Optimization of Steamed Meals Based on Composite Flour (Taro, Banana, Green Bean) and Its Predicted Shelf Life

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Abstract. Ongol-ongol is for food diversification by mixing composite flour of taro, banana and mung bean, then was steamed by hot air. The purpose of this study was to find out the optimum way to produce ‘ongol-ongol’ from composite flour and to know the storage life by prediction method. The research consisted of two stages, namely the determination of the optimum formula of ‘ongol-ongol’ with Design Expert DX 8.1.6 software and the estimation of product shelf life of the optimum formula by ASLT (Accelerated Shelf Life Test) method. The optimum formula of the steamed meal was produced from composite flour and arenga flour with ratio of 50: 50 and flour to water ratio of 1: 1. The proximate content of steamed meal of optimum formula is 36.53% moisture content, ash content of 1.36%, fat content of 14.48%, protein level of 28.5%, and carbohydrate of 44.77% (w/w). Energy Value obtained from 100 g of ‘ongol-ongol’ was 320.8 Kcal. Recommended for steamed meal storage life is 12.54 days at ambient temperature.

1. Introduction
Food demand in Indonesia is increasing as the population grows. Fulfillment of food demand can be done by optimizing local food sources. One of the local food resources that can be an alternative for food diversification is taro (Colocasia esculenta).

Taro, which is a source of carbohydrates, has potential as a substitution of rice, as a raw material for crisp industry and so forth [1]. Taro contains 25.0% carbohydrate, 1.4% protein, 0.4% fat some minerals and vitamins [2]. Taro tubers are low fat, gluten-free and easy to digest [3]. Taro as a carbohydrate source is usually used as a breakfast meal. To increase the nutritional content of breakfast meal, banana and mung bean can be added.

Taro contains low protein, lysine and amino acids, this can be overcome by the addition of green beans. Mung beans have a protein content of 22.9%, and lysine of 1650 mg / 100 g. Banana kepok is rich in several vitamins including carotene (provitamin A) of 192 RE and vitamin B1 0.1 mg / 100 g [4]. Both mung beans and banana ‘kepok’ are available within a year.

One way to integrate these three raw materials is by making composite flour. Research on flour-based composite taro, banana kepok, and mung beans has been done in the manufacture of breakfast cereal ready to eat, such as composite cookies, brownies, pao [5], andflake [6]. Ongol-ongol in which contain composite flour (taro, banana, mung bean) is an Indonesia traditional food. In this study the product to be made is steamed cake, composite flour ratio used refers to previous research. To form the chewy texture of steamed meal based composite flour, it can be added arenga starch [7].
of composite flour is a mixture of different types of flour to make bread with yeast, bread products without yeast, porridge, pasta, and snacks. Another definition of composite flour is mixture of non-wheat flour [8].

The study aimed to (1) find out the optimum formula of composite flour-based steamed cake, (2) to know the carbohydrate, protein, fat, water, ash, dietary and energy content of the optimum composite starch-base steamed cake and (3) the shelf life of composite flour-based steamed cake products.

2. Materials and methods
The main raw materials used in the study were taro flour, banana flour, green bean flour, arenga flour, and water. Additional ingredients used were sugar (sucrose), salt, coconut milk, milk powder, vanilla extract, sodium benzoate, potassium sorbate. The research was conducted at Indonesian Centre for Agriculture Postharvest Research Development, Bogor.

2.1. Methods

2.1.1. First stage. The first stage begins with the preparation of composite flour that was taro flour, banana, and green bean flour. Furthermore, taro, banana, and green bean flour were mixed with a ratio of 50: 30: 20, using a mixer to produce composite flour.

The formulation of Ongol-ongol consists of composite flour and arenga flour,. The addition of sugar, milk powder, salt, coconut milk, and vanilla, was made the same in each formula, the percentage of addition based on total weight of flour. The percentage of ingredients added was 46% sugar, 2% milk powder, 1.46% salt, 51% coconut milk, and vanilla extract 0.8%. The formulation of steamed cake based on composite flour is presented in table 1. The composite flour, arenga flour, and other ingredients was mixed using mixer for 5 min. The dough was then placed in the tray and was steamed at 90°C for 60 min. The cake was put in the vacuum-polypropylene bag and was analyzed for sensory evaluation and physicochemical properties. The procedure of making steamed cake is shown in figure 1.

| Formulation | Composite flour: Arenga starch | Flour: Water |
|-------------|-------------------------------|--------------|
| F1          | 90:10                         | 1:1          |
| F2          | 90:10                         | 1:3          |
| F3          | 90:10                         | 1:5          |
| F4          | 70:30                         | 1:1          |
| F5          | 70:30                         | 1:3          |
| F6          | 70:30                         | 1:5          |
| F7          | 50:50                         | 1:1          |
| F8          | 50:50                         | 1:3          |
| F9          | 50:50                         | 1:5          |
| F10         | 30:70                         | 1:1          |
| F11         | 30:70                         | 1:3          |
| F12         | 30:70                         | 1:5          |
| F13         | 10:90                         | 1:1          |
| F14         | 10:90                         | 1:3          |
| F15         | 10:90                         | 1:5          |

Fifteen samples of Ongol-ongol were tested by 15 panelists [9], for properties of color, flavor, taste, texture and appearances. All responses are used to determine the optimum formula of a composite flour-based steamed meal.
2.1.2. Second stage. This study was to determine the shelf life of steamed cake based on composite flour using ASLT (Accelerated Shelf Life Test)[11] method. To determine accelerated shelf life is by storing food products in various environments. Storage temperatures used to determine shelf life are 10°C, 20°C, and 30°C with parameters of water content, pH, Aw, and free fatty acid as critical factors in the determination of shelf life [10]. The test was carried out at 10, 20, and 30°C. pH, water activity, moisture content, and FFA were measured every 4 days within a month.

2.2 Determination of steamed meals shelf life prediction

2.2.1. Critical parameters. Storage of food in certain environmental conditions causes a change in the foodstuff, which is the result of adjustments to environmental conditions. ASLT (Accelerated Shelf Life Testing) method is one to determine the shelf life of food product. Achour et al [16] used to ASLT analyzed the food product. One of the environmental conditions that affect the changes in the food is temperature [17]. In the second stage of research, the prediction of shelf life of steamed cake based on composite flour were determined which 4 critical parameters namely water content, pH, aw,
and free fatty acid content. Selection of these four parameters is because the four parameters, affect the shelf life of the product.

2.2.2. **Acceleration.** The slope value (k) represents the amount of quality degradation during storage. If the slope value in ln (natural log) is plotted and plotted with 1 / T (1 / temperature in Kelvin) Arrhenius equation will be obtained. Table 5 shows the Arrhenius equation for water, aw, pH, and free fatty acid parameters. Broadly speaking the value of the constant rate of quality degradation reaction (K) at each storage temperature can be estimated using the obtained Arrhenius equation.

3. Results and discussion

3.1. **Formulation of steamed based on composite flour**

Determination of optimum formula of this product was based on organoleptic test and texture analysis. The descriptive organoleptic test was using the sensory attributes of a product are identified, described, and quantified using a trained panelist for this purpose. The intensity or aspect of the descriptive analysis indicates the certain level of each character. The levels were depicted using a measurement scale. Scale selection can use the scale line [9]. Line scale used 10 cm long. Scale number 0 indicates the lowest intensity, while the scale is closer to the number 10, shows highest intensity.

The sensory analysis of Ongol-ongol samples was given as means of all scores given by the panelist (table 2). The lowest color value was found at 90:90 (1:5), while at 70:30 (1:1) was recorded as the highest value. In term of flavor, at 90:10 (1:5) panelist judged 3.34, while at 50:50 (1:1) they gave 6.85. As observed in color and flavor, the taste was recorded as the lowest acceptance at 90:10 (1:5), on the other hand at 50:50 (1:1) was the highest one. The texture was also found to be lower at 90:10 (1:5) and the highest at 50:50 (1:1). The appearance of samples was recorded as the likeness of all sensory properties. From table 2, the panelist judged 50:50 (1:1) was the optimum formula in producing of Ongol-ongol cake.

| Composite flour: Arenga flour | Flour total : water | Organoleptic test | Texture | Desirability |
|------------------------------|--------------------|-------------------|---------|-------------|
|                              | Color | Flavor | Taste | Textu | Appearance | Total Work Cycle (mJ) | Resilience |                     |
| 90:10 1:1                    | 6.48  | 5.29   | 4.1   | 4.77  | 5.54       | 19.67                 | 0.18       | 0.509                |
| 90:10 1:3                    | 3.7   | 5.43   | 4.21  | 3.9   | 3.91       | 6.11                  | 0.53       | 0.391                |
| 90:10 1:5                    | 1.76  | 3.34   | 2.55  | 1.09  | 1.51       | 2.03                  | 0.5        |                      |
| 70:30 1:1                    | 7.36  | 5.44   | 5.52  | 4.9   | 5.81       | 3.36                  | 0.15       | 0.461                |
| 70:30 1:3                    | 3.97  | 5.34   | 4.91  | 4.76  | 4.06       | 8.67                  | 0.63       | 0.487                |
| 70:30 1:5                    | 1.85  | 4.41   | 2.86  | 2.39  | 3.15       | 4.76                  | 0.44       | 0.147                |
| 50:50 1:1                    | 6.72  | 6.85   | 6.55  | 7.09  | 7.44       | 39.51                 | 0.43       | 0.835                |
| 50:50 1:3                    | 3.46  | 5.07   | 3.99  | 3.87  | 4.73       | 7.08                  | 0.52       | 0.353                |
| 50:50 1:5                    | 1.85  | 3.75   | 3.3   | 1.46  | 2.32       | 2.93                  | 0.52       | 0.089                |
| 30:70 1:1                    | 6.75  | 5.82   | 5.87  | 6.28  | 6.42       | 38.65                 | 0.6        | 0.809                |
| 30:70 1:3                    | 2.84  | 5.19   | 4.55  | 5.17  | 4.21       | 2.1                   | 0.27       | 0.248                |
| 30:70 1:5                    | 2.23  | 4.2    | 3.63  | 3.62  | 3.11       | 6.54                  | 0.49       | 0.235                |
| 10:90 1:1                    | 7.44  | 6.53   | 7.05  | 7.37  | 7.55       | 18.91                 | 0.62       | 0.806                |
| 10:90 1:3                    | 2.15  | 4.25   | 3.6   | 3.51  | 3.22       | 12.24                 | 0.52       | 0.246                |
Parameter on texture analysis was Total Work Cycle (TWC) and Resilience. TWC is expressed in units of milliJoule (mJ). TWC is a combination of Hardness Work Cycle and Recoverable Work Cycle. Hardness Work Cycle is defined as the work required to resist the internal strength of the bond in the food material. Meanwhile, Recoverable Work Cycle is defined as work done by food in opposing forces that suppresses when the force is released. TWC test of samples showed that at 50:50 (1:1) obtain 39.5, which consider as elastic. Meanwhile, at 30:70 (1:3) TWC was recorded 2.1, which consider as soft. Resilience is value between Recoverable Work Done and Hardness Work Done. Value of Resilience was 0.1. Resilience as value where food come back to their form as a result of work of speed and strength. Value of Resilience was 0.15-0.63.

Table 2 shows the results of numerical optimization, in which 15 formulas are considered optimal because they have desirability values. Based on table 2, it was found that the formula with composite flour ratio composition: 50:50 arenga starch and water ratio of 50:50 (1: 1) has the highest desirability value of 0.835, so the formula is the optimum formula.

### 3.2. Formula optimum validation

Validation is done on the optimum formula to see the predicted characteristics by DX7 software with the results obtained. The value of the obtained characteristics is between the minimum and maximum predictions. Maximum and minimum prediction values are set by 95% confidence interval. Table 3 shows the actual value obtained, compared to Design Expert DX 8.1.6 (trial version) predictive value.

In the organoleptic test on color the prediction value ranges from 2.59-6.72, the actual value obtained is 6.72. On the flavor of the predicted value and actual value is the same of 6.85. At the minimum predictive value taste parameter of 2.56 and a maximum prediction value of 6.55. In panelist response to texture, the predicted value and the actual value are the same i.e 7.09. The panelist response to the appearance based on the actual value and the predicted value of 7.44.

In texture test response with texture analyzer, it is found that the parameter of TWC is 39.51, while the prediction value is 15.62-63.92 mJ. In the Resilience parameter, the prediction value ranges from 0.31-0.62, while the actual value obtained is 0.43. The value of the organoleptic test and texture test still falls in between the minimum and maximum prediction, so it is still acceptable at 95% confidence interval.

| Parameters       | Actual Value | Prediction value at 95% confidence interval |
|------------------|--------------|---------------------------------------------|
|                  | Minimum      | Maximum                                    |
| Organoleptic     |              |                                             |
| Color            | 6.72         | 2.59                                       |
| Flavor           | 6.85         | 6.85                                       |
| Taste            | 6.55         | 2.56                                       |
| Texture          | 7.09         | 7.09                                       |
| Appearance       | 7.44         | 7.44                                       |
| Texture          |              |                                             |
| Total Work Cycle (mJ) | 39.51      | 15.62                                       |
| Resilience       | 0.43         | 0.31                                       |

### 3.3. Chemical properties of steamed meals

The optimum composite flour-based steamed cake is obtained with composite flour ratio composition: 50:50 arenga starch and total flour ratio: 1: 1 water. Table 4 shows the results of Proximate analysis and value.
Table 4. Proximate analysis and energy value of steamed meals of optimum formula

| Characteristics      | Values |
|----------------------|--------|
| Water content (%)    | 36.53  |
| Ash content (%)      | 1.36   |
| Fat (%)              | 14.48  |
| Protein (%)          | 2.85   |
| Carbohydrate (%)     | 44.77  |
| Energy (Kcal)        | 320.8  |
| Dietary fiber (%)    | 11.38  |

The water content of steamed meal based on composite flour is 36.53%. The presence of water in the product can affect the deterioration of chemical and microbiological quality. The steamed meal sample had 36.53%. This sample is in the range of food with medium moisture content (20-40%) [12]. Ash content is determined by combustion organic compound [12]. The ash content of steamed meal is 1.36%. The fat content of steamed meal is 14.48%, thus producing energy value of 179.08 Kcal. Each gram of fat can produce energy value as much as 9 Kcal [2]. The high content of fat obtained from raw materials of steamed meal is from milk powder. Protein content in steamed meal based is 2.85%. Protein content obtained from green bean powder and milk powder. The energy value generated from the protein is 11.4 Kcal because each gram of protein produces an energy value of 4 Kcal [2].

Carbohydrates are total carbohydrates, so they include fiber content. One gram of carbohydrate produces energy value of 4 Kcal [2]. The content of carbohydrates in the product is 44.7%, resulting in energy value of 179.08 Kcal. The total energy value that can be obtained in 100 of steamed meals is 320.8 Kcal. The value is sum of carbohydrates, proteins, and fats. In this study, the manufacture of steamed meals is expected to be a breakfast substitute food, in one slice of steamed meal for 25 g weight can be produced 80.2 Kcal. In order to meet the needs of calories in the breakfast that is equal to 250 calories, then the steamed cake should be consumed is three pieces of about 75 g.

The dietary fiber content in the product is of 11.38%. Fiber is a component of plant material that cannot be digested [14]. Dietary fiber cannot be digested enzymatically (enzymes produced by humans), so it is not a source of nutrients [13] but contributes to our digestive health [14]. Cellulose, hemicellulose, pectin, lignin, and other substances in indigestible plants are included in dietary fiber [14] The role of dietary fiber for health, prevent coronary heart disease, colon cancer, diabetes, diverticular disease, and obesity [15].

3.4. Shelf life determination
The result shows that the initial quality value of moisture content is 38.27% and the critical limit is 36.39%. Studying water in foods should start with an analytical determination of water content for commercial and legal reasons which are evident [18]. The water content has significant importance for a number of reasons. The determination of water content is therefore the most frequent general analysis performed on foodstuffs [19].
Table 5. Arrhenius equations of quality for water content, aw, pH, and free fatty acid of steamed meals based on composite flour

| Parameters       | Temperature | 1/T (K) | ln K         | Linear equation                          | Arrhenius equation |
|------------------|-------------|---------|--------------|------------------------------------------|--------------------|
|                  | ºC          | K       |              | Ln K vs 1/T(K)                           | Ln K = Ln K0 - Ea/R (1/T) |
| Air              | 10          | 283     | 0.0003       | 0.0024                     | y = 0.7449x - 8.4364 | Ln K = - 8.4364 + 0.7449(1/T) |
|                  | 20          | 293     | 0.0021       | 0.2536                     | R² = 0.5626          |                                 |
|                  | 30          | 303     | 0.0014       | 0.1466                     |                       |                                 |
| aw               | 10          | 283     | -0.0001      | 0.0106                     | y = 0.1414x - 9.2432  | Ln K = -9.2432 + 0.1414(1/T)   |
|                  | 20          | 293     | -0.0001      | 0.1671                     | R² = 0.8913          |                                 |
|                  | 30          | 303     | -0.0001      | 0.2852                     |                       |                                 |
| pH               | 10          | 283     | -0.0080      | 0.4376                     | y = 0.6967x - 5.3    | Ln K = - 5.3 + 0.6967(1/T)     |
|                  | 20          | 293     | -0.0314      | 0.8987                     | R² = 0.7658          |                                 |
|                  | 30          | 303     | -0.0323      | 0.8318                     |                       |                                 |
| Free fatty       | 10          | 283     | 0.0479       | 0.4661                     | y = -0.0392x - 3.0037 | Ln K = - 3.0037 - 0.0392(1/T) |
| acid             | 20          | 293     | 0.0454       | 0.6293                     | R² = 0.9532          |                                 |
|                  | 30          | 303     | 0.0443       | 0.3133                     |                       |                                 |

The initial quality value of aw is 1.000, while the critical limit is 0.997. The effect of water activity on chemical reactions which are important to food stability has been studied extensively [11]. The initial quality value of pH is 5.66 and the critical limit is 5.52. The initial quality value of free fatty acids is 0.07, while the critical limit is 0.603. Basic consideration of the critical limit is when finding steamed meal based on composite flour that has been covered with mold on the surface. The product is a sample stored for three days at room temperature (30ºC).

Steamed meals based on composite flour on water parameter have the quality decreasing equation \(\ln K = - 8.4364 + 0.7449\ (1 / T)\), then to predict shelf life when steamed meal is stored at 10ºC or 283ºK, will yield \(\ln K = -8.43377\) or \(k = 0.00022\), meaning that there will be an increase in water content of 0.00022 per day, so the total quality unit to expire is 2.23.

Table 5 presents estimates of shelf life of steamed meal based on parameters of water, aw, pH, and free fatty acid content at various storage temperatures. The total quality unit is calculated based on the initial quality difference with the critical limit. In the parameters of moisture content and free fatty acid content, the total quality unit is distributed, because in both parameters the quality decrease follows the reaction of the first order. In the parameter aw and the pH of the quality decrease follow the zero order.

In the estimation of shelf life at the various temperatures of 15ºC, 25ºC, and 35ºC, each temperature is converted into Kelvin (K), then included in the Arrhenius equation, to obtain K value (quality degradation constant). Assumption the shelf life on the parameters of water content, aw, pH, and free fatty acid content varies. Estimated shelf life at water content parameters ranged from 24.10-29.09 days. In the aw parameter predicted shelf life is ranged from 29.78-30.96 days. At the pH parameter of presumed shelf life is between 15.35-28.65 days. The presumption of shelf life on the parameters of free fatty acid content ranged from 12.54-12.83 days.

There is a variation in the estimation of shelf life, in which each critical quality parameter produces a different prediction of shelf life. The decision to recommend predicted shelf life data based on the food safety of the product, the data used are short shelf life data [20]. The composite flour-based steamed cake is made with the manual process, and is presumably still lacking in sterility especially in the process of mixing and packaging.

4. Conclusions
The optimum formula of steamed meal are made from ratio composite flour: arenga starch 50:50 and ratio for total composite flour:water 1:1. The prediction of shelf life of the steamed meal is 12.54 day.
References

[1] Deptan 2001 *Talas* http://tanamanpangan.deptan.go.id/doc_upload/Talas.pdf. Accessed: 28 Januari 2012.

[2] Widarso T D 2009 Development of curry taro as ready to eat product (in Indonesian) (Bogor: Bogor Agricultural University)

[3] Apriani RRN 2011 Composit flour formulation from taro, green beans, and banana flour for roasted brownies (in Indonesian) (Bogor: Bogor Agricultural University)

[4] Richana N 2012 *Cassava, sweet potato, botany, process tecnology, cultivation, postharvest* (in Indonesian) (Bandung: Nuansa) p 95

[5] Yuliani S 2009 *Development of taro flour production process with low oksalat concentration (max 100 ppm) with three processed products* (in Indonesian). (Bogor: Balai Besar Penelitian dan Pengembangan Pascapanen Pertanian, Bogor)

[6] Setyadjit 2009 *Composit flour formulation from taro as ingredient of high energy ready to eat breakfast meal* (in Indonesian) (Bogor: Balai Besar Penelitian dan Pengembangan Pascapanen Pertanian Bogor)

[7] Fennema O R 1996 *Food Chemistry Third Edition* (New York: Marcel Dekker, Inc.)

[8] Vendy D A V 1993 *Review of Composite Flour Technology in the Context of Tanzania* (Arusha: Tanzania)

[9] Setyaningsih D, Apriyantono A and Sari M P 2010 *Sendori analysis for food and agro industry* (in Indonesian). (Bogor: IPB Press)

[10] Apriyantono A, Fardiaz , Puspitasari N L, Sedarnawati Y and Budiyanto S 1989 *Food Analysis* (in Indonesian) (Bogor: Pusat Antar Universitas Pangan dan Gizi)

[11] Nelson K A and Labuza T P 1994 *Food Sci. and Nutrition* 22, 1–4: 271-289

[12] deMan J M 1997 *Food Chemical* (in Indonesian). (Bandung: ITB Press)

[13] Linder M C 1992 *Biochemistry of Nutrition and Metabolism* (in Indonesian). (Jakarta: UI Press)

[14] Potter NN 1995 *Food Science* (USA: Chapman and Hall)

[15] Muchtadi D, Palupi N S and Astawan M 1992 *Chemical biochemical and biological method in processed food nutrient evaluation* (in Indonesian) (Bogor: Dikti)

[16] Achour M, Mtimer N, Cornelius C, Zgouli S, Mahjoub A, Ph Thonart and Hamdi M J 2001 *Chem Technology and Biotechnob* 76(6): 624-28

[17] Sukasih E, Sunarmani and Budiyanto J P 2007 *Postharvest Pert* 4(2): 72-82

[18] Mathlouthi M 2001 *Food Control* 12(7): 409-417

[19] Isengard H D 2001 *Food Control* 12(7): 395-400

[20] Koswara S and Kusnandar F 2004 *Case study of food product shelf life estimation* (in Indonesian) (Bogor: IPB)