The characteristic of different formula of low tannin sorghum instant porridge

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Abstract. Sorghum has a potential to be developed as staple food, however the main obstacle is high tannin content which causing bitter taste. Low content of tannin in sorghum flour could be a solution for widening the customer acceptance. Such product produced using low tannin sorghum is instant porridge. Therefore this study aimed to find optimum formula of instant porridge using low tannin sorghum flour. This study using two factors of instant porridge formula, first ratio of low tannin sorghum flour : tapioca (100 : 0; 90 : 10; 80 : 20; 70 : 30; 60 : 40) and the ratio of water (1 : 7; 1 : 9; 1 : 11). Result shows that optimum instant sorghum formula was found in 80 : 20 sorghum : tapioca flour, with the addition of 1 : 11 water ratio. This porridge has desirability value 0.716, water content 4.93%, ash 0.49%, fat 5.92%, protein 8.37% and carbohydrate 85.2%. Moreover the average score of total acceptance is about 4 (like). The optimum formula also has high-quality digestibility and dietary fiber (77.97% and 9.07 %, respectively). According to this study, instant sorghum porridge could be used as alternatives of nutritious and healthy food.

1. Introduction
In the last two decades, there have been changes in people's lifestyles and eating patterns, especially in urban areas. Currently, consumers prefer food products that are instant or fast food (ready to use or ready to eat) and have functional value for health. Instant food products was developed to overcome the problems of using and handling food products that are often faced such as storage, transportation, and time consumption [1].

One form of processed instant food is an instant porridge that can be made from various cereals in addition to wheat, oats, rice, or beans. Sorghum (Sorghum bicolor L. Moench) was a cereal commodity that has not been consumed by many Indonesians. Sorghum productivity is quite high (2.5–6.0 tons/ha) and can be cultivated in all types of soil, including marginal land [2]. Utilization of sorghum was a form of diversification local food to reduce people's dependence on rice and wheat, which until now topped a list of imported commodities. The nutritional value of sorghum is not inferior to rice. Even sorghum contains protein (8–12%) equivalent to flour or higher than rice (6–10%), and fat content (2–6%) is higher than rice (0.5–1.5%). Sorghum products can be intended for the elderly because they have a low glycemic index and high dietary fiber so healthier to consumed [3].

Earlier studies have been done in the utilization of sorghum in Indonesia in various food products [2, 4]. However, instant sorghum product information is still very limited. The high carbohydrate content is possibly sorghum used to process as instant product that can be consumed for breakfast or specific
conditions. The characteristics of this product should be in the form of dry or concentrated, easily dissolved by adding hot or cold water so relatively short time to serve. The process of making instant porridge can be done by various methods including drum drying, baking, and extruding. The most frequently used method is drum drying because its resulting bes the quality of the porridge [5].

The main obstacle processing of sorghum was seed milling and the tannin content in sorghum seeds causes a bitter taste ('sepet'). Tannin is a phenolic component that act as an anti-nutrition for the body. For the sustainability of the utilizing of sorghum in healthy food products, it is necessary to develop sorghum varieties that are low in tannin or low tannin sorghum processing technology. Widowati et al. [6] has developed a technology milling grain for making low tannin sorghum flour. This achievement must be supported by the diversification of low tannin sorghum flour products for the wider use of low tannin sorghum flour in Indonesian society. The purpose of this study is to find optimum formula of low tannin sorghum flour for making instant porridge to support food diversification. The optimization formula of instant porridge was designed using general factorial design with the help of Design Expert 7®. The composition of raw material was 0–40% for tapioca, 60–100% for sorghum and the total amount of flour for each formulation is 100%, and the ratio of the addition of water consists of 3 levels. The optimum formula was a characterization including physical, proximate, sensory, and functional properties.

2. Materials and methods

2.1. Materials

The main ingredient of the study was sorghum grain superior varieties G1.1 from Padjajaran University, Bandung. Additional materials were tapioca, vegetable oil, full cream milk powder, sugar, and salt. The proximate chemicals for analysis purchase from Merck and Sigma Co.

2.2. Methods

2.2.1. Low tannin sorghum flour preparation. Low tannin sorghum preparation refers to the method Widowati [6]. Sorghum was milled using a type 50 no. 1 emery stone for 3 minutes for 100% milling degrees followed by soaking in 0.3% Na₂CO₃ solution for 8 hours. This method could reduce the sorghum tannin content to 78% (from 0.184 to 0.040% tannic acid equivalent).

2.2.2. Instant sorghum porridge formulation. The material formulation in the processing of sorghum porridge is designed by using a general factorial of Design Expert DX 7.1.6 (trial version) software. The design had 15 combinations of formulas with the composition of raw material was 0–40% for tapioca, 60–100% for sorghum and the total amount of flour for each formulation is 100%. The ratio of the addition of water consists of 3 levels, namely 1: 7, 1: 9, and 1:11 with calculations based on flour weight. Two repetitions was done for all treatment combinations. All experiments were carried out randomly to minimize bias (Table 1).

2.2.3. Instant sorghum porridge process. Instant sorghum porridge refers to instant hotong porridge [7] with additional ingredients such as vegetable oil (5%), full cream milk (30%), sugar (40%), and salt (0.02%). The calculation used was that every 100 grams of a dry product are estimated to contain 300 kcal as a minimal calorie. The process of making instant sorghum porridge with drum drying at 80°C, 2.5 rpm.

2.2.4. Characterization of instant sorghum porridge. Characterization of instant sorghum porridge included determination of yield, bulk density, solid density, proximate analysis [8], sensory acceptance conducted by the preferences test method with the parameters being tested were color, aroma, texture, taste, and general acceptance with scores used 1–5 (very dislike-really like). Instant porridge was served in a form that has been rehydrated and ready to eat for 35 (untrained) panelists. After obtaining the
optimum instant sorghum porridge formula, characterization of functional properties was carried out including the determination of dietary fiber, starch digestibility, viscosity (Brookfield viscosity with spindle number 4, and a speed of 100 rpm), and water absorption.

| Table 1. Instant sorghum porridge formulation |
|---------------------------------------------|
| Formula Sorghum flour: tapioca (%) ratio Water ratio |
| 1 100: 0 1: 7 |
| 2 100: 0 1: 9 |
| 3 100: 0 1:11 |
| 4 90: 10 1: 7 |
| 5 90: 10 1: 9 |
| 6 90: 10 1:11 |
| 7 80: 20 1: 7 |
| 8 80: 20 1: 9 |
| 9 80: 20 1:11 |
| 10 70: 30 1: 7 |
| 11 70: 30 1: 9 |
| 12 70: 30 1:11 |
| 13 60: 40 1: 7 |
| 14 60: 40 1: 9 |
| 15 60: 40 1:11 |

2.3. Determination of the optimum formula
D-optimal Combined Design was generated through the software of Design Expert 7.0 ®. The analysis begins with model selection, based on the sequential model sum of a square, model deviation test, and statistical model summary. The significant model was selected with p<0.05, variance analysis (ANOVA) was applied to determine the effect of the mixed ingredients on each response. The optimum formula is determined from the highest desirability value. Value desirability will be obtained after determining the value of the goal to be achieved in the optimum quality of sorghum porridge instant.

3. Results and discussion
3.1. The physical quality of instant sorghum porridge
Variance analysis results showed that the interaction of flour formula and water ratio significantly affected physical quality (p<0.05). The water ratio of 1:11 shows the highest yield of 79.83–81.85%, followed by the water ratio of 1: 9 and 1:7 (Table 2). The increase in yield due to an increase in the water ratio is related to the addition of the amount of water in the slurry. The water in the slurry will diffuse into the starch granules and can cause starch gelatinization in the presence of heating. The more the amount of water is added or the ratio of water to the slurry increases, the more water is diffused into the starch granules, which can cause starch granules to become more swollen and irreversible, thereby increasing product yield. The yield measurement is useful for determining the number of ingredients used to produce a certain amount of product.

The bulk density of instant porridge ranges from 0.09 to 0.19 g/ml and the solid density at 0.13–0.22 g/ml (Table 2). The density of bulk and solid are the physical properties for special foodstuffs and grains. By knowing the density product, it can be estimated the effectiveness and efficiency of the volume of space needed for food with a certain weight. Bulk and solid density are affected by water content, material composition, geometric shape, size, and surface characteristics. Knowledge of density values can be useful when filling material into a stationary container (bulk density) and vibrating during transportation (solid density). Bulk and solid density are needed in terms of space requirements, both during storage and transportation.
In this range water content, the value of ash content of instant sorghum porridge was closely related to the mineral content contained in tapioca substitution decreases the ash content can be reduced. Variance analysis results showed that the interaction of flour formula and water ratio significantly affected all proximate parameters (p < 0.05). The water content for the fifteen formulas ranged from 3.95–7.66% (Table 3). The water content was relatively smaller that made this product was hygroscopic (easily absorbs water). Products with low moisture content must be protected with suitable packaging materials with a low permeability value. Water content was one of the important quality parameters in the instant porridge product. Low levels of water content provide advantages during storage, product with a water content of 3–7% will achieve optimum stability. In this range water content, microbial growth, and proximate reactions that damage materials such as browning, hydrolysis, or fat oxidation can be reduced.

Table 2. The physical interaction of instant sorghum porridge formula

| Formula | Yield (%) | Bulk density (%) | Solid density (%) |
|---------|-----------|------------------|-------------------|
| 1       | 76.10 ^bc | 0.17 ^bc         | 0.23 ^c           |
| 2       | 79.45 ^c  | 0.14 ^b          | 0.16 ^ab          |
| 3       | 80.97 ^d  | 0.15 ^b          | 0.19 ^bc          |
| 4       | 74.44 ^ab | 0.12 ^a          | 0.17 ^b           |
| 5       | 75.30 ^b  | 0.12 ^a          | 0.16 ^ab          |
| 6       | 79.32 ^ab | 0.15 ^b          | 0.20 ^c           |
| 7       | 75.58 ^b  | 0.15 ^b          | 0.19 ^bc          |
| 8       | 78.23 ^cd | 0.13 ^ab         | 0.16 ^ab          |
| 9       | 80.41 ^cd | 0.13 ^ab         | 0.16 ^ab          |
| 10      | 75.01 ^a  | 0.12 ^a          | 0.15 ^a           |
| 11      | 74.61 ^ab | 0.13 ^ab         | 0.18 ^bc          |
| 12      | 80.57 ^cd | 0.14 ^b          | 0.19 ^bc          |
| 13      | 73.29 ^a  | 0.19 ^c          | 0.22 ^c           |
| 14      | 74.40 ^ab | 0.10 ^a          | 0.15 ^a           |
| 15      | 80.91 ^d  | 0.13 ^ab         | 0.17 ^b           |

Note: Values in the same column are followed by different letters shown significantly different (p < 0.05).

3.2. Proximate quality of sorghum instant porridge

Variance analysis results showed that the interaction of flour formula and water ratio significantly affected all proximate parameters (p < 0.05). The water content for the fifteen formulas ranged from 3.95–7.66% (Table 3). The water content was relatively smaller that made this product was hygroscopic (easily absorbs water). Products with low moisture content must be protected with suitable packaging materials with a low permeability value. Water content was one of the important quality parameters in the instant porridge product. Low levels of water content provide advantages during storage, product with a water content of 3–7% will achieve optimum stability. In this range water content, microbial growth, and proximate reactions that damage materials such as browning, hydrolysis, or fat oxidation can be reduced.

Table 3. The proximate interaction of instant sorghum porridge formula

| Formula | Water (%) | Ash (%) | Fat (%) | Protein (%) | Carbohydrates (%) |
|---------|-----------|---------|---------|-------------|-------------------|
| 1       | 7.66 ^d   | 1.16 ^cd| 4.99 ^bc| 8.67 ^g     | 85.18 ^a          |
| 2       | 6.03 ^def | 1.08 ^cd| 5.53 ^ef| 8.89 ^g     | 84.51 ^a          |
| 3       | 7.59 ^e   | 0.85 ^bc| 4.68 ^ab| 8.96 ^c     | 85.52 ^a          |
| 4       | 6.13 ^def | 0.40 ^e | 5.63 ^efg| 7.15 ^d     | 86.83 ^b          |
| 5       | 6.96 ^bcd | 0.87 ^bc| 5.33 ^de| 8.95 ^g     | 84.86 ^a          |
| 6       | 5.78 ^cde | 1.07 ^cd| 5.08 ^cd| 8.44 ^fg    | 85.43 ^a          |
| 7       | 7.37 ^ab  | 1.07 ^cd| 5.65 ^efg| 7.98 ^ef    | 85.30 ^a          |
| 8       | 4.58 ^abc | 1.07 ^cd| 6.66 ^b  | 7.78 ^def    | 84.50 ^a          |
| 9       | 4.93 ^abc | 0.49 ^ab | 5.92 ^g  | 8.37 ^fg    | 85.20 ^a          |
| 10      | 4.29 ^abc | 0.84 ^bc | 4.82 ^bc | 6.36 ^c     | 88.03 ^c          |
| 11      | 7.04 ^ef  | 1.23 ^cd| 5.77 ^fg | 5.94 ^bc    | 87.07 ^b          |
| 12      | 5.41 ^bde | 1.32 ^d  | 5.84 ^fg | 7.54 ^de    | 85.31 ^a          |
| 13      | 4.60 ^abc | 0.95 ^ab | 5.56 ^ef | 8.70 ^fg    | 84.80 ^a          |
| 14      | 4.88 ^abc | 0.51 ^ab | 4.14 ^a  | 5.32 ^ab    | 90.04 ^d          |
| 15      | 3.9 ^a    | 1.20 ^ad | 4.8 ^bc  | 4.81 ^a     | 89.22 ^d          |

Note: Values in the same column are followed by different letters shown significantly different (p < 0.05).

The ash content of instant sorghum porridge ranged from 0.4–1.32%. The greater the amount of tapioca substitution decreases the ash content and increasing water ratio increases the ash content. The value of ash content of instant sorghum porridge was closely related to the mineral content contained in
the ingredients, purity, and cleanliness of the material. Generally, the ash content of those formulas was lower than similar products by Jackson [9]. The protein content of instant porridge protein ranged from 4.81–8.96%. The greater the tapioca substitution decreases the protein content. The protein in instant porridge products mostly from milk and sorghum flour.

The fat content of instant sorghum porridge ranged from 4.14–6.66%. The main source of fat is obtained from full cream milk. Sorghum flour itself contributes fat around 1-2%. The difference in the fat content of instant sorghum porridge may be influenced by the process of oil absorption when cooking sorghum porridge. The process of oil absorption itself is influenced by differences in fiber content and amyllose content of each flour formula. Higher levels of amyllose and fiber will result in higher levels of oil absorption [10]. The carbohydrates content of instant porridge ranged from 84.50 to 90.04 (%). Instant sorghum porridge has high carbohydrate content.

### 3.3. The sensory acceptance of sorghum instant porridge

A product can be well-received if the organoleptic criteria are as expected by consumers. The organoleptic properties of sorghum instant porridge formula are considered including color, aroma, texture, and taste which will accumulate in general acceptance. Table 4 showed the average score of color ratings ranged from 2.8 to 3.6 (dislike-like). The score of 4.1 was obtained from the flour ratio of sorghum at 60%, tapioca at 40%, and the water ratio of 1:7. The addition of 40% tapioca can affect the color of instant sorghum porridge.

The texture of instant porridge is strongly influenced by the composition of starch in the constituent ingredients. The texture acceptance ranging from 2.5–3.7. The taste of instant porridge was more influenced by the distinctive sorghum that was not yet generally known by panelists. The addition of sugar, milk, and full cream is also intended to cover the taste "sepert" of sorghum and gave the acceptance ratings from 2.8 to 3.6 (dislike-like). General acceptance parameters are used to measure the level of panelists’ preference for all the attributes contained in the product. In general, the instant porridge formula showed an average score of 2.8–4 (dislike-like). The difference in the ratio of sorghum flour and tapioca used in porridge products has a significant effect on the panelists’ general acceptance score.

### Table 4. Organoleptic score interaction of instant sorghum porridge formula

| Formula | Total acceptance | Colour  | Aroma  | Texture | Taste  |
|---------|------------------|---------|--------|---------|--------|
| 1       | 3.5 bcd          | 3.8 gh  | 3.6 c  | 3.4 cd  | 3.5 cd |
| 2       | 2.8 a            | 3.4 defg| 3.4 a  | 3.4 d   | 3.4 d  |
| 3       | 3.4 bc           | 3.5 efg | 3.5 bde| 3.5 de  | 3.5 de |
| 4       | 3.6 cd           | 3.3 cde | 3.5 cde| 3.5 de  | 3.5 de |
| 5       | 2.8 a            | 3.2 a   | 3.1 abc| 3.1 abc | 3.1 abc|
| 6       | 3.5 bcd          | 3.4 cdef| 3.1 abcd| 3.4 cde| 3.4 cde|
| 7       | 3.4 bc           | 3.8 fgh | 3.6 c  | 3.1 bcd | 3.2 abc|
| 8       | 3.4 bc           | 3.8 bc  | 3.4 bde| 3.1 bcd | 3.3 abcd|
| 9       | 3.4 bc           | 3.7 efgh| 3.5 cde| 3.4 bcde| 3.6 cd |
| 10      | 3.4 bc           | 2.8 b   | 3.5 cde| 3.4 bcde| 3.6 cd |
| 11      | 3.6 cd           | 3.4 cdef| 3.5 cde| 3.2 bcd | 3.4 bcd|
| 12      | 3.1 abc          | 2.3 b   | 3.4 bde| 3.1 bcd | 2.8 a |
| 13      | 3.1 abc          | 4.1 a   | 3.4 bde| 3.1 bcd | 3.4 bcd|
| 14      | 3.1 abc          | 2. a    | 3.4 bde| 3.1 bcd | 3.4 bcd|
| 15      | 3.3 abc          | 3.4 bde | 3.5 cde| 3.1 abc | 3.5 abc|

Note: Values in the same column are followed by different letters showing significantly different (p<0.05).

The variance analysis results showed the significant interaction of flour formulas and water ratios for organoleptic parameters (p<0.05).
3.4. Determination of the optimum formula

The optimization is carried out in compliance with the criteria of the target that is desired from each parameter. All parameters were used to determine the selected formula (optimum) of the instant sorghum porridge formula. The goals/targets value of each parameter to be achieved in the optimization is shown in Table 5.

Table 5. The goal value of each parameter in numerical optimization

| Parameter                      | Goal value |
|-------------------------------|------------|
| Yield                         | maximize   |
| Bulk density                  | maximize   |
| Solid density                 | maximize   |
| Water content                 | minimize   |
| Ash content                   | minimize   |
| Fat content                   | maximize   |
| Protein content               | maximize   |
| Carbohydrate content          | maximize   |
| Color (score)                 | maximize   |
| Aroma (score)                 | maximize   |
| Texture (score)               | maximize   |
| Taste (score)                 | maximize   |
| Total acceptance (score)      | maximize   |

These criteria above are set in numerical optimization to get desirability value. Desirability has a value of 0 to 1. Table 6 showed the results of numerical optimization, where 3 formula compositions are considered optimal. Figure 1 showed the interaction plot of instant sorghum porridge showed the optimum formula. The highest desirability value was the selecting formula (optimum). The formula with 80% sorghum flour, 20% tapioca, and a water ratio of 1:11 has the highest desirability value at 0.716. Then, this formula was variation and the result can show in Table 7.

Table 6. Three suggested formula from numerical optimization

| No. | Flour Ratio (%) | Water ratio | Desirability |
|-----|-----------------|-------------|--------------|
| 1   | 80:20           | 1:11        | 0.716        |
| 2   | 90:10           | 1:7         | 0.672        |
| 3   | 70:30           | 1:7         | 0.556        |

Figure 1. Interaction plot of optimization formula
Table 7. The optimum quality characteristics of instant sorghum porridge

| Characteristics          | Optimum value |
|--------------------------|---------------|
| Yield                    | 80.41         |
| Density                  | 0.13 g/ml     |
| Solid density            | 0.16 g/m      |
| Water content            | 4.93%         |
| Ash content              | 0.49%         |
| Fat content              | 5.92%         |
| Protein content          | 8.37%         |
| Carbohydrate content     | 85.20%        |
| Color score              | 3.7           |
| Scent score              | 3.5           |
| Texture score            | 3.7           |
| Taste score              | 3.6           |
| Total acceptance score   | 4             |
| Fiber                    | 9.07%         |
| Soluble                  | 3.11%         |
| Insoluble                | 5.96%         |
| Viscosity                | 103 cp        |
| Viscosity                | 82 cp         |
| Starch digestibility     | 77.97%        |
| Water Absorption         | 4.47 g/g      |

3.5. The functional properties of the selected formula

Food can be claimed as a source of dietary fiber if it contains fiber at 3–6 g/100 g. This product can be claimed to be a source of dietary fiber because it contains more than 6 g/100 g of dietary fiber. The optimum formula of instant sorghum porridge had total dietary fiber at 9.07% (w/w); soluble dietary fiber of 3.11% (w/w); and insoluble dietary fiber of 5.96% (w/w). The fiber content of this formula was higher than a similar product that has been reported by Jackson et al [9], Chanadang et al [11], and Moussa et al [12]. The optimum formula had a starch digestibility of 77.97%. Besides the heating process of instant porridge, the process of digestion of starch is influenced by the presence of other food components such as food fiber. The fiber can act as a physical barrier to digestion and making starch difficult to digest by human amylolytic enzymes. Fiber can also slow the passage of food to the channel digest and obstruct the movement of the enzyme so that the process of digestion was slowing [13].

The results of the viscosity test were carried out on instant products in selected formulas at 50 °C was 103 cp and 28°C (room temperature) was 82 cp. The result of viscosity research shows that temperature greatly influences viscosity. The higher the temperature the higher the viscosity, conversely the lower the temperature the lower the viscosity. Water absorption is the amount of water trapped in a molecular matrix under certain conditions. Water absorption is important to reconstitution test. Based on the results, the water absorption of the optimum instant porridge formula was 4.47 g/g. The greater the water absorption of a material, the more perfect the treatment process that is carried out on that material.

4. Conclusions

The formulating of sorghum, tapioca, and the ratio of the addition of water in the making instant sorghum porridge provide significantly different interactions can all physical, proximate quality characteristics, and organoleptic. Based on numerical optimization and plot interaction of the whole formula, the optimum formula was obtained with 80 : 20 sorghum : tapioca flour composition and water ratio of 1:11 with a desirability score of 0.716. The selected sorghum porridge formula has a total acceptance score of 4 and starches digestibility 77.97% and dietary fiber reached 9.07%. Instant
sorghum porridge products can be declared as functional food because they have the requirements for functional food.

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