62 | 8.62 |
| | 70 | 70 | 70 |

2.2.2. Main research

The main research aims to determine the material that will be formulated using the D-Optimal Mixture
Design Expert method as a material that becomes a fixed variable and a material that changes into a
variable as you can see in Table 2.
Table 2. Additives (fixed variables).

| No | Name of Materials      | Amount (%) |
|----|------------------------|------------|
| 1  | Skimmed Milk Powder    | 8.62       |
| 2  | Sucrose                | 3.38       |
| 3  | Water                  | 70         |

|                | Total Fixed Variable  |            |
|----------------|-----------------------|------------|
|                | 82                    |            |
|                | Total Change Variable | 18         |
|                | Total                 | 100        |

Determination of the optimum formula consists of four stages, the first step that must be done is to determine the variables to be combined with their concentration, then determine the response to be measured that has a function of the components in making up the product. Each response variable will be analyzed by design expert 10.0 to get the D-optimal equation with a suitable order (linear, quadratic, cubic). Furthermore, these response variables are used as prediction models to determine the optimal formula. The optimization target value achieved is expressed with desirability which is stated to be a value between 0 to 1. The closer it is to 1, the easier a formula approaches to reach the optimal formula point based on the response variable.

2.2.3. Analysis

The physical analysis conducted in this research includes water absorption, rehydration time, and bulk density. Chemical analysis carried out includes water content and ash content of the gravimetric method [7], analysis of total carbohydrate and sugar content of the Luff Schoorl method, protein content analysis of the Kjedahl method, fat content analysis of the Soxhlet Extraction method [6], and crude fiber content analysis Gravimetric method. An organoleptic test was conducted to determine the level of preference of panelists for instant baby complementary food based on hedonic tests on color, taste, aroma, and texture. This organoleptic test was carried out by 30 panelists using the Hedonic method (preference test). Microbiological analysis was performed on cell count calculation, identification of Coliform bacteria, identification of Salmonella sp. Bacteria, and identification of Staphylococcus aureus bacteria.

3. Results and Discussion

3.1. Preliminary research

The organoleptic test of the hedonic method aims to determine one formula to be optimized. The selected attributes are color, aroma, taste, and texture. Based on Table 1, the F3 sample code is better compared to the F1 and F2 sample codes in terms of color, aroma, taste and texture attributes with a total score attribute of 16.80 (scale 1-5). These advantages are due to the F3 sample code having a small amount of red sorghum flour which is 11% compared to the F1 sample code of 14% and the F2 sample code of 12%. One formula chosen is the sample code F3 in the preliminary test, then used to determine the range for optimization of the formula. Based on the results of the processed design expert 10.0 program obtained 8 formulations.

3.2. Main research

3.2.1. Chemical analysis of instant baby complementary food

The results of the instant baby complementary food chemical analysis can be seen in Table 3. Based on the analysis of water content of instant baby complementary food in the formulation of instant porridge ranges from 3.3807 - 4.3162% and it has a cubic model with a model probability value of 0.3956 which indicates that the model is not significant. Based on the analysis of ash content, it can be seen the largest instant baby complementary food ash content is 2.0314% in sample H and it has a linear model. The results of the analysis of carbohydrate content ranged between 57.7993-59.4510%. Carbohydrate
content has a linear model. The model is significant with a probability value of the model that is less than 0.05 which is equal to 0.0017, which means that the factors in the model significantly affect carbohydrate levels at a significance level of 5%.

The results of the analysis of protein content can be concluded that instant baby complementary food protein levels are in the range of 13.8032-14.0081%. The drying treatment causes changes in the components contained in instant baby complementary food products. The occurring change is a protein hydrolysis. Protein hydrolysis is the process of breaking peptide bonds from proteins into smaller components such as peptones, peptides, and amino acids. Amino acids will then bind with reducing sugar to produce compounds that can evaporate, which can cause a decrease in protein levels in the product [8]. Protein content has a linear model with a probability value of the model of 0.4667. The results of fat content analysis showed that the fat content is in the range of 4.0804-4.4528%. Fat content has a linear model with a probability value of the model of 0.6969.

| Sample | Water Content | Ash Content | Protein Content | Fat Content | Carbohydrate Content | Total Sugar Content | Total Crude Fiber |
|--------|---------------|-------------|-----------------|-------------|----------------------|---------------------|------------------|
| A      | 3.3807        | 1.2939      | 13.8032         | 4.0804      | 58.5678              | 15.6104             | 1.9608           |
| B      | 4.3162        | 1.5712      | 13.8167         | 4.1164      | 59.0807              | 15.5833             | 1.1407           |
| C      | 4.2752        | 1.7431      | 13.8437         | 4.2187      | 58.0139              | 15.7471             | 1.1494           |
| D      | 4.2385        | 1.8536      | 13.8776         | 4.2666      | 57.7993              | 15.9425             | 1.1527           |
| E      | 3.8157        | 1.9019      | 13.8844         | 4.3333      | 58.7887              | 15.4097             | 1.1840           |
| F      | 4.1575        | 1.9066      | 13.8980         | 4.4010      | 58.3652              | 15.6511             | 1.2939           |
| G      | 4.0794        | 1.9755      | 13.9803         | 4.4528      | 58.7208              | 15.5564             | 1.4612           |
| H      | 3.9284        | 2.0314      | 14.0081         | 4.4326      | 59.4510              | 15.4627             | 1.6175           |

Crude fiber is a part of food that is resistant to heat and cannot be hydroyzed by the use of chemicals. The crude fiber content of the test results showed values that were not much different among the samples, which were in the range of 1.1407-1.9608. The results of the analysis of various levels of crude fiber have a cubic model (cubic). The model is not significant with the probability value of the model more than 0.05 which is equal to 0.2258.

The results of the analysis of total sugar levels, it can be seen that the total sugar content of instant baby complementary food has carbohydrate content (in the form of sugar) no more than 30 grams / 100 grams. The results of the analysis of variance from total sugar content data showed total sugar levels have a linear model. The model is significant with a probability value of the model less than 0.05 which is equal to 0.0008. The use of a drying method with a temperature of 50°C for 12 hours affects the total sugar content in the product. According to Norman (1988), during the drying, the foodstuffs lose water content which causes an increase in the content of active substances in the remaining period, so that the sugar content in the product will increase with decreasing water content in the product [9].

3.2.2 Formula optimization of instant baby complementary food
Optimization target values that can be achieved are known as desirability values. This value is zero up to one. The desirability value close to one indicates that the instant baby complementary food can reach the optimal formula in accordance with the desired response variable. Optimized components, target values, limits, and importance at the optimization stage of the formula using the expert 10.0 design program can be seen in Table 4.
Table 4. Optimized components and responses, targets, limits, and importance in the formula optimization stages.

| Names of Component     | Goal       | Upper Limit | Lower Limit | Importance |
|------------------------|------------|-------------|-------------|------------|
| Red Sorghum Flour      | Maximize   | 13.5        | 8.5         | 5 (++++)   |
| Papaya                 | Maximize   | 9.5         | 4.5         | 3 (+++)    |
| Water Content          | Minimize   | 4.82        | 3.38        | 3 (+++)    |
| Ash Content            | Minimize   | 2.03        | 1.29        | 3 (+++)    |
| Carbohydrate Content   | Minimize   | 59.45       | 57.8        | 4 (++++)   |
| Protein Content        | Maximize   | 14.01       | 13.8        | 3 (+++)    |
| Fat Content            | Maximize   | 4.45        | 4.08        | 4 (++++)   |
| Crude Fiber Content    | In range   | 1.96        | 1.14        | 3 (+++)    |
| Total Sugar Content    | Maximize   | 15.94       | 15.41       | 3 (+++)    |

The desirability value result is significantly influenced by the complexity of the component, the range used in the component, the number of components and the response, and the target to be achieved in obtaining the optimum formula. The optimization phase carried out provides one of the best formulas from several suggested formulas with the highest desirability value of 0.585.

The selected formula solution is the optimum formula consisting of 12.25% red sorghum flour and 5.75% papaya. This formula has a desirability value of 0.585, which means this formula will produce products that have characteristics in accordance with the optimization target of 58.5%. This formula is predicted to have a moisture content of 3.544%, ash content of 1.290%, carbohydrate content of 58.677%, protein content of 13.892%, fat content of 4.291%, crude fiber content of 1.833%, and total sugar content of 15.595%. The contour plot graph of this formula can be seen in Figure 1.

![Contour Plot](image)

Figure 1. Graphics of contour plot optimal formulation of instant baby complementary food.

3.2.3. Verification of optimal formula of instant baby complementary food

Based on the verification stage, it can be seen that the verification data is still in accordance with the predictions made by the expert 10.0 design program (Table 5). Confidence interval (CI) is a specific chance interval from the estimated entry of parameters, with limits on both sides (top and bottom) [10]. Prediction interval (PI) shows the range of individual values expected to appear. CI and PI in this study are worth 95%.
Table 5. Results of verification stages and predictions for each response.

| Response          | Prediction | Verification | Cl for Mean          | TI For Mean          |
|-------------------|------------|--------------|----------------------|----------------------|
|                   |            |              | 95% CI low           | 95% CI high          | 95% TI low           | 95% TI high          |
| Water Content     | 3.54       | 4.27         | 2.61                 | 4.48                 | 0.47                 | 6.62                 |
| Ash Content       | 1.29       | 3.71         | 0.63                 | 1.95                 | -0.75                | 3.33                 |
| Carbohydrate      | 58.68      | 37.25        | 58.46                | 58.89                | 57.32                | 60.03                |
| Protein Content   | 13.89      | 15.72        | 13.83                | 13.96                | 13.46                | 14.32                |
| Fat Content       | 4.29       | 4.21         | 4.16                 | 4.42                 | 3.45                 | 5.13                 |
| Crude Fiber       | 1.83       | 0.43         | 1.25                 | 2.41                 | -0.07                | 3.74                 |
| Total Sugar Content | 15.59     | 15.57        | 15.54                | 15.65                | 15.22                | 15.97                |

Based on the generated data that the result difference between the prediction and verification is not too far away on the response of water content, protein, and crude fiber. However, the response of ash, carbohydrate, fat, and total sugar levels have different laboratory test results compared to the predicted results of the expert design program.

3.2.4. Characterization of instant baby complementary food
The results of the characterization were physical, microbiological and organoleptic responses. The characteristics of instant baby complementary food products with formulas that have been optimized can be seen in Table 6. The results of chemical response testing in Table 6, then compared with the Indonesian National Standard [2] about instant baby complementary foods for breast milk.

The analysis results of instant baby complementary food water content optimal formula with the use of 12.25% of red sorghum flour and 5.75% of papaya showed a result of 4.27%. Based on the results of this analysis, the instant baby complementary food water content is optimal in accordance with the standard, where the instant baby complementary food water content based on [2] has a water content of no more than 4 grams / 100 grams. Water content produced by food is influenced by the process of heating, drying, and the nature of food. The cooking and drying treatment generally involves adding heat to food and removing water content in the form of water vapor. If heat is given to food, food temperatures can increase and water in food evaporates [11]. The water content in instant baby complementary food products based on sorghum flour was also thought to be affected by the sugar content in the ingredients and the addition of sugar (sucrose) as much as 3.82%. [12] states that high sugar concentrations will cause an osmotic dehydration process so that the amount of water contained in the material will come out.

The analysis of ash content of instant baby complementary food is 3.71%. Ash content is caused by a drying process factor. Instant baby complementary food ash content of optimal formulation is not in accordance with the standard, where the instant baby complementary food ash content based on [2] has ash content not more than 3.5 gram / 100 gram. The drying process causes a breakdown of water molecular bonding components (H₂O) and also provides an increase in the content of sugars, fats, and minerals resulting in an increase in ash content [13].

The laboratory analysis result of carbohydrate content is 37.25%, therefore, based on the results of the carbohydrate analysis of the instant baby complementary food formulation is not optimal according to the standard. The analysis of protein content showed that the instant baby complementary food protein content was optimal formulation in accordance with the standard. Instant baby complementary food protein content based on Indonesian National Standard is 8-22% [2]. The optimal instant baby
complementary food fat content is 4.21%, lower compared to Indonesian National Standard which is between 6-15% [2]. Low fat content is affected by the heating and drying process. Research by Zuhra (2012) states the amount of fat content in drying with drying air temperature can occur as a result of damage to fat due to relatively high drying temperatures [14].

The analysis results of the crude fiber of instant baby complementary food optimal formula showed different results from the prediction of the expert design program. On the prediction of the results of invisible fiber levels expressed at 1.83% while the results of laboratory analysis of 0.43%. In the measurement of food fiber, it is known that the content of food fiber in instant baby complementary food products is 7.54%. This value is higher than the [2] standard, which has a value of no more than 5 g / 100 gram.

The results of laboratory analysis showed the total sugar content of instant baby complementary food is 15.57%. This result indicated the total sugar content of instant baby complementary food is optimal according to the standard, which is no more than 30 grams / 100 grams. The cooking and drying processes cause the hydrolysis of sucrose into its constituent monomers (glucose and fructose) or invert sugar, causing total sugar yields to increase [15].

The instant baby complementary food iron content in the optimal formulation is 6.19 mg / 100 gram. This value is in accordance with the standards 01-7111.1 of 2005 which is not less than 5 mg / 100 gram. The instant baby complementary food calcium level in accordance with Indonesian National Standard 01-7111.1-2005 is not less than 200 mg / 100 gram. Beta-carotene levels of instant baby complementary food optimal formula does not meet the specifications of instant baby complementary food that is vitamin A content between 3-10 µg / 100 grams. Based on [16] research, beta-carotene content will decrease after going through the heating process. [17] found that 52% of beta-carotene was lost in the drying process using a cabinet dryer.

The value of instant baby complementary food slurry density of the optimal formulation of the analysis results was 0.71 g / mL. Baby food should better have a minimum of slowing or maximum bulk density. Water absorption is a parameter that shows the ability of a material to attract water around it to bind to a particle of material or to survive in a pore between particles of material [18]. The result of instant baby complementary food water absorption is 182%. The rehydration time of the slurry is related to the ability of the slurry particles to absorb the added water. The analysis results are known that the optimal instant baby complementary food rehydration time is 249 seconds.

The laboratory test results on instant baby complementary food showed that there was an absent of Salmonella sp contamination, while the instant baby complementary food test results showed that coliform contamination was 4.3 MPN / g. This value is still within the standard limits set by [2] which is no more than 20 MPN / g. The contamination of Staphylococcus aureus from the instant baby complementary food test shows that it is still within the standard limits set by [2] which is no more than 1.0 x 10² colonies per gram. The testing of the instant baby complementary food total slurry of the optimal formula exceeds the maximum limit of the number of microbes that have been set by [2], which is 3.4 x 10⁴ colonies / g.

Overall organoleptic testing, based on average panelist ratings, showed that the selected formula instant baby complementary food with red sorghum flour and papaya fruit was acceptable to the panelists. The calorie adequacy results in instant baby complementary food in the optimal formulation studied were 67.89 kcal. The total calories of instant baby complementary food are taken into consideration in determining the serving size and function. Overall toddlers aged 7 to 23 months need 880 kcal calories. Energy intake from breast milk is 437 kcal / day, so the energy obtained from instant baby complementary food is 346 kcal / day.
Table 6. Formula optimal characteristics of instant baby complementary food.

| No | Parameter                        | Measure          | Result  |
|----|----------------------------------|------------------|---------|
|    | **Chemical Analysis**            |                  |         |
| 1  | Water Content                    | %                | 4.27    |
| 2  | Ash Content                      | %                | 3.71    |
| 3  | Carbohydrate Content             | %                | 37.25   |
| 4  | Protein Content                  | %                | 15.72   |
| 5  | Fat Content                      | %                | 4.21    |
| 6  | Crude Fiber Content              | %                | 0.43    |
| 7  | Total Sugar Content              | %                | 15.57   |
| 8  | Dietary Fiber                    | %                | 7.54    |
| 9  | Fe                               | mg/100gram       | 6.19    |
| 10 | Calcium                          | mg/100gram       | 640.80  |
| 11 | Beta Carotene                    | mg/kg            | 0.58    |
| 12 | Total Calorie                    | kcal/30 g        | 67.89   |
|    | **Physical Analysis**            |                  |         |
| 13 | Bulk Density                     | g/ml             | 0.71    |
| 14 | Water Absorption                 | %                | 182     |
| 15 | Rehydration Time                 | Second           | 249     |
|    | **Microbiology Analysis**        |                  |         |
| 16 | *Coliform*                       | MPN/g            | 4.3     |
| 17 | Total Plate Count                | Colony/g         | 3.4 x 10^4 |
| 18 | *Salmonella* sp                  | G                | -       |
| 19 | *Staphylococcus aureus*          | Colony/g         | 1.0 x 10^2 |
|    | **Organoleptic Analysis**        |                  |         |
| 20 | Aroma                            | Scale 1-6        | 4.13    |
| 21 | Taste                            | Scale 1-6        | 4.33    |
| 22 | Color                            | Scale 1-6        | 4.33    |
| 23 | Texture                          | Scale 1-6        | 4.4     |

4. Conclusions

An optimal formulation for the instant baby complementary food product is to use 12.25% red sorghum flour and 5.75% papaya. Organoleptic test results showed that instant baby complementary food formula can be accepted by panellists. The results of product characterization produced from the optimum formula indicate that instant baby complementary food needs to be reformulated to meet SNI 01-7111.1-2005 especially to meet the need for fat content, dietary fiber content and beta carotene levels.

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