# Comparison of Color Quality Measurement Using Chromameter and Image Processing for Dehydrated Strawberry Products

Farisa Adelina Sitanggang, M. Maksum Machfoedz, and Mohammad Affan Fajar Falah(✉)

Department of Agroindustrial of Technology, Universitas Gadjah Mada, Yogyakarta, Indonesia
{mmaksum,affan_tip}@ugm.ac.id

**Abstract.** Color is one of the important parameters to consider regarding to quality and perception of consumers acceptance in agro-industrial products. However, standard color measurement using colorimeter have an expensive cost and the need for trained individual to operate, then, other measurement can be done using image processing approach for lower cost and simple operation. The purpose of this research is to compare color measurement of the dehydrated strawberry using Chromameter, which is a standard tool with image processing approach that made in the box as an alternative color detection measurement.

Dehydrated strawberry products are made by a combination of osmotic dehydration and drying using tray dryers and have some characteristics. Parameter of color measurement on dehydrated strawberry products is carried out using a Chromameter and the Image Processing Approach in Box. The parameter of color quality of the products was measured in lightness (L*), redness (a*), yellowness (b*) and using equation were calculated for color change (ΔE*) and hue angle (h°). Comparison of the color measurement results obtained were analyzed using statistical analyses of Statistic Package for Social Science (v.22.0, International Business Machines Corporation, New York) and calculated the root mean square error (RMSE) method and then resulted data value were checked statistically for the Independent T-Test for parametric and Mann-Whitney Test for non-parametric.

Based on the results, color measurement using for the parameter of redness (a*) and color change (ΔE*) from Chromameter and the Image Processing Approach in Box were similar and not significance difference between these tools. Another color parameter of lightness (L*), yellowness (b*), and hue angle (h°) were significantly different between these tools. For the RMSE calculation, the results for the lightness component (L*) are 7.39; the redness component (a*) is 1.41; yellowness component (b*) of 2.27; the discoloration component (ΔE*) is 2.04 and the hue angle component (h°) is 5.92. These low value of the RMSE indicate that Image Processing Approach in Box can be detected color of the dehydrated strawberry and their changes of the color especially redness (a*) and color change (ΔE*) well, but the accuracy level still need to be improved.

**Keywords:** chromameter · color quality · dehydrated strawberry · image processing


N. Huda et al. (Eds.): ICSAFE 2021, ABSR 25, pp. 4–17, 2022.
https://doi.org/10.2991/978-94-6463-090-9_2

## 1 Introduction

Strawberries (*Fragaria x ananassa*) are considered as one of the fruit commodities with high economic value and high nutritious fruit, and as a non-climacteric type of fruit, strawberries are harvested when the fruit has turned red [1]. Consumers also favor this fruit because of its healthy and beneficial contents to the body, which contains vitamin c, potassium, folic acid, high antioxidants, and considered as a low-fat fruit [2]. Aside from the advantages mentioned above, strawberries also possess disadvantages such as, prone to defectiveness (easily damaged) and a relatively short shelf-life especially in tropical environment. At normal tropical air temperatures, strawberries can only had 3–4 days shelf-life after harvest, whereas if it's longer, then the strawberries will start to become defective. Moreover, strawberries mechanical influences and environmental conditions in the tropics can also accelerate the deterioration of the quality in strawberries.

The problem of fresh strawberries that are rapidly decaying and short shelf-life, further postharvest handling is important, one of the method to make an extended shelf-life is as drying process. Drying is the process transferring heat energy from the drying medium into the material to reduce the moisture content of the material by evaporating the water in the material. Therefore, the development of microorganisms that can cause decaying is hampered [3]. However, the drawback of the drying process is that the application of high temperatures during the process can cause a decrease in quality such as alterations in color, shape, texture, and loss of nutritional content in the material [4]. One of the efforts to maintain the nutritional content of the dehydrated material is by using the osmotic dehydration method. Osmotic dehydration is carried out by immersing the material that will be dehydrated, in a high concentration (hypertonic) solution, such as sucrose, glucose fructose, glycerol, etc. After conduction the osmosis dehydration method, the strawberries are dehydrated using tray dryers. Therefore, the result of osmotic dehydration and drying with tray dryers will produce a product, namely dehydrated strawberries.

The high concentration solution used was a strawberry concentrate solution made from fresh strawberries, sucrose, and distilled water. The use of sucrose will help prevent the dehydrated material from coming into contact with oxygen so that it will reduce the rate of enzymatic browning that will occur at the end of the drying process. In addition, in terms of taste for dehydrated fruit, sucrose is more acceptable because it gives a sweet taste, but is not suitable for use on vegetables [5]. While the use of strawberry juice concentrate is to enrich the dehydrated fruit with bioactive ingredients which during the process will be lost [4]. Strawberry concentrate solution used in the osmosis dehydration process had a concentration of 50°Brix. Brix degrees are degrees used to express the level of dissolved solids such as sucrose in a solution. Dissolved solids such as sucrose or sugar have hygroscopic properties, where solids will enter and will bind to free water in foodstuffs, thereby reducing water activity in the ingredients [6].

Quality parameters in fresh and processed food products that can be visually seen by consumers are called sensory characteristics. The sensory characteristics of food products consists of color, appearance, shape, taste, and texture [7]. Changes in texture and color in dry food products also an allurement for consumers [8]. In ref. [9], color attribute on dry food is one of the most important quality parameters in terms of initial acceptance for consumers. However, the color measurement tool, namely the Chromameter, has several drawbacks such as the expensive price of the tool and the necessity of for human resources to operate it. In addition to the Chromameter, color measurement can also be done with alternative artificial color detection tool such as the Image Processing Approach in Box, and also unknown the level of suitability of the tool for dehydrated food products is yet to be known compared to the Chromameter. The objective of this research is to analyze the comparison on the color measurement on dehydrated strawberry using standard method of Chromameter with the Image Processing Approach in Box, as an alternative low cost and simple color detection tool.

## 2 Materials and Method

A. *Sample Preparations*

In ref. [10] the dehydrated strawberry samples are in the form of slices made with a combination of osmosis dehydration and tray dryers. Fresh strawberries that will be made into dehydrated strawberry products are cultivated in the Inggit Strawberry Orchard located in the Agrotourism Area of Banyoroto Village, Ketep Pass, Sawangan, Magelang, Central Java. The strawberry variety that is cultivated and used is California with a characteristic in the form of a cordate, medium size, bright green leaf surface, and has a rather long preservation life span [11].

The process of making dehydrated strawberries begins with osmotic dehydration, which conducted by soaking strawberries in a strawberry concentrated solution made from a mixture of strawberries, sugar, and aquadest. The strawberries are soaked in the concentrated solution and stirred for 60 min using a Magnetic Heated Strirer (IKA C-MAG HS7, IKA, China). Then dehydrated in a tray dryer (MKS-FDH6, Maksindo, Indonesia). Tray dryer is a drying machine consisting of shelves with holes that serves as a medium for hot air circulation [12]. Drying process is carried out for 9 h at 70 °C. Afterwards, the dehydrated strawberries are stored in a desiccator for 36–48 h to reduce the water content contained in the strawberries. Storage condition of the samples were not environmentally controllable, where air temperature and relative humidity in the room could be fluctuated (Fig. 1).

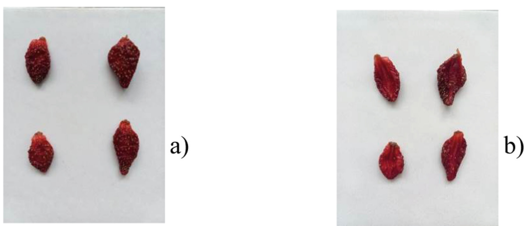


**Fig. 1.** Dehydrated Strawberry Product Visual a) Front Side; (b) Back Side

B. *Measurement of Color Components*

The color notation system used is from the Commission International de I Declaration (CIE) with the measured color components being lightness (L*), redness (a*), yellowness (b*), and advanced color parameters, namely discoloration (ΔE*) and hue angle ($h^o$). The L* value indicates a change in brightness with a value range of 0 (black)–100 (white). Value of a* signify the red-green mixed chromatic color with a positive a (a+) from a range of 0–+100 for red, and a negative a value (−a) ranging from 0–80 for green. Meanwhile, the b* value represent the chromatic color of the blue-yellow mixture with a value of +b (b positive) from 0–+70 for blue, and −b (b negative) from 0 to −70 for yellow [13].

Advanced color parameters known as ΔE* indicates value changes or differences in the appearance of dehydrated strawberries as a result of L * a * b value and the $h^o$ value is the result of the color identity used to distinguish one color from another and ranges from 0° (total red), 90° (yellow), and 180° (green) [14]. The two advanced color parameters can be calculated by the formula:

$$Hue\ Angle = h = tan^{-1}\left(\frac{b*}{a*}\right)^{o} \tag{1}$$

$$\Delta E = \sqrt{\Delta a^2 + \Delta b^2 + \Delta L^2} \tag{2}$$

C. *Color Measurement Instrument*

Observations were carried out for 32 days and measurements were conducted every 2 days until the 26th day. On the 27th day until the 32nd day, the samples were measured every day. The samples used aggregate to 4 samples with each sample's data being collected at 2 different points. The data used is the average value of color measurements from the four sample (L*, a*, b*, hue, dan ΔE*).

1) Chromameter

Chromameter fundamentally works using a sensor that mimics on how the human eye works in perceiving colors and afterwards quantifies color by measuring the three basic components of color known as primary colors (red, green, and blue) [15]. Color measurement is done by sticking the tip of the chromameter receptor (shaped as a flat surface) on the dehydrated strawberry. During the measurement, the flat part of the instrument must be completely covered. If there is any light that accidentally enters from the side of the optics, the reading value produced by the tool will be inaccurate. This research used Chromameter (CR-400, Konica Minolta Sensing, Japan).

2) Image Processing Approach in Box (IPAB)

The Image Processing Approach in Box used in this research is a modified tool of the Quality Detection Tool Without Fruit Damage from [16]. The Image Processing Approach in Box basically works as a digital image processor, which in ref. [17], is the process of digitally observing and analyzing an image using a computer. Color measurement is done by taking pictures using a camera installed in the Image Processing Approach in Box which afterwards the obtained images are processed using the Graphical User Interface (GUI) on MATLAB (R2015a).

D. *Statistical Analysis*

The color measurement data obtained are statistically analyzed using Statistic Package for Social Sciene (v.22.0, International Business Machines Corporation, New York) for the independent t-test (parametric) or the Mann Whitney Test (non-parametric) to determine the average differences of two independent populations/groups of data. Prior to carry out statistical analysis, a normality test was first performed on each color component data. Tests are carried out to determine whether the data is normally distributed or not. In this research, the Shapiro-Wilk method is used for the normality test. If the data for each color component is normally distributed, then the test will continue with the independent t-test. However, if the data is not normally distributed, the test will continue with the Mann Whitney Test.

E. *Accuracy Test*

The calculation of fallibility is necessary to determine if the tested model has a high level of accuracy or not. Calculations are conducted by Microsoft Excel (Office 16, Microsoft Corporation, Washington). Calculating the prediction of fallibility can be done by four methods specifically the mean absolute error (MAE), the root means square error (RMSE), the mean square error (MSE), and the mean absolute percentage error (MAPE) [18]. The greater the fallibility value, the lower the accuracy of the model. In this research, the accuracy test used is the root mean square error (RMSE).

Root Mean Square Error (RMSE) is the square root of the average amount of squares obtained from the difference between the actual value (y) and the observed value (yi) in a number of (n) data. RMSE portrays how spread out the difference between sortilege and measurement values are [19]. Mathematically, RMSE, can be calculated by the formula below:

$$\text{RMSE} = \sqrt{\frac{1}{\boldsymbol{n}} \sum_{\boldsymbol{i}=1}^{\boldsymbol{n}} (\boldsymbol{y} - \boldsymbol{y}_{\boldsymbol{i}})^2} \quad (3)$$

The calculation of RMSE uses the root operation where the result of the fallibility value will have the same value scale as the realized value or the sortilege value. Therefore, the RMSE indicator is easier to understand compared to MSE indicator. To find out the RMSE value obtained is propitious or not, it can be calculated by the formula as written down below:

$$\text{Scatter Index (SI)} = \frac{\boldsymbol{RMSE}}{\boldsymbol{Rata - Rata\ Nilai\ Observasi}} \times 100\% \quad (4)$$

If scatter index (SI) $< 5\%$, the model can be said to have a very good accuracy. If SI $< 10\%$, the model can be said to have a good accuracy, and if SI $> 10\%$, it can be said that the model has a low accuracy [20].

## 3 Result and Discussion

A. Color Quality Parameter Measurement

1) Lightness (L*), Redness (a*), and Yellowness (b*)

The average comparison regarding the lightness (L*), redness (a*), and yellowness (b*) component between Chromameter and the IPAB can be seen in Fig. 2.

a. Lightness (L*)

The results based on Fig. 2 exhibit the average lightness of dehydrated strawberries obtained with IPAB has a higher value than the Chromameter. The average lightness value obtained using the Chromameter ranged from 36.47–37.63. Whereas the lightness value obtained from the IPAB ranged from 41.73–46.68. According to the data mentioned, the lightness value showed fluctuating results and tend to decrease during storage. Changes in the lightness value indicate a change in the color of dehydrated strawberries to be darker than before. This discoloration can occur due to environmental conditions during storage and the occurrence of metabolic processes in dehydrated strawberries.

In ref. [21], research with the same combination method on the color component as measured by the Chromameter, the lightness value ranged from 29.43–31.34 with nine repetitions in the middle of the dehydrated strawberries. Then in ref [10], the lightness value obtained ranged from 23.56–32.08 with twelve repetitions in the middle of the dehydrated strawberry, while in the latest study the lightness value ranged from 23.22–23.33 with three repetitions on dehydrated strawberry skin [22]. The difference in the results obtained can be caused by environmental conditions of storage and metabolic processes that occur in dehydrated strawberries. Storage temperature greatly affects the lightness value obtained, because heating affects the stability of anthocyanin pigments. Fruits with red skins usually contain a lot of anthocyanin pigments. Anthocyanins are active antioxidant pigments that can protect plants from visible light radiation in the solar spectrum [23]. The higher the storage temperature of strawberries, the degradation or decrease in anthocyanin levels will be greater because heating affects the stability of anthocyanin pigments.

Lightness value result are tested whether it's normally distributed or not with the normality test. If the data is normally distributed, therefore will continue to the difference test known as independent t-test (parametric). However, if the data is not normally distributed, the Mann-Whitney test (non-parametric) will be carried out. The results of this analysis test indicate whether there are any differences between the results of color measurements using the Chromameter and IPAB. Based on statistical analysis utilizing independent t-test for comparative test, it was shown that there was a significant difference between the lightness component value using the Chromameter and the IPAB ($p < 0{,}05$). The difference in the lightness value component produced by the two tools has a significant value of 0.05. The outcome of this statistical analysis were accordance [24], where in this research, there was a difference in the lightness component with a significant value of 0.01 [24]. This IPAB were also received copyright from directorate general of intellectual property right of ministry of law and human right in 2020 with recording number 000192384 [25].

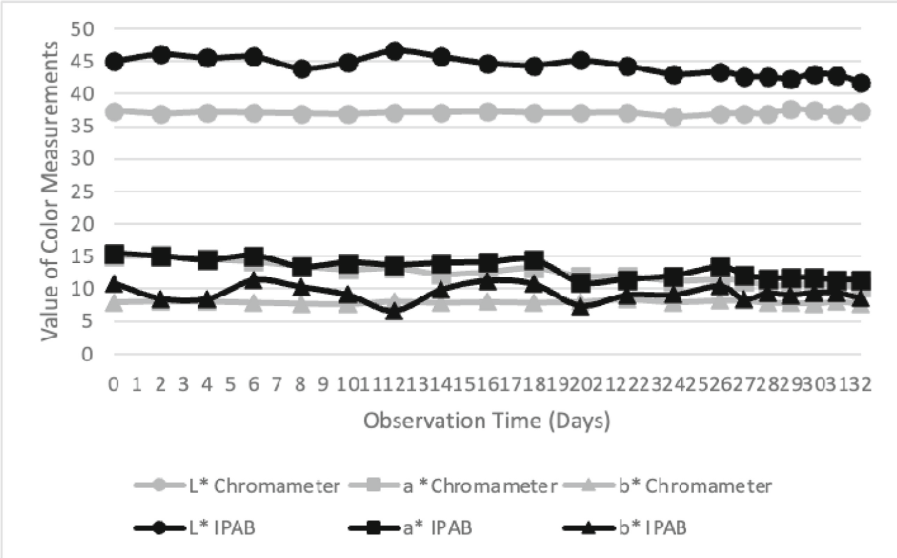


**Fig. 2.** Lightness (L*), redness (a*), yellowness (b*) of dehydrated strawberry that measure using chromameter and image processing approach in a box (IPAB) for 32 days storage in a tropical temperature condition without controlled.

This research indicates the difference in the value of the lightness component produced by the Chromameter and the IPAB, was caused by the distinction in the light source. In addition, there is an interaction effect of light on the object being measured, such as reflection, absorption, scatter and shadow as a result of light blocked by certain parts of the object. The light source used in the Chromameter is Xenon lamp, while IPAB's light source consist of four 7-Watt Phillip LED lamp. In addition, there is an interaction effect of light on the object being measured, such as reflection, absorption, scatter and shadow as a result of light blocked by certain parts of the object.

b. Redness (a*)

The result based on Figure 2 indicates, the average result of the redness of dehydrated strawberries obtained with IPB has a value that is not too different from that of the Chromameter. The redness value obtained from the four samples using the chromameter ranged from 10.34–15.15, whereas IPAB the redness value obtained ranged from 10.98–15.45. From both tools, the redness value indicates that the four samples of dehydrated strawberries have a dominant color of red. During storage, the redness values of the tools signify fluctuating results and tend to decrease. Occurring changes in the value of redness indicate a decrease in the red color of dehydrated strawberries.

In ref. [21], research with the same combination method on the color component as measured by the Chromameter, the redness value ranges from 23.20–28.33 with nine repetitions in the middle of the dehydrated strawberry. Then in ref. [10] the redness value obtained ranged from 19.82–47.52 with twelve repetitions in the middle of the dehydrated strawberry, the lightness value ranged from 10.64–10.87 with three repetitions on dehydrated strawberry skin [22]. The difference in the results obtained can be caused by respiration rate and some enzymatic processes that still occur in each product after drying. The rate of respiration that occurs affects the stability of the anthocyanin pigment contained in the product during storage.

Redness value result are tested whether it's normally distributed or not with the normality test. If the data is normally distributed, therefore will continue to the difference test known as independent t-test (parametric). However, if the data is not normally distributed, the Mann-Whitney test (non-parametric) will be carried out. The results of this analysis test indicate whether there are any differences between the results of color measurements using the Chromameter and IPAB. Based on statistical analysis using independent t-test with the purpose of comparative test, it is shown that there is no significant difference between the value of the redness component using the Chromameter and the IPAB ($p > 0.05$). There was no significant difference on the redness component between the Chromameter and the IPAB with a significance value of 0.172. Through the statistical analysis, the results shown are in accordance with the results of [24], where in this study there was no difference in the redness component with a significance value of 0.248. Regarding the measurement of the redness component, IPAB can measure color decently and has a sufficiently high accuracy [24].

c. Yellowness (b*)

The result based on Fig. 2 indicates the average yellowness of dehydrated strawberries obtained with IPAB has a very fluctuating value and higher than the Chromameter. The yellowness value obtained from the four samples using a Chromameter ranged from 7.61–8.37. Whereas, the yellowness value obtained using IPAB ranged from 6.60–11.37. From the two tools, the yellowness value indicates that the four samples of dehydrated strawberries have a dominant color of yellow. During storage, the yellowness values of the tools showed fluctuating results and tend to decrease. Occurred changes in the value of yellowness indicate a decrease in the yellow color of dehydrated strawberries.

Research with the same combination method on the color component as measured by the Chromameter, the yellowness value ranged from 12.54–18.95 with nine repetitions in the middle of the dehydrated strawberries [21]. Then in [10] the yellowness value obtained ranged from 11.92–38.85 with twelve repetitions in the middle of the dehydrated strawberry, while the yellowness value ranged from 3.25–3.42 with three repetitions on the dehydrated strawberry skin [22]. The average b* value of all samples of strawberries was lower than the value of a* - chromameter because the skin of the dehydrated strawberry samples measured had more red color than yellow.

Yellowness value result are tested whether it's normally distributed or not with the normality test. If the data is normally distributed, therefore will continue to the difference test known as independent t-test (parametric). However, if the data is not normally distributed, the Mann-Whitney test (non-parametric) will be carried out. The results of this analysis test indicate whether there are any differences between the results of color measurements using the Chromameter and IPAB. Based on statistical analysis using independent t-test with the purpose of comparative test, it was shown that there was a significant difference between the yellowness component value using the Chromameter and the IPAB ($p < 0,05$). The difference in the value of the yellowness component generated by the two tools has a significance value of 0.05. Therefore, the outcome of this statistical analysis is not consonant with the outcome, where in this research there was no difference in the lightness component with a significance value of 0.225 [24].

In this research, the difference in the yellowness component value produced by the Chromameter and the IPAB was caused by the selection of a background color that is not consonant with the object. With the utilization of digital images, such as used in IPAB, variations in background color can influence the color measurements [26]. Furthermore, differences in the outcome obtained compared to previous research may occur due to time differences on data retrieval. Data retrieval on previous research were taken continuously every 30 minutes for 3 days, whereas in this research, data were collected every 2 days and as of the 26th day, the data was collected every day.

2) Color Change (ΔE*) and Hue Angle (ho)

The average comparison regarding the color change (ΔE*) and hue angle (ho) component between Chromameter and the IPAB can be seen in Fig. 3.

a. Color Change (ΔE*)

The result based on Fig. 3 indicates the average color change of dehydrated strawberries obtained from IPAB has a very fluctuating value and higher than the Chromameter. The color change values obtained from the four samples using a chromameter ranged from 2.91–5.00. On the other hand, color change value obtained from IPAB ranged from

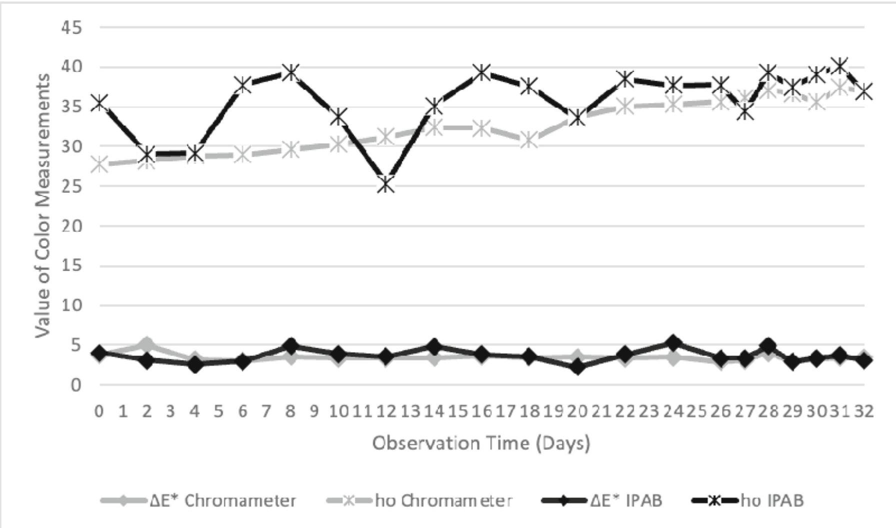


**Fig. 3.** Color Change (ΔE*), Hue Angle ($h^o$) of dehydrated strawberry that measure using chromameter and image processing approach in a box (IPAB) for 32 days storage in a tropical temperature condition without controlled.

2.25–5.27. The ΔE* value obtained tend to be low which signifies the color difference from the two sides of the dehydrated strawberries are not too distinctive.

In ref. [21], research with the same combination method on the color component as measured by the Chromameter, the color change values ranged from 62.22–67.40 with nine repetitions in the middle of the dehydrated strawberries. Then in ref. [10] the color change values obtained ranged from 70.51–73.39 with twelve repetitions in the middle of dehydrated strawberries, while in the latest research the color change values ranged from 0.12–0.28 with three repetitions on the dehydrated strawberry skin [22]. The difference in the results obtained can be caused by concentration of anthocyanin pigments on the product during storage [27]. The range of color change values obtained is very small which can be caused by reduced enzymatic processes caused by reduced water content in dehydrated strawberries.

Color change value result are tested whether it's normally distributed or not with the normality test. If the data is normally distributed, therefore will continue to the difference test known as independent t-test (parametric). However, if the data is not normally distributed, the Mann-Whitney test (non-parametric) will be carried out. The results of this analysis test indicate whether there are any differences between the results of color measurements using the Chromameter and IPAB. Based on statistical analysis using mann whitney with the purpose of comparative test, it is shown that there is no significant difference between the value of the color change component using the Chromameter and the IPAB ($p > 0.05$).The color change component value between the Chromameter and the IP was not significantly different with a significance value of 0.417. This matter can occur due to lack of real difference in the redness component. Calculations on the color change component value is related to the lightness, redness, and yellowness component value.

b. Hue Angle ($h^o$)

The result based on Fig. 3 indicates the average results of dehydrated strawberries obtained with IPAB have a fluctuating value and higher than the Chromameter. The hue angle values obtained from the four samples using a chromameter ranged from 27.77–37.37, whereas IPAB ranged from 25.30–40.11. From the two tools, the results of the hue angle showed that the four samples of dehydrated strawberries possess a red color.

In ref. [10], research with the same combination method on the color component as measured by the Chromameter, the hue angle values obtained ranged from 0.63–1.59 with twelve repetitions in the middle of dehydrated strawberries, while in the latest study the hue angle values ranged from 16.93–17.62 with three repetitions on the dehydrated strawberry skin [22].

Hue angle value result are tested whether it's normally distributed or not with the normality test. If the data is normally distributed, therefore will continue to the difference test known as independent t-test (parametric). However, if the data is not normally distributed, the Mann-Whitney test (non-parametric) will be carried out. The results of this analysis test indicate whether there are any differences between the results of color measurements using the Chromameter and IPAB. Based on statistical analysis using Mann Whitney for comparative test, it is known that there is a significant difference between the hue angle component value between the Chromameter and the IPAB ($p < 0.05$). The difference in the hue angle component value produced by the two tools has a significance value of 0.05.

In this research, the difference in the hue angle component value produced by the Chromameter and the IPAB can be caused by a significant difference in the yellowness component using IPAB. The calculation of the hue angle component value is related to the redness and yellowness component value.

### B. *Analysis for Comparison of Chromameter and IPAB*

The accuracy test used is the root mean square error (RMSE) because the indicator is easier to understand than the MSE and calculations using the square root will show the error rate on a small scale. In order to cognize how good the RMSE value obtained or not, the scatter index (SI) calculation can be used.

#### 1) Lightness (L*), Redness (a*), and Yellowness (b*)

The RMSE results will exhibit how straggle the difference in the lightness component value produced by the IPAB compared to the Chromameter. Based on the calculations, the RMSE value obtained regarding the lightness component using IPAB is 7.24, whereas the SI value obtained is 16.38%. The RMSE value obtained is beyond far from the value 0 and the SI value for the lightness component is >10%. The RMSE value of the lightness component using IPAB exceeds the limit. Therefore, in this matter, the use of IPAB regarding the lightness component value, has a poor accuracy.

The RMSE results will indicate how straggle the difference in the redness component value produced by the IPAB compared to the Chromameter. Based on the calculations, the RMSE value obtained for the redness component by using IPAB was 1.00, whereas the SI value obtained was 7.63%. The RMSE value obtained is close to 0 and the SI value for the redness component is <10%. The RMSE value of the redness component using IPAB is within the limits. Therefore, it can be concluded that the redness component value using the IPAB has an adequately high accuracy.

The RMSE results will show how spread out the difference in the value of the yellowness component produced by the IPAB compared to the Chromameter. Based on the calculations, the RMSE value obtained or the yellowness component using IPAB is 1.90, while the SI value obtained is 20.24%. The RMSE value obtained is beyond far from the value 0 and the SI value for the yellowness component is >10%. The RMSE value of the yellowness component using IPAB exceeds the limit. Therefore, the value of the yellowness component using IPAB has a poor accuracy.

#### 2) Color Change ($\Delta E^*$) and Hue Angle ($h^o$)

The RMSE results will show how spread out the difference in the color change component value produced by the IPAB compared to the Chromameter. Based on the calculations, the RMSE value obtained for the color change component using IPAB was 0.84, whereas the SI value obtained was 22.90%. The RMSE value obtained is close to 0 but the SI value for the color change component is >10%. This occurs when the denominator is very small while calculating the SI value. The RMSE value of the color change component using IPAB is within the limits. Therefore, the value of the color change component using IPAB has an adequately high accuracy.

Through the RMSE results, it will be shown how straggle the difference in the value of the hue angle component produced by IPAB compared to the Chromameter. Based on the calculations, the RMSE value obtained for the hue angle component using IPAB is 4.63. whereas the SI value obtained is 12.92%. The RMSE value obtained is beyond far from the value 0 and the SI value for the hue angle component is $>10\%$. By using IPAB, the RMSE value of the hue angle component exceeds the limit and the value of the hue angle component using IPAB has a poor accuracy.

Based on the comparative analysis that have been done, IPAB can measure several color components with the average value obtained no different when compared to the Chromameter and has a fairly high accuracy seen from the RMSE value close to zero [18], on the redness component (1.00) and color change (0.84), and the scatter index value is below 10% [20]. However, in the lightness, yellowness, and hue angle components, the average value of the measurement results is different when compared to the Chromameter and the accuracy obtained is still relatively low with a scatter index value of more than 10%.

## 4 Conclusion

Based on the results of statistical analysis and accuracy tests, the results of measuring the color of dehydrated strawberries using Image Processing Approach in Box exhibit that the tool can favorably detect the color of dehydrated strawberries and their color change, especially in the redness and color change components, compared to the Chromameter. However, the accuracy still needs to be improved to reach maximum results.

**Acknowledgment.** Authors make a sincerely gratitude to Universitas Gadjah Mada for their financial support with contract number: 3143/UN1.P.III/DIT-LIT/PT/2021, and also for Faculty of Agricultural Technology Universitas Gadjah Mada for the support of research during Pandemic Covid-19.

## References

1. J.M. Olias, C. Sanz, and A.G. Perez, “Postharvest handling of strawberries for fresh market”, Science Publisher. inc. USA, 2001.
2. E. Kesumawati, E. Hayati, and M. Thamrin, “Pengaruh naungan dan varietas terhadap pertumbuhan dan hasil tanaman stroberi (fragaria sp) didataran rendah.” Journal Agrista 16 (1): 14-15, 2012.
3. A. Chandra, and R. Judy, “pengaruh berbagai proses dehidrasi pada pengeringan daun stevia rebaudiana” prosiding seminar nasional teknik kimia “kejuangan”. Universitas UPN Veteran. Yogyakarta, 2018
4. J. Kowalska, H. Kowalska, A. Marzec, T. Brzeziński, K. Samborska, and A. Lenart, “Dehydrated strawberries as a high nutritional value fruit snack”, Food Science Biotechnology, 27(3), 799-807, 2017.

5. S. Daniel.. “Osmosis-puffing sebagai suatu alternatif proses pengeringan buah dan sayuran.” Jurnal Keteknikan Pertanian Vol 20 No 1, 2006.
6. A. E. Rodrigues, and A. M. Maria, “Effective diffusion coefficient behavior in osmotic dehydration of apples slices considering shrinking and local concentration dependence”, Journal of Food Process Engineering, 207-208. 2007.
7. R. Hayati, A. Marliah, and F. Rosita, “Sifat kimia dan evaluasi sensori bubuk kopi arabika”, Jurnal Florstek, 66-75, 2012.
8. H. Mahanom, A. H. Azizah and M. H. Dzulkifli, “Effect of different drying methods on concentrations of several phytochemicals in herbal preparation of 8 medicinal plants leaves”, Mal. J Nutr. Vol 5: 47-54, 1999.
9. B. Johannes and R. Borquez, “Quality retention in strawberries dehydrated by emerging dehydration methods”, Food Research International, 63, p. 42-48, 2014.
10. R M. Putri, I.W.F Aziz, M.A.F. Falah, “Physical quality changes of dehydrated strawberry affected by different packaging in a tropical environment”, IOP Conf. Series: Earth and Envi. Sci. 759, 2020.
11. N. Sondari, L. Amalia and S. Aminah, “Mengidentifikasi Beberapa Varietas Tanaman Stroberi Bersama Petani di Kecamatan Pasirjambu Kabupaten Bandung” Jurnal Qardhul Hasan: Media Pengabdian kepada Masyarakat, 6 (1): 16, 2020.
12. Rohanah, Heryanto and B. Rachmat. “Rancang bangun alat pengering tipe rak sistem double blower”, Politeknik Negeri Malang. Malang, 2005.
13. S. T. Soekarto, “Dasar-dasar pengawasan dan standarisasi mutu pangan”, Bogor: Machine Vision Press, 1990.
14. Pakiding, F. Lande, J. Muhidong and O. S. Hutabarat, “Profil sifat fisik buah terung belanda (Cyphomandra betacea). Jurnal AgriTechno, 8 (2): 131-139, 2015.
15. P. Phatare, U. Opara, and F. Al-Said, “Colour measurement and analysis in fresh and processed food: a review*,* Journal of Food Bioprocess Technol Vol 6, 2013.
16. R D. Lestari, M A F Falah., M Ainuri., C A Nugroho, “Panduan praktis alat pendeteksi perubahan kualitas fisik buah secara kontinu. Universitas Gadjah Mada. Yogyakarta, 2019. Copyright number 000192385-2020.
17. Sutoyo, T. Mulyanto, E. Mulyanto, V. Suhartono, O. D. Nurhayati, Wijanarto, “Teori pengolahan citra digital”, Yogyakarta: Andi Press, 2009.
18. S. Singgih, “Metode peramalan bisnis masa kini dengan minitab dan SPSS”, Jakarta: PT Elex Media Komputindo, 2009.
19. C.J. Willmott, and K. Matsuura, “Advantages of the mean absolute error (MAE) over the root mean square error (RMSE) in assessing average model performance”, Climate Research, 30, 79-8, 2005.
20. M. Ling, & K. Liu, “Probabilistic prediction of significant wave height using dynamic bayesian network and information flow”, Water 2020, 12, 2075, 2020.
21. I.C. Ardhani, R.M. Putri, M.A.F. Falah and K.H. Widodo, “Determination of Production Factors of Dehydrated Strawberries by Using Taguchi Method Approach”, *IOP Conf. Series: Earth and Envi. Sci.* 653, 2020.
22. H. Septiana Sabila, “Karakterisasi kualitas produk stroberi kering (Dehydrated Strawberry) berdasarkan penerimaan konsumen. Yogyakarta: Universitas Gadjah Mada, 2021.
23. Merzylak., Alexei., Anatoly. Reflectance spectral features and non-destructive estimation of chlorophyll, carotenoid and anthocyanin content in apple fruit”, Postharvest Biology and Technology, 197-211, 2003.
24. N. Catur Sapto, “Pemantauan perubahan kualitas fisik stroberi segar (*Fragaria x ananassa var. Oso Grande*) menggunakan machine vision selama penyimpanan. Yogyakarta: Universitas Gadjah Mada, 2020.

25. Falah, M.A.F, Ainuri, M, Nugroho, C.S, Lestari R.D.N. Kode Pemrograman Komputer Pemantauan Perubahan Kualitas Fisik Buah Secara Kontinu Menggunakan Raspberry Pi. Copyright number 000192384-2020.
26. Y. Guo, "Quality evaluation of tourmaline red based on uniform color space," Cluster Computing, Springer 20(4): 3393–3408, 2017.
27. A.J. Keutgen, and E. Pawelzik, "Quality and nutrition value of strawberry fruit under longterm salt stress", Journal Food Chemistry, 107: 1413–1420, 2008.