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To cite this article: F Aulia and W B Sunarharum 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **475** 012040

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Beetroot (Beta vulgaris L. var. rubra L.) flour proportion and oven temperature affect the physicochemical characteristics of beetroot cookies

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Abstract. Red beetroot (Beta vulgaris L. var. rubra L.) is one of the agricultural commodities that is very beneficial for human health, one of the benefits is to facilitate the transport of nutrients throughout the body and maintain the number of red blood cells. However, the utilization of red beetroot commodities is still limited, especially in Indonesia. For this reason, innovation is required in the manufacture of red beetroot derivative products. This study aims to know the effect of beetroot flour proportion and oven temperature on the physicochemical characteristics of beetroot cookies. This study was conducted by using Factorial Randomized Block Design consisting of two treatment factors, i.e., proportion of beet flour (10%, 15%, and 20%) and oven temperature (160˚C, 170˚C, and 180˚C) in three replicates. Statistical analysis was performed using Minitab 17. Best treatment was selected by Multiple Attribute method. The results showed that the factor of increasing the proportion of beetroot powder and oven temperature had a significant effect on lightness, redness, yellowness, hardness, fracturability, moisture content, and crude fiber of the cookies. The interaction between the two factors of beetroot powder proportion and oven temperature was significantly (α=0.05) affecting the brightness, redness, and yellowness, and crude fiber, but did not significantly affect hardness, fracturability, and moisture content. Best treatment was the cookies made of 15% proportion of beetroot and 180˚C of oven temperature that contains potassium of 476.16 mg / kg, magnesium of 2045.76 mg / kg, and phosphorus (P) of 2801.6 mg / kg.

1. Introduction
Red beetroot (Beta vulgaris L. var. rubra L.) is an agricultural commodity that has root characteristics that are bulging similar to tubers, which are often referred to as beets. Red beet is a beetroot variety with dark red tuber color. This type of bit has been cultivated in several highlands in Indonesia [1]. Red beetroot itself is widely planted in highlands with an altitude of more than 1,000 m above sea level. Despite high production of red beetroots in some areas in Indonesia, the utilization is considered as very limited.

Generally, red beetroot is consumed fresh as a salad or juice. In this study, red beetroot-based product was developed. Product development is carried out through substituted red beetroot powder as raw material for making cookies. Beet powder is a functional food that can provide natural colors in the manufacture of food products. The red color of beets is produced by red betacyanine and yellow betaxanthine, both of which are groups of pigments betalaine or betanine. Betacyanine is a water-soluble pigment, contains antioxidants, anti-inflammatory, hepatoprotective, and anti-cancer
compounds [2]. Beside antioxidants, beetroot contains minerals such as manganese, sodium, potassium, magnesium, iron, and copper that play an important role in human metabolism and health [3]. Beetroot consumption could maintain a well-nourished body since it may help to regulate blood pressure, cholesterol and triglycerides, as well as helping to prevent or treat various malignancies such as leukemia and radiation effect [3]. The high levels of iron are useful for pregnancy and menstruation [4].

In order to increase beetroot consumption, it is necessary to incorporate beetroot into a product such as bakery product that gain lots of interest and popularity these days. One of beetroot-based product that can be developed is cookies, a type of biscuit made of soft, crispy dough, and when broken the cross section looks less dense textured [5]. In the cookies making, several factors may influence its physical and sensory as well as nutritional quality such as oven temperature. The study was carried out to know the effect of beetroot flour (further mentioned as powder) proportion and oven temperature on the physicochemical characteristics of beetroot cookies.

2. Materials and Method

2.1. Materials

Fresh red beetroots were from local market in Malang, East Java. The ingredients for cookies such as wheat flour, butter, sugar, baking powder, vanilla powder, egg, and salts were purchased locally.

2.2. Methods

Research was conducted in factorial design and analysis was performed in triplicates. Beetroot powder was made from fresh beetroots. Fresh beetroot were washed, blanched at 85°C for 6 minutes before further peeling and slicing to a 2 mm thickness by using slicer. Beetroot slices were dried in a cabinet dryer at 68°C for 8 hours prior to further grinding with disc mill and sieving to a 40 and 60 mesh. Beetroot cookies were prepared by substituting wheat flour with beetroot using pre-determined formulation (wheat flour to beetroot flour ratio of 90:10, 85:15, and 80:20) and were baked at 160°C, 170°C, and 180°C for 20 minutes.

Cookies were analysed for colour by measuring Lightness (L*), redness (a*), and yellowness (b*) by using color reader (Konica Minolta) and texture (hardness and fracturability) by using Texture Profile Analyzer [6]. The moisture and crude fiber were determined based on AOAC standard method [7] while potassium (K), phosphorus (P), and magnesium (Mg) content were analyzed by Atomic Absorption Spectroscopy [8,9]. The best treatment was selected by using the Multiple Attribute [10], Results and Discussion.

Data analysis was performed in Minitab 17 Statistical Software (Minitab Inc., State College, Pennsylvania, USA) followed by a Fisher LSD post-hoc test with a confidence interval of 95% for any significant difference.

3. Results and Discussion

3.1. Raw materials characteristics

Color, moisture content, and crude fiber data of fresh beetroot and beetroot powder was shown in Table 1.

| Parameter               | Fresh          | Powdered        |
|-------------------------|----------------|-----------------|
| Brightness (L*)         | 40.1±0.3       | 37.6±0.3        |
| Redness (a*)            | 14.9±0.7       | 10.1±0.8        |
| Yellowness (b*)         | 3.4±0.5        | 3.8±0.2         |
| Moisture content (%)    | 92.12±0.5      | 13.63±0.9       |
| Crude fiber (%)         | 5.39±0.2       | 2.26±0.27       |

Notes: data mean ±standard deviation (n=3)
Based on Table 1, it can be seen that the powder generally has a lower lightness (L*), redness (a*), moisture and crude fiber while there was a little increase in yellowness (b*). According to Sari [11], heating is a factor that greatly affects the stability of the betalain pigment. During the heating process, the possibility of breaking the bond causes a reduction in red to pale red or changes to bright yellow. Heating can also cause chemical changes that turn food products into brown and tend to be dark. The process is called the Maillard reaction, that is, the reaction that occurs due to lipid oxidation and the interaction between amino acids and lipid oxidation products [12].

3.2. Color measurement

The result of colour measurement of the samples can be seen in Table 2. Results of these studies has indicated that proportion of beetroot, oven temperature and interactions between two factors has a significant effect (α = 0.05) on lightness (L*), redness (a*), and yellowness (b*) of beetroot cookies.

| Treatments | Lightness (L*) | Redness (a*) | Yellowness (b*) |
|------------|---------------|--------------|-----------------|
| 90:10 160  | 46.3±0.2a     | 10.2±0.1ef   | 11.1±0.3a       |
| 90:10 170  | 44.5±0.3b     | 9.6±0.5f     | 9.1±0.0b        |
| 90:10 180  | 41.6±0.2c     | 7.1±0.3g     | 8.3±0.2c        |
| 85:15 160  | 41.5±0.2c     | 13.3±0.5ab   | 7.6±0.3cd       |
| 85:15 170  | 41.3±0.3c     | 12.6±0.4bc   | 7.0±0.2de       |
| 85:15 180  | 40.5±0.4d     | 11.4±0.2de   | 6.7±0.4ef       |
| 80:20 160  | 38.3±0.1e     | 14.0±0.4a    | 6.8±0.2ef       |
| 80:20 170  | 35.6±0.2f     | 12.2±0.4bcd  | 6.2±0.1fg       |
| 80:20 180  | 32.4±0.2g     | 12.0±0.2cd   | 5.7±0.2g        |

Notes: Data mean ±standard deviation (n=3). Numbers accompanied by different notations showed significant differences (α = 0.05)

From Table 2, it is known that the higher of beetroot powder proportion, it would decrease the L* and b* value of beetroot cookies while increasing the a*. The L* value decreased with the reduction in the proportion of wheat flour due to the loss of white color or lightness contribution from the flour. The results also showed that cookies have more a* than the b* suggested due to more pigment betalaine content, particularly betacyanine, that contributes to the red color [13].

This study had also indicated that the higher oven temperature decreased the L*, a*, and b* value, suggested due to low stability of betacyanine on heating process [14]. It has been reported that betacyanine was stable at temperature below 40°C [15]. Besides, other reaction due to high temperature might also contribute to the color change such as Maillard reaction [12].

3.3. Texture and moisture analysis

Result of texture measurement and moisture analysis of the samples is provided in Table 3. Based on Table 3, it can be seen that proportion of beetroot and oven temperature had a significant effect on hardness, fracturability, and moisture of beetroot cookies (α = 0.05), but interaction between two factors was not significant. The higher the incorporation of beetroot was found to decrease hardness and fracturability of beetroot cookies while the moisture decreased. The increase in oven temperature is linear with the increase in hardness and fracturability but not for moisture. This trend is suggested due to the contribution of some components in beetroots such as carbohydrates, protein, and fibers [16] that interacts during baking process to produce cookies texture. The water holding capacity of cookies was greater due to hydroxyl groups of cellulose in fiber, which is able to bind with free water molecules through hydrogen bonding [17].
Table 3. Texture analysis data of beetroot cookies

| Wheat Flour: Beetroot Powder (%) | Hardness (g) | Fracturability (g) | Moisture Content (%) |
|----------------------------------|--------------|--------------------|---------------------|
| 90:10                            | 697.933a     | 721.456a           | 4.412b              |
| 85:15                            | 624.211b     | 576.889b           | 6.501a              |
| 80:20                            | 525.244c     | 502.411c           | 6.774a              |
| Oven Temparture (°C)             | Hardness (g) | Fracturability (g) | Moisture Content (%) |
| 180                              | 656.589a     | 650.789a           | 5.795b              |
| 170                              | 607.822b     | 597.378b           | 6.253ab             |
| 160                              | 582.978b     | 552.589c           | 6.639a              |

Notes: Data mean ±standard deviation (n=3). Numbers accompanied by different notations showed significant differences (α = 0.05)

3.4. Cookies fiber content
Table 4 showed the result of crude fiber analysis. The ANOVA result indicated that the proportion of beetroot and oven temperature had a significant effect (α = 0.05) on the fiber while the interaction between the two factors was not significant.

Table 4. Crude fiber of beetroot cookies

| Treatments                  | Crude Fiber (%) |
|-----------------------------|-----------------|
| Wheat Flour : Beetroot Powder (%) | Oven Temperature (°C) |           |
| 10                          | 160             | 3.55±0.37de    |
| 10                          | 170             | 3.40±0.43e     |
| 10                          | 180             | 3.33±0.42e     |
| 15                          | 160             | 4.45±0.38cd    |
| 15                          | 170             | 4.02±0.14cde   |
| 15                          | 180             | 4.93±0.35bc    |
| 20                          | 160             | 6.10±0.19a     |
| 20                          | 170             | 4.47±0.19cd    |
| 20                          | 180             | 5.89±0.39ab    |

Notes: Data mean ±standard deviation (n=3). Numbers accompanied by different notations showed significant differences (α = 0.05)

From Table 4, it is revealed that the higher proportion of beetroot powder tend to increase crude fiber content. This can be explained due to high fiber content of the added beetroot as can be seen in Table 1, that fresh beetroot contains 5.39±0.2 % of crude fiber while beetroot powder has a lower content of 2.26±0.27%. In the previous studies, it has been reported that the incorporation of 20% beetroot powder in cookies were able to doubled fiber content of cookies [16]. This is then related to the texture and other cookies properties including ability to bind water and functional properties.

3.5. Mineral component
The mineral content was evaluated on the best treatment sample and the analysis was currently limited to potassium (K), magnesium (Mg), and phosphorus (P) content (Table 5). The best treatment was the cookies made of 15% proportion of beetroot using baking oven temperature at 180°C (data not shown).
Table 5. Mineral component of beetroot cookies compared to commercial product

| Mineral Component | Beetroot cookies |
|-------------------|------------------|
| Potassium (mg/kg)  | 476.16           |
| Magnesium (mg/kg)  | 2,045.76         |
| Phosphorus (mg/kg) | 2,801.6          |

Table 5 showed differences in and commercial product. The current beetroot cookies formula offers a higher magnesium (Mg) content of 17.5%, while also provides potassium (K) and phosphorus (P) content of 0.3% and 12%, respectively. The addition of beetroot powder had also been reported to increase minerals such as calcium, phosphorus, iron, zinc evaluated on previous study [16].

4. Conclusions
The incorporation of beetroot powder in different proportion and oven temperature had a significant influence ($\alpha=0.05$) on physical and compositional properties of beetroot cookies to some extent, such as the effect on lightness, redness, yellowness, hardness, fracturability, moisture content, and crude fiber. The interaction between the two factors or treatments also affecting some of the parameters. The changes in cookies properties is suggested due to different composition and interactions between components in the beetroot formula during cookies making. The best treatment was the cookies made of 15% of beetroot flour and oven temperature at 180˚C. The current result had indicated that the current beetroot cookies has a potential as nutritious food product. However, further research was required in order to show more benefits and functionality of using beetroots.

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