

The effect of size reduction and steaming duration on the characteristics of purple sweet potato as the initial process of annealing flour making

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Abstract

Sweet potato flour is a semi-finished product that can be used as raw material in the production of cookies, cakes, breads, and other bakery products. However, the resulted flour of purple sweet potato will undergo a color changing, becoming pale purple and non-uniform as a result of the degradation of anthocyanin pigments occurring in the processing process, a condition that consumers do not like. This study was to determine the standardized size of sweet potatoes cuttings and duration of steaming to produce purple sweet potato flour with a deep purple color, uniform and high anthocyanin content, so that the physical appearance of purple sweet potato will be preferably by consumers. Research method used was experimental method of Randomized Block Design, consisting of 6 treatments and 3 times repetitions. The results show that sweet potato with chips form of 3 cm and the duration of steaming of 35 minutes gave sweet potato with the best characteristics, e.i 6.61 pH, color intensities of L, a* and b* were 22.46, 9.05 and -5.43 respectively, 4464.62 ppm (mg/kg) anthocyanin, 11.5% total starch and 13.04% degree of gelatinisation.

Keywords: anthocyanin degradation, purple sweet potato, size reduction, steaming duration

1. Introduction

Flour is a semi-finished product, produced from the reduction in grain size of food ingredients which can be used as raw material or additives for making derivative products such as cookies, cake, bread, and other bakery products. Flour derived from the purple sweet potato's can also act as a natural dye in the resulted products so that it has the potential to be developed in its effort to improve local wisdom. Besides, purple sweet potato has a good nutrition for health. The processing of purple sweet potato into flour is carried out through various processes including physical modification of hydrothermal annealing (soaking at 50° C for 4 hours), steaming, and drying (Sunyoto *et al.*, 2017). However, based on the results of the previous study, the resulting flour color could change becoming pale purple due to the degradation of anthocyanin pigments caused by its processing, where the anthocyanin content degraded due to several factors: pH, temperature, light, oxygen, solvents, enzymes and metal ions (Patras *et al.*, 2010) [19].

Apart from discoloration, the color of purple sweet potato is also not uniform, which may be caused by the differences in surface area on the pieces of material. The shape of the cuts gives a various form such as cubes, thin slices, chips, and bars. Each shape gives purple color sweet potato flour of different colors. It is believed that the surface area of a material can affect the quality of the color of purple sweet potato flour, because during annealing, the greater the surface of the material, the more anthocyanin in the material dissolve in water. This is due to the nature of anthocyanins which are easily soluble in water, and the greater the surface area of the material, the more anthocyanins will dissolve (Saati *et al.*, 2016) [22]. Purple sweet potato flour which is not uniform will be disliked by consumers, therefore color standardization needs to be done in the process of making

purple sweet potato flour.

In order to maintain the purple color of the flour produced, it needs to be preceded by a steaming process before the drying process. According to Jang *et al.* (2005) [10] and Truong *et al.* (2010) [28], the steaming process can deactivate anthocyanase enzymes, polyphenol oxidase, and peroxidase so that they cannot degrade anthocyanin. Steaming before drying can improve the quality of anthocyanin in the material to be processed and eliminate unwanted changes due to the oxidation process in the food stuff. However, the duration of steaming can affect the anthocyanin content of the ingredients. According to Patras *et al.* (2010) [19], the temperature and duration of heating have a strong influence on anthocyanin stability. Steaming for a certain time actually decreases the content of purple sweet potato anthocyanin (Maharani *et al.*, 2016) [14]. Therefore it is necessary to determine the steaming duration in accordance with the sweet potato pieces in the process of making purple sweet potato flour before drying.

The objective of this study was to create a standard procedure in the making of purple sweet potato flour to produce purple sweet potato flour with uniformly deep purple color which has a high amount of anthocyanin and to determine the proper shape of sweet potato pieces and duration of steaming.

2. Methods

The materials used was purple sweet potato of *Biang* varieties, 4-4.5 months of harvesting age obtained from research farmland of Faculty of Agriculture, Padjadjaran University, Ciparanje, Jatinangor, and distilled water which were used as annealing soaking on sweet potatoes.

The method used in this study was the experimental method of Randomized Block Design with 3 replications based on

the Duncan test. The experiment consisted of 6 treatments with a combination of 3 forms of size reduction and 2 steaming duration. The treatments were as follows:

- A = Cubes shape with 2 x 2 x 2 cm dimension and 25 minutes steaming duration
- B = Cubes shape with 2 x 2 x 2 cm dimension and 35 minutes steaming duration
- C = Chips form of 3 cm thick and 25 minutes steaming duration
- D = Chips form of 3 cm thick and 35 minutes steaming duration
- E = Slices shape of 1 mm thick and 25 minutes steaming duration
- F = Slices shape of 1 mm thick and 35 minutes steaming duration

duration

The variables tested were pH using a pH meter (Indonesian National Standard: SNI 06-6989.11-2004), color intensity using chromameter (AOAC, 2005), anthocyanin content based on the Lambert Beer method (AOAC, 2005), and starch content based on the Luff Schroll method (Indonesian National Standard: SNI 3451: 2011).

3. Results and Discussion

The observed sweet potato characteristics after steaming comprises pH value, color intensity, anthocyanin and starch content, and degree of gelatinization. The effect of size reduction and steaming duration shown in Table 1, Table 2, Table 3, Table 4, Table 5.

Table 1: The Effect of Size Reduction and Steaming Duration on the pH Value of Purple Sweet Potato

	Treatment	Average of pH Value
A	Cubes 2 x2 cm, 25 minutes steaming	6.41 ± 0.211 ^a
B	Cubes 2 x2 cm, 35 minutes steaming	6.40 ± 0.306 ^a
C	Chips 3 cm thick, 25 minutes steaming	6.50 ± 0.255 ^a
D	Chips 3 cm thick, 35 minutes steaming	6.61 ± 0.271 ^a
E	Slices 1 mm thick, 25 minutes steaming	6.34 ± 0.178 ^a
F	Slices 1 mm thick, 35 minutes steaming	6.22 ± 0.375 ^a

Note: Data consists of 3 replications and Standard Deviation.

Numbers marked with a small and different letter show a significant difference at the 5% level (P < 0.5).

The results showed that between treatments did not give a significant different effect on pH values. This shows that each form of size reduction and steaming duration gave no effect on the pH value of purple sweet potato. It can be seen in each treatment with distilled water solvents, the average pH value of each treatment was 6 which means that anthocyanin in sweet potato is purple. According to Mahmudatussa'adah, *et al.*, (2014) [15], purple sweet potato anthocyanin at a strong acid of pH 1-3 is red, at weak acids of pH 4-6 is purple, at pH 7 is blue color, at a weak alkaline of pH 8-9 is green, and at pH 10-14 is yellow.

Chips treatment with 35 minutes of steaming duration (D) has the highest pH of 6.61 which means that the color of the treatment has a purple color, more concentrated than other treatments, this was in accordance with the aim of the study because pH 6.61 is close to pH 7 which is blue, so that the purple color of D treatment is more concentrated than other treatments.

Figure 1. shows that the three shapes of size reduction have the same color, purple, but in the form of chips, is more concentrated than the others. This is because Cubes and slices shapes have a large surface area so that the anthocyanin is easily degraded during annealing immersion as well as the thermal steaming process.

Marco *et al.* (2011) stated that at pH 1-2 the form of anthocyanin changes. Anthocyanin dominant is in the form of flavium cation which is red, at pH <6 turns into carbinol and part of it becomes quinonoidal which is blue to purple. At pH 7-9 quinonoidal is dominantly blue, and at pH > 9 the chalcone is yellow. The study of Jiang *et al.* (2019) [11], where anthocyanins, with increasing heating time, at pH 3 the red color becomes pink, at pH 5 the purple changes to yellow, and at pH 7 blue color changes into brown. Sinela *et al.* (2017) [24], reported that the brown index correlates with anthocyanin degradation. The loss of anthocyanin is always accompanied by an increase in brown color.

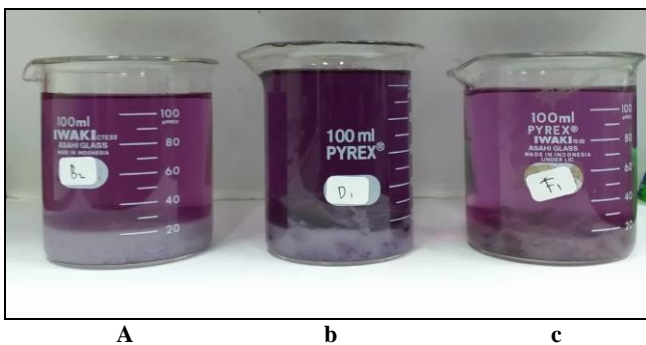


Fig 1: The Color of Sweet Potato at the pH Testing, a) Cubes Shape, b) Chips Form, c) Slices Shape

Table 2: The Effect of Size Reduction and Steaming Duration on the Color Intensity of Purple Sweet Potato

	Treatment	Average Value L	Average Value a*	Average Value b*
A	Cubes 2 x2 cm, 25 minutes steaming	31.65 ± 0.93 ^a	14.32 ± 2.00 ^a	-8.27 ± 1.28 ^a
B	Cubes 2 x2 cm, 35 minutes steaming	30.46 ± 0.90 ^a	12.63 ± 2.85 ^a	-6.66 ± 0.83 ^b
C	Chips 3 cm thick, 25 minutes steaming	23.50 ± 0.92 ^b	9.38 ± 1.91 ^b	-4.62 ± 1.69 ^b
D	Chips 3 cm thick, 35 minutes steaming	22.46 ± 0.65 ^b	9.05 ± 1.18 ^b	-5.43 ± 1.18 ^b
E	Slices 1 mm thick, 25 minutes steaming	37.62 ± 1.04 ^c	13.50 ± 0.71 ^a	-7.12 ± 0.64 ^c
F	Slices 1 mm thick, 35 minutes steaming	37.04 ± 0.61 ^c	13.40 ± 1.92 ^a	-5.63 ± 0.92 ^b

Note: Data consists of 3 replications and Standard Deviation.

Numbers marked with a small and different letter show a significant difference at the 5% level (P < 0.5).

Table 3: The Effect of Size Reduction and Steaming Duration on the Anthocyanin Content of Purple Sweet Potato

	Treatment	Average of Anthocyanin Content of (ppm)
A	Cubes 2 x2 cm, 25 minutes steaming	2914.40 ± 0.907 ^a
B	Cubes 2 x2 cm, 35 minutes steaming	3030.84 ± 0.979 ^a
C	Chips 3 cm thick, 25 minutes steaming	3773.95 ± 0.422 ^b
D	Chips 3 cm thick, 35 minutes steaming	4464.62 ± 0.677 ^b
E	Slices 1 mm thick, 25 minutes steaming	1852.12 ± 0.518 ^c
F	Slices 1 mm thick, 35 minutes steaming	2430.12 ± 0.526 ^c

Note: Data consists of 3 replications and Standard Deviation.

Numbers marked with a small and different letter show a significant difference at the 5% level (P < 0.5).

Based on data on Table 2 the treatment of size reduction forms have a significant effect on the values of L, a*, and b*, but did not give a significant effect on the steaming duration. Treatment A, C, and E in the form of size reduction of Cubes, Chip, and Slices at the steaming duration of 25 minutes gave a significant effect on the values of L, a* and b*. Likewise in treatment B, D, and F the form of size reduction of Cubes, Chips and Slices at 35 minutes steaming duration showed a significant effect on the values of L, a* and b*. However, treatments A and B, C and D, E and F for each form of size reduction at different steaming duration did not give a significant effect on the values of L, a* and b*. The desired color quality of sweet potato should have a low level of lightness, redness and yellowness because the desired quality of flour is deep purple color. According to Shaliha *et al.* (2017) [23], the higher the level of lightness, the brighter color the steamed sweet potato will be.

Based on the parameters of L, a* and b*, the size reduction of Chips form showed the highest color strength compared to the shape of Cubes and Slices, because size reduction of Chips shape has the lowest level of lightness, redness, and yellowness.

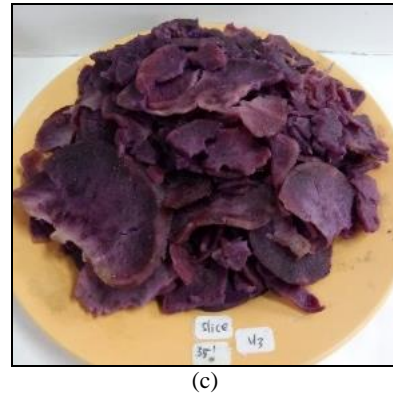


Fig 2: Purple Sweet Potato Color after 35 minutes Steaming: (a) Cubes, (b) Chips and (c) Slices



(a)



(b)

The size reduction of Chips shape showed a bluish red color which tends to be purple. This can be seen also from the pH value which is in the range of bluish red. This means the shape of the Chip pieces has a deep purple color, and it can also be seen in the parameter of the anthocyanin content. Fathinatullahbah *et al.* (2014) reported that anthocyanin color extract at L value 25.88; a* value 24,17 and b* value - 4.77 showed a deep purple color because it has a low lightness value. Figure 2 shows, the treatment of size reduction of Chips shape produces the darkest purple color between the treatment of size reduction of Cubes shape and the Slices shape, which is in accordance with the objective of the study.

The size reduction with the Cubes and Slices form has a high lightness which means the anthocyanin in that conditions it has been highly degraded. Due to the size reduction of the Cubes and Slices have a large surface area, the water vapor produced during steaming will easily absorb the material, so that the anthocyanin in the material is very easily degraded resulted in the increase of material lightness. Anthocyanin is an antioxidant compound that is not stable when exposed to heat which is in accordance with Li *et al.* (2015) [13] statement that the hydroxyl group on anthocyanin molecules can influence color instability due to heat treatment. The decrease in density of purple sweet potato is due to the temperature causing color stability and anthocyanin decomposition from aglycone to chalcone or colorless (Yudiono, 2011) [30]. However, the overall sweet potato after having steamed, has a more purple color than the fresh sweet potato. According to Truong *et al.* (2010) [28], the steaming process can activate the anthocyanase enzyme, polyphenol oxidase and peroxidase so that it does not degrade anthocyanin which causes a decrease in color quality.

The purple color of the material can be influenced by the content of anthocyanin in the material. Likewise, the results of the research on the amount of anthocyanins in Table 3, the difference in the size reduction form has a significant difference in the amount of anthocyanin, but did not significantly affect the steaming duration. The size reduction of Chips shape was significantly different from the size reduction of Cubes and Slices shape, and the shape of the size reduction of Cubes was significantly different from the Slices form. In order to produce sweet potato flour with a deep purple color, it is necessary to use sweet potato with a high amount of anthocyanin.

It can be seen that the highest amount of anthocyanin was the size reduction of Chips form with 35 minutes steaming duration which has the amount 4464.62 ppm of anthocyanin, while the lowest amount of anthocyanin, 1852.12 ppm, was the size reduction of Slices shape with 25 minutes of steaming duration. This is because the Chips shape has a small surface area, while the shape of the Slices size reduction has a large surface area. The greater the surface area, the easier the anthocyanin to degrade during the annealing immersion process, given that the anthocyanin properties dissolve with water. According to Fellow (2016), cutting too thin can reduce the active substances contained

in the material. Therefore, a good form of size reduction to maintain the anthocyanin content in the material is the size reduction of Chips form. Supported by the color intensity's value, the Chips shape of size reduction has a low value of lightness which indicates that sweet potatoes have thick purple, positive a* (redness) values which show red, and b* (yellowness) which indicate blue .

Based on the statistical tests data (Table 3), the steaming duration in each form of size reduction was not significantly different from the amount of purple sweet potato anthocyanin. This is because the range of steaming duration was too close so that it did not give a significant difference in the amount of anthocyanin in the steamed sweet potatoes. However, the amount of anthocyanin with a steaming duration of 35 minutes was higher than the steaming duration of 25 minutes in each form of size reduction. Steaming is one of the effective methods of processing food ingredients to maintain the anthocyanin content in purple sweet potatoes because it avoids existing compounds from being insoluble in heating media (Shaliha, 2017) [23]. The high anthocyanin type in the root tuber, anthocyanidin is mainly in the form of cyanidin and peonidin (Jiao *et al.*, 2012). Cyanidin gives the blue color and peonidin gives the red color (Montilla *et al.*, 2011).

Table 4: The Effect of Size Reduction and Steaming Duration on the Starch Content of Purple Sweet Potato

	Treatment	Average Starch Content (%)
A	Cubes 2 x2 cm, 25 minutes steaming	10.31 ± 0.96 ^a
B	Cubes 2 x2 cm, 35 minutes steaming	11.36 ± 1.81 ^a
C	Chips 3 cm thick, 25 minutes steaming	10.18 ± 1.54 ^a
D	Chips 3 cm thick, 35 minutes steaming	11.50 ± 1.53 ^a
E	Slices 1 mm thick, 25 minutes steaming	10.47 ± 1.80 ^a
F	Slices 1 mm thick, 35 minutes steaming	11.33 ± 1.76 ^a

Note: Data consists of 3 replications and Standard Deviation.

Numbers marked with a small and different letter show a significant difference at the 5% level (P < 0.5).

Table 5: The Effect of Size Reduction and Steaming Duration on the Degree Gelatinisation of Purple Sweet Potato

	Treatment	Average Degree of Gelatinisation (%)
A	Cubes 2 x2 cm, 25 minutes steaming	22.88 ± 3.51 ^a
B	Cubes 2 x2 cm, 35 minutes steaming	21.26 ± 1.22 ^a
C	Chips 3 cm thick, 25 minutes steaming	14.68 ± 1.63 ^b
D	Chips 3 cm thick, 35 minutes steaming	13.04 ± 2.25 ^b
E	Slices 1 mm thick, 25 minutes steaming	32.35 ± 2.95 ^c
F	Slices 1 mm thick, 35 minutes steaming	40.20 ± 3.15 ^d

Note: Data consists of 3 replications and Standard

Deviation

Numbers marked with a small and different letter show a significant difference at the 5% level (P < 0.5).

Statistical data tests on Table 4, showed that the shape of the size reduction and steaming duration did not give a significant effect on the starch content of purple sweet potato. Furthermore, whatever the form of size reduction and no matter of how long the steaming duration, they did not give any significant effect on the starch content of sweet potato. It is known that starch consists of two fractions, namely amylose and amylopectin. Both fractions play a role in determining the physical, chemical, and functional characteristics of starch. Amylose is a water soluble starch fraction, while amylopectin is a water insoluble fraction (Winarno, 2004) [29]. Amylose contributes to the characteristics of the gel because the presence of amylose affects gel formation, while amylopectin plays a role in preventing intermolecular interactions resulting in a soft gel

(Hee, 2005) [9].

Purple sweet potato before steaming was modified by annealing. Starch modification by annealing includes physical starch modification. Annealing modification is a physical treatment of starch granules with excess water (>65% w/w) or moderate water (40-55% w/w) at temperatures below the gelatinization temperature at a certain time. Annealing modification aims to improve the characteristics of natural starch which tends to be less stable towards the heating process, mechanical processes, and not resistant to acid (Oktavianti and Putri, 2015) [18].

Based on the analytical results, size reduction of chips form with 35 minutes steaming duration has the highest starch content of 11.50%, which was the best treatment. According to Ginting *et al.* (2015) [8], sweet potatoes which have a thick flesh of purple color actually have a higher starch content, making it suitable for processing into flour.

Based on the statistical tests on Table 5, the size reduction

form showed a significant effect on the degree of sweet potato gelatinization. The treatment of A, C, and E for each form of size reduction at 25 minutes gave significantly different results, also treatment B, D, and F each form of size reduction at 35 minutes steaming duration showed a significantly different result. This is because the surface area of each material is different. The greater the surface area of the material, the higher the degree of gelatinization produced.

The highest degree of gelatinization was the Slices form of size reduction, this is due to the large surface area of the Slices which causes water vapor to easily absorb into the material and is quickly absorbed into the amorphous region. According to Jie *et al.* (2011), the absorption of water into materials as big as 5–40% causes starch gelatinization to take place in two stages. The first stage was helical dislocation of amylopectin and then helical coil transition (melting). The second stage was an opening of amylopectin helix that forms an amorphous gel. Water absorbed in the amorphous region causes starch granules to lose the stability of their crystalline structure and thus lose the nature of birefringence (Ratnayake and Jackson, 2006) [21]. More amylose comes out from the starch granules during the gelatinization process causes the high degree of gelatinisation. The form of Chips of the size reduction has only a small surface area so it is difficult to absorb water vapor, causing the lower degrees of gelatinization makes the gelatinization process was not perfect.

Water content of starch suspensions below 60% will cause melting of crystalline amylopectin, loss of birefringence and partial morphological deformation of starch granules (Crowther, 2012) [4]. Daomukda *et al.* (2011) [5] stated that gelatinization of starch requires excess water into the material so that intermolecular bonds of starch (hydrogen bonds) are broken. The size and number of crystalline regions of starch decreases and water can diffuse into this area, dividing the crystalline area into amorphous regions.

The difference of steaming duration in the form of Cubes and Chips did not give a significant different result, but the steaming duration in the form of Slices showed significantly different results. The heating time for 35 minutes produces a high degree gelatinization in the form of slices from the size reduction. Taewee (2011) [27], explained that the ability of steaming process to produce a perfect gelatinization depends on the temperature and time of steaming. According to Chuang and Yeh (2004) [1], the residence time increases with the degree of gelatinization. Low gelatinization levels cause weak bonding of structures on the surface of the material, making more amylose is released when the ingredients are cooked and the adhesiveness of the material increases (Chaudary *et al.*, 2008) [2].

4. Conclusions

Purple sweet potato with various treatments of size reduction and steaming duration showed a significantly effect on the color intensity and the amount of anthocyanin, but did not give a significantly effect on the pH value and starch content. The size reduction treatment in Chips form with 35 minutes steaming duration produces sweet potatoes with the best characteristics, having a pH value of 6.61, L color intensity of 22.46; a* 9.05 and b* -5.43. The amount of anthocyanin was 4464.62 ppm (mg/kg), total starch was 11.5% and degree gelatinisation 13,04%. Furthermore, it can be concluded that in the making of purple sweet potato

flour to produce flour with a deep purple color, the best treatment was a Chips shape size reduction and 35 minutes steaming duration.

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