Formulation of mashed potatoes (Solanum tuberosum L.) as Tengger culinary product

C G Perdani, S Wijana and A Yamin

Department of Agro-industrial Technology, Faculty of Agricultural Technology
Universitas Brawijaya, Malang, Indonesia

E-mail: cgadizza@ub.ac.id

Abstract. Indonesia is one of the tourist destination countries because of its natural beauty. Bromo Tengger Semeru National Park (TNBTS) is one of the destinations that becomes the main destination of tourists. In addition to natural attractions, culinary tourism can be an alternative in developing the tourism industry of TNBTS. A local cuisine has an important role to attract the hearts of tourists because they will be interested to try the local cuisine. Potato is one of the leading commodities in Ngadas Village TNBTS. The objective of this research was to obtain the optimal formulation of the mashed potato product. In this research, the linear programming was used as an optimisation analysis. The objective function was to minimise the cost of mashed potatoes production. The design of mashed potato composition was made of 4 types: formulation A (using cassava starch), composition B (using rice starch), C composition (using corn starch) and D composition (without using starch). The best treatment obtained was the addition of corn starch. Preparation of 100 g of mashed potato was made with 50 g of mashed potato, 20 g corn starch, 13 Ml water, 5 g of milk powder, 4 g of cheese and the rest were salt and pepper. The average value of the hedonic test on the addition of corn flour was 4.85 (acceptance). The cost of making 200-gram mashed potatoes was IDR 5,038.00.

1. Introduction

Indonesia is one of the tourist destinations in the world because it has wonderful natural attractions. Many tourists, both domestic and foreign, choose Indonesia as a destination country. Besides of natural attractions, culinary tourism can be an alternative in Tengger Semeru National Park (TNBTS) tourism industry. The culinary industry in Indonesia has a great potential to be developed into a tourist destination for foreign and local tourists because of the diversity of cuisine each region [1]. Although culinary tourism is often considered a complementary tourism product, its potential is attractive to develop. It is an opportunity to develop culinary tourism in the tourism area of TNBTS.

The problem is how to produce a product with good quality, so that it can be developed into a souvenir product from Tengger. According to Fiani and Japarianto [2], the quality of food has an important role in purchasing decisions. Some commodities of the Central Tengger, especially the village of Ngadas Ponkokusumo, Malang include potatoes (Solanum tuberosum), cabbage (Brassica oleracea), Onion Prei (Allium ampeloprasum), and fennel (Foeniculum vulgare). Potato is one of the leading commodities in Ngadas Village. Potato plants cultivated in the Tengger mountain region are yellow granola potatoes. According to Asandhi [3] granola potatoes contain low starch content (16% - 18%) with high moisture content of more than 80%). Therefore, this type is suitable to be used for making of mashed potatoes. Various types of raw material for making mashed include tubers, nuts, and seeds.
This research aimed to explore potential of granola potatoes as one of local culinary foods for the culinary tourism of the region, particularly in Ngadas village Poncokusumo District, Malang, East Java. Through the product innovation by utilising local agricultural commodity as the main ingredient of food product can contribute to increase the local economy.

2. Materials and Method

2.1. Characterisation of raw materials

The main raw material for making mashed potatoes is a granola type obtained from Ngadas Village, Poncokusumo District, and Malang. According to Setiadi [4], granola potatoes have different characteristics from the other types of yellow potatoes such as Atlantic and Vanda Potatoes.

2.2. Formulation of mashed potatoes using linear programming

Three main aspects must be considered when using the linear programming, namely, decision variables, objective functions and functional constraints that were formulated into the mathematical system. In its application, the optimisation supporting data were obtained from previous research, data on the Indonesian National Standard (SNI 01-7111.1-2005) of instant porridge. Supporting data used included data on carbohydrate, protein, fat, sugar content and the prices of each raw material for mashed potato production. Besides supporting data in the form of standard data on potato content, the data serve as a determinant of the maximum and minimum limits for determining the composition of raw materials to be used. Mathematical formulation of the linear programming in this research is as follows:

1. Decision variables
   X1 = Potato
   X2 = milk powder
   X3 = Cheese
   X4 = Starch
   X5 = Salt
   X6 = Pepper
   X7 = Water

2. Objective function of this research is minimizing the cost of production mashed potatoes
   a) Formula A (with Cassava starch)
      \[ \text{Min } Z = 1100X1 + 9000X2 + 10000X3 + 800X4 + 500X6 + 1000X7 \]
   b) Formula B (with Rice starch)
      \[ \text{Min } Z = 1100X1 + 9000X2 + 10000X3 + 800X4 + 500X6 + 1000X7 \]
   c) Formula C (with corn starch)
      \[ \text{Min } Z = 1100X1 + 9000X2 + 10000X3 + 800X4 + 500X6 + 1000X7 \]
   d) Formula D (without Starch added)
      \[ \text{Min } Z = 1100X1 + 9000X2 + 10000X3 + 800X4 + 500X6 + 1000X7 \]

3. Functional constrain
   a) Formula A (with Cassava starch)
      \[ X1 + X2 + X3 + X4 + X5 + X6 + X7 \leq 81.6\% - 87.8\% \] (Moisture content)
      \[ X1 + X2 + X3 + X4 + X5 + X6 + X7 \geq 40.2\% \] (Protein)
      \[ X1 + X2 + X3 + X4 + X5 + X6 + X7 \leq 3\% \] (Fat)
      \[ X1 + X2 + X3 + X4 + X5 + X6 + X7 \geq 22.3\% \] (Carbohydrate)
   b) Formula B (with Rice starch)
      \[ X1 + X2 + X3 + X4 + X5 + X6 + X7 \leq 81.6\% - 87.8\% \] (Moisture content)
      \[ X1 + X2 + X3 + X4 + X5 + X6 + X7 \geq 40.2\% \] (Protein)
      \[ X1 + X2 + X3 + X4 + X5 + X6 + X7 \leq 3\% \] (Fat)
\[ X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 \geq 22.3\% \] (Carbohydrate)

c) Formula C (with Corn starch)
\[ X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 \leq 81.6\% - 87.8\% \] (Moisture content)
\[ X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 \geq 40.2\% \] (Protein)
\[ X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 \leq 3\% \] (Fat)
\[ X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 \geq 22.3\% \] (Carbohydrate)

d) Formula D (without Starch added)
\[ X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 \leq 81.6\% - 87.8\% \] (Moisture content)
\[ X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 \geq 40.2\% \] (Protein)
\[ X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 \leq 3\% \] (Fat)
\[ X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 \geq 22.3\% \] (Carbohydrate)

The experimental design carried out refers to the results of data optimisation analysis using a linear programming. The design of mashed potato composition was made of 4 types, namely composition A (using additional tapioca flour), composition B (using additional rice flour), composition C (using additional corn flour) and composition D (without using additional flour).

2.3. Mashed potato production

The process stages of making mashed potatoes began with washing potatoes in the running water. Then potatoes steamed for 30 minutes. Steamed potatoes should be peeled then weighed based on the formula. The steamed potatoes were then mashed using a potato masher. Cheese and milk powder dissolved in warm water. If the formula required of the starch addition, the starch should be diluted in water and cooked (70-90°C) the solution until the starch gelatinized. All the ingredients mixed based on the results of linear programming formulation [11].

2.4. Sensory evaluation

The mashed potato samples were analysed for appearance, taste, flavour and texture liking using the method: hedonic scale method [12]. Twenty-five semi-trained panellists, were asked to rate the samples on the basis of a 7-point hedonic scale anchored by: 1 = 'Strongly disliked'; 2 = 'Moderately disliked'; 3 = 'Slightly disliked'; 4 = 'Indifferent'; 5 = 'Slightly liked'; 6 = 'Moderately liked', and 7 = 'Strongly liked'. The samples were presented monadically following a completely randomised design. Mineral water was available as neutralisers between samples to avoid carryover effects. Before each assessment, the subjects were informed about the task. In addition to the oral information, a detailed set of written instructions on the testing methods was available in each booth. A total of 50 grams of each mashed potatoes at 45 °C was served to each subject in a coded cup. The tests were performed in the sensory laboratory under conditions of standard light and temperature (29 °C).

2.5. Statistical analysis

Friedman test (non-parametric) was carried out for the rating test data to determine the overall significance of the main effects and interactions between the mashed potatoes samples (n = 5) and panellists (n = 25), followed by Mann Whitney test. A p-value below 0.05 was considered statistically significant. The acceptance index of each mashed potatoes sample was calculated by the percentage of respondents who indicated that they ‘slightly liked’, ‘moderately liked’, or ‘strongly liked’ the product. The selection of the best formulation was determined by giving the ideal value for each parameter tested based on the Multiple Attribute analysis [10].
2.6. Cost calculation
The cost calculation was done by calculating the raw materials and energy cost needed for making mashed potatoes per 200 g packaging unit.

3. Results and Discussion
3.1. Mashed potatoes formulation
The results of the design of the mashed potato composition in this study is shown in Table 1 for formula A, Table 2 for formula B, Table 3 for formula C and Table 4 for formula D. According to the Table 1, 2, 3 and 4 mashed potatoes with cassava starch added meet the standard in moisture content, protein, fat and carbohydrate attribute. Likewise, with the formula A, formula B, C and D can fulfil the standard of moisture content, fat and carbohydrate. In terms of production costs, formula A has the lowest production cost compared to other formulas. This is due to the raw material price of Cassava starch is cheaper than the price of other raw materials.

Table 1. Formula A with cassava starch added

| Ingredient | Potato | Milk powder | Cheese | Cassava starch | Salt | Pepper | Water | Total | Standard (%) |
|------------|--------|-------------|--------|----------------|------|--------|-------|-------|--------------|
| Ingredient (%) | 50 | 5 | 4 | 20 | 4 | 3 | 13 | 100 |
| Moisture content | 79.8 | 11.3 | 29.5 | 12.2 | 0.4 | 1.2 | 100 | 57.137 | 81.6 – 87.8 |
| Protein | 2 | 25.9 | 20 | 0.5 | 0 | 11.5 | 0 | 3.54 | 4.2 Min |
| Fat | 0.1 | 25.9 | 26.6 | 0.3 | 0 | 6.8 | 0 | 2.673 | 3 Max |
| Carbohydrate | 19.7 | 40 | 3.3 | 86.9 | 0 | 0 | 0 | 29.362 | 22.3 Min |
| Usage | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 100 | Min |
| Price/ 100 Gram (IDR) | 1100 | 9000 | 10000 | 800 | 100 | 500 | 1000 | 1709 |

Table 2. Formula B with rice starch added

| Ingredient | Potato | Milk powder | Cheese | Rice starch | Salt | Pepper | Water | Total | Standard (%) |
|------------|--------|-------------|--------|------------|------|--------|-------|-------|--------------|
| Ingredient (%) | 50 | 5 | 4 | 20 | 4 | 3 | 13 | 100 |
| Moisture content | 79.8 | 11.3 | 29.5 | 11.1 | 0.4 | 1.2 | 100 | 56.917 | 81.6 – 87.8 |
| Protein | 2 | 25.9 | 20 | 7 | 0 | 11.5 | 0 | 4.84 | 4.2 Min |
| Fat | 0.1 | 25.9 | 26.6 | 0.5 | 0 | 6.8 | 0 | 2.713 | 3 Max |
| Carbohydrate | 19.7 | 40 | 3.3 | 80 | 0 | 0 | 0 | 27.982 | 22.3 Min |
| Usage | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 100 | Min |
| Price/ 100 Gram (IDR) | 1100 | 9000 | 10000 | 1700 | 100 | 500 | 1000 | 1889 |
### Table 3. Formula C with corn starch added

| Ingredient       | Potato | Milk powder | Cheese | Corn starch | Salt | Pepper | Water | Total | Standard (%) |
|------------------|--------|-------------|--------|-------------|------|--------|-------|-------|---------------|
| Ingredient (%)   | 50     | 5           | 4      | 20          | 0.4  | 1.2    | 100   | 57.097 | 81.6 -- 87.8  |
| Moisture         | 79.8   | 11.3        | 29.5   | 12          | 0.4  | 1.2    | 100   | 70.657 | 81.6 -- 87.8  |
| Protein          | 2      | 25.9        | 20     | 9.2         | 0    | 11.5   | 0     | 5.28   | 4.2 Min       |
| Fat              | 0.1    | 25.9        | 26.6   | 3.9         | 0    | 6.8    | 0     | 3.393  | 3 Max         |
| Carbohydrate     | 19.7   | 40          | 3.3    | 73.7        | 0    | 0      | 0     | 26.722 | 22.3 Min      |
| Usage            | 1      | 1           | 1      | 1           | 1    | 1      | 1     | 100    | Min           |
| Price/ 100 Gram (IDR) | 1100 | 9000        | 10000  | 1100        | 100  | 500    | 1000  | 1769   |               |

### Table 4. Formula D without starch added

| Ingredient       | Potato | Milk powder | Cheese | Salt | Pepper | Water | Total | Standard (%) |
|------------------|--------|-------------|--------|------|--------|-------|-------|---------------|
| Ingredient (%)   | 70     | 5           | 4      | 4    | 3      | 13    | 100   | 70.657        |
| Moisture         | 79.8   | 11.3        | 29.5   | 0.4  | 1.2    | 100   | 70.657 | 81.6 -- 87.8  |
| Protein          | 2      | 25.9        | 20     | 0    | 11.5   | 0     | 3.84  | 4.2 Min       |
| Fat              | 0.1    | 25.9        | 26.6   | 0    | 6.8    | 0     | 2.633 | 3 Max         |
| Carbohydrate     | 19.7   | 40          | 3.3    | 0    | 0      | 0     | 15.922 | 22.3 Min      |
| Usage            | 1      | 1           | 1      | 1    | 1      | 1     | 100   | Min           |
| Price/ 100 Gram (IDR) | 1100 | 9000        | 10000  | 100  | 500    | 1000  | 1769  |               |

3.2. Sensory analysis results

3.2.1. Colour

The results of hedonic test of mashed potatoes colour can be seen in Table 5. Based on the Friedman test, the comparison formulation of mashed potatoes with the starch addition has significantly different (α = 0.05) on the colour hedonic scale of mashed potatoes.

| Formula                      | Hedonic scale for colour | ∑ The hedonic rank of colour |
|------------------------------|--------------------------|------------------------------|
| formula A with cassava starch| 4.16                     | 67.5<sup>bc</sup>            |
| formula B with rice starch   | 4.52                     | 75.5<sup>a</sup>             |
| formula C with corn starch   | 4.84                     | 85.5<sup>ab</sup>            |
| formula D without starch added| 3.72                   | 52.5<sup>c</sup>             |
| commercial product           | 5.08                     | 94.0<sup>a</sup>             |

* Different subscript letters indicate significantly difference within each column (p<0.05)

Mashed potatoes with rice starch and corn starch has a more attractive appearance compared to those with cassava starch. This is due to the higher content of amylose in corn and rice starch when compared to cassava starch. Ingredients containing high amylose, if boiled the amylose is extracted by hot water, so it looks like white milk [6].
3.2.2. Flavour
The average value of the favorite color of mashed potato can be seen in Table 6. The Friedman Test showed that the comparison treatment of the flour addition to mashed potatoes was significantly different ($\alpha = 0.05$) on the value of the aroma preference.

The panellist’s assessment for the aroma of the commercial products had the lowest value, it was presumably caused by the commercial product produced from potato powder without additional ingredients such as cheese powder and gelatinized starch. Whereas in the other samples, mashed potatoes were made of fresh potatoes, which has more potato aroma. The addition of seasoning and spices like pepper, improved the mashed potatoes aroma. According to Sundari, increasing the number of ingredients such as milk, cheese, pepper, onions, and salt will be affected the taste and aroma, of the mashed potatoes [7].

| Formula                      | Hedonic scale for flavour | $\sum$ The hedonic rank of flavour |
|------------------------------|---------------------------|-----------------------------------|
| formula A with cassava starch| 5.00                      | 89.5$^a$                          |
| formula B with rice starch   | 4.52                      | 74.0$^a$                          |
| formula C with maize starch  | 5.04                      | 87.0$^a$                          |
| formula D without starch added| 4.64                      | 76.0$^a$                          |
| commercial product           | 3.56                      | 48.5$^b$                          |

* Different subscript letters indicate significantly difference within each column ($p<0.05$)

3.2.3. Taste
The average results of the favourite value of mashed potatoes taste can be seen in Table 7. The Friedman Test showed that the treatment of kind starch added to the mashed potato was significantly different ($\alpha = 0.05$) in the hedonic scale of the mashed potato flavour.

| Formula                      | Hedonic scale for taste | $\sum$ The hedonic rank of taste |
|------------------------------|-------------------------|---------------------------------|
| formula A with cassava starch| 4.60                    | 81.0$^{ab}$                     |
| formula B with rice starch   | 4.28                    | 74.0$^b$                        |
| formula C with maize starch  | 4.72                    | 86.5$^{ab}$                     |
| formula D without starch added | 5.16                    | 96.5$^a$                        |
| commercial product           | 2.96                    | 37.0$^c$                        |

* Different subscript letters indicate significantly difference within each column ($p<0.05$)

According to Antarlina [8], the quality of cakes with a mixture of corn starch, with other flour is not different from the cakes without corn starch added, as long as the taste is acceptable. The protein content of corn flour is higher than protein content of cassava flour. The addition of Cassava flour in herbal noodle did not change the taste of the herbal noodle [9]. Therefore, the addition of Cassava starch in the formulation of mashed potatoes which is not excessive will not affect the taste of the mashed potato.
3.2.4. Texture
The results of the average hedonic scale of mashed potato taste can be seen in Table 8. The Friedman Test showed that the treatment of the kind starch added to the mashed potatoes was not significantly different (α = 0.05) in the hedonic scale of mashed potato texture.

From the results of hedonic tests, mashed potatoes formulation with the addition of starch and samples of commercial products had almost the similar value for the preference of texture attributes. In the mashed potato formula, A, B and C, the texture result was not too moist compared to commercial product. The addition of starch in the formulation of mashed potatoes, can increase the water holding capacity of mashed potatoes. Water holding capacity (WHC) is the interaction between components in flour such as protein and starch with water that occur in food [9].

| Formula                      | Hedonic scale for texture | ∑ The hedonic rank of texture |
|------------------------------|---------------------------|------------------------------|
| formula A with cassava starch| 4.64                      | 78.0                         |
| formula B with rice starch   | 4.72                      | 84.0                         |
| formula C with maize starch  | 4.76                      | 79.0                         |
| formula D without starch added | 3.80                   | 55.5                         |
| commercial product           | 4.56                      | 77.5                         |

3.3 Selection of the best formulation
The best treatment was chosen from treatments that had a minimum value of L1, L2, and L ~. The results of calculating the best treatment can be seen in Table 9.

| Formulation  | L1    | L2    | L~    |
|--------------|-------|-------|-------|
| Formula A    | 0.079 | 0.012 | 0.045 |
| Formula B    | 0.098 | 0.009 | 0.042 |
| Formula C    | 0.033 | 0.003 | 0.021 |
| Formula D    | 0.137 | 0.019 | 0.067 |
| Commercial product | 0.191 | 0.016 | 0.106 |

Based on the calculation of the Multiple Attribute in the Table 9, the best treatment was obtained in Formula C, which was formulated with the addition of corn starch. The results obtained in these treatments were considered the best compared to other treatments. This was known from the values of L1, L2, and L ~ the smallest of each parameter. The characteristic of the best formulation shown on the Table 10.
Table 10. Characteristic of the best formulation

| Attribute      | Result (%) | Indonesian National Standard (SNI 01-7111.1-2005) |
|----------------|------------|--------------------------------------------------|
| Protein        | 1.79       | min. 4.2                                         |
| Fat            | 1.22       | max 3                                            |
| Water          | 74.27      | 81.6-87.8                                        |
| Ash            | 1.31       | max 3.5                                          |
| Carbohydrate   | 21.41      | min. 22.3                                        |

The best formulation of mashed potatoes (formula A with corn starch added) has protein content about 1.79%, while the mashed potatoes quality standard require the minimum protein content about 4.2%. The fat content of the best formulation mashed potatoes was 1.22%, while the maximum fat content of mashed potatoes standard require maximum 3% for fat content. According to the Table 10, the best formulation of mashed potatoes can fulfill the Indonesian National Standard for fat content, ash content but was not met the requirement about protein content, water content and carbohydrate content.

4. Conclusions
The best treatment was obtained in the formulation with the addition of corn starch. The highest hedonic value for the mashed potato formulation with corn starch added was 4.84 (scale assessment 1-7) of all parameters (colour, aroma, taste, and texture). The cost of making 200 g mashed potatoes was 5,038.00 (IDR). The best formulation for mashed potato has the potential to develop culinary tourism in the Tengger area.

Reference
[1] Besra E 2012 Potensi wisata kuliner dalam mendukung pariwisata di kota Padang (The potential of culinary tourism in supporting tourism in Padang City) J. Ris. Akun. Bis. 12 1 83-91. [In Indonesian]
[2] Fiani M, Japariano E 2012 Analysis of food quality and brand image influence to purchase decision kecik roti Bakery Ganes's in Solo City J. Mark. Man. 1 1 1-8.
[3] Asandhi A, Sastrosiswojo S, Suhardi, Abidin Z, Subhan 2001 Kentang (Potato) Badan Litbang Pertanian Balai Penelitian Hortikultura Lembang Lembang. [In Indonesian]
[4] Setiadi 2009 Budidaya kentang (Potato cultivation) Penebar Swadaya. [In Indonesian]
[5] Hevis 2016 Smoked cheddar mashed potatoes: healthy and easy homemade for your best friend Gramedia.
[6] Sholihah 2015 Resep kue basah dan kue kering (Recipee for cake and pastries) Kanisius. [In Indonesian]
[7] Sundari D, Almasyhuri, Astuti L 2015 Pengaruh proses pemasakan terhadap komposisi zat gizi bahan pangan sumber protein (The effect of cooking process on nutrient composition of food sources of protein) J. Tek. Kes. 25 4 236. [In Indonesian]
[8] Antarlina S S, Utomo J . 2012 Kue kering dari ballan tepung campuran jagung, gude dan kedela. Corn (Gude and soy mix flour ballan cookies) Risalah Seminar Hasil Penelitian Tanaman Pangan Malang. [In Indonesian]
[9] Dessuara C 2014 pengaruh tepung tapioka sebagai bahan substitusi tepung terigu terhadap sifat fisik mie herbal basah (The influence of tapioca flour as a substitute for wheat flour on the physical properties of wet herbal noodles) *J. Tek. Pert.* 4 2 89-90. [In Indonesian]

[10] Zeleny, M 1982 Multiple criteria decision-making McGraw Hill.

[11] Yamin, Ashabul 2017 Formulasi dan eksplorasi kuliner Tengger berbasis kentang (Formulation and exploration of Tengger culinary based on potato commodity) Undergraduate Thesis Universitas Brawijaya Malang. [In Indonesian]

[12] Granato D, Masson M L, Ribeiro C B 2012 Sensory acceptability and physical stability evaluation of a prebiotic soy-based dessert developed with passion fruit juice *J. Ciênc. Tecnol. Aliment. Campinas* 32 1 119-125.