PROGRESS IN COLOR, COLORANTS AND COATINGS

available online @ www.pccc.icrc.ac.ir

Prog. Color Colorants Coat. 13 (2020), 41-51

Ministry of Science, Research and Technology
Institute for Color Science and Technology

Study of Drying Method Types on the Physicochemical Characteristics of Purple-Fleshed Sweet Potato Extract Powder

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ARTICLE INFO

Article history:
Received: 12 Dec 2018
Final Revised: 22 Jun 2019
Accepted: 23 Jun 2019
Available online: 22 Jul 2019

Keywords:
Anthocyanin
Drying
Purple sweet potato
Physicochemical Characteristics.

ABSTRACT

The purpose of this study was to obtain the best anthocyanin pigment extract powder from 3 types of drying process, vacuum drying, spray drying, and freeze-drying. The duration and temperature for each type of drying process are 15 h with temperature of 40 ^oC, 2 h with temperature of 120 ^oC (inlet) and 60 ^oC (outlet), 24 h with temperature of -50 ^oC respectively. This research used the Randomized Block Design method consisting of three treatments with four replications. If there is a significant difference between treatments, the test is continued with the Duncan test. Three drying methods, namely: Treatment A = Vacuum Drying, Treatment B = Spray Drying, Treatment C = Freeze-drying. The Freeze-drying method produces the best characteristics with total anthocyanin 121.63 mg/100 g (DB), color intensity L (brightness) 64.20, a* (redness) 65.60, b* (yellowness) 18, 52, water content 5.00%, hygroscopicity 12.87%, solubility 97.21%, dissolution time 151 seconds, pH level 2.93, yield 28.69%, and PSA 0.95 µm. Based on the experiment's result, freeze-drying method was the most suitable parameter for physiochemistry characteristic. It has the highest amount of anthocyanin, the highest antioxidant activity, and the smallest amount of PSA (Particle Size Analyzer). Prog. Color Colorants Coat. 13 (2020), 41-51© Institute for Color Science and Technology.*

1. Introduction

Purple sweet potato is a food crop found in many areas of Indonesia. It is rich in antioxidants because it contains anthocyanin pigments. Sweet potato plants is one of the carbohydrate-producing plants, fourth after rice, corn and cassava [1]. Sweet potatoes can grow well and give benefits if the climate requirements are appropriate during their growth. The growth temperature ranges from 10-40 °C and the optimum temperature is 21-27 °C [2]. Sweet potato plants *(Ipomoea batatas L.)* are food crops and belong to the ubiquitous group from Latin America [3]. Sweet potatoes, in plant systematics (taxonomy), are classified as follows: Division of Spermatophyta (seed plants), Subdivision of Angiosperms (Closed plants), Class of Dicotyledon (Seeds with two pieces), Order of Convolvulales, Family of Convolvulaceae, Genus Ipomoea, Species *Ipomoea batatas L. Sin batatas edulis choisy*. Sweet potatoes are classified as seasonal (short-lived) cassava plants. Farmers in Indonesia cultivate sweet potato plants because they have a short harvest time, around 3-4 months. This plant grows on the ground surface with a plant length up to 3 meters, depend on the variety [4].

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Pigments are substances that found on the surface of an object so that when illuminated with perfect white light will give a certain sensation of color that can be captured by the eye. Nowadays, the use of synthetic dyes that are not permitted is widely used by producers, including rhodamine B and methane yellow because it has a relatively cheap price, high stability of light, pH, temperature, and oxygen, more attractive appearance, and has good color uniformity [5]. The dye that produced from the extraction process has liquid concentrates form, which has disadvantages, namely the short shelf life of extracts [6]. Drying is a method to remove or excrete some water from material by evaporating water using heat energy. Usually, the water content is reduced to a limit so that microbes cannot grow in it [7].

The good drying method for pigment powder is using a not too high temperature, with maximum heating permits (<60 °C) and even and fast drying process [8]. The drying method can be chosen based on economic considerations and the nature of raw materials. One of the simple and appropriate drying tools for drying pigments is vacuum ovens [9].

Vacuum drying oven method at temperature of 40 °C produced pigment powder of purple sweet potato that has a water content of 1.18%, colored red with color intensity (a^*) 32.32, soluble time 103.17 s, and hygroscopicity 10.70 % [10]. Based on preliminary experiments, the drying time of anthocyanin extract into pigment powder using a vacuum oven at temperature of 40 °C for a minimum of 18 h to produce the characteristic of red pigment powder. Comparison between extract of blanching cassava and non-blanching clitoria flower that can produce the highest total of anthocyanin. The addition of 10% of maltodextrin, 24 h maceration time, and acidified aquades with tartaric acid ratio of 1:5 in a vacuum oven for 15 h at 40 °C can produce the best physicochemical characteristics with total anthocyanin of purple sweet potato and cliteria flower in the amount of 53.02 mg/L and 48.43 mg/L [2].

The process of spray drying on anthocyanin encapsulation of purple sweet potato, affected by inlet temperature and the percentage of maltodextrin. Optimization of those process used RSM with the CCD method, produced the best condition at temperature of 96 °C and 5% of maltodextrin. This data can be used for preparing anthocyanin powder of purple sweet potato commercially, using spray drying technology. The novelty of this study is that the sweet potatoes used in this study were purple sweet potato from the result of Unpad breeding, extraction using ultrasound, and freeze-drying which resulted in nanoparticle-sized powder. Therefore, this research aims to produce natural dyes that come from micro-sized purple sweet potatoes, the stability of the color depends on good pH and temperature, and has a long shelf life.

2. Materials and Methods

2.1. Research Materials and Tools

The main raw material used was purple-Fleshed sweet potato BIANG variety (Figure 1). The supporting raw materials used are aquades, 1% tartaric acid, filter cloth, and aluminum foil. The analysis materials used were potassium chloride buffer solution (0.025 M) pH=1, sodium acetate buffer solution (0.4 M) pH=4.5, concentrated acetic acid and HCl, maltodextrin. While the tools used are pH meters, oven blowers, desiccators, analytical scales, aluminum plates, krustang, digital UV-Vis spectrophotometers, cuvettes, stirring rods, 100 mL beaker glass, 5 mL measuring pipettes, 10 and 25 mL volumetric flasks, vials glass, laptop, and camera. The tools used are analytical scales, knives, cutting boards, boilers, blenders, magnetic stirrers, a set of centrifugation devices, beaker glass, spatulas, rotary evaporators, vacuum drying, spray drying, freeze-drying, grinder, baking sheet, aluminum foil, and basin.

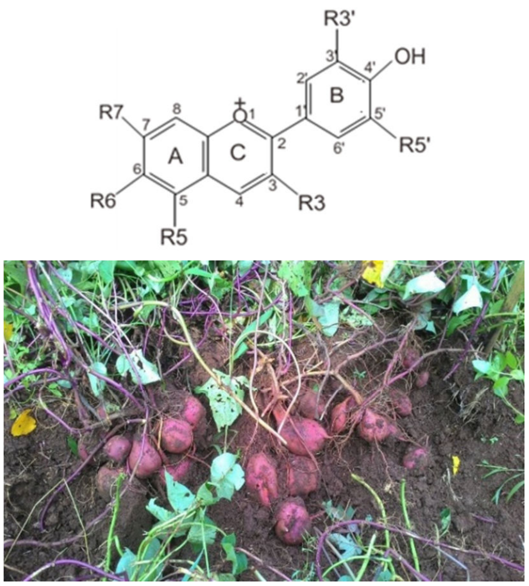

Figure 1: Purple sweet potatoes and basic structures of kation flavylium (antosianidin).

2.2. Research methods

The research method used in the experimental method was Randomized Group Design consisting of three treatments with four replications. If there is a significant difference between treatments, the test is continued with the Duncan test. The drying methods, namely: 1) Treatment A = Vacuum Drying, 2) Treatment B = Spray Drying and 3) Treatment C = Freeze-drying (Figure 2).

1) Observation criteria: a) Color intensity using Spektrofotometer CM-5, b) Level of hygroscopicity, c) Solubility, d) Soluble time; 2) Chemistry characteristics: a) Anthocyanin concentrate using pH-Differential-Lambert Beer method, b) Water content, c) pH using a pH meter, d) Antioxidant using DPPH method (Without statistic test); 3) Rendemen and 4) Measurement of particle diameter and SEM.

The particle diameter of result solution from grinding and squeezing was measured by Particle Size Analyzer (PSA) with Beckman Coulter brand that conducted at Nano Center of Universitas Padjadjaran Jatinangor, Sumedang. PSA's characterization was carried out at temperature of 25 °C using air solvents, a refractive index of 1.3328, and viscosity degree of 0.8878 cP. After the drying process with vacuum drying machines, spray drying, and freeze-drying, the powder obtained was measured again with particle size testing instruments PSA (Particle Size Analyzer) and SEM (Scanning Electron Microscope).

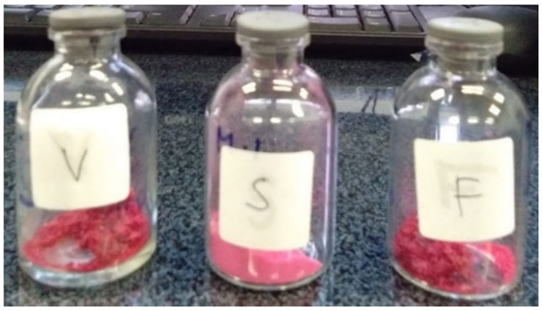

Figure 2: Purple sweet potato extract powder.

2.3. Research Procedure

This research aims to determine the type of drying method that is optimal for the extractive characteristics of encapsulated powder of anthocyanin. The following are the stages of activities carried out in the study. The process of making extracts of purple sweet potato anthocyanin powder explained was presented in Figure 3.

Before doing the first step, pure-bred purple sweet potato was blanched with ultrasound for 120 minutes, which has been damaged and separates parts that cannot be eaten like tuber skin. After that, washed the purple sweet potato by flowing clean water and then drained and weighed 500 grams to determine the yield of pigment powder.

The size reduction is using a knife. Slicing was carried out longitudinally with a thickness of ± 1 cm sweet potato slices. Extraction of blanched-with-120-minutes-ultrasound purebred purple sweet potato. After blanching, the sweet potato is mixed with the extracting solution, which is aquades and 1% tartaric acid with a ratio of ingredients and extracting solution is 1:5. Extraction is carried out aimed at removing pigment compounds from the tissue material. Extraction using ultrasound method with three treatments of maceration time, namely 1, 3, and 6 hours. The sweet potato slurry is carried out using a magnetic stirrer at room temperature.

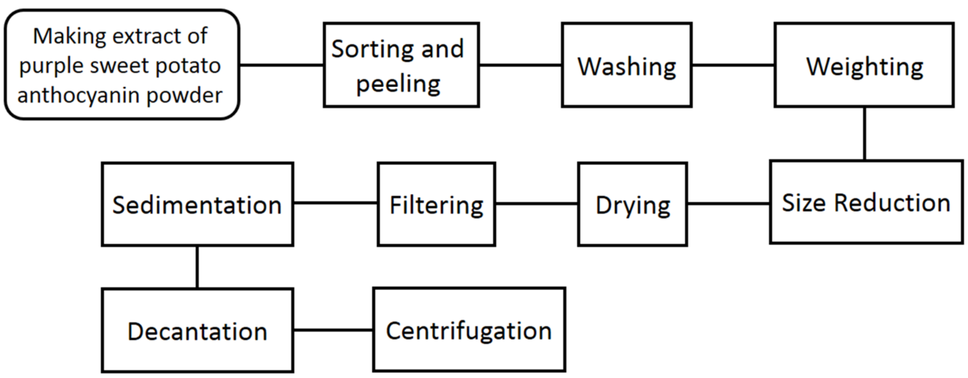

Figure 3: Diagram of process of making purple sweet potato anthocyanin's extract powder.

The drying process was done in blower oven for 15 h with temperature of 60 ^{o}C. Before doing the drying method, the purple sweet potato was steamed for 15 min.

The filtering of purple sweet potato was done to separate the pigment compounds produced during extraction with starch which is still mixed with sweet potato pulp. After the screening process, the filtrate in the form of pigment and sediment in the form of starch is obtained. The filtration process has not been able to separate the starch as a whole which is still mixed in the pigment filtrate so that it needs to be settled for 12 hours at room temperature.

Next, decantation aims to separate the constituent mixture in the form of liquid and solids. The principle of decantation is the difference in the form of matter in a mixture, which is between solids and liquids so that by using decantation techniques, liquids can be separated from the mixture. Last, centrifugation aims to separate the liquid pigments and solids in the form of starch because of the centrifugal force. The principle of centrifugation is that the material is inserted into a centrifuge tube and then rotated in a centrifuge device. Centrifugation was carried out at a speed of 5000 rpm for 15 minutes at room temperature.

The process of making pigment powder is encapsulated with the following stages of activity was showed in Figure 4. The first step is concentration. Concentration aims to increase the concentration of pigment compounds by evaporating as much as 50% of the solvent by vacuum using a rotary evaporator. The concentration process is carried out at temperature of 50 °C until V = ½ Initial volume and produces concentrated anthocyanin extract. After that, mix with DE 10-12 maltodextrin. The process of mixing concentrated extracts with dextrins (encapsulation) was carried out using a magnetic stirrer until homogeneous. Encapsulation aims to protect active compounds from oxidation damage and increase the solubility of pigment powder. Maltodextrin used in DE 10-12 maltodextrin mixed with 10% of the total solids and batch mills for 30 minutes. The next step is the drying process. Drying was carried out using a VWR Scientific vacuum oven with a pressure of 25 in Hg at the temperature according to treatment (to produce dry pigment extract). Smoothing aims to facilitate handling when dissolved in water. Smoothing is carried out using a grinder for 15 seconds to produce fine textured pigment powder, then in ball mills and meshed with 400 mesh.

3. Results and Discussion

3.1. Color Measurment

Based on the results of the statistical test, it shows that the effect of the drying method of the anthocyanin pigment powder of purple sweet potato, dried cassava blanching, has a significant effect on the color produced. The results of statistical tests can be seen in Table 1. According to the Duncan test at the level of 5%, the treatment of the drying method using the vacuum, spray and freeze method gave significantly different results for the value of L* from the anthocyanin pigment. The brightness value (L*) shows the brightness intensity, where the higher the L* value indicates the higher the brightness intensity. The highest average L* value in the drying method treatment using the freeze method is 64.20 and the lowest in the vacuum method is 44.56, the change in the resulting value is significant. the value of a* is the intensity of red color with the treatment of vacuum drying method, spray and freeze which gives significantly different results to the value of a* of the anthocyanin pigment.

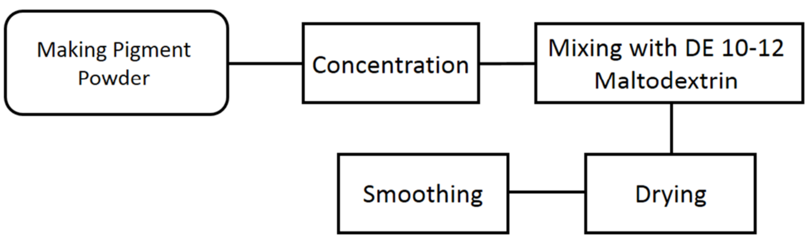

Figure 4: Diagram of process of making pigment powder.

Table 1: Anthocyanin pigment color value in purebred purple sweet potato analysis.

Treatment	L*	a*	b*
Vacuum	44.56 ± 0.153	35.91 ± 0.070	20.64 ± 0.405
Spray	59.18 ± 0.201	48.16 ± 0.033	20.69 ± 0.116
Freeze	64.20 ± 0.196	65.60 ± 0.205	18.52 ± 0.170

Description: The same letter shows no significant difference at the level of 5% according to the Duncan test.

The redness value (a*) shows the brightness intensity, where the higher the value of a* indicates the higher the brightness intensity. The highest average a* value in the drying method treatment using the freeze method is 65.60 and the lowest in the vacuum method is 35.91, the change in the resulting value is significant. The value of b* is the intensity of the yellow color produced on the treatment of vacuum, spray and freeze-drying anthocyanin pigment extract powder. The higher the value of b* indicates the higher the intensity of yellow color. Based on the 5% level test, the average value of b* on 30 minutes ultrasound was significantly different from the value of b* on ultrasound 60, 90 and 120 minutes. The highest b* value on ultrasound 120 minutes and the lowest value b* obtained on ultrasound 30 minutes. The longer the ultrasound time shows the intensity of the yellow color increases.

3.2. Water Content

The highest moisture content of anthocyanin pigment was obtained from the freeze method of 5.00% while the lowest water content is from the vacuum method with 2.25%. This shows that the drying method has a significant effect on the moisture content of anthocyanin pigment. The results of statistical tests can be seen in Table 2. A significant difference between the drying temperature and the temperature of the dried material, the greater the speed of heat transfer into the material so that it can accelerate evaporation of water in the material [12]. This shows that the higher the drying temperature, the lower the water content produced. The evaporation process of powder products generally has a moisture content below 5% [13]. In addition, based on the Indonesian National Standard 01-2970-2006, the quality requirements for powder products have a maximum water content (b/b) of 5% [14]. Therefore, the water content contained in pigment powder should refer to the standard water content of powder products, which is below 5%. Based on Table 2, the water content of pigment powder (b/b) at the drying temperature of 40 °C for 15 hours was 6.14% which showed that the powder product was not yet standard, while the pigment powder moisture content at drying temperature 50 °C for 7 hours and 60 °C for 4 hours has been in accordance with the standards of powder products, which range from 3.27 to 4.60%.

3.3. Total Anthocyanin

The effect of the vacuum drying method, spray and freeze on anthocyanin pigment powder has a significantly different effect on the total anthocyanin produced. The results of statistical tests can be seen in Table 3. Based on Table 3, the highest anthocyanin pigment powder anthocyanin obtained in the freeze-drying method with 121.63 mg / 100g while the lowest total anthocyanin in the vacuum drying method was 94.93 mg / 100g. This shows that the drying method has a significant effect on the total anthocyanin of anthocyanin pigment powder. Purple sweet potato anthocyanin pigment powder ranges from 94.93 mg/100g-121.63 mg/100g. Total anthocyanin pigment powder between treatment drying methods has high anthocyanin. This is influenced by the nature of the anthocyanin pigment which is well dissolved in water, as well as the type of coating material used during the microencapsulation process. Anthocyanin pigments have polar molecules that are more soluble in polar solvents such as water than non-polar solvents [15].

Table 2: Water content in purebred purple sweet potato anthocyanin pigment analysis.

Treatment	Water Content (%wb)
Vacuum	2.25 ± 0.165
Spray	4.23 ± 0.391
Freeze	5.00 ± 0.243

Description: The same letter shows no significant difference at the level of 5% according to the Duncan test.

Table 3: Total anthocyanin in purebred purple sweet potato pigment powder analysis.

Treatment	Total Anthocyanin (mg/100 gram) db
Vacuum	94.93 ± 0.971
Spray	105.81 ± 0.804
Freeze	121.63± 0.768

Description: The same letter shows no significant difference at the level of 5% according to the Duncan test.

3.4. pH

The effect of the method of vacuum drying, spray and freeze on the pH of anthocyanin pigment powder has no significant effect on the pH produced. The statistical test results of ultrasound extraction time on anthocyanin pigment solutions can be seen in Table 4. Based on Table 4, the pH of the pigment solution has almost the same average, it is due to the use of tartaric acid in the same amount in the treatment of vacuum, spray and freeze-drying, which is 2.93-2.90. The range of pH=2-4 has a small effect on the speed of anthocyanin destruction during the heating process under the absence of oxygen, but the presence of large amounts of oxygen can accelerate the degradation of anthocyanins in the pH range 2-4 [16]. Anthocyanin has stability at low pH (acid), which is around 2-3. The stability of pH values is due to the role of tartrate acid added to anthocyanin extract because tartrate acid is a good acid in maintaining pH stability so that the resulting encapsulated anthocyanin pigment is also quite stable. The stability of the encapsulated anthocyanin pigment pH is also supported based on the previous discussion that the color of the pigment produced in all treatments is still red which indicates that the pigment is still in the form of a stable flavium cation.

3.5. Yield

Based on the results on the table below (Table 5), it shows that the effect of the vacuum drying, spray and freeze method on the yield of anthocyanin pigment powder gives no significant effect on the yield produced. Based on Table 5, the highest yield on vacuum drying was 34.31% and the lowest yield in spray drying was 28.31%. The higher drying temperature in the vacuum oven shows that the yield of pigment powder produced decreases. In accordance with Wulandari's research [10], the yield of purple sweet potato anthocyanin powder at temperatures of 40 °C, 50 °C, 60 °C were 8.25%, 7.46%, and 7.57%, respectively.

Table 4: pH level in purebred purple sweet potato analysis.

Treatment	pH
Vacuum	2.90 ± 0.075
Spray	2.89 ± 0.071^{c}
Freeze	2.93± 0.056

Description: The same letter shows no significant difference at the level of 5% according to the Duncan test.

Table 5: Yield in Purebred Purple Sweet Potato Analysis.

Treatment	Yield
Vacuum	34.31 ± 0.157
Spray	28.31 ± 5.484
Freeze	28.69± 0.441

Description: The same letter shows no significant difference at the level of 5% according to the Duncan test.

3.6. PSA (Particle Size Analyzer)

The effect of the method of vacuum drying, spray and freeze on the PSA of anthocyanin pigment powder has a significantly different effect on the size of the particles produced. The results of statistical tests can influence the drying method of anthocyanin pigments can be seen in Table 6. Based on Table 6, the particle size (median ratio) of the smallest anthocyanin pigment solution in the spray drying method was 1.80 µm while the largest size in the freeze-drying method is 1.25 µm. The particle size obtained depends on the destruction process used. The smaller the particle size, the faster the dissolution time and the better solubility.

3.7. Solubility

The Table 7 below shows that the effect of vacuum drying method, spray and freeze-drying on the solubility of anthocyanin pigment powder has no significant effect on the solubility level produced. Based on Table 7, the highest level of solubility of anthocyanin pigment powder was obtained in the spray drying method of 99.31% while the lowest was obtained in the freeze-drying method, 97.21%. However, the drying method carried out does not significantly affect the change in solubility level. This shows that the drying method has no significant effect on the level of solubility of anthocyanin pigment powder.

The level of solubility of purple sweet potato anthocyanin powder ranged from 97.21% to 99.31%. It is a high level of solubility. This is influenced by the nature of the anthocyanin pigment which dissolves well in water. Anthocyanin pigments have polar molecules that are more soluble in polar solvents such as water than non-polar solvents [15]. The high solubility of anthocyanin pigments can occur due to the drying method of the produced pigment powder, then the size reduction is carried out using a grinder with the same time treatment so as to produce a smooth pigment powder.

Table 6: Anthocyanin pigment psa in purebred purple sweet potato analysis.

Treatment	PSA (µm) Mean / Median Ratio
Vacuum	1.80 ± 0.033
Spray	1.25 ± 0.111
Freeze	1.95 ± 0.049

Description: The same letter shows no significant difference at the level of 5% according to the Duncan test.

Table 7: Purple sweet potato anthocyanin pigment powder solubility level analysis.

Treatment	Solubility (%)
Vacuum	97.35 ± 0.484
Spray	99.31 ± 0.560
Freeze	97.21 ± 0.165

Description: The same letter shows no significant difference at the level of 5% according to the Duncan test.

Solubility is also influenced by the coating material in the form of maltodextrin, where the hydroxyl group of dextrin monomers (D-glucose unit) in water forms hydrogen bonds with water molecules around it. A large number of reactive hydroxyl groups will increase the amount of water so that it becomes more soluble in water. In addition, high solubility is also influenced by the value of DE used in maltodextrin. Maltodextrin used in this study has a fairly high value of 15.

3.8. Soluble Time

The Table 8 below shows that the effect of the method of vacuum drying, spray, and freeze on the dissolution time of anthocyanin pigment powder has a significant effect. Based on Table 8, the fastest soluble pigment powder time is in the spray method, which is 146.00 seconds and the longest dissolution time in the vacuum method, which is 159.00 seconds. The time to dissolve the anthocyanin pigment produced by this study is longer than the time of dissolution of the anthocyanin pigment powder produced in Wulandari's Study [10]. The encapsulated anthocyanin pigment dissolution time in this study ranged from 154.38 to 190.04 seconds, whereas in the Wulandari's study the dissolved time of purple sweet potato anthocyanin pigment powder saluted with dextrin 6% ranged from 103.17 to 142.67 seconds. This can occur because, at the wettability stage, the entry of water into the particles occurs long enough due to the air trapped in the pigment powder particle bond so that the soluble time needed is longer than the Wulandari's study [10].

3.9. Hygroscopicity

The effect of vacuum, spray and freeze-drying methods on the hygroscopic anthocyanin pigment powder had a significantly different effect on the hygroscopicity produced. The results of statistical tests can be seen in Table 9. Based on Table 9, the highest hygroscopicity of anthocyanin pigments was found in the vacuum method, which is 11.23%, while the lowest is in the freeze method is 12.87%. This is because the hygroscopicity of the product is influenced by the moisture content. According to the classification issued by the GEA Niro Research Laboratory (2005) that materials with a <10% hygroscopicity level are classified as non-hygroscopic, 10.1%-15% of the material is classified as slightly hygroscopic, 15.1%-20% of the material is hygroscopic [17].

Table 8: Purple sweet potato anthocyanin pigment soluble time analysis.

Treatment	Soluble Time (Seconds)
Vacuum	159.00 ± 3.742
Spray	146.00 ± 0.816
Freeze	151.00 ± 1.414

Description: The same letter shows no significant difference at the level of 5% according to the Duncan test.

Table 9: Encapsulated purple sweet potato anthocyanin pigment hygroscopicity analysis

Treatment	Hygroscopicity Level (%)
Vacuum	11.23 ± 0.140
Spray	12.14 ± 0.459
Freeze	12.87 ± 0.680

Description: The same letter shows no significant difference at the level of 5% according to the Duncan test.

3.10. Best Treatment Determination

The best treatment is determined based on observational criteria which include the intensity of red with a*, water content, solubility, dissolution time, hygroscopicity, yield, and anthocyanin concentration. The matrix for determining the best treatment of anthocyanin pigments from purple sweet potato can be seen in Table 10. The level of hygroscopicity is the ability of materials to absorb water from the environment until the material is no longer able to absorb. The lower the percentage of hygroscopicity, the better the product. The results of the observations showed that all treatments had significantly different effects. The freeze-drying treatment produced the lowest hygroscopicity of 12.87% which showed that the treatment was included in the best treatment.

The pH of encapsulated anthocyanin pigments is determined by pH which is in accordance with anthocyanin stability standards. The results of the observations showed that all treatments gave no significant effect. The pH range of encapsulated anthocyanin pigments ranges from 2.89-2.93. This value is in accordance with the anthocyanin pH standard, which ranges from 2-3. Therefore, all treatments are included in the best treatment.

Soluble time is one of the determinants of the quality of the pigment powder produced. The faster it dissolves, the better the product. The results of the observations show that solubility has different effects significantly. Vacuum treatment results in the fastest dissolution time of 159 seconds so that the treatment is included in the best treatment. The yield was determined by the highest yield of the encapsulated anthocyanin pigment. The results showed that vacuum drying produced the highest yield of 34.31%. Therefore, freeze-drying is one of the best treatment because it can increase the economic value if it commercialized. The anthocyanin concentration was determined by the highest concentration of anthocyanin pigments. The results of the observation showed that all treatments did not give a significant effect on anthocyanin concentrations. Therefore, freeze-drying is one of the best treatment.

The drying extract of freeze was stated to have the best antioxidant activity compared to purple sweet potato powder extract using spray and vacuum drying. The extracts that used vacuum drying had an IC50 value of 101.12 ppm, while extracts using spray had an IC50 value of 119.98 ppm and the highest yield was obtained from extracts using freeze-drying which was 94.81 ppm (Table 10). The best treatment using freeze dryer with a total score of 53 is purple sweet potato powder which has the highest anthocyanin concentration, strong antioxidant activity, nano-sized, low hygroscopic, good soluble time and solubility. Based on Figure 3, it was found that SEM photo testing showed the visualization of the surface of the test material (sweet potato powder particles). From SEM photos can be seen the image of the surface of the test object and can also be seen the particle size. The results of the PSA and SEM tests carried out in this test used a 3000x magnification (Figure 5).

On the results of SEM photo testing with 3000x magnification, the morphology of sweet potato powder particles and the size of the sweet potato powder particles was known. From the morphology, it can be seen the particles of sweet potato powder and its size. Viewed from SEM photos the shape of the particles of sweet potato powder on average shows an imperfect round shape, but there are other particle shapes such as imperfect oval and others, there are also lumps of particles of sweet potato powder. And the average percentage of particles of sweet potato powder reaches an average size on the nanometer scale, but there are still particles that are micrometer-sized. Clots are caused by the Agglomeration process.

Table 10: Antioxidant activity of purple sweet potato powder.

Treatment	The Average of Antioxidant Activity IC_{50} (ppm)
Vacuum	101,12 ± 0.33
Spray	119,98 ± 0.30
Freeze	94.81 ± 0.24

Source: Personal documentation (2018).

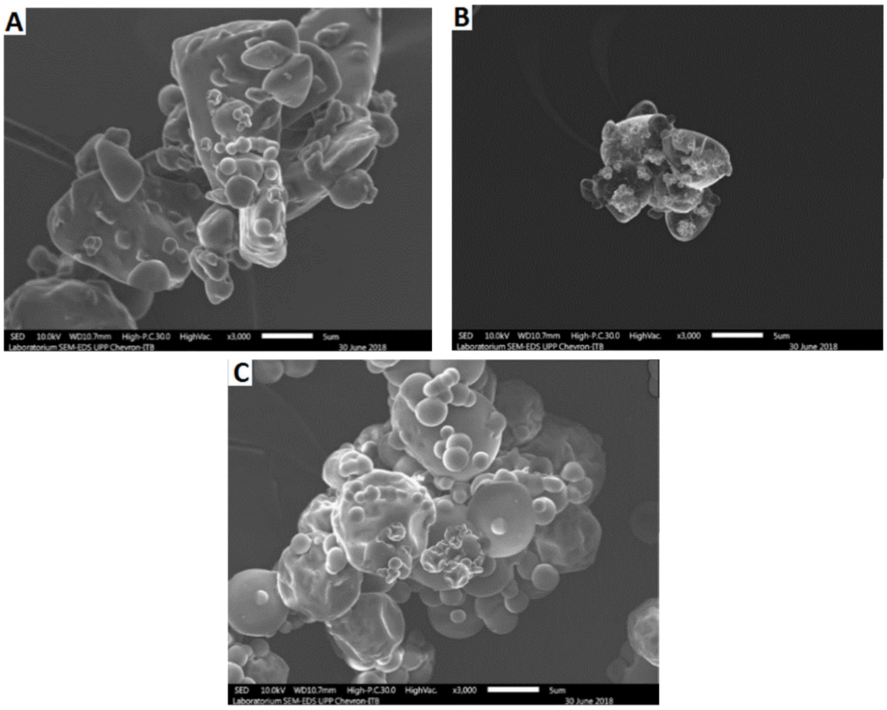

Figure 5: SEM (scanning electron microscope) anthocyanin powder (vacuum drying)(A), anthocyanin powder (spray drying)(B) and anthocyanin powder (frozen drying)(C).

4. Conclusion

Freeze-drying method is the best method in making purple sweet potato dyes with the color of dark dye powder, high total anthocyanin, strong antioxidant activity, low hygroscopic, low moisture content, dissolved time, good solubility, and micro-sized.

Acknowledgments

This research was funded by Penelitian Unggulan Strategis Nasional (PUSN) from Ministry of Research, Technology and Higher Education of the Republic of Indonesia awarded to Dr. Sc. Agr. Agung Karuniawan, Ir., M. Sc. Agr.

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How to cite this article:
H. Hariadi, M. Sunyoto, B. Nurhadi, A. Karuniawan, Study of Drying Method Types on the Physicochemical Characteristics of Pure-Bred Purple Sweet Potato Extract Powder of Unpad Collection. Prog. Color Colorants Coat., 13 (2020), 41-51.