Selected purple-fleshed sweet potato genotypes with high anthocyanin contents

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Abstract. Purple-fleshed sweet potato with high anthocyanins is beneficial to health due to its antioxidant activity. Therefore, 13 promising genotypes of purple-fleshed sweet potato and two improved varieties as checks (Antin 2 and Antin 3) were studied their physical, chemical and sensorial characteristics. The results showed that the flesh colors ranged from red-purple, deep purple to white purplish and their lightness values (L*) negatively correlated with anthocyanin contents ($R^2 = 0.65$). Six promising genotypes contained anthocyanins >100 mg/100 fw with the highest value observed in RIS 10051-01 (155.47 mg/100 g fw) that was similar to Antin 2. Antin 3 showed the highest content of anthocyanins among all genotypes (177.48 g/100 g fw). MSU 10002-05 and MSU 10010-43 genotypes had higher dry matter contents (33.43% and 37.85%) than Antin 2 and Antin 3, suggesting their promising use for flour processing. High anthocyanins is normally associated with a bitter taste, however the steamed tubers of two deep purple genotypes, namely MSU 10010-43 and Antin 3 and one white purplish genotype (MSU 10001-15) were fairly liked for their color, texture and taste attributes, hence they are tailored for steamed food purposes. This information supports the breeder to release a new variety of purple-fleshed sweet potatoes.

1. Introduction
The interest in purple-fleshed sweet potato containing anthocyanins has been increasing in recent years due to its benefits for human health. Sweet potato anthocyanins have antioxidant and free-radical scavenging capacities [1,2] that may prevent aging, cancer and degenerative diseases, such as atherosclerosis and arthritis [3,4]. Anthocyanins also have physiological functions as antimutagenic, hepatoprotective, antihypertensive, antihyperglycemic, antimicrobial, anti-inflammatory and antiobesity [5,6,7,8]. In addition, anthocyanins in sweet potato showed high stability to heat treatments and UV irradiation, which is desirable for food ingredients and natural food colorant [5,9]. Sensitiveness of anthocyanins to pH changes makes them also promising to be used as smart food packaging materials as a visual color indicator for spoiled food products [10].

Anthocyanins with the major components of peonidin and cyanidin have been identified in purple-fleshed sweet potato, which is acylated with caffeic, ferulic and p-hydroxy-benzoic acid [11,12]. These acylated forms give advantages to heat and light stability as well as antioxidant activity [4]. A wide range of anthocyanins was reported in different purple-fleshed sweet potato cultivars that ranging from 60 mg/100 g fw in Ayamurasaki, a Japanese cultivar [5] up to 243 mg/100 g fw in a Peru’s Cultivar [13]. Anthocyanin contents of 1.86 mg up to 123.92 mg/100 g fw were observed in 12 purple-fleshed sweet
potato cultivars grown in Indonesia [14]. The purple color intensity of the flesh highly correlated with the anthocyanins content [15].

Three purple-fleshed sweet potato varieties, namely Antin 1, Antin 2, and Antin 3 have been released by The Indonesian Ministry of Agriculture, which contains anthocyanins 8.4 mg, 130.2 mg, and 150.7 mg/100 g fw, respectively [16]. Breeding activities are yet being performed to improve the agronomic characters and anthocyanins content as well as the sensorial attributes in order to enhance the adoption by farmers and utilization by food industries. Currently, about 89% of sweet potato is used for foods [17]; however, the products are limited to traditional foods. Therefore, the presence of anthocyanins in purple-fleshed sweet potato needs to be promoted as a functional food to increase both the consumption level and a variety of sweet potato based-food products. This study aimed to identify the physical and chemical characteristics as well as sensorial attributes of promising purple-fleshed sweet potato genotypes in terms of supporting the utilization of selected genotypes once they released as new varieties.

2. Methods
Fifteen purple-fleshed sweet potato genotypes, including Antin 2 and Antin 3 varieties as checks were grown in Ponokusumo, Malang and harvested after 4.5-month planting. The study was performed at the Food Chemistry Laboratory of Iletri, Malang and arranged using a randomized complete design with 3 replicates. Observations were done for Hunter colours (L*, a*, b*) of the fresh tuber flesh using a colour reader Minolta CR-200b, and chemical composition, including dry matter and moisture contents (gravimetry) according to SNI 01-2891-1992 [18], reducing sugar and starch contents (Nelson-Somogy method and acid hydrolysis) as referred to [19]. The anthocyanins content was analyzed using the method employed by [20] for extraction procedures and [21] for measurement (pH-different method) at \( \lambda = 520 \text{ nm} \) and \( \lambda = 700 \text{ nm} \). Total anthocyanins (mg/100 g) were calculated equivalent to cyanidin 3-glycoside. ANOVA was used for data analysis and followed by an LSD test to check the differences between genotypes. The sensorial attributes of the steamed tubers, such as color, texture, and taste were also observed using a Hedonic test with 20 panelists.

3. Results and discussion
3.1. Physical and chemical characteristics of fresh sweet potato tuber
The flesh tuber colors varied from white purplish, red-purple to deep purple (Table 1), depending upon the component of anthocyanins that may have blue, red and purple colors. Peonidin and cyanidin are the major anthocyanin components in sweet potato and the flesh would give red-purple color if the proportion of peonidin > 1, while it would be purple-blue or grey if cyanidin is predominant [4,15]. MSU 10001-32 genotype had the highest lightness (L*) value (white purplish flesh), while RIS 10043-02 and Antin 3 showed the smallest L* value (deep purple) (Table 1). The L* values of both genotypes were slightly smaller (deeper purple) than that of MSU 06028-71 genotype (37.10) [14]. However, Leksrisompong et al. [22] observed smaller L* values (15.3 to 19.4) in three purple genotypes from North Carolina, USA. The range of L* values (35.57-52.63) was smaller than those of purple-fleshed genotypes (37.10-77.07) reported by Ginting et al. [14], suggesting that more deep purple genotypes obtained at present study. Deep-purple genotypes are suitable for flour ingredient and natural colorant, while for making snacks, noodles, juice, and jam, the red-purple genotypes are preferred [23].

The anthocyanin content negatively correlated with the lightness value (L*) with \( R^2 = 0.65 \) (Figure 1). The smaller the L* value, the deeper the purple color of the flesh, the higher the content of anthocyanins as seen in Antin 3 variety (Table 1 and 2). The redness (a*) showed a positive correlation with anthocyanins content \( (R^2 = 0.44) \), while the yellowness (b*) had no correlation. This reflects that the red color contributes more to anthocyanins content rather than the yellow color, particularly for those contained more peonidin than cyanidin [15]. Therefore, L* and a* values can be used for breeding activity, which normally working with lots of samples to rapidly estimate the anthocyanin content in purple-fleshed sweet potato.
Three genotypes had high moisture (>73.5%) as presented in Table 2, nine genotypes were medium, including Antin 2 and Antin 3 as checks, while three genotypes contained low moisture (<65.5) referring to [14]. RIS 10043-02 showed the highest moisture content (77.94%), while the lowest value was seen in MSU 10001-15 and MSU 10002-05. Ginting et al. [14] noted a slightly lower moisture range in 12 purple-fleshed genotypes (60.1-75.9%). Such differences in moisture content may be due to genotype, growing conditions, and harvesting time (maturity and dry or wet season). Sweet potato with moisture content >70% normally has moist and tender texture when boiled or steamed, while those with moisture content <60% give dry or floury texture [24].

### Table 1. The flesh colors of 15 purple-fleshed sweet potato genotypes.

| Genotype      | Visual color | Hunter colors |
|---------------|--------------|---------------|
|               | L* a* b*     |               |
| RIS 10043-02  | Deep purple +++ | 36.70 gh 33.63 g 11.20 def |
| RIS 10053-01  | Red purple +  | 40.53 cd 44.10 bc 11.90 cde |
| RIS 10051-01  | Red purple +  | 40.03 de 43.50 bcd 10.63 f |
| MSU 10001-32  | White purplish + | 52.63 a 53.90 a 10.83 ef |
| MSU 10001-15  | White purplish ++ | 42.87 b 46.33 b 10.33 f |
| MSU 10002-05  | Deep purple +++ | 38.47 ef 38.47 ef 12.30 bcd |
| MSU 1003-06   | White purplish ++ | 41.67 bc 39.30 def 10.67 f |
| MSU 1003-07   | Deep purple   | 43.13 b 44.23 bc 14.47 a |
| MSU 10008-35  | Deep purple +  | 40.13 cd 38.93 ef 11.10 def |
| MSU 10010-43  | Deep purple +  | 40.57 cd 43.73 bc 12.67 bc |
| MSU 10010-50  | Deep purple ++ | 38.47 ef 42.20 bcde 10.87 ef |
| MSU 10018-40  | Deep purple   | 42.53 b 41.33 cde 13.43 ab |
| MSU 10021-26  | Deep purple +++ | 37.97 fg 41.13 cde 10.67 f |
| Antin 2       | Red purple +  | 40.80 cd 42.17 bcde 11.10 def |
| Antin 3       | Deep purple +++ | 35.57 h 35.57 fg 10.23 f |

Values followed by the same letters are not significantly different (P< 0.05)

L*: lightness level that ranges from 0 (dark/black) to 100 (light/white)
a*: green (–100) up to red (+100)
b*: blue (–100) up to yellow (+100)
+ = deeper purple color

![Figure 1](image1.png)  
**Figure 1.** The relation between lightness (L*) and anthocyanins content of 15 purple-fleshed sweet potato genotypes.

![Figure 2](image2.png)  
**Figure 2.** The relation between moisture and dry matter contents of 15 purple-fleshed sweet potato genotypes.

The dry matter contents were significantly different between genotypes with the highest value obtained in MSU 10001-15 genotype (38.96%), while RIS 10043-02 had the lowest value (20.71%) as presented in Table 2. This was in agreement with the lowest and highest moisture content in both
genotypes as both were negatively correlated with $R^2 = 0.98$ (Figure 2) as also noted in 12 purple-fleshed sweet potatoes with $R^2 = 0.88$ [14]. Four genotypes had dry matter contents higher than those of Antin 2 and Antin 3 varieties and three of them contained considerably high dry matter (>35%), even higher than Jizi 01 variety from China, c.a. 31.8% [25], indicating their potential use for flour and starch ingredients. Starch is the predominant component (60-70%) of the dry matter [26], thus genotypes with high dry matter contents would give high recovery in flour and starch processing.

Table 2. Chemical composition of 15 purple-fleshed sweet potato genotypes.

| Genotype     | Moisture (%) | Dry matter (%) | Reducing sugar (% $dw$) | Starch (% $dw$) | Anthocyanins (mg/100 g $fw$) |
|--------------|--------------|----------------|-------------------------|----------------|-------------------------------|
| RIS 10043-02 | 77.94 a      | 20.71 m        | 4.13 d                  | 52.86 j        | 142.12 de                     |
| RIS 10053-01 | 65.68 hi     | 35.20 c        | 4.99 c                  | 62.03 efg      | 83.54 i                       |
| RIS 10051-01 | 72.81 d      | 27.73 i        | 4.96 c                  | 64.35 cd       | 155.47 bc                     |
| MSU 10001-32 | 74.08 c      | 26.50 k        | 4.88 c                  | 61.39 fg       | 27.01 l                       |
| MSU 10001-15 | 62.32 j      | 38.96 a        | 4.99 c                  | 70.49 a        | 72.81 j                       |
| MSU 10002-05 | 62.54 j      | 37.85 b        | 1.90 g                  | 64.14 cde      | 139.37 c e                    |
| MSU 10003-06 | 69.93 f      | 31.88 e        | 5.84 b                  | 63.80 cde      | 91.90 h                       |
| MSU 10003-07 | 70.23 f      | 30.46 g        | 2.82 e                  | 62.93 def      | 53.55 k                       |
| MSU 10008-35 | 73.08 d      | 27.04 j        | 5.73 b                  | 58.47 hi       | 81.30 i                       |
| MSU 10010-43 | 66.27 h      | 33.43 d        | 2.34 f                  | 65.17 c        | 103.83 g                      |
| MSU 10010-50 | 71.27 e      | 28.85 h        | 2.69 ef                 | 62.64 def      | 112.31 f                      |
| MSU 10018-40 | 74.77 b      | 25.69 l        | 7.56 a                  | 59.59 gh       | 68.19 j                       |
| MSU 10021-26 | 65.30 i      | 31.09 f        | 5.76 b                  | 69.85 a        | 148.61 cd                     |
| Antin 2      | 68.94 g      | 30.10 g        | 4.44 d                  | 57.31 i        | 157.66 b                      |
| Antin 3      | 65.85 hi     | 33.08 d        | 2.86 e                  | 67.40 b        | 177.48 a                      |

Values followed by the same letters are not significantly different ($P < 0.05$).

$dw$ = dry weight, $fw$ = fresh weight

MSU 10018-40 genotype exhibited the highest reducing sugar content (7.56% $dw$), while MSU 10002-05 had the lowest value (1.90% $dw$) (Table 2). The reducing sugar content of MSU 10018-40 was fairly high (> 6.8% $dw$), whilst nine genotypes had medium values and five genotypes were low (3.9% $dw$) [14]. Eight genotypes had reducing sugar contents higher than that of Antin 2, one genotype was similar, while two genotypes were lower than Antin 3, suggesting this set of promising genotypes mostly had higher reducing sugar than those of the check varieties. These values were also much higher than the reducing sugar contents of 12 purple-genotypes that ranged from 0.9-4.4% $dw$ [14].

Genotypes significantly dictated the starch content that ranged from 52.86% $dw$ (RIS 10043-02) to 70.49% $dw$ (MSU 10001-15) as seen in Table 2. The starch content positively correlated with the dry matter content with $R^2 = 0.69$ (the data are not shown), indicating that the dry matter content can be quantitatively used to predict the starch content. A similar phenomenon was also revealed by [27] in 240 sweet potato clones with $r > 0.8$. Two genotypes had higher starch content relative to Antin 3 and 10 genotypes were higher than that of Antin 2, while only one genotype contained lower starch than those of both varieties, reflecting their suitability for flour and starch processing purposes.

The anthocyanin contents were significantly different between sweet potato genotypes, ranging from 27.01 mg (MSU 10001-32) to 177.48 mg/100 g $fw$ (Antin 3) as presented in Table 2. No one of 13 promising genotypes had anthocyanins content higher than Antin 3; however, RIS 10051-01 showed similar content to that of Antin 2. About six promising genotypes had anthocyanin contents > 100 mg/100 g $fw$, reflecting that they are rich in anthocyanins and potential for healthy food ingredients and natural colorant [28]. Ginting et al. [14] reported that only two among 12 purple genotypes contained anthocyanins 110.26 mg and 123.92 mg/100 g $fw$. In fact, the anthocyanin contents of Antin 2 and Antin 3 in this study were higher than those listed in the variety description that was 130 and 150 mg/100 g $fw$, respectively [16]. Growing conditions, particularly altitude that would dictate the levels of light and
temperature, planting season, fertilization and harvesting time may contribute to such differences in anthocyanin contents [29].

Three genotypes with white purplish-fleshed colors also contained considerably higher anthocyanins relative to that of Antin 1, a white purplish variety with anthocyanins content 7.96 mg/100 g fw [14]. These genotypes are suitable for ingredients of deep-fried chips [23]. The anthocyanin contents obtained in this study were lower than those observed in purple sweet potatoes originated from Peru and US (243 mg/100 g fw and 210 mg/100 g fw, respectively) as reported by Cisneros-Zevallos and Cisneros-Zevallos [13] and Truong et al. [30]. However, the values were within those of purple sweet potatoes noted by previous researches [5,31,32,33] c.a. 60 mg, 84-174 mg, 101,83 mg, and 85-90 mg/100 g fw, respectively.

3.2. Sensorial attributes of the steamed tubers

The colors of steamed tubers derived from eight genotypes were fairly liked, including Antin 2 and Antin 3, while seven genotypes were slightly liked (Figure 3). Among six promising genotypes with anthocyanin contents > 100 mg/100 g fw, only MSU 10010-50 and MSU 10010-43 genotypes had good scores of color acceptance. Anthocyanins are not stable against heat that would considerably degrade with the elevated temperature of 80-100 °C [34]. This associate with the color change/reduction due to opening the pyrylium ring of anthocyanins and chalcone formation (colorless). Organic acids and sugars may also be degraded during thermal processing that leads to anthocyanins transformation into brown compounds [35]. This consequently would influence the color acceptance of the steamed tubers. The extent of color changes are highly dictated by the chemical structures of anthocyanins in the state of mono, di or non acylated with phenolic acids, number, and type of sugar and organic acid attached as well as heating conditions [34]. A decrease of anthocyanins up to 50% was reported during steaming for 10 min. at 121°C [12].

![Figure 3. Sensorial attributes of the steamed tubers of 15 purple-fleshed sweet potatoes.](image)

Acceptance score: 1 = Dislike very much, 2 = Dislike moderately, 3 = Like slightly, 4 = Like moderately, 5 = Like very much

Figure 3. Sensorial attributes of the steamed tubers of 15 purple-fleshed sweet potatoes.

The texture of steam tubers varied from being disliked to fairly liked (Figure 3). Antin 3 was fairly liked due to its mealy or dense texture, similar to those of five promising genotypes in which two genotypes, namely MSU 10002-05 and MSU 10010-43 contained anthocyanins > 100 mg/100 g fw. Meanwhile, Antin 2 which had softer texture was slightly liked as well as the other seven genotypes and one genotype was disliked (fairly soft/moist). High moisture contents of the fresh tubers may contribute to such soft/moist texture after steaming [24]. Taste as highly affected by the aroma, sweetness, and texture were ranging from being disliked to fairly liked (Figure 3). High scores were noted for Antin 3, MSU 10001-15 and MSU 10010-43, while
others were mostly similar to Antin 2 (slightly liked). Purple sweet potato normally has a bitter taste and astringent mouthfeel [22] due to anthocyanins and phenolic compounds. This suggests that steamed purple sweet potato is not tailored for direct consumption and more suitable if the subsequent mashed tuber is used for making sauce, juice, noodle, jam, cake and snacks [23]. However, to some extent such taste can be neutralized by the presence of sugars, both as an initial sugar in the fresh tubers and as a result of α-amylase activity during steaming [36], giving different levels of sweetness between genotypes. The overall evaluation showed that the steamed tuber of MSU 10001-15 gave the highest scores for color, taste, and texture, followed by MSU 10010-43 and Antin 3, while RIS 10043-02 had the lowest acceptance (Figure 3).

4. Conclusion
Among 15 genotypes studied, eight genotypes contained considerably high anthocyanins (>100 mg/100 fw) and Antin 3 variety exhibited the highest value. One promising genotype, namely RIS 10051-01 had anthocyanins content 155.47 mg/100 g fw, similar to that of Antin 2 variety. MSU 10010-43 and MSU 10002-05, the deep purple genotypes showed high dry matter contents c.a. 33.43% and 37.85% that was higher than Antin 3, suggesting their suitability for flour processing. The steamed tubers of MSU 10001-15, MSU 10010-43 and Antin 3 genotypes gave the highest scores for color, texture, and taste acceptance. These characteristics are essential for the selection of variety releases in addition to their superior agronomic characters.

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