The effects of baking on the quality attributes of dried beetroot (Beta vulgaris L.)

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Abstract. In the vegetable preservation process, baking treatment is commonly applied to enhance the end-product quality. This study was carried out to observe baking influences as an alternative pretreatment toward dried beetroot quality. A completely randomized design with different baking times (0, 15, 30, and 45 min) at 200°C was adjusted on beetroot before sliced and dried (50±5°C, 24 h). The result showed that baking treatments significantly affected the whole quality attributes of dried beetroot. There was an increase in anthocyanin, total phenolic, total sugar, and pigment intensity of dried beetroots with the more prolonged baking treatment. Dried beetroot prepared by 45 min baking treatment contained total anthocyanin 109.57 mg/100 g, total phenolic 8.66 mg/100 g, and total sugar 5.13%. Baking treatment for 45 min also resulted in intense color development of redness (a*) and yellowness (b*), although the lightness (L*) reduced due to dark color formation.

1. Introduction

Red beetroot (Beta vulgaris L.) had become a popular vegetable and gained much worldwide attention in recent years due to its functional properties as antitumor, anti-inflammatory, and hepatoprotective [1]. These beneficial effects contributed to its valuable compound content such as polyphenols, betacyanins, flavonoids, carotenoids, folates, vitamins, and minerals [2,3]. Some research also associated beetroot nutritional value with its high sucrose content [4]. Moreover, beetroot is an excellent natural pigment source and has been widely used in food, beverages, and confectionery industries. However, like other agricultural products, beetroot is perishable due to its high moisture content. Therefore, proper preservation is needed to prolong its self-life.

Drying is an ancient food preservation method that has been used all over the world to ensure the year-round availability of horticulture products. Principally, the drying method is determined to reduce the water content of food to prevent microbial spoilage and other deterioration reaction [5]. Moreover, the lightweight of dried products leads to smaller storage space and saving distribution costs [6]. Besides, processing beetroot into the dried form would make it easy to use as an ingredient in various food applications, beverages, and confectionery products [7].

Convection drying is the most common practice among several drying methods, especially in developing countries where the postharvest handling facilities are not well established [8]. In the convective method, heat transfer allows hot air to circulate through the products and led the water to be
removed [9]. However, this method is frequently associated with vegetable physicochemical deterioration. Therefore, several pretreatment methods have been applied to enhance the quality of dried products.

Baking is a typical conventional method to prepare the beetroots before consumed as salad or juice. This preparation method is convinced able to improve food characteristics and enhance digestibility [10]. Baking treatment also offers better preservation on maintaining most bioactive compounds of beetroot than other cooking methods [11]. However, there was limited information about the influences of baking treatments on dried-product characteristics.

Previous observations in beetroot characteristics were mostly focused on the betalain as the primary pigment compound [4,12,13], while anthocyanin was commonly neglected even though it also plays a role in beetroot's color pigmentation and present in relatively high concentration [14]. It was reported that betalain pigmentation effects representing the beetroot red color are similar to anthocyanin compounds [15]. Moreover, the presence of betalain, anthocyanin, and phenolic compounds in beetroot have made this crop among the top ten vegetables with the highest antioxidant capacity, which has an essential role in preventing several chronic diseases, including cancer [16,17]. Other prominent characteristics necessary to learn in beetroot products are sugar and color changes. Information about these two attributes is necessary for food industries to optimize their processing conditions. Thus, this study was carried out to observe different baking time effects on dried beetroot quality attributes, mainly on its anthocyanin, phenolic, total sugar, and color changes.

2. Methods

2.1. Materials
Fresh harvested organic beetroots were purchased from a farmer in Ngablak, Magelang district. About 30 kg beetroot were sorted and washed to eliminate the dirt and then peeled to obtain the flesh. One part of beetroots was used for the preliminary cooking test, while two-thirds of them were used for baking treatments, and the remaining part was used for fresh beetroot analyses.

For the baking experiment, peeled beetroots were wrapped with aluminum-foils and arranged in the oven (Memmert UN55) at 200°C. Baking treatment was applied for 0, 15, 30, and 45 min. After baked, beetroots were sliced into small chips (± 2 mm of thickness) and dehydrated in the convection cabinet dryer (50±5°C) for 24 h. Dried beetroots were packed in polyethylene (PE) plastic bags with 0.08 mm thickness and placed in the airtight container before further analysis. All processing steps during sample preparation were performed immediately to prevent sample degradation. For use as analytical samples, the dried beetroots were finely ground with a sample mill.

2.2. Analyses
Analysis of dried beetroot consisted of anthocyanin, total phenolic, total sugar, and color index. Measurement of total anthocyanin used pH-differential spectrophotometry [18], while total phenolic was identified using the Folin-Ciocalteu assay [12], and total sugar was determined using a spectrophotometer with glucose as a standard [19]. The color index was measured using Hunter Lab Scan Spectrocolorimeter (Hunter Associates Lab, Inc., Reston, VA, USA) with the CIE L*a*b* method. The L* value defines the lightness, a* value illustrates the redness color, and b* value represents the yellowness color.

2.3. Statistical analysis
This current experiment implemented a completely randomized design with four levels of baking time was replicated three times. Data evaluation utilized a one-way analysis of variance (ANOVA) at a significant difference of p ≤ 0.05. Further examination to compare different means used the Duncan Multiple Range Test. SPSS 20.0 statistical software (SPSS Inc., Chicago, IL, USA) was operated in statistical analysis.
3. Results and discussion

3.1. Total anthocyanin
In this study, the anthocyanin content of raw beetroot was about 146.36 mg/100 g (data not shown) and then declined to 74.20 mg/100 after dried. However, the baking treatment can enhance the total anthocyanin content of dried beetroot (figure 1). The figure shows that the anthocyanin content of dried beetroot is significantly increased with the more extended baking time (p ≤ 0.05). The anthocyanin content of dried beetroot prepared with baking for 15, 30, and 45 min reached 84.38, 95.68, and 109.57 mg/100 g, respectively. This result conforms to the previous finding, which declared a significant anthocyanin enhancement in colored-flesh potatoes after baking for 5 min [18]. This phenomenon is probably related to an excessive anthocyanin release due to heat-induced treatment [14].

![Figure 1. Total anthocyanin of dried beetroot prepared with a different baking time.](image)

3.2. Total phenolic
The phenolic compounds are often associated with antioxidant properties, which prevented the oxidative damage induced by free radicals [20]. This present study showed significant differences in dried beetroot's total phenolic content prepared with different baking times (p ≤ 0.05). Figure 2 reveals that the more extended baking time induces higher total phenolic content of dried beetroot. The total phenolic of dried beetroot without baking preparation was about 1.72 mg/100 g. Meanwhile, the total phenolic of dried beetroot prepared with baking for 15, 30, and 45 min was 4.02, 5.95, and 8.66 mg/100 g, respectively. It was presumed that heating treatment might enhance phenolic compound accessibility by disrupting the plant cell and breakdown the matrix complex bound [14,21]. Another researcher speculated that phenolic-like complexes products formed due to Maillard reaction during heat-treatment might contribute to the higher absorbance reading of phenolic content [22].

A previous study reported that beetroot's phenolic content remains constant even after baking for 3 hours and has no difference with the raw beetroot, while the drying process tends to decrease the phenolic content of fresh beetroot [14]. Consistent with the previous finding, this present study exhibits that unbaked dried beetroot phenolic content is lower than fresh beetroot and baked dried beetroot. As information, the fresh beetroot phenolic content in this study was approximately 115.1 mg/100 g (data not shown).
Figure 2. Total phenolic of dried beetroot prepared with a different baking time.

3.3. Total sugar
The result shows that the baked dried beetroot's total sugar content is higher than the unbaked dried beetroot (figure 3). The more extended baking treatment significantly increase the sugar content of dried beetroot (p ≤ 0.05). Baking treatment for 15, 30, and 45 min resulted in total sugar of dried beetroot around 1.95, 3.67, and 5.13%, respectively. This finding is similar to the former investigation in sweet potato, which reported a significant increase in sugar content due to baking treatment [10,23]. It was noted that sugar increased in baked products is mainly dominated by maltose compounds, which resulted from sucrose breakdown during thermal processing [23,24]. Another report assumed that heating treatment induces polysaccharide hydrolysis resulted in sugar release [21]. The whole hypothesis is plausible, considering that beetroot is rich in carbohydrates, mainly sucrose [25].

Figure 3. Total sugar of dried beetroot prepared with a different baking time.

3.4. Color index
Color is a critical quality attribute of the dried product that affected the product attractiveness [7]. This present study reveals that baking treatment generated a darker color in dried beetroot, indicated by the lower L* value with the longer baking times (p ≤ 0.05). Several studies have mentioned that high temperature and long-term heating during baking would trigger a Maillard reaction, a chemical reaction of reducing sugars with protein and its derivatives, resulting in a brown color formation [26,27].

The increasing of a* value, which indicated a higher intensity of red color, is detected in dried beetroot prepared by 30 and 45 min baking treatment (p ≤ 0.05). This occurrence might be associated
with higher extracted betalain from beetroot tissue due to high thermal processing [28]. A similar finding was also reported in pasteurized beetroot [25].

Meanwhile, a significant difference of \( b^* \) value is detected in dried beetroot prepared by 45 min baking treatment (\( p \leq 0.05 \)). A previous study reported that the higher \( b^* \) value might be related to the browning color formation due to an extended high temperature [29]. The increasing of \( b^* \) value in beetroot might also be affected by betanin cleavage into light-yellow betalamic acid and colorless cyclo-dopa-5-O-\( \beta \)-glucoside during thermal processing [30], considering that betanin and isobetanin are two major compounds of peeled beetroot [28]. The color index of dried beetroot prepared with a different baking time can be seen on the table 1.

**Table 1.** The color index of dried beetroot prepared with a different baking time.

| Attributes       | Baking times (min) |
|------------------|--------------------|
|                  | 0                  | 15  | 30    | 45    |
| Lightness (L*)   | 4.28±0.31\(^a\)    | 3.23±0.17\(^b\) | 2.82±0.09\(^b\) | 2.24±0.12\(^c\) |
| Redness (a*)     | 0.24±0.07\(^a\)    | 0.29±0.04\(^a\) | 0.46±0.06\(^b\) | 0.65±0.05\(^c\) |
| Yellowness (b*)  | 1.21±0.06\(^a\)    | 1.28±0.08\(^a\) | 1.34±0.06\(^a\) | 1.60±0.15\(^b\) |

Note: Means followed by the different letters in the same row are significantly different (\( p \leq 0.05 \)).

**4. Conclusions**

The application of baking in beetroot as a preparation method is effective in improving the dried beetroot quality. Prolonged baking treatment until 45 min significantly increased the anthocyanin, total phenolic, total sugar, and redness color index of dried beetroot. It is assumed that high temperature and the extended baking process might induce several bioactive compounds released by disrupting the cell wall or plant tissues, breaking down the matrix complexes, or converting its molecular structure. However, the baking treatment also reduced the lightness of the dried beetroot due to the Maillard reaction.

**References**

[1] do Carmo E L, Teodoro R A R, Félix P H C, de Barros Fernandes R V, de Oliveira E R, Veiga T R L A, Borges S V and Botrel D A 2018 Stability of spray-dried beetroot extract using oligosaccharides and whey proteins *Food Chemistry* **249** 51–9

[2] Lech K, Figiel A, Wojdylo A, Korzeniowska M, Serowik M and Szarycz M 2015 Drying kinetics and bioactivity of beetroot slices pretreated in concentrated chokeberry juice and dried with vacuum microwaves *Drying Technology* **33** 1644–53

[3] Neha P, Jain S K, Jain N K, Jain H K and Mittal H K 2018 Chemical and functional properties of beetroot (*Beta vulgaris* L.) for product development: A review *International Journal of Chemical Studies* **6** 3190–4

[4] Fu Y, Shi J, Xie S-Y, Zhang T-Y, Soladoye O P and Aluko R E 2020 Red beetroot betalains: perspectives on extraction, processing, and potential health benefits *Journal of Agricultural and Food Chemistry* **68** 11595–611

[5] Rakecejeva T, Galoburda R, Cude L and Strautniece E 2011 Use of dried pumpkins in wheat bread production *Procedia Food Science* **1** 441–7

[6] Nistor O-V, Seremet (Ceclu) L, Andronoiu D G, Rudi L and Botez E 2017 Influence of different drying methods on the physicochemical properties of red beetroot (*Beta vulgaris* L. var. Cylindra) *Food Chemistry* **236** 59–67

[7] Figiel A 2010 Drying kinetics and quality of beetroots dehydrated by combination of convective and vacuum-microwave methods *Journal of Food Engineering* **98** 461–70

[8] Sagar V R and Suresh K P 2010 Recent advances in drying and dehydration of fruits and vegetables: a review *J Food Sci Technol* **47** 15–26

[9] Maisnam D, Rasane P, Dey A, Kaur S and Sarma C 2017 Recent advances in conventional drying
of foods J Food Technol Pres. 1 25–34
[10] Owusu-Mensah E, Oduro I, Ellis W O and Carey E E 2016 Cooking treatment effects on sugar profile and sweetness of eleven-released sweet potato varieties Journal of Food Processing and Technology 7 1–6
[11] Ramos J A, Furlaneto K A, Lundgren G A, Mariano-Nasser F A de C, Mendonça V Z, Nasser M D and Vieites R L 2018 Stability of bioactive compounds in minimally processed beet according to the cooking methods Food Science and Technology 38 643–6
[12] Paciulli M, Medina-Meza I G, Chiavaró E and Barbosa-Cánovas G V 2016 Impact of thermal and high pressure processing on quality parameters of beetroot (Beta vulgaris L.) LWT - Food Science and Technology 68 98–104
[13] Ravichandran K, Saw N M M T, Mohdaly A A A, Gabr A M M, Kastell A, Riedel H, Cai Z, Knorr D and Smetanska I 2013 Impact of processing of red beet on betalain content and antioxidant activity Food Research International 50 670–5
[14] Ramos J A, Furlaneto K A, de Mendonça V Z, Mariano-Nasser F A D C, Lundgren G A, Fujita E and Vieites R L 2017 Influence of cooking methods on bioactive compounds in beetroot Semina: Ciências Agrárias 38 1295–302
[15] Székely D, Illés B, Stéger-Máthé M and Monspart-Sényi J 2016 Effect of drying methods for inner parameters of red beetroot (Beta vulgaris L.) Acta Universitatis Sapientiae, Alimentaria 9 60–8
[16] Fissore E N, Rojas A M, Gerschenson L N and Williams P A 2013 Butternut and beetrootpectins: characterization and functional properties Food Hydrocolloids 31 172–82
[17] Yasaminshirazi K, Hartung J, Fleck M and Graef-Hoenninger S 2020 Bioactive compounds and total sugar contents of different open-pollinated beetroot genotypes grown organically Molecules 25 1–15
[18] Lachman J, Hamous K, Orsak M, Pivec V, Hejtmanková K, Pazderu K, Dvorak P and Cepl J 2012 Impact of selected factors - Cultivar, storage, cooking and baking on the content of anthocyanins in coloured-flesh potatoes Food Chemistry 133 1107–16
[19] Gunes M, Dollek U and Elmastas M 2017 Phytochemical changes in heated Rosa species fruits and seeds Czech Journal of Food Sciences 35 346–51
[20] Bhandari M R and Kawabata J 2004 Organic acid, phenolic content and antioxidant activity of wild yam (Dioscorea spp.) tubers of Nepal Food Chemistry 88 163–8
[21] Xu Y, Chen Y, Cao Y, Xia W and Jiang Q 2016 Application of simultaneous combination of microwave and steam cooking to improve nutritional quality of cooked purple sweet potatoes and saving time Innovative Food Science and Emerging Technologies 36 303–10
[22] Francisco M L L D and Resurreccion A V A 2009 Total phenolics and antioxidant capacity of heat-treated peanut skins Journal of Food Composition and Analysis 22 16–24
[23] Wei S, Lu G and Cao H 2017 Effects of cooking methods on starch and sugar composition of sweetpotato storage roots PLoS ONE 1–10
[24] Lončarić A, Svrakačić B, Tiban N N, Kopjar M and Piližota V 2016 Effect of baking and steaming on physicochemical and thermal properties of sweet potato puree preserved by freezing and freeze-drying Croatian Journal of Food Science and Technology 8 90–8
[25] Vujadinovic D P, Odzkovic B V, Grujic R D, Peric M and Pavlovic M B 2014 Influence of heat treatment process on the acceptability of pasteurized beetroot Quality of Life 5 39–45
[26] Arkoub-Djemoune L, Boulekbache-Makhfou L, Zeghichi-Hamri S, Bellili S, Boukhalfa F and Madani K 2016 Influence of the thermal processing on the physicochemical properties and the antioxidant activity of a solanaceae vegetable: eggplant Journal of Food Quality 39 181–91
[27] Sui X, Yap P Y and Zhou W 2015 Anthocyanins during baking: their degradation kinetics and impacts on color and antioxidant capacity of bread Food Bioprocess Technology
[28] Sawicki T and Wiczkowski W 2018 The effects of boiling and fermentation on betalain profiles and antioxidant capacities of red beetroot products Food Chemistry 259 292–303
[29] Ng M L and Sulaiman R 2018 Development of beetroot (Beta vulgaris) powder using foam mat
drying \textit{LWT} - \textit{Food Science and Technology} \textbf{88} 80–6

[30] Rodriguez-Amaya D B 2019 Update on natural food pigments - A mini-review on carotenoids, anthocyanins, and betalains \textit{Food Research International} \textbf{124} 200–5