Color Instrument Analysis of Octopus Drying Using Solar Hybrid Dryer

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Abstract. Octopus drying in Kaur Regency, Bengkulu Province, is done by direct sun drying. It causes low color quality due to UV light. Solar hybrid drying with UV protection is needed to control the color quality of the octopus. Different body parts of octopuses have thickness differences, so the color of each part is different. This research aims to investigate the color instrument analysis using the solar hybrid dryer, including L*, a*, b*, hue angle, Chroma, and ΔE of the octopus body parts during the drying period. The leading equipment was a solar hybrid dryer with 14% UV protection. The experimental design was Completely Randomized Design (CRD) with a factor of body parts divided into five parts (B1, B2, B3, B4, and B5). The color changes were analyzed using the kinetics equation. Overall, the octopus body parts had a significant effect on L*, Chroma, and ΔE, while they had no significant impact on Hue Angle.

1 Introduction

Dried octopus (*Octopus sp*.) is a featured product from Kaur Regency, Bengkulu Province. They usually process the product by drying it directly under sunlight. It causes low-quality physical conditions, especially in terms of color, due to UV radiation. Octopus is a sensitive aquatic product that degrades during storage [1,2]. Proper handling is needed to protect the physical condition, especially the color, such as drying [3]. Octopus drying was investigated using an oven [4], but it still needed a high cost and was challenging to apply in the Kaur Regency, Bengkulu province. The solar hybrid dryer is widely used for drying methods because it is cheap and applicable to middle-class society.

The drying process is influenced by factors such as the environment, equipment, and product. Solar hybrid dryers could beat the drying time and maintain the quality standard [5]. It also increases the temperature to beat the drying time [6]. The wall construction can be covered by UV protection to protect the color. The solar hybrid dryer with UV protection can protect the quality, especially the color of the food products, for example, aquatic product [7], coffee [8], and herbal leaves [9]. Another factor that influences the drying process is the thickness of the product. The high thickness of the product will affect the drying time, which also affects the product quality [10]. Octopus has different thicknesses in each body part. So, it is necessary to divide the octopus into some parts depending on the body's thickness.

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Color is an important quality that influences consumers to choose a high-quality food product [11]. The drying process influences the color change of the product. Moreover, there is an effect from heat causing the browning [12,13]. The color instrument, including L* (lightness), a* (greenness or redness), and b* (blueness or yellowness), can be analyzed to hue angle (H), chroma (C*), and color difference (ΔE) [14]. Kinetics equations could be modeled during the food process [12–15]. The previous research on color analysis in the food process was done in longan flesh [16], fish [13,17], brown shrimp [18], and squid [19]. The color change analysis for the octopus process is rarely found, especially in drying. Hence, this research aims to investigate the color instrument analysis using the solar hybrid dryer, including L*, a*, b*, hue angle, chroma, and ΔE of the octopus body parts during the drying period.

2 Methods

2.1 Time and place

This research was carried out in December 2023 in the Department of Agricultural Technology, Faculty of Agriculture, University of Bengkulu, Bengkulu, Indonesia.

2.2 Materials

The main ingredient was octopus, which was transferred from Kaur Regency, Bengkulu Province. The octopus' body was divided into five parts, including head (B1), mantle (B2), top tentacle (B3), middle tentacle (B4), and bottom tentacle (B5) based on the body thickness. The leading equipment was a solar hybrid dryer with 14% UV protection. The colorimeter measured the color instruments.

2.3 Experimental design

The experimental design was Completely Randomized Design (CRD) with a factor of body parts divided into five parts. The body parts were head (B1), mantle (B2), top tentacle (B3), middle tentacle (B4), and bottom tentacle (B5) based on the body thickness. They were performed in triplicate.

2.4 Experimental procedure

The experiment was started by cutting the octopus' body into five parts based on the different thickness. The thickness average of the head (B1), mantle (B2), top tentacle (B3), middle tentacle (B4), and bottom tentacle (B5) were 5.30; 6.16; 21.72; 17.30; 9.18 mm, respectively. The color sample was measured by colorimeter with 3 points. The raw data including L*, a*, and b* were measured periodically in every hour.

2.5 Analysis

The color data, including L*, a*, and b* values, were measured using a colorimeter. The investigated spots were examined in 3 parts for each sample. The a* and b* values were analyzed to hue angle to determine the octopus's color during the drying period using Equation 1 [20].

$$H(°) = \tan^{-1}\frac{b^*}{a^*} \text{ x } 57{,}3 \quad (1)$$

The a* and b* values were also analyzed to chroma to know the color intensity of the octopus during the drying period using Equation 2 [14,21].

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad (2)$$

The L*, a*, and b* values were analyzed to color difference during the octopus drying period using Equation 3:

$$\Delta E = \sqrt{(L^*_0 - L^*_t)^2 + (a^*_0 - a^*_t)^2 + (b^*_0 - b^*_t)^2} \quad (3)$$

where 0 is initial time and t is current time [14][22–24].

The color changes during the octopus drying period using the kinetics equation, as shown in Equation 4:

$$\frac{dC}{dt} = \pm k.\, C^n \quad (4)$$

where the C is color parameters, and n is order. The order can be 0, 1, or 2, which depends on the graph and the highest coefficient determination [3,21,25].

All the data were analyzed using the Analysis of Variance (ANOVA) at the significant level of 5%. The differences were compared using further analysis of Duncan's Multiple Range Test (DMRT) with $p<0.05$.

3 Results and discussion

3.1 Lightness

Fig. 1 illustrates the lightness change during drying in a solar hybrid dryer for 0 to 10 hours. Generally, the amount of lightness went down for all the samples. The initial lightness for all samples was 41.90. Then, the heads' (B1) lightness decreased from the initial value to 23.76. It was the lowest value of the other parts, which were for mantle (B2), top tentacle (B3), middle tentacle (B4), and bottom tentacle (B5) decreased from the initial value to 26.14; 29.54, 28.4, and 26.75, respectively. The decreased number of lightness indicated that the samples were changed from light to darker. The solar hybrid dryer had a higher temperature than the environment, so the color change of the samples could be influenced by high free amino acid contents, which affected the non-enzymatic browning reaction [26].

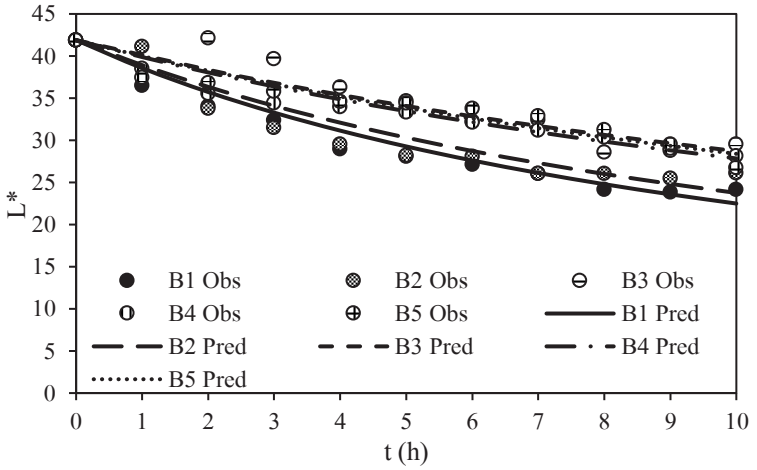

Fig 1. The lightness (L*) change of octopus' body parts drying using solar hybrid dryer

All samples' lightness behavior changed and were analyzed using a kinetics equation [14]. Based on the curves, they were analyzed by second-order kinetics with the average of R^2 was 0.9362, as shown in Table 1. The ANOVA analysis indicated that the kinetics values significantly influenced the octopus' body parts. The different subsets are shown in different superscripts in the same column by DMRT ($p<0.05$). The highest kinetics value was head (B1), which meant that the highest change of lightness on the head part was due to it being the lowest thickness of the octopus' body parts. On the contrary, the lowest kinetics value was the top tentacle (B3), which had the highest thickness of the octopus' body parts. The quality change of the product was influenced by the thickness of the product during the food process, especially in the drying process [10].

Table 1. The kinetics (k) and determination coefficient (R^2) of lightness (L*) change of octopus' body parts drying using solar hybrid dryer

Octopus' Body Parts	$\mathbf{k\ (10^{-3}h^{-1})}$	$\mathbf{R^2}$
Head (B1)	2.06 ± 0.36^{c}	0.9731
Mantle (B2)	1.82 ± 0.23^{c}	0.9086
Top Tentacle (B3)	1.10 ± 0.13^{a}	0.9178
Middle Tentacle (B4)	1.20 ± 0.38^{b}	0.9623
Bottom Tentacle (B5)	1.13 ± 0.22^{b}	0.9193

The different superscripts show the significantly different values in the same column by DMRT ($p<0.05$).

3.2 Hue Angle

Fig 2 provides data on the hue angle (H) change of octopus' body parts drying using solar hybrid dyer for 0 to 10 hours. Generally, it is essential to notice that the number of hue angles went down for all the samples. The initial hue angle was 46.30, and then it decreased to the range from 18.10 to 28.21. Based on the hue angle chart, they indicated the color change from yellow-red (YR) to red (R) [27]. The red color indicated that the browning still happened to all the samples due to the high temperature of the equipment, which affected the non-enzymatic browning reaction [26].

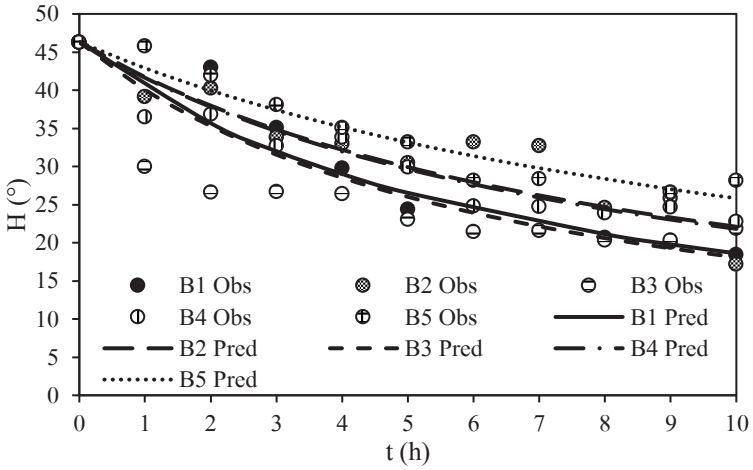

Fig 2. The Hue Angle change of octopus' body parts drying using solar hybrid dryer

All samples' hue angle behavior had different changes, and they were analyzed using a kinetics equation [14]. They were analyzed by second-order kinetics, with an average of R^2 0.9008, as shown in Table 2. The ANOVA analysis indicated that the kinetics values did not significantly influence the octopus' body parts. However, the hue angle changes still happened due to the heat transfer in the drying process from the drying environment and products. The red color was supposed to be affected by the Maillard reaction [28].

Table 2. The kinetics (k) and determination coefficient (R^2) of Hue Angle change of octopus' body parts drying using solar hybrid dryer

Octopus' Body Parts	$\mathbf{k\ (10^{-3}h^{-1})}$	$\mathbf{R^2}$
Head (B1)	3.21 ± 0.69	0.9731
Mantle (B2)	2,37 ± 0.40	0.8387
Top Tentacle (B3)	3.37 ± 1.97	0.8607
Middle Tentacle (B4)	2.42 ± 0.59	0.9152
Bottom Tentacle (B5)	1.71 ± 1.09	0.9549

3.3 Chroma

Fig 3 provides data on the chroma (C*) change of octopus' body parts drying using a solar hybrid dryer for 0 to 10 hours. Generally, it is essential to notice that the number of chroma went down for all the samples. The initial chroma value for all samples was 7.85; then, they went down to the range of 2.85 to 6.86. The decreased number of chroma indicated that the color saturation of all the samples was also decreased [14].

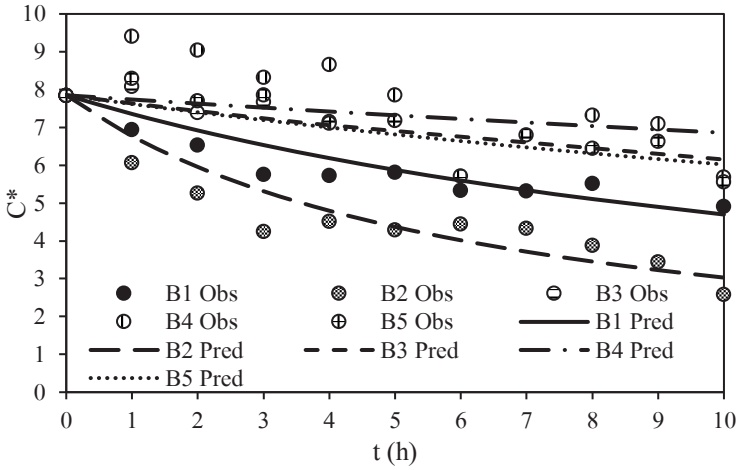

Fig 3. The chroma change of octopus' body parts drying using solar hybrid dryer

The behavior of chroma of all samples had different changes, and they were analyzed using second-order kinetics with the average of R^2 was 0.8151, as shown in Table 3 [14]. The ANOVA analysis indicated that the kinetics values significantly influenced the octopus body parts, and the different subsets are shown in different superscripts in the same column by DMRT ($p<0.05$). The highest kinetics value was mantle (B2), which means that the most significant change of chroma on the mantle was due to the part's characteristics and thickness. The lowest kinetics value was the top tentacle because it had the highest thickness among octopus body parts [29].

Table 3. The kinetics (k) and determination coefficient (R^2) of chroma change of octopus' body parts drying using solar hybrid dryer

Octopus' Body Parts	$\mathbf{k\ (10^{-2}h^{-1})}$	$\mathbf{R^2}$
Head (B1)	4.91 ± 0.03^{bc}	0.8510
Mantle (B2)	6.19 ± 0.03^{c}	0.8889
Top Tentacle (B3)	0.67 ± 0.02^{ab}	0.7893
Middle Tentacle (B4)	0.82 ± 0.01^{ab}	0.7901
Bottom Tentacle (B5)	0.77 ± 0.00^{a}	0.7779

The different superscripts show the significantly different values in the same column by DMRT ($p<0.05$).

3.4 ΔE

Fig 4 provides the color difference (ΔE) change data of octopus body parts drying using a solar hybrid dryer from 0 to 10 hours. It is essential to notice that the number of color differences increased for all the samples. The initial color difference was 0, then they rose from the initial value to the range from 9.81 to 21.06. The increased number of color differences indicated the increased values during the drying period.

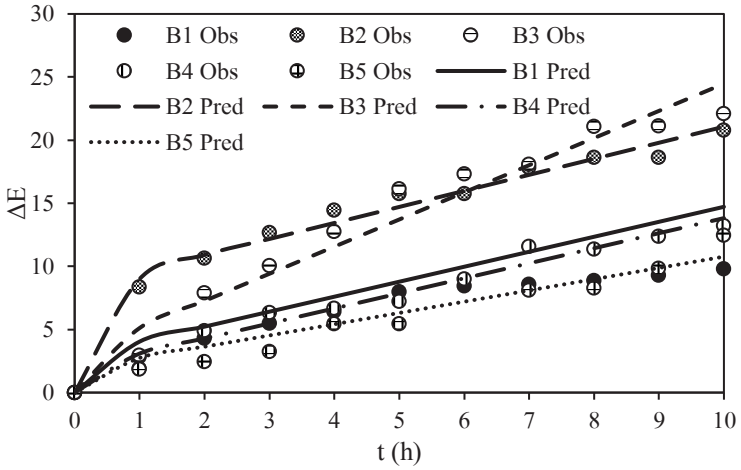

Fig 4. The Color Difference change of octopus' body parts drying using solar hybrid dryer

The behavior of chroma of all samples had different changes and was analyzed using 0 order kinetics with the average of R^2 of 0.939, as shown in Table 1 [14]. The ANOVA analysis indicated that the kinetics values significantly influenced the octopus' body parts. The different subsets are shown in different superscripts in the same column by DMRT ($p<0.05$). The highest kinetics value was the top tentacle (B3), with the highest thickness.

Table 4. The kinetics (k) and determination coefficient (R^2) of Color Difference change of octopus' body parts drying using solar hybrid dryer

Octopus' Body Parts	k (h^{-1})	R^2
Head (B1)	1.19 ± 0.26^{a}	0.8754
Mantle (B2)	1.27 ± 0.84^{b}	0.9870
Top Tentacle (B3)	2.15 ± 0.42^{b}	0.9645
Middle Tentacle (B4)	1.19 ± 0.59^{ab}	0.9879
Bottom Tentacle (B5)	0.89 ± 0.52^{ab}	0.9548

The different superscripts show the significantly different values in the same column by DMRT ($p<0.05$).

4 Conclusion

The kinetics of Lightness (L*) change of the sample were in the range of 1.10×10^{-3} to 2.06×10^{-3} h^{-1}, with the average of R^2 was 0.9362. The kinetics of the Hue Angle change of the sample were in the range of 1.71×10^{-3} to 3.37×10^{-3} h^{-1}, with the average of R^2 being 0.9008. The kinetics of Chroma change of the sample were in the range of 0.67×10^{-2} to 6.19×10^{-2} h^{-1}, with the average of R^2 was 0.8151. The kinetics of Color Difference (ΔE) change of the sample were in the range of 0.89 to 2.15 h^{-1} with the average of R^2 was 0.9539. Overall, the octopus body parts had a significant effect on L*, Chroma, and ΔE while they had no significant effect on Hue Angle.

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Data availability statement: The data presented in this study are available in the article.

Author contribution statement: Arina Fatharani: conceptualization, methodology, analysis, and writing the original draft. Faulina Maissy: investigation and analysis. Yuwana Yuwana: conceptualization and methodology. Ulfah Anis: conceptualization and review.

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