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The effect of dryer and trehalose concentration on characteristics of mangosteen as natural dyes

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Abstract

The purpose of this study was to determine the effect of the type of dryer and the addition of trehalose concentration on the physicochemical characteristics of mangosteen skin dye. The research design used a Randomized Group Design (RAK) with a 3x3 factorial pattern consisting of 2 (two) factors with 2 (two) replications, resulting in 18 experimental units. Factor d is the type of drying equipment consisting of 3 levels, namely d1 (freeze dryer), d2 (cabinet dryer), and d3 (rotary vacuum dryer), while factor t is the concentration of trehalose consisting of 3 levels, namely t1 (5%), t2 (10%), and t3 (15%). The responses in this study include chemical responses such as water content and pH value, and physical responses including color intensity, yield calculation, hygroscopicity, solubility, and aW. There are chemical and physical responses with selected samples, namely anthocyanin content, antioxidant activity, and Scanning Electron Microscope analysis. The results showed that the type of tool influences the water content, pH value, L*a*b* color intensity, total yield, solubility, and aW. The concentration of trehalose affects the water content, pH value, color intensity L*a*, yield amount, solubility, and aW, but does not affect the color intensity b*. The interaction between the type of drying equipment and trehalose concentration affects the pH value, color intensity a*b*, yield amount, solubility, and aW, but does not affect the water content response and color intensity L*.

Keywords: Dryer, Mangosteen peels, Natural dyes, Trehalose concentration.

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1. Introduction

The mangosteen is a plant that can be used in its entirety, including the fruit meat, fruit skin, leaves, stems, and roots. This is because mangosteen commodities have good content for health. People usually enjoy the taste of mangosteen fruit

without knowing that the skin of the mangosteen fruit also has benefits. The utilization of mangosteen rinds by the community and vendors is still lacking and not even used; they are just thrown away because they are considered waste.

The development of the food industry has increased the use of synthetic dyes to produce industrial food. Synthetic dyes are coloring materials that are less safe when consumed by humans. It is necessary to increase the manufacture of natural dyes, one alternative to obtaining food coloring substances by extracting. One of the natural dyes that can be extracted is anthocyanin.

Research on mangosteen peel for the manufacture of natural dyes stems from the industry's need to find natural dye sources that are safer and more environmentally friendly than the synthetic dyes used today. Synthetic dyes are known to contain harmful chemical compounds and can cause side effects on health and the environment. Several studies have been conducted to learn more about xanthone compounds in mangosteen rind and their potential as natural dyes.

Mangosteen fruits contain pigments and active compounds, such as antioxidants, that provide health benefits. An appropriate pH during drying can assist in maintaining the stability of these pigments and active compounds, thus maintaining the nutritional quality and potential health benefits of the dried product. pH can also influence the chemical reactions that occur during drying and affect the flavor characteristics of the product. Some chemical compounds in mangosteen fruit can undergo changes or degradation depending on the pH present during the drying process. Each drying equipment has different drying parameters, such as temperature, time, and humidity, which can affect the pH and characteristics of the final product.

Natural dye powders produced from natural ingredients such as mangosteen peel generally require a drying process to maintain quality and color stability. Improper drying can result in discoloration and loss of active compounds in the natural dye powder. Traditional drying methods such as sun drying have several disadvantages, such as long drying time, susceptibility to environmental pollution, and inconsistent results.

Anthocyanins have met the requirements as additional food coloring because they do not cause damage to foodstuffs or packaging and are not toxic substances to the body, so they are permitted internationally as food coloring substances [1]. The total anthocyanin value that experienced the lowest rate of decline was the sample that was treated at refrigerator temperature in a dark bottle, with a decrease of 39.67% [2]. This shows that anthocyanin stability is better maintained at low temperatures than at room temperature.

The mangosteen rind can be used as a raw material for natural dyes [3]. The results of this study indicate that natural dyes produced from mangosteen rind can be used in food and beverage products. In addition, it can be an antimicrobial material to inhibit the growth of bacteria that cause skin infections.

Trehalose is a non-reducing disaccharide composed of two α-glucose molecules connected by α, α-1,1-glycosidic bonds. This sugar is found in a variety of organisms, including bacteria, yeasts, fungi, insects, invertebrates, and both low and higher plants, and can serve as a source of energy and carbon [4].

The addition of 5% trehalose concentration in food can affect the thermal stability of the product [5]. Trehalose can help protect protein and fat structures in food from heat damage during processing or storage. Trehalose with a concentration of 10% in food can provide benefits as an antioxidant and natural preservative [6]. Trehalose can protect food products from oxidative damage and extend their shelf life. The addition of trehalose at a concentration of 15% in foods such as processed meat can increase the tenderness and shelf life of the product [7].

2. Materials and Methods

2.1. Materials

Raw materials used in the production of dyes from mangosteen rind mangosteen (Garcinia mangostana L.), namely mangosteen fruit rind obtained from Antri Cimahi Market, West Java and stabilizers, for the stabilizer used in this study is trehalose obtained from e-commerce. Chemicals used for analysis are distilled water, 5% tartaric acid, DPPH, and ethanol chemicals obtained from chemical equipment stores and e-commerce.

2.2. Preparation of Mangosteen Peel Extract

Preparation of materials is done by preparing mangosteen fruit and trehalose sugar for the next process. The mangosteen fruit that has been prepared is sorted first to separate fruit that is suitable for consumption from reject fruit or fruit that has damage. Washing is done to ensure that the skin of the mangosteen fruit is protected from dirt. In this process, trimming is carried out, which is the process of separating the fruit from the skin of the mangosteen fruit. Then, size reduction is performed to facilitate the next stage. In this process, only a knife is used as a cutting tool. Blanching is done by heating the mangosteen fruit skin with water vapor media at a temperature of 80°C for 5 minutes and then cooling it with cold water. This is followed by the first drying at a temperature of 60°C for 6 hours; this process aims to convert mangosteen skin into mangosteen skin cassava for the extraction process. Extraction of mangosteen peel is performed using Ultrasound-Assisted Extraction for 120 minutes with a 1:5 distilled water solvent and 5% tartaric acid. The filtering process aims to separate the extract from the mangosteen peel. Furthermore, centrifugation is carried out; in this process, a technique for separating particles or components in a mixture is utilized by employing the centrifugal force generated from the rapid rotation of a device called a centrifuge at a speed of 8000 rpm for 10 minutes. The next process is evaporation using heat or pressure. After that, mixing is carried out; in this process, the mangosteen peel extract is mixed with predetermined concentrations of trehalose, namely 5%, 10%, and 15%. Then, a pH check is performed to determine the initial pH of the mangosteen skin dye extract and to find out whether there is a change in pH during the drying process. After that, the second drying is carried out; in this process, a freeze dryer is used at a temperature of -40°C for 12 hours, a cabinet dryer at a temperature of 60°C for 6 hours, and a rotary vacuum dryer at a temperature of 60°C for 4 hours.

2.3. Chemical Analysis of Mangosteen Peel Dye Extract

2.3.1. Moisture Content Analysis

The main objective of gravimetric method analysis is to determine the percentage of water content in a sample. Gravimetric method water content analysis helps in ensuring product safety and suitability. Gravimetric method moisture content analysis is also used to control the production process [8]. The procedure for analyzing the water content using the gravimetric method involves heating an empty cup in an oven at 105ºC for 30 minutes, then placing it into an desiccator for 15 minutes and weighing it (W0). Then, 2 grams of the sample is placed in a cup that has a known weight and weighed (W1), after which it is dried in the oven at 105ºC for 3 hours. The cup and its contents are then placed in a desiccator for 15-30 minutes, after which they are weighed again and dried for 1 hour. This process is repeated until a constant weight (W2) is achieved. Moisture content can be calculated using:

$$\text{Moisture Content (\%)} = \frac{(W1-W2)}{(W1-W0} \; x \; 100\%$$

Description:

W_0: Weight of empty cup (g).

W_1: Weight of cup + initial sample (before drying process) (g).

W_2: Weight of cup + constant sample (after drying process) (g).

2.4. pH Analysis

The concept of pH as a measure of the acidity or basicity of a solution is crucial. Heating an acidic solution can cause a decrease in pH due to an ionization reaction that is accelerated by heating [9]. However, an increase in pH is also possible due to changes in the complex chemical balance. The process begins with the pH meter being turned on and the sample to be measured for pH being prepared. Next, calibrate the pH meter by dipping the electrode in pH 7 buffer, then pressing the 'Read' button and leaving it until the scale on the pH meter is read. Electrodes that have been dipped in pH 7 buffer are rinsed using distilled water and dried with tissue paper. The dried electrode is then dipped again in pH 4 buffer. The 'Read' button is pressed again and left until the scale on the pH meter is read. The electrode is rinsed again with distilled water and dried with tissue paper before being dipped into the concentrated extract sample to be measured. The pH value of the sample is indicated by a number on the monitor that remains unchanged, and the word 'Ready' appears.

2.5. Anthocyanin Content Analysis

Anthocyanin Content Analysis Procedure pH-Differential-Lambert Beer Method [10]. The first step is making a buffer solution; there are two buffer solutions, namely potassium chloride buffer and sodium acetate buffer. For the preparation of 0.0025 M potassium chloride buffer (pH 1), one liter of the solution is obtained by mixing 1.86 grams of KCl with 980 mL of distilled water in a beaker. Then, the pH is measured and adjusted to obtain pH 1 by adding concentrated HCl. After that, the solution is transferred into a volumetric flask and filled with distilled water until the solution reaches a volume of 1 liter. For the preparation of 0.4 M sodium acetate buffer solution (pH 4.5), one liter of solution is obtained by mixing 54.43 grams of sodium acetate with 960 mL of distilled water in a beaker. After that, the pH is measured and adjusted until a pH 4.5 solution is obtained using concentrated HCl, and then the solution is transferred into a volumetric flask and adjusted with distilled water until the solution reaches a volume of 1 liter.

The spectrophotometer was turned on and allowed to stand for ± 30 minutes before being used for measurement. The correct dilution factor must first be determined by diluting the sample with KCl buffer (pH 1) until the absorbance of the sample at 510 nm is less than 1.2 (optimum absorbance range 0.2-0.8). After that, the final volume of the sample was compared with the initial volume in order to obtain the dilution volume. The sample dilution factor is x mL of sample dissolved into a test tube containing x mL of KCl buffer pH 1 or sodium acetate buffer pH 4.5 and then shaken. Each buffer is put into a cuvette, and then the cuvette is inserted into the spectrophotometer to be measured at the wavelengths to be used (510 and 700 nm) so that the spectrophotometer can be zeroed. The 510 nm wavelength is the maximum wavelength for cyanidin-3-glucoside, and the 700 nm wavelength is the wavelength used to correct for the presence or absence of sediment still present in the sample. If it is completely clear, then the absorbance value at 700 nm is zero. Each sample solution was dissolved with potassium chloride buffer pH 1 and sodium acetate pH 4.5 with a predetermined dilution factor. Samples dissolved using pH 1 buffer were allowed to stand for 15 minutes, as well as samples dissolved using pH 4.5 buffer, before measurement. The absorbance of the reconstituted sample (A) was measured using the formula. The concentration of anthocyanin pigment in the sample was calculated using the following formula:

$$A = (A510 - A700)\ pH\ 1{,}0 - (A510 - A700)\ pH\ 4{,}5$$

Calculation of levels in the sample using the following formula;

$$anthocyanin\ concentration\ \left(\frac{mg}{L}\right) = c = \frac{AxBMxFPx1000}{\varepsilon \text{ x } b}$$

Description:

c: concentration (M) or (mol/L)

A: Absorbance of anthocyanin sample at the measured wavelength

ε: molar absorptivity of cyanidin-3-glucoside = 26900L/(mol.cm)

b: cuvette thickness = 1 cm

BM: molecular weight of cyanidin-3-glucoside = 448.8 g/mol
FP = Dilution Factor

2.6. Antioxidant Activity Analysis

Antioxidant Activity Analysis Procedure DPPH Method [11]. Preparation of DPPH solution: dissolve DPPH in ethanol to a concentration of 0.1 mM. Store the DPPH solution in a dark bottle and keep it in a cool, dark place. Prepare the sample to be tested by weighing and dissolving it in a suitable solvent. The sample solution should be diluted to the appropriate concentration for analysis. If necessary, perform filtration first to remove any particles or precipitates that may be present in the sample. Then prepare a control solution by adding the solvent used to dissolve the sample into the DPPH solution, so that the DPPH solution becomes the same as the diluted sample solution. Mix the sample with DPPH by adding equal volumes of sample solution and control solution into different test tubes. Also, add an equal volume of DPPH solution to each test tube. Mix the sample and DPPH well. After mixing, incubate the test tubes in the dark for 30 minutes to 1 hour at room temperature or a suitable temperature. After incubation, measure the absorbance of the sample and control solutions at a wavelength of 517 nm using a UV-Vis spectrophotometer. Note the absorbance values produced by the sample and control. Antioxidant activity is measured by the IC50 value. The lower the IC50 value, the better the antioxidant activity in a product.

Calculate the percentage of DPPH inhibition by the sample using the following formula:

$$\%\ Scavenging\ activity = \frac{control\ absorbance - sample\ absorbance}{control\ absorbance}\ x\ 100\%$$

2.7. Physical Analysis of Mangosteen Peel Dye Extract

2.7.1. Color Intensity Analysis

Color intensity analysis test steps according to Kikuzaki, et al. [12]. The method used in this color measurement is L*a*b*. L* indicates lightness, a* indicates red (+a*) and green (-a*), while b* indicates yellow (+b*) and blue (-b*). Color measurement with a chromameter begins with the tool calibration step. The tool calibration step is performed by placing the optical head vertically on a standard white plate with the back of the plate facing the light source. After the calibration stage is completed, the sample is placed in the cuvette contained in the chromameter, and up to three repetitions (triplo) are performed.

2.8. Yield

Yield is the ratio between the weight of the yield produced and the raw materials [13]. Yield can be defined as the ratio of the yield produced to the raw materials or inputs used, and can be expressed as a percentage or other numerical comparison, the yield is calculated based on the following formula:

$$\%\ Yield = \frac{\text{weight of mangosteen peel colorant extract (g)}}{\text{base weight}}\ x\ 100\%$$

2.9. Hygroscopicity

The first step in testing the hygroscopicity level [14] involves placing a desiccant in the form of a saturated solution of ammonium chloride into the desiccator. A sample, in the form of pigment powder, is weighed to 0.5 grams and then placed in a desiccator with a relative humidity (RH) of 79.5%. The weight increase of the sample is recorded every 10 minutes for the first 30-40 minutes and then every 20 minutes thereafter. The weight gain usually reaches a maximum and then decreases, eventually reaching a steady rate. When the maximum weight is reached, the analysis can be stopped; this process usually does not take more than 4 hours. The hygroscopicity level can be calculated using the following formula:

$$\text{Higroskopisitas} = \frac{(\%\ Wi + \%\ FW)\ x100}{100 + \%Wi}$$

Description:
% Wi = (weight of absorbed water (g))/(weight of material (g)) x 100
% FW = initial moisture content of the material (%)

2.10. Solubility Analysis

Solubility measurement was carried out to determine the solubility of the instant powder produced. Initially, the powder sample was weighed at 5 grams, then dissolved in 100 ml of water and filtered using filter paper. After the filtering process, the filter paper and residue were dried in an oven at 105°C for 3 hours, then cooled in a desiccator and weighed [15]. The water-insoluble sample can be calculated using the following formula:

$$\text{Insolubility} = \frac{w2 - w1}{w3}\ x\ 100\%$$

$$\%\text{Solubility} = 100 - \%\text{Insolubility}$$

Description:
w_1 = Weight of empty filter paper (g)
w_2 = Weight of filter paper containing water insoluble part (g)
w_3 = sample weight (g)

2.11. aW Analysis

Testing aW by using an aW meter [16]. The first step is to calibrate the aW meter to ensure the accuracy of the measurement results, then prepare the sample to be tested. The sample to be tested is placed inside the aW meter according to the instructions. The aW meter will measure the water activity in the sample and display the results. The measurement results will be displayed as the water activity value or available water content in the sample. Interpret the results according to the relevant standards or desired quality requirements.

2.12. Scanning Electron Microscope (SEM)

Scanning Electron Microscope (SEM) testing [17]. Before the sample is inserted into the specimen chamber, the sample is first prepared by attaching the powder to the double carbon tape that has been attached to the holder. After that, blow air using a blower towards the powder to ensure that the powder sticks firmly to the carbon tape. If there is powder that is not firmly attached, it is feared that the powder will be sucked in during the SEM vacuuming process.

2.13. Statistical Analysis

The experimental design model used in this research is a factorial pattern in a Randomized Group Design (RAK) using the theory [18]. The main research had a 3x3 factorial with 2 replications, resulting in 18 experimental units. Consists of two factors, namely the type of dryer (d) consisting of 3 levels (freeze dryer, cabinet dryer, rotary vacuum dryer) and trehalose concentration (t) 3 levels (5%, 10%, 15%).

3. Results and Discussion

The results of physicochemical analysis of mangosteen peel coloring extract indicate that the interaction between drying factors and trehalose concentration has an effect.

Table 1.
Average results of the analysis of mangosteen peel colorant extract with physicochemical properties evaluated: pH, color intensity a*, b*, yield, hygroscopicity, solubility, aW.

Code	pH	a*	b*	yield	Hygroscopicity	Solubility	aW
d1t1	3.48±0.01	23.08±0.35	8.62±0.21	14.65±0.40	2.05 ± 0.21	99.00±0.21	0.51± 0.01
d1t2	3.50±0.02	17.49±3.37	8.35±0.59	17.14±0.28	1.55 ± 0.35	99.13±0.32	0.58± 0.01
d1t3	3.54±0.04	19.10±0.46	6.97±0.67	22.10±0.04	1.15 ± 0.21	99.38±0.11	0.59± 0.01
d2t1	3.52±0.02	10.16±0.42	6.10±0.07	9.25±0.35	4.35 ± 0.21	96.25±0.21	0.43± 0.00
d2t2	3.57±0.02	7.68±0.35	5.12±0.66	14.00±0.28	3.35 ± 0.21	93.80±0.35	0.45± 0.00
d2t3	3.58±0.03	11.20±0.49	5.56±0.21	16.75±0.21	1.95 ± 1.24	96.65±0.28	0.46± 0.00
d3t1	3.38±0.02	18.51±0.40	11.23±0.21	8.90±0.42	0.65 ± 0.47	98.50±0.21	0.61± 0.01
d3t2	3.44±0.04	14.90±0.21	10.39±0.49	15.20±0.14	0.55 ± 0.30	98.60±0.35	0.61± 0.01
d3t3	3.51±0.04	13.98±0.59	11.56±0.21	18.33±0.60	0.35 ± 0.31	96.45±0.35	0.61± 0.01

Note: d1 (freeze dryer); d2 (cabinet dryer); d3 (rotary vacuum dryer); t1(trehalose 5%); t2(trehalose 10%); t3(trehalose 15)

3.1. pH Analysis

Based on Table 1. show that the type of drying equipment factor (d), trehalose concentration factor (t) and the interaction of the type of drying equipment with trehalose concentration (dt) significantly affect the pH value. Based on Table 1. it can be seen that the interaction of the type of drying equipment with trehalose concentration in each treatment is significantly different, with the highest average pH value of 3.58 ± 0.03 in the cabinet dryer factor with 15% trehalose concentration and the lowest average pH value of 3.38 ± 0.02 in the rotary vacuum dryer factor with 5% trehalose concentration.
Drying with lower temperatures tends to maintain better the content of polyphenolic compounds [19]. Trehalose can affect environmental pH indirectly through its influence on chemical reactions and enzyme activity [20].

*3.2. Color Intensity a**

Based on Table 1. shows that the type of drying equipment factor (d), trehalose concentration factor (t) and the interaction of the type of drying equipment with trehalose concentration (dt) significantly affect the color intensity a*. Based on Table 1. it can be seen that the interaction of the type of drying equipment with trehalose concentration in each treatment is significantly different, with the highest a* color intensity average value of 23.08 ± 0.35 in the freeze dryer drying equipment factor with 5% trehalose concentration and the lowest a* color intensity average value of 7.68 ± 0.35 in the cabinet dryer drying equipment factor with 10% trehalose concentration.

The drying of fruits and vegetables can produce unwanted color changes [21]. The addition of trehalose in spray-dried red beet extract products can positively affect color intensity [22]. Trehalose can help maintain the natural color and prevent the degradation of anthocyanin pigments during drying.

*3.3. Color Intensity b**

Based on Table 1, it shows that the type of drying equipment factor (d), trehalose concentration factor (t), and the interaction of the type of drying equipment with trehalose concentration (dt) significantly affect the color intensity b*. Based on Table 1, it can be seen that the interaction of the type of drying equipment with trehalose concentration in each treatment

is significantly different, with the highest average value of b* color intensity of 11.56 ± 0.21 in the rotary vacuum dryer with 15% trehalose concentration and the lowest average value of b* color intensity of 5.12 ± 0.66 in the cabinet dryer with 10% trehalose concentration.

This color intensity shows that during the drying process, it, the color of the material or food product due to temperature and the length of drying time. This can be caused by the release of some pigments due to the release of cell fluid during cooking or processing, resulting in a decrease in color intensity [23]. The effect of the addition of trehalose on the quality of convectively dried pears is discussed [24]. The results showed that the addition of trehalose affected the color parameter b* (blue-yellowish color).

3.4. Yield

Based on Table 1 shows that the type of drying equipment factor (d), trehalose concentration factor (t), and the interaction of the type of drying equipment with trehalose concentration (dt) significantly affect the yield. Based on Table 1. it can be seen that the interaction of the type of dryer with trehalose concentration in each treatment is significantly different, with the highest average yield value of 22.10 ± 0.04% on the freeze dryer factor with 15% trehalose concentration and the lowest average yield value of 8.90 ± 0.42% on the rotary vacuum dryer factor with 5% trehalose concentration.

The type of dryer used can affect the yield and characteristics of the resulting product [25]. In this study, the yield of okra dried by convection dryer was lower than that of the microwave dryer. As the concentration of trehalose increased, it tended to increase the yield value of the mangosteen peel coloring extract. The more sugar added in the process of making soursop leaf powder drink using the co-crystallization method increases the yield of the final product [26].

3.5. Hygroscopicity

Based on Table 1 shows that the type of drying equipment factor (d), trehalose concentration factor (t) and the interaction of the type of drying equipment with trehalose concentration (dt) significantly affect hygroscopicity. Based on Table 1 it can be seen that the interaction of the type of dryer with trehalose concentration in each treatment is significantly different, with the highest average hygroscopicity value of 4.35 ± 0.21% in the cabinet dryer with 5% trehalose concentration and the lowest average hygroscopicity value of 0.35 ± 0.31% in the rotary vacuum dryer with 15% trehalose concentration.

The type of dryer used can affect the yield and characteristics of the resulting product [25]. In this study, the yield of okra dried by convection dryer was lower than that of microwave dryer. The drying sour cherries using various drying methods, the results concluded that faster drying methods and with high temperatures can reduce the hygroscop icity of the final product due to a more significant reduction in water content [27]. Trehalose can be used as a dehydrating agent in organic solvents [28]. Trehalose tends to form hydrogen bonds with water, which helps reduce moisture in organic solvents, so it can affect the hygroscopicity of the solvent.

A hygroscopicity level of ,10% are classified as non-hygroscopic materials, 10.1-15% are classified as slightly hygroscopic materials, 20.1-25% of materials are classified as very hygroscopic [14]. In this study, mangosteen peel dye extract is included in the average non-hygroscopic.

3.6. Solubility

Based on Table 1 shows that the type of drying equipment factor (d), trehalose concentration factor (t), and the interaction of the type of drying equipment with trehalose concentration (dt) significantly affect solubility. Based on Table 1 it can be seen that the interaction of the type of dryer with trehalose concentration in each treatment is significantly different, with the highest solubility average value of 99.38 ± 0.11mol/L in the freeze dryer with 15% trehalose concentration and the lowest solubility average value of 93.80 ± 0.38mol/L in the cabinet dryer with 10% trehalose concentration.

The effect of drying methods, including freeze-drying and drying with hot air, on the physico-chemical properties of food, including solubility [29]. The higher the concentration of trehalose will increase the solubility of mangosteen peel coloring extract. This is because sugar has a high solubility in water, causing the higher the concentration of trehalose used, the greater the increase in solubility [26].

3.7. aW

Based on Table 1 shows that the type of drying equipment factor (d), trehalose concentration factor (t) and the interaction of the type of drying equipment with trehalose concentration (dt) significantly affect aW. Based on Table 1 it can be seen that the interaction of the type of dryer with trehalose concentration in each treatment is significantly different, with the highest aW average value of 0.61 ± 0.01 in the rotary vacuum dryer with 15% trehalose concentration and the lowest aW average value of 0.43 ± 0.00 in the cabinet dryer with 5% trehalose concentration.

The drying can affect the aW of a material [30]. An effective drying process can reduce aW, which in turn can affect the stability, sensory quality, and shelf life of the product [31]. Trehalose has the ability to form a protective matrix around proteins during freeze drying [31]. This can help maintain the structural stability of the protein and reduce the negative effects of increased aW.

3.8. Moisture Content

Table 2.
Effect of Dryer Type on Moisture Content (%).

Type of dryer	Average response
d1 (Freeze dryer)	8.35 ± 0.58[c]
d2 (Cabinet dryer)	3.37 ± 0.13[a]
d3 (Rotary vacuum dryer)	5.98 ± 0.42[b]

Table 3.
Trehalose Concentration to Moisture Content (%).

Trehalose concentration	Average response
t1 (F5%)	5.70 ± 2.02[ab]
t2 (10%)	5.60 ± 1.83[a]
t3 (15%)	6.40 ± 2.27[b]

Based on the results of ANOVA calculations, it shows that the type of drying equipment factor (d) and the trehalose concentration factor (t) have a significant effect on the water content of mangosteen peel dye extract but no effect on the interaction of the two (dt). Based on Table 2 it can be seen that the type of drying equipment and the concentration of trehalose in each treatment are significantly different, with the highest average water content of 8.35 ± 0.58% in the freeze dryer factor and the lowest average water content of 3.37 ± 0.13% in the cabinet dryer factor. Drying equipment with faster and more efficient drying mechanisms, such as combination drying or vacuum drying, can produce products with lower moisture content in a shorter time [25].

Based on Table 3, it can be seen that the concentration of trehalose in each treatment is significantly different, with the highest average moisture content of 6.40 ± 2.27% in the 15% trehalose concentration factor and the lowest average moisture content of 5.60 ± 1.83% in the 10% trehalose concentration factor. The results of this study indicate that the type of drying equipment and the trehalose concentration factor have an effect. The addition of trehalose in food powder products, such as powdered beverages or other products, can significantly reduce water content [32]. Trehalose has the ability to form bonds with water and help maintain product stability.

3.9. Anthocyanin Content Analysis

Table 4.
Total Anthocyanins of Selected Samples

Code	Absorbance Value				Absorbance	Total Anthocyanin (mg/L)
	Absorbance 510		Absorbansce700			
	pH-1.0	pH-4.5	pH-1.0	pH-4.5		
d_1t_3	0.447	0.432	0.039	0.086	0.062	10.34

Based on Table 4, it can be concluded that the anthocyanin content in sample code d1t3, with the type of freeze dryer and the addition of 15% trehalose concentration using the pH-Differential method, is 10.34 mg/L. Acidic conditions will affect the state of extraction. More acidic conditions will cause more anthocyanin pigments to be in the form of colored flavilium or oxonium cations, and absorbance measurements will show a greater amount of anthocyanins.

3.10. Antioxidant Activity

Table 5.
Antioxidant Activity Analysis Results (ppm) Selected Samples.

Sample	Antioxidant activity in IC_{50} Value (ppm)
Mangosteen peel coloring extract	79.3159

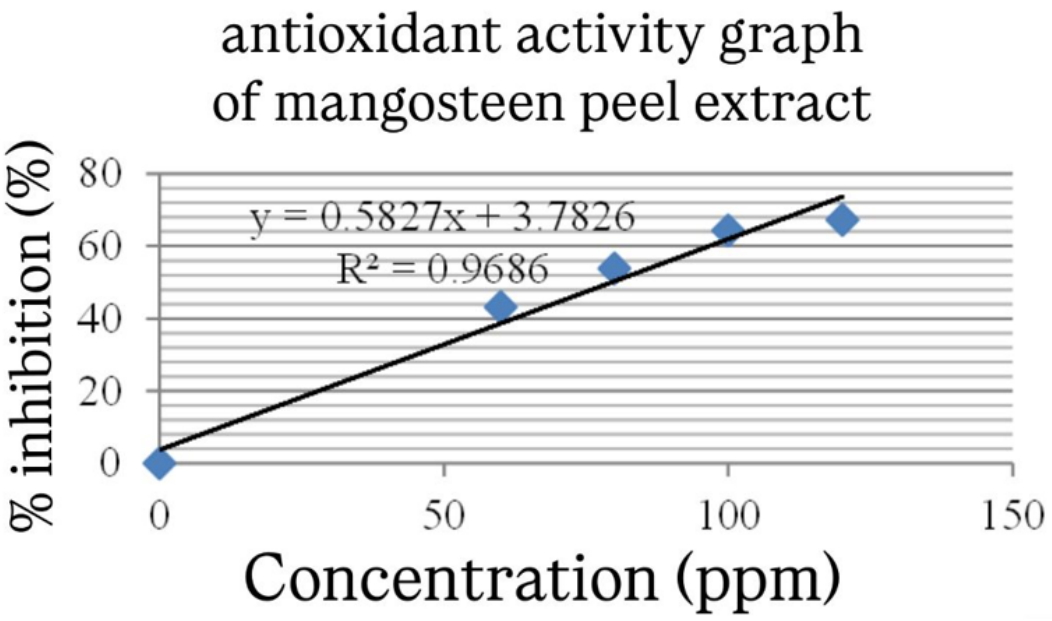

Figure 1.
Antioxidant activity graph of mangosteen peel coloring extract with freeze dryer and 15% trehalose concentration.

Based on Table 5 the results of the analysis of antioxidant activity using the DPPH method on the selected mangosteen fruit peel dye extract, namely the freeze dryer with a concentration of trehalose of 15%, the results show that mangosteen fruit peel dye extract has antioxidant activity with an IC50 value of 79.3159 ppm, it can be concluded that the level of antiocidan in mangosteen fruit peel dye is strong.

3.11. Color Intensity Analysis
*3.11.1. Color intensity L**

Table 6.
Effect of Dryer Type on Color Intensity L*

Type of dryer	Average response
d1 (Freeze dryer)	60.59 ± 1.33^{b}
d2 (Cabinet dryer)	38.76 ± 0.45^{a}
d3 (Rotary vacuum dryer)	59.74 ± 1.14^{b}

Table 7.
Trehalose Concentration to Color Intensity L*.

Trehalose concentration	Average response
t1 (F5%)	51.98 ± 9.18^{a}
t2 (10%)	53.13 ± 10.61^{ab}
t3 (15%)	53.97 ± 10.50^{b}

Based on the results of ANOVA calculations, it shows that the type of drying equipment factor (d) and the trehalose concentration factor (t) have a significant effect on the L* color intensity of mangosteen peel dye extract but do not affect the interaction between the two (dt). Based on Table 5, it can be seen that the type of drying equipment and trehalose concentration in each treatment are significantly different and not significantly different, with the highest average water content of 60.59 ± 1.33 in the freeze dryer drying equipment factor and the lowest average water content of 38.76 ± 0.45 in the cabinet dryer drying equipment factor. The process of drying at high temperatures tends to produce darker or lower products in lightness [33]. This can occur because high heating can cause chemical reactions, including the Maillard reaction, which can change pigments and cause discoloration.

Based on Table 6 it can be seen that the concentration of trehalose in each treatment is significantly different, with an average L* color intensity of 53.97 ± 10.50 in the 15% trehalose concentration factor and the lowest average L* color intensity of 5.60 ± 1.83% in the 5% trehalose concentration factor. The results of this study indicate that the type of dryer and the trehalose concentration factor have an effect [24].

3.12. Scanning Electron Microscope

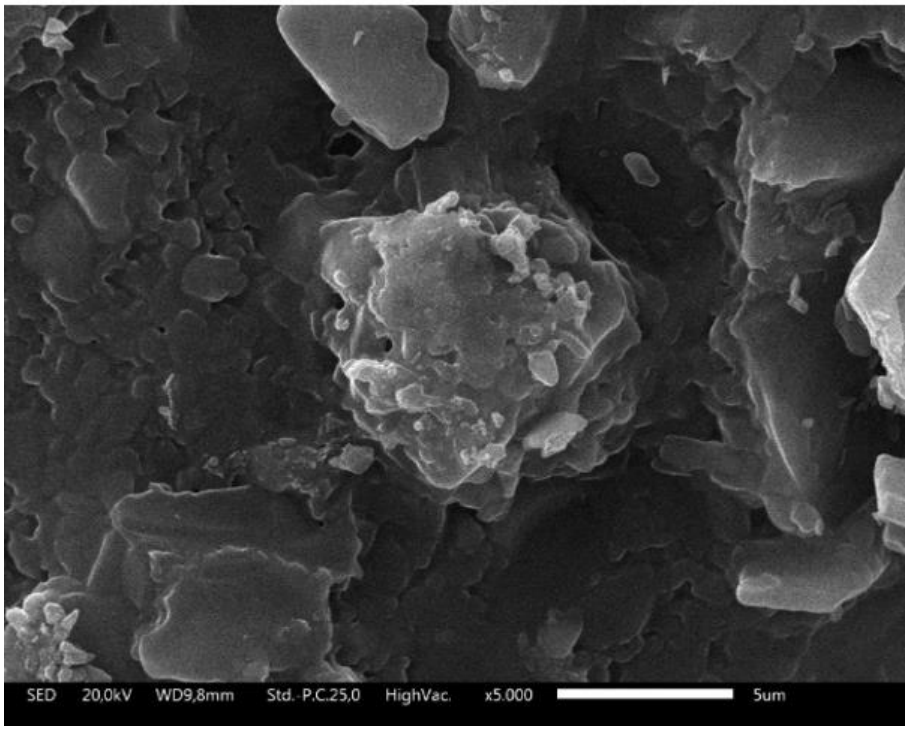

Figure 2.
SEM with 5,000x magnification.

In Figure 2, it can be seen that the surface morphology of mangosteen peel dye extract powder has an irregular and heterogeneous shape; this shape is observed in the pores on the granule after being enlarged. The heterogeneous shape of the mangosteen skin dye extract powder can indicate that the active substance xanthone is not entirely contained within the mangosteen skin dye extract powder granule but is also found on the surface of the granule. According to Khamanga et al., in their research in 2012, the SEM results of mangosteen peel granules show heterogeneous granule shapes, and the presence of pores in the drug causes dissolution to occur quickly at the beginning of dissolution [33].

4. Conclusion

Based on the results of research on the manufacture of mangosteen peel dye extract, it can be seen that the type of drying equipment affects the chemical and physical responses of mangosteen peel dye extract (Garcinia mangostana L.). The concentration of trehalose affects the chemical and physical responses of mangosteen peel dye extract (Garcinia mangostana L.). The interaction of the type of drying equipment and trehalose concentration affects the chemical and physical responses of mangosteen fruit peel dye extract (Garcinia mangostana L.).

Based on this study, the best chemical analysis produced was the moisture content of 8.35% on the freeze dryer factor and 6.40% on the 15% trehalose concentration factor, a pH of 3.58, an anthocyanin content of 10.34 mg/L, and an antioxidant activity of 73.3159 ppm. The best physical analysis results were an L* color intensity of 60.59 in the freeze dryer factor and 53.97 at 15% trehalose concentration, an a* color intensity of 23.08, a b* color intensity of 5.12, a yield of 22.10, a hygroscopicity of 0.35, a solubility of 99.3, and an aW of 0.61. In the above study, the best treatment results were obtained from the freeze dryer treatment with a 15% trehalose concentration.

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